MICHIGAN DEPARTMENT OF TRANSPORTATION
MDOT

AGRICULTURAL BY-PRODUCTS FOR ANTI-ICING AND DEICING USE IN MICHIGAN

Steve Kahl, Corrosion Specialist
Structural Research Unit
Michigan Department of Transportation
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16. Abstract

Keeping Michigan highways and roads clear of snow and ice during the winter can be a significant challenge to an agency's resources and personnel. The widespread use of rock salt (sodium chloride) to remove snow and ice and facilitate a 'bare pavement' level of service has provided for the increased safety of motorists for some time. However, deicing salt use has some detrimental side effects.

In recent years anti-icing compounds developed from agricultural by-products (ABP), have been introduced. Manufacturers claim that ABP's perform better, are environmentally friendly, and are less corrosive than conventional anti-icing and deicing materials. These products have shown promise in trial applications within Michigan, primarily for anti-icing operations, but improved performance of deicing chemicals used in conjunction with ABP's has also been documented.

This report summarizes the MDOT anti-icing experience, based on usage during the winters of 1999-2002 in the Southwest Region. The Southwest Region is located in southwest lower Michigan, and typically experiences heavy lake-effect winter precipitation. Several major routes pass through this region, namely I-94, I-69, US-12, US-31, and US-131. Anti-icing practices resulted in lower material costs, lower salt use, and lower accident rates along the I-94 corridor. It is recommended that agencies consider implementing anti-icing for winter maintenance operations on trunkline routes.

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Executive Summary

Keeping Michigan highways and roads clear of snow and ice during the winter can be a significant challenge to an agency's resources and personnel. The widespread use of rock salt (sodium chloride) to remove snow and ice and facilitate a 'bare pavement' level of service has provided for the increased safety of motorists for some time. However, deicing salt use has some detrimental side effects. The damage to the ecosystem from chloride ions has been documented, along with the corrosive effects to metals.

Several strategies have been suggested to deal with the effects of using rock salt. One approach has been direct substitution with chloride-free chemicals. Another idea is to use salt with added corrosion inhibitors to offset or delay the effects of corrosion, which is usually less expensive than complete substitution of chloride-based deicers. Unfortunately, alternatives to salt can be very expensive, and may require additional applications to obtain the same result.

In recent years anti-icing compounds developed from agricultural by-products (ABP) have been introduced. Manufacturers claim that ABP's perform better, are environmentally friendly, and are less corrosive than conventional anti-icing and deicing materials. These products have shown promise in trial applications within Michigan and elsewhere in the nation. The primary use is for anti-icing operations, but improved performance of deicing chemicals used in conjunction with ABP's has also been documented.

A Research Advisory Panel (RAP), composed of personnel from several MDOT Regions, and the C & T Division in Lansing, was formed to receive input and guidance on the ABP evaluation project, and to disseminate information quickly. However, in order to evaluate ABP's used for anti-icing, the anti-icing methodology itself required further study. Evaluation included application of ABP's on trial roadways, analysis of cost effectiveness, ABP prewetting effect on salt usage, using ABP's for anti-icing and deicing operations, and accident statistics review. Because ABP's are supplied from different agricultural processes, they are subject to variability in composition. Therefore, specifications for ABP's were developed.

This report summarizes the MDOT anti-icing experience during the winters of 1999-2002 in the Southwest Region. The Southwest Region is located in southwest lower Michigan, and typically experiences heavy lake-effect winter precipitation. Several major routes pass through this region, namely I-94, I-69, US-12, US-31, and US-131.

Anti-icing is a snow and ice control strategy designed to prevent the formation of an ice-pavement bond by timely application of a chemical freezing point depressant. Fewer chemicals are needed to prevent ice from forming than to remove it, and less plowing effort is needed to remove unbonded ice and snow from the pavement. Once applied, the chemical remains on the pavement, and will work for the next storm event, until diluted out by precipitation. Liquids are usually best suited for this purpose, as the pavement is generally dry, and traffic action will disperse other materials (for example, if rock salt was used for anti-icing).

In contrast to anti-icing operations, traditional snow and ice control practice is to wait until an inch or more of the snow accumulates on the pavement before beginning to plow and treat the highway with chemicals or abrasives. A compacted snow layer is formed that is tightly bonded to the pavement surface. A subsequent deicing of the pavement is then necessary, usually requiring a large quantity of chemical to work its way through the snow pack to reach the pavement and destroy or weaken the bond. Although requiring less information and training than for anti-icing, deicing may provide less safety as a result of the inherent delay.

Repeat applications of chemicals were necessary for both anti-icing and deicing. In most cases, the anti-icing liquids were applied before the onset of precipitation, and the deicing salts applied after accumulation on the roadway surface had occurred. Initial application rates for anti-icing were 35 gallons per lane-mile. However, inexperience with anti-icing compounds in 1999-2000 led to application of rock salt immediately following anti-icing liquid placement. The dark colored appearance of applied ABP on the highway was mistaken for black ice, because of the dark brown color.

As more experience was gained, anti-icing methods became more efficient. Application rates for anti-icing were lowered to 25 gallons per lane-mile. For the 2000-2001 winter, the ABP used was a clear color, and thus the appearance as sprayed on the roadway did not resemble black ice and therefore prevented unnecessary applications of deicing salts.

One MDOT maintenance garage used APB's exclusively for deicing operations, at a cost of $30.22/lane-mile. The application rate of 25 gallons/lane-mile for deicing corresponded to a dry weight of 97 lb./lane-mile. Compared to the prewetted salt rate of 250 lbs./lane-mile, the environmental impact of salt is reduced 61 percent, albeit at considerable expense. However, chloride-free deicers would have cost considerably more; using CMA at 400 lb./lane-mile (application rate needs to be increased to match performance of salt) at a unit cost of $600/ton would have cost $120 per lane-mile! The pilot program serves to emphasize that ABP liquids should be used for anti-icing operations and prewetting rock salt, rather than used for deicing.

Costs for the cleanup of compacted snow and ice vary, but are reportedly reduced with anti-icing, in terms of man-hours and equipment. Further, the corrosion inhibiting APB's reduce equipment maintenance by preventing or minimizing rusting of the truck hoppers, spinners, and other parts. Cost effectiveness of ABP's is sometimes difficult to determine, as many highly variable local costs (e.g., unit materials cost, labor rates, storage) need evaluation. Indirect costs (travel delay costs) should also be considered.

Overall highlights of the SW Region pilot program include:

- Anti-icing led to overall decreased material costs the past three winter seasons;
- Prewetting rock salt reduced its use by 28-38 percent;
- Prewetted rock salt used for traction control reduced abrasives (sand) use by 78 percent;

- Cost savings of prewetting rock salt averaged $1.69/lane-mile for materials;

- ABP liquids should be used for anti-icing and prewetting rock salt, but not for deicing;

- Anti-icing practices maintained bare pavements longer, which bought response time in storm events, up to an hour in some cases;

- Anti-icing practices in 2001-02 helped to reduce the frequency of winter accidents on I-94 as compared to previous years with similar numbers of storm events.

When ABP liquids are used appropriately for anti-icing, they can be a powerful tool in providing safer roads to the traveling public at less cost. The following are recommendations for anti-icing to be adopted as a strategic tool for winter maintenance operations in Michigan, based on the benefits of using anti-icing:

- It is recommended that MDOT and local agencies responsible for winter maintenance operations on trunkline routes consider implementing anti-icing. Anti-icing is an effective tool to use for responding to higher level of service (LOS) expectations from the traveling public.

- Agencies considering implementing anti-icing should contact those agencies currently practicing anti-icing to determine how to get started: What equipment, budget, and materials are required; the process of dealing with the public; and training needs for its own agency personnel. A successful anti-icing program needs the buy-in of all participants.

- It is recommended that an anti-icing training program be developed for operators and managers of agencies conducting or considering anti-icing. The training should explain when anti-icing is appropriate, incorporate decision making scenarios, and familiarize staff with the "Manual of Practice for an Effective Anti-icing Program: A Guide for Highway Winter Maintenance Personnel" (FHWA-RD-95-202).

- It is also recommended that agencies adopt a benefit/cost methodology to formally track and document the costs and benefits of anti-icing. This can entail use of TAPER (Temperature, Application rate, Product used, storm Event, Results) logs, assignment of task-specific time sheet coding, and other means of tracking costs.

Action Plan

1. Engineering Operations Committee
   a. Approve recommendations in Report R-1418, Agricultural By-Products for Anti-icing and Deicing Use in Michigan.

2. Regions
   a. Consider implementing anti-icing as a strategy for winter maintenance operations.
   b. The Region liaison engineers will work with the Construction and Technology and Maintenance Divisions to create an ad hoc committee to develop an implementation plan for an anti-icing program (including guidelines, budget, and training).
   c. Contact appropriate personnel in Southwest Region for information on storage and equipment needs, and training requirements.

3. Construction and Technology Division/Structural Research Unit
   a. Develop statewide specifications for anti-icing chemicals.
   b. Assist Regions in development of quality control procedures and testing.
   c. Participate in the ad hoc committee.

4. Region Services Unit, Bureau/Division Training
   a. Develop and schedule anti-icing training program for snowplow operators and managers as recommended by the ad hoc committee.

Introduction

Keeping Michigan highways and roads clear of snow and ice during the winter can be a significant challenge to an agency's resources and personnel. The widespread use of rock salt (sodium chloride) to remove snow and ice and facilitate a 'bare pavement' level of service has provided for the increased safety of motorists for some time. However, deicing salt use has some detrimental side effects. The damage to the ecosystem from chloride ions has been documented, along with the corrosive effects to metals. Consequently, frequent repair and rehabilitation of bridges has resulted. The cost due to corrosion of steel and reinforced concrete alone is significant, estimated at $3.9 billion annually (Koch, 2002).

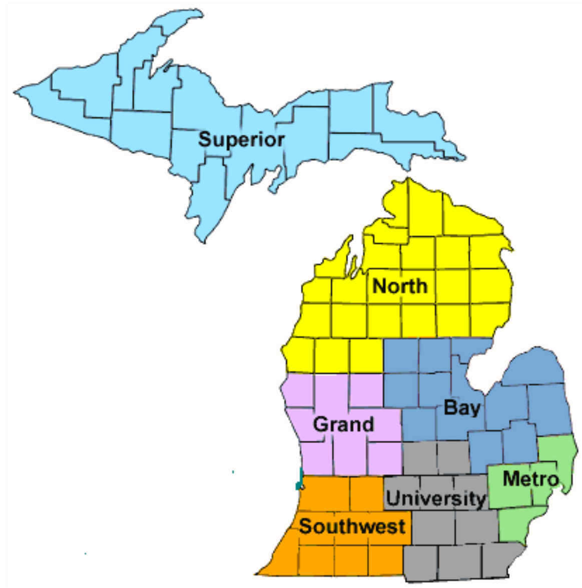
Several strategies have been suggested to deal with the effects of using rock salt. One approach has been direct substitution with chloride-free chemicals, such as Calcium Magnesium Acetate (CMA). Unfortunately, alternatives to salt can be very expensive, and require additional applications to obtain the same result. Another idea is to use salt with added corrosion inhibitors to offset or delay the effects of corrosion, which is usually less expensive than complete substitution of chloride-based deicers. Although these options can reduce the impact of chlorides on the environment, the application method has not changed. Past practice has been to break the snow and ice bond with the pavement by applying chemicals after significant precipitation has occurred. This practice also leads to inefficient material use, as traffic action and forward velocity of the salt truck means that most of the salt (an estimated 80 percent) ends up on the shoulder, and not where it is needed - in the traveled lanes.

In recent years anti-icing compounds developed from agricultural by-products (ABP), have been introduced. Manufacturers claim that ABP's perform better, are environmentally friendly, and are less corrosive than conventional anti-icing and deicing materials. These products have shown promise in trial applications within Michigan and elsewhere in the nation. The primary use is for anti-icing operations, but improved performance of deicing chemicals used in conjunction with ABP's has also been documented.

Using ABP's for anti-icing benefits the Michigan Department of Transportation (MDOT) by providing the required high level of service (bare pavements) quicker, while reducing the chemical application rate and inhibiting the corrosive effect of chloride ions. For an interstate system, anti-icing can support higher service level objectives such as maintaining bare pavements throughout a storm or returning to bare pavements as quickly as possible, and therefore becomes more practical.

A Research Advisory Panel (RAP), composed of personnel from several MDOT Regions, was formed to receive input and guidance on the anti-icing project, and to disseminate information quickly. In addition, studying ABP prewetting effect on salt usage and evaluating performance of the ABP both for anti-icing and deicing was done. However, in order to evaluate ABP's used for anti-icing, the anti-icing methodology itself required further study. Evaluation included accident statistics review, application of ABP's on trial roadways, cost effectiveness, and collection of logs from snowplow operators. Because ABP's are supplied from different agricultural processes, they are subject to variability in composition. Therefore, specifications for ABP's needed development, as well as usage criteria.

Figure 1. MDOT Regions



This report summarizes the MDOT anti-icing experience during the winters of 1999-2002 in the Southwest Region. The Southwest Region is located in southwest lower Michigan (Figure 1), and typically experiences heavy lake-effect winter precipitation. Several major routes pass through this region, namely I-94, I-69, US-12, US-31, and US-131.

Anti-icing Versus Traditional Snow and Ice Removal

Although not a new idea, dating as far back as 1950, lately anti-icing has been gaining acceptance. Anti-icing is a snow and ice control strategy designed to prevent the formation of an ice-pavement bond by timely application of a chemical freezing point depressant. Fewer chemicals are needed to prevent ice from forming than to remove it, and less plowing effort is needed to remove unbonded ice and snow from pavements. Liquids are usually best suited for this purpose, as the pavement is generally dry, and traffic action will disperse other materials (for example, if rock salt was used for anti-icing). However, this method requires a higher level of training and experience to be effective. In addition, modern tools should be used in conjunction with anti-icing. For example, Roadway Weather Information Systems (RWIS) could be used to predict storm events for effective planning.

Once applied, the chemical remains on the pavement, and will work for the next storm event. Even if traditional deicers such as rock salt and brine were used with an anti-icing strategy, reports have documented decreased use around 30 percent (Blackburn, 1994). The obvious short-term savings of material cost and vehicle operating expenses are complemented by the long-term effect of reducing salt (chloride) exposure to bridges and the surrounding environment. Furthermore, surface water quality standards are becoming more stringent, with chloride ions recognized as damaging to the ecosystem.

In contrast to anti-icing operations, traditional snow and ice control practice is to wait until an inch or more of the snow accumulates on the pavement before beginning to plow and treat the highway with chemicals or abrasives. A compacted snow layer is formed that is tightly bonded to the pavement surface. A subsequent deicing of the pavement is then necessary, usually requiring a large quantity of chemical to work its way through the pack to reach the pavement and destroy or weaken the bond. Although requiring less information and training than for anti-icing, deicing may provide less safety as a result of the inherent delay. In spite of this, deicing will remain important in snow and ice control for lower priority service levels.

Prewetting of deicing salt stockpiles is sometimes done to prevent clumping during truck loading and deicing operations. Using ABP's for prewetting has been shown to have an additional benefit by causing deicing chemicals and abrasives to adhere to the pavement surface. In addition, the prewetted rock salt begins to melt the precipitation immediately.

Level of Service (LOS)

Michigan's system of state highways, county roads and municipal streets totals 119,929 miles. As of 2000, MDOT had jurisdiction over the 9,704 route mile state highway system, which includes all "I," "U.S.," and "M" numbered highways. Michigan's 89,488 miles of county roads are under the jurisdiction of 83 county road commissions and its 20,737 miles of municipal streets are owned by 533 incorporated cities and villages (MDOT, 2002). It is estimated that more than 50 percent of the total vehicle miles traveled in the state are across state-maintained roads (D'Itri, 1992).

Each MDOT Region determines the extent to which maintenance services will be provided to a roadway section in its jurisdiction. This is accomplished by the assignment of a level of service (LOS) goal. LOS will largely be determined by the importance of the roadway, and other factors including the average daily traffic (ADT). During winter storms, Michigan follows a three-level system based on traffic volumes, described below (Source: SW Region Maintenance).

> Category 1. "Green" roads, which have high traffic volumes (more than 5,000 ADT), receive continuous plowing and salting until the storm is over.
>
> Category 2. "Yellow" roads, with moderate traffic volumes (2,500 to 5,000 ADT), are plowed and salted sufficiently to keep the middle eight feet in a reasonably bare, wet condition. A bare condition is obtained during the next regular working day.
>
> Category 3. "Red" roads, or low traffic volume roads (less than 2,500 ADT), are plowed during the winter storm. Sand is applied to hills, curves, and intersections. After the storm, during the next regular working day, salt is applied to these roads to remove the ice pack and bring the pavement to a bare condition.

At times a storm's severity can surpass MDOT's ability to meet LOS goals. At those times the roadway condition can be lower than the LOS goal established. During these times all available resources are utilized both during and after the storm event to reach established goals.

Concrete Scaling and Metal Corrosion

One of the main indirect costs of traditional deicing chemicals is their corrosive effect on metals. To minimize this damage, Washington State Department of Transportation (WSDOT) and the Pacific Northwest Snowfighters (PNS) Association (http://www.wsdot.wa.gov/fossc/maint/pns/), require the use of corrosion inhibiting deicers, or those that contain a corrosion-inhibiting admixture. An anti-icing chemical can be considered corrosion inhibiting if it is at most 30 percent the corrosion value of salt, as evaluated by NACE standard TM-01-69 (1976 rev.), as modified by

PNS. The evaluation consists of subjecting steel washers to different solutions, including a control specimen of salt solution and distilled water for the 'blank'. Once the steel corrosion rates are calculated, they are blank corrected by subtracting out the corrosion rate for distilled water. Then the results are normalized to the salt corrosion rate. This results in an effectiveness percentage factor, which is used in calculating the final bid factor.

The WSDOT test ranked the relative corrosiveness of several common solid deicers, summarized in Table 1. Although Calcium Magnesium Acetate (CMA) is only 8 percent as corrosive as salt, it is approximately 20 times more expensive, at $600/ton.

Table 1. Relative Corrosiveness of Selected Deicing Agents

Chemical	**Relative Corrosiveness**	**Relative Cost Per Ton F.O.B.**
Calcium Chloride	120	12 (50 lb. bags)
Sodium Chloride (rock salt)	100	1.0 (bulk ton)
Magnesium Chloride	80	15 (50 lb. bags)
Water	10	---
CMA	8	20 (50 lb. bags)

Several liquid anti-icing compounds were tested by WSDOT, summarized in Table 2. All chemicals were tested as a 3 percent solution, representing a typical field concentration when applied to roadways. The corrosion rate was based on mass loss of steel coupons. For the 2000-2001 winter, several bidders for the MDOT SW Region contract had submitted test results for corrosion rates. These values are also included in the table. As can be seen, all submitted products for the SW Region for the 2000-2001 winter season were below the recommended relative corrosiveness value of 30.

Table 2. Comparative Corrosion Rates for Selected ABP's.

Chemical	**Corrosion Rate, mils per year**	**Relative Corrosiveness**
Sodium Chloride	52.94	100
Magnesium Chloride, $MgCl_2$, 30% (uninhibited)	17.44	33
Magnesium Chloride, $MgCl_2$, 30% (inhibited)	11.08	21
Distilled Water	3.82	7.2
Ice Ban	3.71	7.0
Ice Ban Magic (mixed 1:1 with $MgCl_2$ solution)	2.98	5.6
Source: Minnesota Corn Processors		

Chemical	Corrosion Rate, mils per year	Relative Corrosiveness
From 2000-2001 SW Region bids:		
Ice Beeter M-50 (mixed 1:1 with $MgCl_2$ solution)	3.11	5.9
Caliber M-1000 (mixed 1:9 with $MgCl_2$ solution)	11.81	22
Ice Ban M-80 (mixed 1:4 with $MgCl_2$ solution)	1.85	3.5
First Down! (mono and dicarboxylic acid salts + aldosides, mixed 1:1 with water)	1.61	3.0
Ice Ban CM-80 (mixed 1:4 with $CaCl_2$ solution)	4.79	9.0
Ice Ban CM-93 (mixed 7:93 with $CaCl_2$ solution)	9.63	18

Concrete scaling and asphalt stripping were investigated by the Highway Innovative Technology Evaluation Center (HITEC) as the use of magnesium chloride based anti-icing chemicals gained widespread use. Concrete scaling is the deterioration of concrete subjected to freeze-thaw cycling in the presence of moisture. It is caused by hydraulic stresses resulting from expansion in volume of water when it freezes. Chlorides in deicing salts can significantly increase concrete scaling, possibly due to increased osmotic pressure in addition to expansion of freezing water, and/or when dissolved salts recrystallize in the concrete pores. The relative effects of Ice Ban and six other deicing agents were evaluated at the FHWA Turner-Fairbank Laboratory, using ASTM C672. Results indicated that magnesium chloride and Ice Ban exhibited negligible scaling after 259 freeze-thaw cycles. Calcium chloride solutions, however, were 2.5 times more detrimental than salt (Croteau, 1999). Prior MDOT experience with calcium chloride brines indicated premature scaling of concrete, which led to initial exclusion of calcium chloride-based anti-icing compounds in the pilot program. At present, more research is needed on calcium chloride-based ABP's, but they are no longer excluded from consideration.

Asphalt pavement stripping was investigated, and again magnesium chloride-based ABP's had the least effect on bituminous pavements (Croteau, 1999). In fact, the product appeared to protect the asphalt from moisture-induced damage.

ABP effects on motor vehicles were investigated, including pavement friction. Results from Nebraska tests indicate that the skid resistance after application at 42 gallons per lane-mile was identical to wet pavement skid resistance (Croteau, 1999). Further, the dried residue was comparable to dry pavement friction values. The results of MDOT friction testing in February 2002 indicated a drop in pavement friction values of 7 percent immediately after applying anti-icing liquids, but the short-term reduction in friction values was not a safety concern (MDOT, 2002). The anti-icing liquid application rate for this test was 20 gallons per lane-mile.

Winter maintenance equipment was visually evaluated, including truck bodies and augers, and found to be relatively un corroded (Croteau, 1999). Rock salt prewet with ABP's had significantly reduced corrosion damage compared to untreated rock salt, which supported laboratory tests that indicated the corrosion rate was only a fraction of that from untreated rock salt use.

Windshield smearing was investigated, and no smearing was detected from dried ABP residue (Croteau, 1999).

<u>Operating Characteristics and Limitations</u>

Anti-icing application will vary with climatic conditions. Some of the more important variables are discussed in *PROACTIVE GUIDE TO SNOW AND ICE CONTROL: A Guide for Highway Winter Maintenance Personnel* (Keep, 2000):

> 'Pavement surface temperature directly influences the formation, development, and ultimately the breaking of a bond between fallen or compacted precipitation and the road surface. It also determines the required application rates of any chemical treatments to achieve desired results. Unless some external source of heat or cold is present, the pavement temperature will generally follow changes in air temperature. How quickly surface temperatures and road temperatures equalize . . . is determined by many factors. For road sections without obstructions to a clear sky view, solar radiation during the day enhances roadway warming and exposure to the clear night sky in most cases accelerates cooling when compared to sheltered areas.'
>
> 'Another important climatic factor is the type and rate of precipitation either falling or expected. Together with pavement temperature, type and rate of precipitation are important variables to consider when performing winter operations.'(Keep, pg. 5)

Although rock salt or prewetted salt can be used for anti-icing, predominant practice is to use ABP's in liquid form. A Strategic Highway Research Program (SHRP) report concluded that liquids appear to be more effective than dry chemicals for anti-icing (Alger et.al., 1994). These liquids are composed of approximately 30 weight percent of alkali salts, whereby the chemical acts as a freezing point depressant. The freezing point of the resulting solution is called the eutectic temperature. As the percentage of active ingredient changes, the eutectic temperature of the solution changes. In other words, as the applied chemical is diluted by snow melt, the freezing point of the liquid rises, until it reaches the pavement temperature and stops working.

When the air temperature is equal to the dew point, water will condense on a surface. If the air and/or ground temperature are below freezing, the moisture becomes frost or even black ice.

Also, humidity influences some aspects of anti-icing chemical performance. Early reports of accidents attributed to reduced road surface traction from application of anti-icing materials led to a study being performed to investigate 'slipperiness' (Leggett, 1999). The number of reported incidents is small, less than 1/1000th of 1 percent of all liquid anti-icing treatments. Reabsorption of water from the air will occur with hygroscopic compounds as the relative humidity increases. The initial transition from solid to liquid involves an intermediate state where the material is in a slurry form. The study investigated this very temporary effect (less than one second in duration) on reducing friction on the surface of a glass plate, making the surface more slippery. Overall, the primary environmental factor influencing the potential for ‘slipperiness’ was determined to be relative humidity (Leggett, 1999). The report concluded that inexperience with anti-icing erroneously led to attributing accidents to slippery roads as a direct consequence of application (Leggett, 1999). This may be due to the perception that spraying a compound in liquid form on snowy roads alarmed drivers, who expected the liquid to immediately freeze over. Most ABP’s applied to road surfaces give friction values similar to, or greater than, wet pavement. However, most incidents of ‘slipperiness’ were reported in the fall season, where humidity levels are low (50 percent or less) and temperatures are near freezing (around 40° F), and on bridge decks. Most of the reported incidents also had a two-week period between the last rainfall and application of anti-icing compound, thus indicating build-up of road grime and dirt. Excess application rates may have been a contributing factor; accordingly the fall application should be less than the typical winter application rate. A rule of thumb is to stop anti-icing liquid application when the temperature difference between air and dew point is three degrees (°F) or less.

The Federal Highway Administration (FHWA) published a report entitled “Manual of Practice for an Effective Anti-icing Program: A Guide for Highway Winter Maintenance Personnel.” In the report, guidelines are given for anti-icing applications. The overall anti-icing strategy is organized into three ‘toolboxes’: operations, decision-making, and personnel. The operations toolbox lists equipment available for applying solid and liquid chemicals, prewetted salt or sand, and plowing. The decision-making toolbox describes what is needed for good practice, namely weather forecasting, road conditions, RWIS, patrols giving localized conditions, and tools to evaluate treatment effectiveness. The personnel toolbox is made up of staff trained in anti-icing, and how to use decision tools properly, and the on-call/standby procedures.

Application rates will vary, but for many conditions, applying enough liquid to leave the surface damp is sufficient. FHWA application rate guidelines are included in the Appendix. By using the guidelines, an agency can develop its own application rate table specifically developed for local conditions. For example, if a light snow storm is predicted with temperatures in the 25-32 °F range, the initial dry chemical application rate is given at 100 lb./lane-mile. If a liquid product is 30 percent by weight magnesium chloride, and weighs 10 lb./gallon, then the dry chemical content is 10 lb./gallon × 0.30, or 3.0 lb./gallon dry chemical. Therefore, (100 lb./lane-mile)/(3.0 lb./gallon), or 33 gallons/lane-mile would be the appropriate application rate.

It is important to ensure that equipment being used to deliver the chemicals is calibrated before winter operations begin. Quality control is also important; specific gravity is often used to confirm active ingredients are in the proper concentration. MDOT has a procedure for verifying lot to lot consistency, contained in the contract specification (Appendix B).

Pilot Program, Southwest Region

Beginning in 1998, the Southwest (SW) Region studied the feasability of using ABP’s for anti-icing. A letter recommending the use of ABP’s was sent by Construction and Technology (C&T)

Division in December 1998, in response to ABP's that had been evaluated by the New Materials Committee. Due to reports of increased benefit of corrosion inhibitors added to ABP's, however, their effect on highway structures and appurtenances became a desired study objective for the Structural Research Unit. Growing media attention spurred by positive reports also encouraged development of anti-icing methods in Michigan.

A joint cooperative effort was made between the SW Region and C & T, to track, document, and improve the anti-icing process that had already been in use that winter. C & T would provide technical resources, specification guidelines, and evaluation of ABP usage.

A meeting was held to discuss and share information related to anti-icing methodology. Members of the Research Advisory Panel (RAP) attended, representing several Regions. The SW Region, having experimented with anti-icing in 1998, had decided that it had merit, and expanded the test locations to encompass more miles of interstate freeway. This meant acquisition of new equipment, proper storage facilities, and providing a specification for the materials. For application of the liquid chemicals, liquid spreader tanker trucks were used; they were designed to work over two lanes, to effect one pass per route. See Figure 2.

Figure 2. Anti-icing Truck

1999-2000 winter season

The product specification sheet for anti-icing compounds used during the 1999-2000 winter season was a one page description of magnesium chloride-based ABP's. The requirements listed specific gravity of 1.24 ± 0.02, total dissolved solids $\leq$ 41%, and 'the ABP must perform at temperatures lower than -35 (°F or °C).' For quality control, the certified weight slip was to be compared to the gallons delivered multiplied by specific gravity.

The first delivery of the product, Mountain Products M50 Road Deicer, was for 4,550 gallons to the Niles garage, with unit pricing at $1.12/gallon.

The first trials were conducted along portions of US-31 and US-12 in Berrien County, with anti-icing liquid application rates applied in the test section at 40 gallons per lane-mile. Both test sections and control sections covered thirty-two lane-miles, with the control section using the rock salt only. Early results indicated some success, with anti-icing material cost savings averaging $2.58 per lane-mile. Table 3 summarizes anti-icing and deicing use by date for each major route. Data were extracted from TAPER (Temperature, Application rate, Product used, storm Event, Results) logs.

Table 3. Cost Summary, Anti-icing Pilot Program, SW Region, 1999-2000 Winter.

US-31	Southbound - Test Section		Northbound - Control Section	Cost Per Lane-Mile ($)	
Application Dates	Total Gallons anti-icing	Total Tons rock salt	Total Tons rock salt	Test	Control
11/29/99	200	0	0	$7.00	$0.00
12/15-17/99	0	28	34	$21.88	$26.56
12/20-24/99	300	50	78	$49.56	$60.94
12/27-29/99	900	42	35	$64.31	$27.34
1/16-19/00	800	26	45	$48.31	$35.16
1/19-24/00	1,100	47	76	$75.22	$59.38
1/25-28/00	1,100	17	67	$51.78	$52.34
1/28-2/14/00	1,050	71	110	$92.22	$85.94
2/17-19/00	1,000	44	91	$69.38	$71.09
US-12 - includes nb and sb routes, no control section.					
12/20-21/99	50	4	--	$4.88	$0.00
1/19-24/00	700	49	--	$62.78	$0.00
Totals	7,200	378	536	$49.76 (avg.)	$52.34 (avg.)

Another important benefit realized was a 28 percent reduction in salt use, with 388 total tons of salt (including 10 tons of salt as liquid) deposited on the test section, compared to 536 total tons of salt deposited on the control section for the season.

After initial review of the anti-icing experience, a consultant was called in to familiarize crews with the methodology and limitations of anti-icing. The consultant, Mr. Dale Keep of Ice and Snow Technologies LLB, is a recognized expert in anti-icing. Formerly with Washington State DOT, he had pioneered the early anti-icing work, and had been instrumental in developing specifications for ABP liquids. He was also involved in forming the Pacific Northwest Snowfighters (PNS) Association.

Mr. Keep conducted the training seminar on November 14, 2000, at the SW Region office to introduce SW Region staff to anti-icing practice and limitations. About 50 people were in attendance, including snowplow operators and garage superintendents. The emphasis was on recognizing anti-icing as another tool in the toolbox, rather than a one-size-fits-all application. Limitations were discussed, typical misuse of deicing and anti-icing practices were mentioned, and the importance of maintaining accurate TAPER logs was emphasized. According to Mr. Keep, once these limitations are acknowledged, anti-icing becomes successful.

2000-2001 winter season

For the 2000-2001 winter season, a contract specification was developed to assist the SW Region in assuring quality control of products used for anti-icing. In the specification the material requirements are listed, as well as delivery and bid price adjustments. At first only magnesium chloride ABP's were being considered for use. Due to the large number of ABP's submitted with varying chemical formulations, however, subcategories were created within the specification. All bidders were required to submit samples for testing. These samples were sent to an independent lab to screen for compliance with material specifications. Those that did not pass the requirements were immediately disqualified. The screened products were then evaluated based on a best buy factor, which incorporated price adjustments for chemical composition and corrosion inhibiting factors. The winning bid had a price of $0.69 per gallon. However, early in the season, the supplier that initially won the bid was terminated for noncompliance, and the next supplier was chosen. Such factors as: insufficient quantities delivered, more than two days between deliveries with no responsive communication, and material quality issues, led to the dismissal.

After supply issues were resolved, the maintenance garages proceeded with applying the anti-icing compound to designated test sections. However, delays in acquiring tanker equipment prevented application in early-mid December of 2000. Six garages were designated with test and control sections, summarized in Table 4, with the scope greatly expanded as compared to 1999-2000. As can be seen, three garages had no control section specified.

Table 4. 2000-2001 Anti-icing areas of responsibility

Maintenance Garage	Test Section	Control Section (no anti-icing)
Coloma	—	I-94 snow routes
Kalamazoo	I-94 - 92 to 60 mile marker	US-131 - Stadium Drive (BL-94) south to Centre Avenue
Marshall	I-94 - Jackson County Line to 110 mile marker	I-94 - 110 to 92 mile marker (Kalamazoo/Calhoun county line)
Niles	US-31 - Indiana State Line to Whalton Road; US-12 - M-60 interchange west to Redbud Trail	US-31 - Whalton Road, north 8 miles
Paw Paw Central Repair Facility	I-94 - 60 to 23 mile marker	—
Sawyer	I-94 - 23 mile marker to Indiana State Line	—

The total amount of anti-icing liquids purchased went from a total of 7,200 gallons in 1999-2000 to more than 200,000 gallons (33,000 gallons per garage) in 2000-2001. Costs per garage averaged out to $0.87 per gallon with the new supplier.

User delay costs were analyzed as speed is reduced from 70 mph due to snow and/or ice. Although user delay cost studies are associated with construction projects, the same approach was used to estimate impact of weather delays. User cost analysis software, titled Construction Congestion Cost (CO3) is used by MDOT for pavement life cycle cost analysis. It is based on user cost analysis recommended by the FHWA (Walls & Smith, 1998), and was developed by the University of Michigan. User costs are computed by multiplying the quantity of additional Vehicle Operating Costs (VOC), delay, and number of crashes by the unit cost rates of each component.

As can be seen below in Figure 3, I-94 user delay costs approach $200 per hour per mile (phpm) as speeds are reduced due to weather conditions. Reduction in work zone traffic capacity of up to 19 percent due to snow can be expected (Taehyung, 2001). Therefore, 19 percent of the delay cost can be approximated as cost due to snow and/or ice. The costs due to snow and/or ice can approach $38 phpm. If anti-icing liquid is applied at 25 gallons per lane-mile (gplm), at a cost of $22, the user delay costs would help to justify their use (in addition to safety benefits, discussed later).

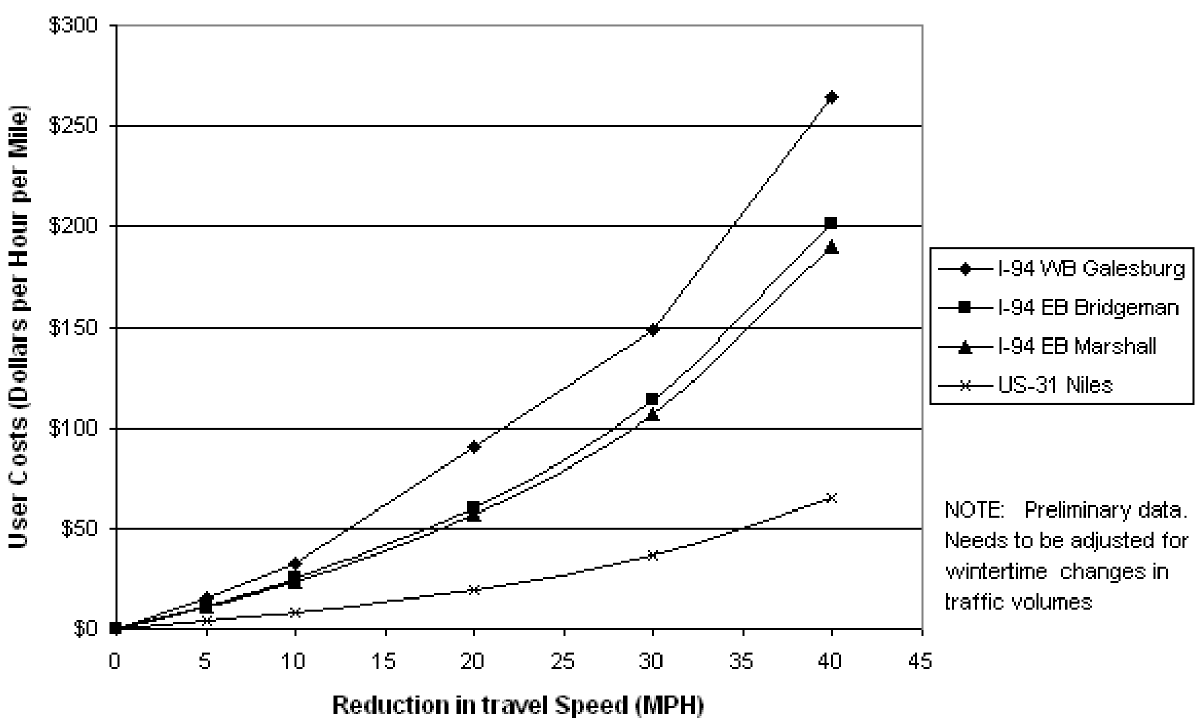


Figure 3. User Delay Costs

The material costs for deicing and anti-icing materials were compared. Refer to Table 5.

Table 5. Cost Summary, Anti-icing Pilot Program, SW Region, 2000-2001 Winter.

Garage	Total Tons Salt	Total Gallons Anti-Icing	Lane-miles Control Section	Lane-miles Test Section	Total number of applications 2000-2001	Material Cost per lane-mile per application ($)
Coloma	1372	0	195	0	99	$1.78
Marshall	2048	21609	72	124	216	$1.65
Niles	1493	11506	32	64	313	$1.58
Paw Paw	0	35015	0	168	6	$30.22
Sawyer	4086	16340	0	138	258	$3.27
Kalamazoo	2582	18060	24	192	252	$1.47

As can be seen, the Paw Paw garage had the highest cost per lane-mile, at $30.22. The reason is that the anti-icing liquid was used for deicing, which can drive up the cost considerably. Application rates would need to be at least 35 gplm for liquids to perform as deicers, to penetrate the snow and ice pack and loosen the bond to the pavement. Anti-icing application rates, however, were in the 20-25 gplm range - a difference of up to $13/lane-mile. From a material cost standpoint, using prewetted rock salt would be a better choice for deicing ($4.75/lane-mile).

Out of a total of 735 individual TAPER log summaries, 636 (87 percent) indicated total quantities of salt/sand/ABP used. The logs did not indicate which portion was test section, and which was control section; in fact, three garages did not have designated control sections. The control sections (no ABP used) amounted to only 14 percent of the total lane-miles treated. Therefore it will not be possible to determine the overall reduction in rock salt use, an important criterion for cost-effectiveness.

Although application locations were not explicitly stated on the TAPER logs, after review of summarized data, certain applications of both rock salt and ABP liquid occurred on the same days. Refer to Table 6.

Table 6. Excerpted data from Marshall Garage TAPER logs, 2000-2001 winter season.

Date of Application	Salt (tons)	ABP (gal)	Material Cost per LM ($) Control Section	Material Cost per LM ($) Test Section
12/15/00	13.5	2840	$5.62	$19.24
1/4/01	41	2944	$16.62	$19.94
1/26/01	124	3018	$50.27	$20.44
2/1/01	58	2500	$23.51	$16.94

When anti-icing liquids were used, the cost decreased overall by $4.87 per lane-mile for the same LOS. This was an improvement over the last winter's $2.58 per lane-mile cost savings, based on material use.

Customer complaints about an unpleasant odor when sprayed on their vehicles had arisen the previous season, and one in particular had noticed a very bad burning smell emanating from the engine compartment. This resulted in a minor change to the specifications, as well as a change in the application method for the tanker sprayer trucks. Currently, one lane is sprayed at a time to prevent spraying anti-icing liquid onto passing vehicles.

2001-2002 winter season

The 2001-2002 winter season saw expanded use of anti-icing liquids as compared to previous years. However, the winter season was milder than expected, leading to a surplus of anti-icing liquids at seasons' end. Out of 78,000 gallons purchased, 60,800 were used. The remainder is stored at the Paw Paw Central Repair facility. Table 7 summarizes material use and cost.

Table 7. Cost Summary, Anti-icing Pilot Program, SW Region, 2001-2002 Winter

Material Cost:	Salt ($/ton) $30.00	Liquid ($/gal) $0.84			
Garage	**Pretreated Salt (tons)**	**Anti-icing (gal)**	**Lane-miles**	**$/Lane-mile**	**$/Lane-mile, with 400 lb salt app rate**
Coloma	1522	0	10877	$4.20	$6.72
Kalamazoo	814	6000	7115	$4.14	$6.20
Marshall	1487	1700	11627	$3.96	$6.26
Niles	659	5200	4706	$5.13	$7.65
Paw Paw	0	5455	218	$21.00	n/a
Sawyer	1506	42452	11435	$7.07	$9.44
Total All Materials	5987	60807			
Total Cost, $	**$179,624.70**	**$51,077.88**			

The Coloma, Kalamazoo, and Marshall garages are located along roughly the same latitude, and cover I-94 snow routes. By comparing these three, the cost difference was slight, at most $0.24/lane-mile when using anti-icing versus deicing alone. However, the rock salt was treated with Caliber M-2000, at 8 gallons per ton. This resulted in rock salt application rates being lowered from 400 to 250 lb./lane-mile, a decrease in rock salt use of 38 percent. So even with prewetted rock salt, using anti-icing in addition to deicing leads to reduced cost per lane-mile when comparing to similar geographic locations. Had the application rates for rock salt been similar to last years' (400 lbs./lane-mile), the price difference would have been closer to $0.50/lane-mile, in favor of anti-icing. Cost savings for prewetted salt equaled $1.69/lane-mile, taking into account the additional cost of 8 gallons per ton prewetting.

Abrasives (sand) were substituted with prewetted rock salt for use as traction control in 2001-2002. Table 8 summarizes the sand use reduction as compared to last season (source: SW Region Maintenance).

Table 8. Abrasives use 2000-2002.

Winter Season	Sand use, Tons
2000-2001	8906.5
2001-2002	1971.0
Percent Reduction in use	77.9

Although not specifically tracked, the three-fourths reduction in sand use will save cleanup costs, and possible environmental impacts are reduced, as less sand will be pumped from catch basins.

An important benefit to anti-icing is related to response time. Generally, when a storm hits, the crews are called in and the trucks loaded up, and they are sent out to their respective routes. This can take up to an hour and a half. During that time, significant precipitation can develop on the roadway. With anti-icing, the roads had remained clear for over an hour after the storm event had begun, allowing the trucks to get out on the roads (source: SW Region Maintenance).

Climatological data is available for this region, summarizing storm events per county over the last several years. This way a more detailed comparison can be made to evaluate accident data. See Table 9.

Table 9. Summary of storm events by county, from 1995-2001.

County	Storm Events 1995-6	Storm Events 1996-7	Storm Events 1997-8	Storm Events 1998-9	Storm Events 1999-2000	Storm Events 2000-01
Allegan	5	8	14	12	5	9
Barry	3	2	9	11	1	4
*Berrien	4	6	10	1	2	2
Branch	3	2	7	1	0	2
*Calhoun	3	2	10	8	0	4
Cass	4	4	10	1	1	2
*Kalamazoo	4	3	9	10	1	4
St. Joseph	3	2	5	1	0	3
*Van Buren	5	7	12	12	4	8
Totals	34	36	86	57	14	38
Total (*)	16	18	41	31	7	18

* I-94 passes through these counties
Source: The National Oceanic and Atmospheric Administration (NOAA)

Accident statistics were summarized along portions of I-94, encompassing the periods before and during the anti-icing pilot program. Anti-icing did not start on I-94 until the 2000-2001 winter season. For the four counties that I-94 passes through, a comparison of the accident data from winter seasons with similar number of storm events (1995-6, 1996-7, and 2000-01) show a marked reduction in the number of wintertime accidents (icy, slushy, snowy).

In order to determine a statistically significant correlation between number of storm events and number of accidents, a linear regression analysis was done. The linear regression analysis attempts to fit a linear model to describe the relationship between the two sets of data. If the P-value is less than 0.05 (95 % confidence interval), this is an indicator that there is a statistically significant relationship between the number of storm events and the number of accidents. The R-squared coefficient indicates the fitness of the model to describe the variability of the independent variable (in this case, the # of storm events each winter).

Linear regression analysis was computed for two cases; one including the winter season with anti-icing, and one without. The purpose was to determine what effect anti-icing had on the linear regression modeling. If the included data still revealed a strong correlation, then the reduced accident rates would probably not be related to anti-icing. However, if the correlation was weak, this case would show that the anti-icing season was an outlier, and that anti-icing did directly influence the accident rate. Table 10 summarizes the statistical data for both cases.

Table 10. Statistical analysis of I-94 winter accidents (snowy, icy, slushy) from 1995-2001.

I-94 Test Section: From Indiana State Line to Old US-27 at Marshall				
Winter Season	**# Accidents (Icy, Slushy, Snowy)**	**Statistical Parameter**	**Case 1: Anti-icing included in analysis**	**Case 2: Anti-icing not included in analysis**
1995-1996	867	Linear Model	$D = 961-13.85 \times I$	$D = 1185-19.65 \times I$
1996-1997	812			
1997-1998	349	P-Value	0.23	0.01
1998-1999	629			
		R-squared	0.2473	0.9621
2000-2001*	430			
		Relationship	Weak	Very Strong
2001-2002	N/A			

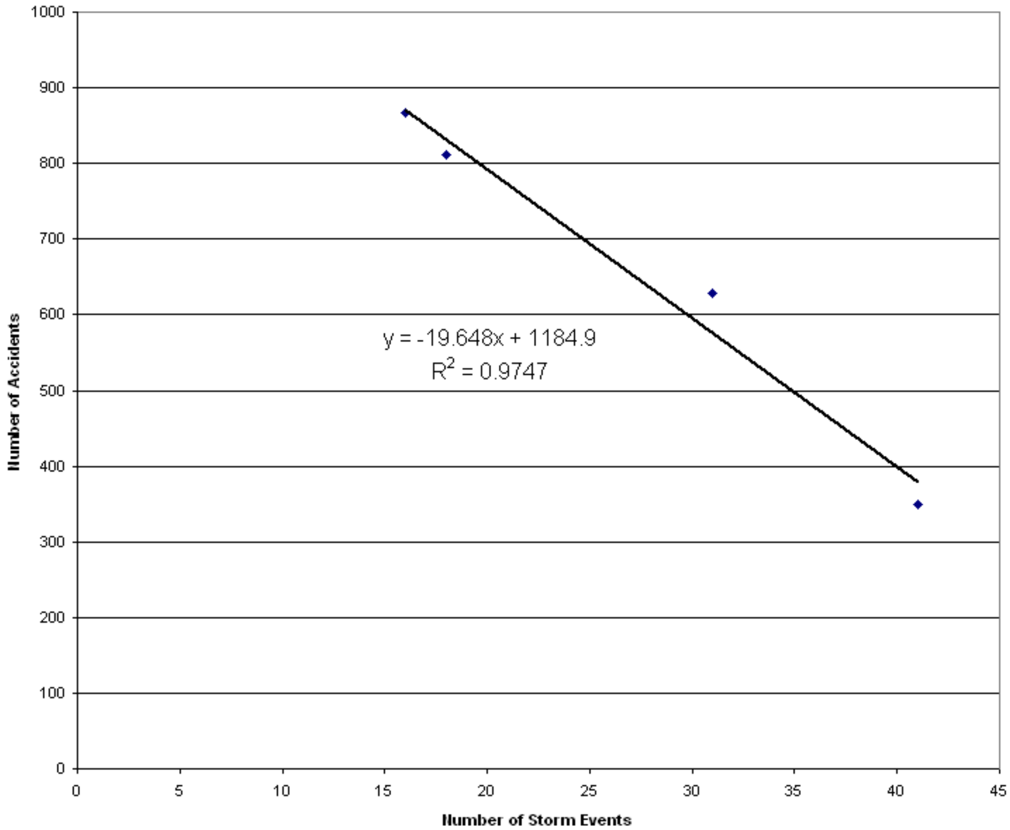
* = start of anti-icing on I-94

D = Dependent variable, the # of accidents

I = Independent variable, the # of storm events

Based on the statistical analysis for Case 2, there should have been approximately 831 accidents for the 2000-2001 winter. Since there were only 430, this indicated that anti-icing did have an effect in reducing the accident rate. It should be noted that the winter of 1999-2000 was not included in either case for the final analysis, due to the limited number (7) of storm events; the model is not extrapolated below 16 storm events. Figure 4 shows the linear regression model of

Figure 4. Linear Regression Model, Case 2.



Case 2. Although this model seems to defy convention, other studies have confirmed a similar trend of fewer accidents with increasing exposure time to snow and ice (Blackburn).

Conclusions

To maintain the desired LOS, repeat passes were necessary for both anti-icing compounds and deicing compounds. In most cases, the anti-icing compounds were applied before the onset of precipitation, and the deicing salts applied after accumulation on the roadway surface had occurred. Application rates for anti-icing were initially 35 gallons per lane-mile. Furthermore, inexperience with anti-icing compounds in 1999-2000, from the appearance of treated roadways, led to application of rock salt immediately following liquid placement. The dark colored appearance of applied ABP on the highway was mistaken for black ice, because of the dark brown color.

As more experience was gained, anti-icing methods became more efficient. Application rates for anti-icing lowered to 25 gallons per lane-mile. For the 2000-2001 winter, the ABP used was a clear color, and thus the appearance as sprayed on the roadway did not resemble black ice and therefore prevented unnecessary applications. Responding to customer concerns, the SW Region also changed the liquid spray application from two lanes to one lane per pass, to avoid spraying passing vehicles.

Preliminary cost-benefit results show a trend in reduced cost per lane-mile, based on materials alone. A summary of the last three seasons is presented in Table 11.

Table 11. Summary of cost savings and reduction in salt use.

Winter Season	Cost Savings per lane-mile (excluding Paw Paw Central Repair Facility)	% Reduction in rock salt use
1999-2000	$2.58	28
2000-2001	$4.87	N/A
2001-2002	$0.20	38

The largest material cost savings (in certain instances) was $4.87/lane-mile. Rock salt used in 1999-2000 test sections amounted to 28 percent less than that used in control sections. For the 2001-02 season, material cost savings weren't as significant as the previous year, at most about $0.20/lane-mile. However, prewetting showed a clear advantage, reducing salt use by 38 percent, at a savings of $1.69/lane-mile. This is a reason, in part, why the anti-icing material cost savings weren't as large as the previous season.

The Paw Paw Central Repair Facility used APB's exclusively for deicing operations, at a cost of $30.22/lane-mile. The application rate of 25 gallons/lane-mile corresponded to a dry weight of 97 lb./lane-mile. Compared to the prewetted salt rate of 250 lbs./lane-mile, the environmental impact of salt is reduced 61 percent, albeit at considerable expense. However, chloride-free deicers would have cost considerably more; using CMA at 400 lb./lane-mile (application rate needs to be increased to match performance of salt) at a unit cost of $600/ton would have cost $120 per lane-mile! The pilot program serves to emphasize that ABP liquids should be used for anti-icing operations and prewetting rock salt, rather than used for deicing.

Costs for the cleanup of compacted snow and ice vary, but are reportedly reduced with anti-icing, in terms of man-hours and equipment (Boselly). Further, the corrosion inhibiting APB's reduce equipment maintenance by preventing or minimizing rusting of the truck hoppers, spinners, and other parts. Cost effectiveness of ABP's is sometimes difficult to determine, as many highly variable local costs (e.g., unit materials cost, labor rates, storage) need evaluation. Indirect costs (travel delay costs) should also be considered.

Overall highlights of the SW Region pilot program include:

- Anti-icing led to overall decreased material costs the past three winter seasons;
- Prewetting rock salt reduced its use by 28-38 percent;

- Prewetted rock salt used for traction control reduced abrasives (sand) use by 78 percent;

- Cost savings of prewetting rock salt averaged $1.69/lane-mile for materials;

- ABP liquids should be used for anti-icing and prewetting rock salt, but not for deicing;

- Anti-icing practices maintained bare pavements longer, which bought response time in storm events, up to an hour in some cases;

- Anti-icing practices in 2001-02 helped to reduce the frequency of winter accidents on I-94 as compared to previous years with similar numbers of storm events.

Anti-icing, when used properly within limitations, can be a powerful tool in providing safer roads to the traveling public at less cost. The following are recommendations for anti-icing to be adopted as a strategic tool for winter maintenance operations in Michigan, based on the benefits of using anti-icing:

- It is recommended that MDOT and local agencies responsible for winter maintenance operations on trunkline routes consider implementing anti-icing. Anti-icing is an effective tool to use for responding to higher level of service (LOS) expectations from the traveling public.

- Agencies considering implementing anti-icing should contact those agencies currently practicing anti-icing to determine how to get started: What equipment, budget, and materials are required; the process of dealing with the public; and training needs for its own agency personnel. A successful anti-icing program needs the buy-in of all participants.

- It is recommended that an anti-icing training program be developed for operators and managers of agencies conducting or considering anti-icing. The training should explain when anti-icing is appropriate, incorporate decision making scenarios, and familiarize staff with the "Manual of Practice for an Effective Anti-icing Program: A Guide for Highway Winter Maintenance Personnel" (FHWA-RD-95-202).

- It is also recommended that agencies adopt a benefit/cost methodology to formally track and document the costs and benefits of anti-icing. This can entail use of TAPER (<u>T</u>emperature, <u>A</u>pplication rate, <u>P</u>roduct used, storm <u>E</u>vent, <u>R</u>esults) logs, assignment of task-specific time sheet coding, and other means of tracking costs.

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Appendix A
Operations Guide for Maintenance Field Personnel
(Taken from Appendix C of FHWA-RD-95-202)

Operations guide for Maintenance Field Personnel

C.1 Introduction

This appendix is a guide to highway anti-icing operations for maintenance field personnel. Its purpose is to suggest maintenance actions for *preventing* the formation or development of packed and bonded snow or bonded ice during a variety of winter weather events. It is intended to complement the decision-making and management practices of a systematic anti-icing program so that roads can be efficiently maintained in the best possible condition.

The guidance is based upon the results of four years of anti-icing field testing conducted by 15 State highway agencies and supported by the Strategic Highway Research Program (SHRP) and the Federal Highway Administration (FHWA). It has been augmented with practices developed outside the U.S., where necessary, for completeness. The recommendations are subject to refinement as U.S. highway agencies gain additional experience with anti-icing operations. Final decisions for their implementation rests with management personnel.

C.2 Guidance for anti-icing operations

Guidance for anti-icing operations is presented in Tables 8 to 13 for six distinctive winter weather events. The six events are:

1. Light Snow Storm
2. Light Snow Storm with Period(s) of Moderate or Heavy Snow
3. Moderate or Heavy Snow Storm
4. Frost or Black Ice
5. Freezing Rain Storm
6. Sleet Storm

The tables suggest the appropriate maintenance action to take during an initial or subsequent (follow-up) anti-icing operation for a given precipitation or icing event. Each action is defined for a range of pavement temperatures and an associated temperature trend. For some events the operation is dependent not only on the pavement temperature and trend, but also upon the pavement surface or the traffic condition at the time of the action. Most of the maintenance actions involve the application of a chemical in either a dry solid, liquid, or prewetted solid form. Application rates ("spread rates") are given for each chemical form where appropriate. These are suggested values and should be adjusted, if necessary to achieve increased effectiveness or efficiency, for local conditions. *The rates given for liquid chemicals are the equivalent dry chemical rates*. Application rates in volumetric units such as L/lane-km (or gal/lane-mi) must be calculated from these dry chemical rates for each chemical and concentration.

Comments and notes are given in each table where appropriate to further guide the maintenance field personnel in their anti-icing operations.

C.3 Glossary of terms

Black ice. Popular term for a very thin coating of clear, bubble-free, homogeneous ice which forms on a pavement with a temperature at or slightly above 0ºC (32ºF) when the temperature of the air in contact with the ground is below the freezing-point of water and small slightly supercooled water droplets deposit on the surface and coalesce (flow together) before freezing.

Dry chemical spread rate. The chemical application rate. For solid applications it is simply the weight of the chemical applied per lane kilometer (or mile). For liquid applications it is the weight of the dry chemical in solution applied per lane kilometer (or mile).

Freezing rain. Supercooled droplets of liquid precipitation falling on a surface whose temperature is below or slightly above freezing, resulting in a hard, slick, generally thick coating of ice commonly called glaze or clear ice. Non-supercooled raindrops falling on a surface whose temperature is well below freezing will also result in glaze.

Frost. Also called hoarfrost. Ice crystals in the form of scales, needles, feathers or fans deposited on surfaces cooled by radiation or by other processes. The deposit may be composed of drops of dew frozen after deposition and of ice formed directly from water vapor at a temperature below 0ºC (32ºF) (sublimation).

Light snow. Snow falling at the rate of less than 12 mm (1/2 in) per hour; visibility is not affected adversely.

Liquid chemical. A chemical solution; the weight of the dry chemical in solution applied per lane kilometer (or mile) is the chemical application rate – the "dry chemical spread rate" – used in this appendix.

Moderate or heavy snow. Snow falling at a rate of 12 mm (1/2 in) per hour or greater; visibility may be reduced.

Sleet. A mixture of rain and of snow which has been partially melted by falling through an atmosphere with a temperature slightly above freezing.

Slush. Accumulation of snow which lies on an impervious base and is saturated with water in excess of its freely drained capacity. It will not support any weight when stepped or driven on but will "squish" until the base support is reached.

Table 8. Weather event: light snow storm.

PAVEMENT TEMPERATURE RANGE, AND TREND	INITIAL OPERATION				SUBSEQUENT OPERATIONS			COMMENTS
	pavement surface at time of initial operation	maintenance action	dry chemical spread rate, kg/lane-km (lb/lane-mi)		maintenance action	dry chemical spread rate, kg/lane-km (lb/lane-mi)		
			liquid	solid or prewetted solid		liquid	solid or prewetted solid	
Above 0°C (32°F), steady or rising	Dry, wet, slush, or light snow cover	None, see comments			None, see comments			1) Monitor pavement temperature closely for drops toward 0°C (32°F) and below 2) Treat icy patches if needed with chemical at 28 kg/lane-km (100 lb/lane-mi); plow if needed
Above 0°C (32°F), 0°C (32°F) or below is imminent;	Dry	Apply liquid or prewetted solid chemical	28 (100)	28 (100)	Plow as needed; reapply liquid or solid chemical when needed	28 (100)	28 (100)	1) Applications will need to be more frequent at lower temperatures and higher snowfall rates 2) It is not advisable to apply a liquid chemical at the indicated spread rate when the pavement
ALSO -7 to 0°C (20 to 32°F), remaining in range	Wet, slush, or light snow cover	Apply liquid or solid chemical	28 (100)	28 (100)				temperature drops below -5°C (23°F) 3) Do not apply liquid chemical onto heavy snow accumulation or packed snow
-10 to -7°C (15 to 20°F), remaining in range	Dry, wet, slush, or light snow cover	Apply prewetted solid chemical		55 (200)	Plow as needed; reapply prewetted solid chemical when needed		55 (200)	If sufficient moisture is present, solid chemical without prewetting can be applied
Below -10°C (15°F), steady or falling	Dry or light snow cover	Plow as needed			Plow as needed			1) It is not recommended that chemicals be applied in this temperature range 2) Abrasives can be applied to enhance traction

Notes

CHEMICAL APPLICATIONS. (1) Time initial and subsequent chemical applications to *prevent* deteriorating conditions or development of packed and bonded snow. (2) Apply chemical ahead of traffic rush periods occurring during storm.

PLOWING. If needed, *plow before chemical applications* so that excess snow, slush, or ice is removed and pavement is wet, slushy, or lightly snow covered when treated.

Table 9. Weather event: light snow storm with period(s) of moderate or heavy snow.

PAVEMENT TEMPERATURE RANGE, AND TREND	INITIAL OPERATION				SUBSEQUENT OPERATIONS					COMMENTS
	pavement surface at time of initial operation	maintenance action	dry chemical spread rate, kg/lane-km (lb/lane-mi)		maintenance action	dry chemical spread rate, kg/lane-km (lb/lane-mi)				
			liquid	solid or prewetted solid		liquid		solid or prewetted solid		
						light snow	**heavier snow**	**light snow**	**heavier snow**	
Above 0°C (32°F), steady or rising	Dry, wet, slush, or light snow cover	None, see comments			None, see comments					1) Monitor pavement temperature closely for drops toward 0°C (32°F) and below 2) Treat icy patches if needed with chemical at 28 kg/lane-km (100 lb/lane-mi); plow if needed
Above 0°C (32°F), 0°C (32°F) or below is imminent;	Dry	Apply liquid or prewetted solid chemical	28 (100)	28 (100)	Plow as needed; reapply liquid or solid	28 (100)	55 (200)	28 (100)	55 (200)	1) Applications will need to be more frequent at lower temperatures and higher snowfall rates 2) Do not apply liquid chemical onto
ALSO -4 to 0°C (25 to 32°F), remaining in range	Wet, slush, or light snow cover	Apply liquid or solid chemical	28 (100)	28 (100)	chemical when needed					heavy snow accumulation or packed snow 3) After heavier snow periods and during light snow fall, reduce chemical rate to 28 kg/lane-km (100 lb/lane-mi); continue to plow and apply chemicals as needed
-10 to -4°C (15 to 25°F), remaining in range	Dry, wet, slush, or light snow cover	Apply prewetted solid chemical		55 (200)	Plow as needed; reapply prewetted solid chemical when needed			55 (200)	70 (250)	1) If sufficient moisture is present, solid chemical without prewetting can be applied 2) Reduce chemical rate to 55 kg/lane-km (200 lb/lane-mi) after heavier snow periods and during light snow fall; continue to plow and apply chemicals as needed
Below -10°C (15°F), steady or falling	Dry or light snow cover	Plow as needed			Plow as needed					1) It is not recommended that chemicals be applied in this temperature range 2) Abrasives can be applied to enhance traction

Notes

CHEMICAL APPLICATIONS. (1) Time initial and subsequent chemical applications to *prevent* deteriorating conditions or development of packed and bonded snow. (2) *Anticipate increases in snowfall intensity. Apply higher rate treatments prior to or at the beginning of heavier snowfall periods to prevent development of packed and bonded snow.* (3) Apply chemical ahead of traffic rush periods occurring during storm.

PLOWING. If needed, *plow before chemical applications* so that excess snow, slush, or ice is removed and pavement is wet, slushy, or lightly snow covered when treated.

Table 10. Weather event: moderate or heavy snow storm.

PAVEMENT TEMPERATURE RANGE, AND TREND	INITIAL OPERATION				SUBSEQUENT OPERATIONS			COMMENTS
	pavement surface at time of initial operation	**maintenance action**	**dry chemical spread rate, kg/lane-km (lb/lane-mi)**		maintenance action	dry chemical spread rate, kg/lane-km (lb/lane-mi)		
			liquid	solid or prewetted solid		liquid	solid or prewetted solid	
Above 0°C (32°F), steady or rising	Dry, wet, slush, or light snow cover	None, see comments			None, see comments			1) Monitor pavement temperature closely for drops toward 0°C (32°F) and below 2) Treat icy patches if needed with chemical at 28 kg/lane-km (100 lb/lane-mi); plow if needed
Above 0°C (32°F), 0°C (32°F) or below is imminent;	Dry	Apply liquid or prewetted solid chemical	28 (100)	28 (100)	Plow accumulation and reapply liquid or solid	28 (100)	28 (100)	1) If the desired plowing/treatment frequency cannot be maintained, the spread rate can be increased to 55 kg/lane-km (200 lb/lane-mi) to accommodate longer operational cycles
ALSO **-1 to 0°C (30 to 32°F)**, remaining in range	Wet, slush, or light snow cover	Apply liquid or solid chemical	28 (100)	28 (100)	chemical as needed			2) Do not apply liquid chemical onto heavy snow accumulation or packed snow
-4 to -1°C (25 to 30°F), remaining in range	Dry	Apply liquid or prewetted solid chemical	55 (200)	42-55 (150-200)	Plow accumulation and reapply	55 (200)	55 (200)	1) If the desired plowing/treatment frequency cannot be maintained, the spread rate can be increased to 110 kg/lane-km (400 lb/lane-mi) to accommodate longer
	Wet, slush, or light snow cover	Apply liquid or solid chemical	55 (200)	42-55 (150-200)	liquid or solid chemical as needed			operational cycles 2) Do not apply liquid chemical onto heavy snow accumulation or packed snow
-10 to -4°C (15 to 25°F), remaining in range	Dry, wet, slush, or light snow cover	Apply prewetted solid chemical		55 (200)	Plow accumulation and reapply prewetted solid chemical as needed		70 (250)	1) If the desired plowing/treatment frequency cannot be maintained, the spread rate can be increased to 140 kg/lane-km (500 lb/lane-mi) to accommodate longer operational cycles 2) If sufficient moisture is present, solid chemical without prewetting can be applied
Below -10°C (15°F), steady or falling	Dry or light snow cover	Plow as needed			Plow accumulation as needed			1) It is not recommended that chemicals be applied in this temperature range 2) Abrasives can be applied to enhance traction

Notes CHEMICAL APPLICATIONS. (1) Time initial and subsequent chemical applications to *prevent* deteriorating conditions or development of packed and bonded snow -- *timing and frequency of subsequent applications will be determined primarily by plowing requirements*. (2) Apply chemical ahead of traffic rush periods occurring during storm.
PLOWING. *Plow before chemical applications* so that excess snow, slush, or ice is removed and pavement is wet, slushy, or lightly snow covered when treated.

Table 11. Weather event: frost or black ice.

PAVEMENT TEMPERATURE RANGE, TREND, AND RELATION TO DEW POINT	TRAFFIC CONDITION	INITIAL OPERATION			SUBSEQUENT OPERATIONS			COMMENTS
		maintenance action	dry chemical spread rate, kg/lane-km (lb/lane-mi)		maintenance action	dry chemical spread rate, kg/lane-km (lb/lane-mi)		
			liquid	solid or prewetted solid		liquid	solid or prewetted solid	
Above 0°C (32°F), steady or rising	Any level	None, see comments			None, see comments			Monitor pavement temperature closely; begin treatment if temperature starts to fall to 0°C (32°F) or below and is at or below dew point
-2 to 2°C (28 to 35°F), remaining in range or falling to 0°C	Traffic rate less than 100 vehicles per h	Apply prewetted solid chemical		7-18 (25-65)	Reapply prewetted solid chemical as needed		7-18 (25-65)	1) Monitor pavement closely; if pavement becomes wet or if thin ice forms, reapply chemical at higher indicated rate 2) Do not apply liquid chemical on ice so thick
(32°F) or below, *and* equal to or below dew point	Traffic rate greater than 100 vehicles per h	Apply liquid or prewetted solid chemical	7-18 (25-65)	7-18 (25-65)	Reapply liquid or prewetted solid chemical as needed	11-32 (40-115)	7-18 (25-65)	that the pavement can not be seen
-7 to -2°C (20 to 28°F), remaining in range, *and* equal to or below dew point	Any level	Apply liquid or prewetted solid chemical	18-36 (65-130)	18-36 (65-130)	Reapply liquid or prewetted solid chemical when needed	18-36 (65-130)	18-36 (65-130)	1) Monitor pavement closely; if thin ice forms, reapply chemical at higher indicated rate 2) Applications will need to be more frequent at higher levels of condensation; if traffic volumes are not enough to disperse condensation, it may be necessary to increase frequency 3) It is not advisable to apply a liquid chemical at the indicated spread rate when the pavement temperature drops below -5°C (23°F)
-10 to -7°C (15 to 20°F), remaining in range, *and* equal to or below dew point	Any level	Apply prewetted solid chemical		36-55 (130-200)	Reapply prewetted solid chemical when needed		36-55 (130-200)	1) Monitor pavement closely; if thin ice forms, reapply chemical at higher indicated rate 2) Applications will need to be more frequent at higher levels of condensation; if traffic volumes are not enough to disperse condensation, it may be necessary to increase frequency
Below -10°C (15°F), steady or falling	Any level	Apply abrasives			Apply abrasives as needed			It is not recommended that chemicals be applied in this temperature range

Notes

TIMING. (1) Conduct initial operation in advance of freezing. Apply liquid chemical up to 3 h in advance. Use longer advance times in this range to effect drying when traffic volume is low. Apply prewetted solid 1 to 2 h in advance. (2) In the absence of precipitation, liquid chemical at 21 kg/lane-km (75 lb/lane-mi) has been successful in preventing bridge deck icing when placed up to 4 days before freezing on higher volume roads and 7 days before on lower volume roads.

Table 12. Weather event: freezing rain storm.

PAVEMENT TEMPERATURE RANGE, AND TREND	INITIAL OPERATION		SUBSEQUENT OPERATIONS		COMMENTS
	maintenance action	chemical spread rate, kg/lane-km (lb/lane-mi)	maintenance action	chemical spread rate, kg/lane-km (lb/lane-mi)	
Above 0°C (32°F), steady or rising	None, see comments		None, see comments		1) Monitor pavement temperature closely for drops toward 0°C (32°F) and below 2) Treat icy patches if needed with prewetted solid chemical at 21-28 kg/lane-km (75-100 lb/lane-mi)
Above 0°C (32°F), 0°C (32°F) or below is imminent	Apply prewetted solid chemical	21-28 (75-100)	Reapply prewetted solid chemical as needed	21-28 (75-100)	Monitor pavement temperature and precipitation closely
-7 to 0°C (20 to 32°F), remaining in range	Apply prewetted solid chemical	21-70 (75-250)	Reapply prewetted solid chemical as needed	21-70 (75-250)	1) Monitor pavement temperature and precipitation closely 2) Increase spread rate toward *higher indicated rate* with decrease in pavement temperature or increase in intensity of freezing rainfall 3) Decrease spread rate toward *lower indicated rate* with increase in pavement temperature or decrease in intensity of freezing rainfall
-10 to -7°C (15 to 20°F), remaining in range	Apply prewetted solid chemical	70-110 (250-400)	Reapply prewetted solid chemical as needed	70-110 (250-400)	1) Monitor precipitation closely 2) Increase spread rate toward *higher indicated rate* with increase in intensity of freezing rainfall 3) Decrease spread rate toward *lower indicated rate* with decrease in intensity of freezing rainfall
Below -10°C (15°F), steady or falling	Apply abrasives		Apply abrasives as needed		It is not recommended that chemicals be applied in this temperature range

Notes

CHEMICAL APPLICATIONS. (1) Time initial and subsequent chemical applications to *prevent* glaze ice conditions. (2) Apply chemical ahead of traffic rush periods occurring during storm.

Table 13. Weather event: sleet storm.

PAVEMENT TEMPERATURE RANGE, AND TREND	INITIAL OPERATION		SUBSEQUENT OPERATIONS		COMMENTS
	maintenance action	chemical spread rate, kg/lane-km (lb/lane-mi)	maintenance action	chemical spread rate, kg/lane-km (lb/lane-mi)	
Above 0°C (32°F), steady or rising	None, see comments		None, see comments		1) Monitor pavement temperature closely for drops toward 0°C (32°F) and below 2) Treat icy patches if needed with prewetted solid chemical at 35 kg/lane-km (125 lb/lane-mi)
Above 0°C (32°F), 0°C (32°F) or below is imminent	Apply prewetted solid chemical	35 (125)	Plow as needed, reapply prewetted solid chemical when needed	35 (125)	Monitor pavement temperature and precipitation closely
-2 to 0°C (28 to 32°F), remaining in range	Apply prewetted solid chemical	35-90 (125-325)	Plow as needed, reapply prewetted solid chemical when needed	35-90 (125-325)	1) Monitor pavement temperature and precipitation closely 2) Increase spread rate toward *higher indicated rate* with increase in sleet intensity 3) Decrease spread rate toward *lower indicated rate* with decrease in sleet intensity
-10 to -2°C (15 to 28°F), remaining in range	Apply prewetted solid chemical	70-110 (250-400)	Plow as needed, reapply prewetted solid chemical when needed	70-110 (250-400)	1) Monitor precipitation closely 2) Increase spread rate toward *higher indicated rate* with decrease in pavement temperature or increase in sleet intensity 3) Decrease spread rate toward *lower indicated rate* with increase in pavement temperature or decrease in sleet intensity
Below -10°C (15°F), steady or falling	Plow as needed		Plow as needed		1) It is not recommended that chemicals be applied in this temperature range 2) Abrasives can be applied to enhance traction

Notes

CHEMICAL APPLICATIONS. (1) Time initial and subsequent chemical applications to *prevent* the sleet from bonding to the pavement. (2) Apply chemical ahead of traffic rush periods occurring during storm.

Appendix B
Contract Specification for Southwest Region
for
2001-2002 Winter Season

MICHIGAN DEPARTMENT OF TRANSPORTATION

CONTRACT SPECIFICATION FOR
AGRICULTURAL BYPRODUCTS (ABP) FOR ANTI-ICING

C&T:SCK May 28, 2002

a. Description. Agricultural Byproducts (ABP) for anti-icing use are the concentrated liquid residues from the processing of grains and other agricultural products. They are derived from the processing of agricultural raw materials, primarily corn. The liquid residues are typically combined with 25-30 percent alkali chloride solution in a 1:1 volumetric ratio. The resulting mixture is sprayed onto roads and bridges for anti-icing use.

b. Materials. All materials shall meet the requirements as specified herein.

1. No products will be accepted that contain constituents in excess of the following established total concentration limits as tested in accordance with the methods listed in the Appendix. Test results from an independent laboratory shall be submitted. The material tested shall be of the same composition as the material submitted.

Table 1. Hazardous constituent concentration limits.

Hazardous Constituent	Maximum Concentration Limit, parts per million (ppm)
Arsenic	5.00
Barium	10.0
Cadmium	0.20
Chromium	0.50
Copper	3.00
Cyanide	0.20
Lead	1.00
Mercury	0.05
Total Phosphorus	60.0
Selenium	5.00
Zinc	15.0

2. pH - The pH of liquid chemical products shall be within the limits of 6 to 9.

3. The product shall not contain greater than 1.0% (V/V) Total Settleable Solids and shall have ninety-nine percent (99.0%) of the Solids Passing through a Number 10 sieve after being stored at -17.8° C +/- 1° C (0° F +/- 2° F) for 168 hours (Test Method Number 6).

4. The contractor shall be responsible for all clean up expenses of any product delivered and/or applied that is found to be contaminated. This includes, but is not limited to, clean up measures as needed for the following: storage facility, yard, equipment, and roadside. In addition, the contractor shall be liable, as determined by MDOT, for causing any unanticipated extraordinary damages to equipment used in the storage or distribution of the chemical products.

5. MDOT has the right to accept or reject products based upon material composition. Each product will be assessed for the potential of causing a decrease in the public safety. Acceptance or rejection of a product based on composition shall be final and in the best interest of MDOT.

6. Concentration of as delivered product ingredient(s) shall not exceed ± 1.5 % of product formulation as specified in bid form.

7. Odor/Residual Effect - The anti-icing liquid shall not have a disagreeable odor, as determined by MDOT personnel. A mild, sweet odor, typical of anti-icing products formulated with ABP's, is not cause for rejection. However, if sprayed on a hot surface, the ABP anti-icing liquid will not burn or otherwise generate disagreeable odors.

8. Mixing of different ABP formulations - The product will be examined for the formation of solids and the ability of the chemical product to maintain a non-stratified suspension without agitation, when mixed with other types of ABP residues.

9. In addition to the general specifications, the following requirements also apply to category products.

a. Liquid Magnesium Chloride with ABP

Product must contain no less than 16.0% +/- 1.5% magnesium chloride by weight as $MgCl_2$. Bid evaluations will consider only the portion that is magnesium chloride. Weight per gallon will be established according to the specific gravity and percentage of processing residue, product, and additive contained in the product bid as indicated by the bidder.

An independent certified analysis showing compliance with all the above requirements must be submitted with the bid along with an intended use statement for the product. Exceptions to the requirements must be stated and MDOT reserves the right to reject the product.

b. Liquid Calcium Chloride with ABP

Product must contain no less than 17.5% +/- 1.5% calcium chloride by weight as $CaCl_2$. Bid evaluations will consider only the portion that is calcium chloride. Weight per gallon will be established according to the specific gravity and percentage of processing residue, product, and additive contained in the product bid as indicated by the bidder.

An independent certified analysis showing compliance with all the above requirements must be submitted with the bid along with an intended use statement for the product. Exceptions to the requirements must be stated and MDOT reserves the right to reject the product.

c. Other Blended ABP formulations (generally designated as "chloride-free")

The product must contain the active ingredient(s) as specified in the bid form (Test Method Number 1). Weight per gallon will be established according to the specific gravity and percentage of processing residue, product, and additive contained in the product bid as indicated by the bidder.

3. Delivery of product

1. The bill of lading and invoice for each shipment must contain the following information:

a. Name of product.

b. Manufacturer of product.

c. Destination of delivery.

d. Total number of units being delivered.

e. Total weight of delivery (certified scale ticket).

f. Lot number of product (products) being delivered. The lot number must enable MDOT personnel to track a delivered product back to its manufacture point, date of manufacture, and specific batch.

g. Transport information. Name of transporting company, tank, trailer, or rail car number, point and date of origin.

h. Percent concentration of product ingredients, and specific gravity. The invoice must include all of the above and the following information:

1. Contract unit of measure.

2. Contract unit price for product delivered.

3. Total price for units delivered.

4. A copy of the original bill of lading.

5. Prices are F.O.B. delivered and unloaded to each drop point listed on attachment.

MDOT will not process invoices for payment until the bidder has met all requirements under this section.

2. The Contractor will be responsible for all necessary equipment to transfer liquid chemical products to MDOT storage tanks.

3. MDOT storage tanks shall be fitted with an appropriately sized male pipe fitting to allow for unloading of product.

4. One sample of the liquid product being delivered will be taken from the delivered shipment before the product is completely unloaded. A one quart sample will be taken from the transfer hose only after no less than one half of the load has been discharged, or the sample may be taken with a bailer tube.

5. Each shipment shall be accompanied by a current and clearly legible MSDS.

6. An anti-foaming agent will be available from the contractor for use as needed, at no additional charge to MDOT, to control foaming during loading, unloading, and agitation of liquid chemical products.

7. Orders may be placed by fax. The official order date shall be the date of the fax transmittal if received by the contractor before 2:00 p.m. EST and the next day if received by the contractor after 2:00 p.m. EST. The contractor shall fax back to MDOT a confirmation of receipt and an estimate of the order shipment date within 2 business hours.

8. All material is subject to inspection and analysis as delivered. No precipitate or flocculation in liquid products shall be allowed in excess of the specification limits. Material portraying these or other uncharacteristic traits when delivered may be immediately rejected at the option of MDOT or its representative at the delivery location. All products may be assessed price adjustments for late deliveries or poor quality. Any problems must be noted at the point of delivery, documented, and relayed to a supervisor for action.

9. Liquidated Damages. Deliveries shall be made during normal working hours (Monday through Friday between the hours of 8:00 A.M. and 2:30 P.M. for all time zones), unless otherwise requested or agreed to by MDOT. Two (2) days advance notification of delivery shall be given. Any deliveries made without proper advance notification or outside of the established delivery times (unless otherwise authorized in advance and in

writing) will be assessed an initial price adjustment of 25% of the purchase price of the product.

NOTE: Other charges if applicable will be adjusted when a price adjustment is taken as a reduction of purchase price.

Delivery shall be made on or within two (2) calendar days or less on all orders received by the contractor during the months of October to April and 15 calendar days or less on orders placed during other months. In the event the contractor fails to deliver within two calendar days as required, on day 3 or 16, a 25% late delivery price adjustment will be assessed. An additional 5% price adjustment per day will be assessed for each day of delay beginning with day 4 or 17 (depending on month of order) and continuing until delivery is made.

The late delivery fee assessment will be deducted from the payment of the invoice for the specific load of product not delivered according to the terms of this agreement. Consistently late deliveries may result in contract termination.

During the months of October to April, when orders larger than 10,000 gallons per location are placed, 10,000 gallons of that order must be delivered within the 2 day time period or penalties will apply. If the contractor can not deliver the entire order at once, the balance must be delivered in a minimum of 10,000 gallon quantities on daily deliveries beginning immediately after the first delivery, or as agreed to by the purchaser. This section does not prohibit delivery of an entire order at one time nor any other delivery schedule that exceeds the conditions of this specification.

10. Any assessments or deductions charged for improper notification and/or delivery will be accompanied with verification of order and delivery date.

11. Price adjustments assessed for late deliveries caused by what the contractor feels are "reasonable or uncontrollable circumstances" shall within seven (7) calendar days be addressed to the respective MDOT Region staff. The Region staff will consult their respective Engineer for a decision. The decision of the Engineer to accept or to deny the claim will be final and in the best interest of MDOT.

12. MDOT agrees to purchase a minimum of____% shown on the Category item listing. The Contractor shall agree to furnish up to a maximum of 30% more than the quantities indicated on the attached Category item listing. These percentages apply only to the Region total awarded to the Contractor, not each individual MDOT drop point within a Region that is awarded to the Contractor. Those percentages of the Region Total awarded to the Contractor may be distributed to any MDOT drop point within a certain Region that are awarded to the contractor. MDOT is not limited to these percentages per drop point.

13. The Contractor agrees that they will supply storage at no additional cost to MDOT for any portion of product less than 60% of each Category item listing. The Contractor will provide MDOT certified proof of ownership of material until such time material can be delivered to drop point(s). No additional shipping charges will be made at that time.

4. Field inspection, unloading, sampling, and testing

BEFORE ALLOWING ANY PRODUCT TO BE UNLOADED, MDOT PERSONNEL SHOULD FOLLOW THE PROCEDURES LISTED BELOW.

A. INSPECTION

1. Document and maintain records on all deliveries, including those that are rejected.

2. Check to assure that the product is being delivered according to the terms of the contract. This includes but is not limited to the following:

    a. Date of the order.
    b. Date and time of delivery.
    c. Verification of advance delivery notification.
    d. Delivered within allowable times.
    e. Name of delivery company and license plate numbers.
    f. Is any price adjustment assessments required?
    g. Is the product being delivered what you ordered?
    h. Document all procedures prior to unloading of product.
    i. Verify that all papers required of a delivery are present, complete, and legible.

3. Legible and current MSDS sheet.

4. Certified weight slip.

5. Accurate, complete, and legible bill of lading and/or invoice with the information as required in Section C, Part 1.

B. SAMPLING AND TESTING

1. One sample of all products will be taken from each load of product being delivered at the time of delivery. Clearly label samples for identification. If testing is desired, send the samples directly to a qualified Laboratory. Samples sent to the Laboratory will be tested for conformance to the specifications to insure product quality.

Be sure the chain of custody form is placed in the box and contains at least the following information: Manufacturer or contractors name, name of product, lot number of product, shipping date, date received, name of delivery point, quantity of material delivered, and name and phone number of person who received the load and took the samples. Test results from the Laboratory will be final and in the best interest of MDOT. The contractor will be notified of test results only if a problem is detected.

2. Check and record the specific gravity and pH of the samples if desired. For pH testing, use 1 part product diluted with 4 parts distilled water.

C. UNLOADING

The product must be completely formulated and mixed at the original manufacturing plant location. Post adding of corrosion inhibitors or any other ingredients (other than anti-foaming agents) and splash mixing is unacceptable after the product has left the original manufacturing plant.

1. Visually inspect the load to determine if there are any obvious reasons why the load should be rejected.

2. Note the amount of product currently in storage prior to unloading.

3. Visually inspect the delivered product again while unloading. If problems are noted that are a cause for rejection of the load, halt the unloading process. Take photos if applicable and record any pertinent information. Conduct the following procedures if the material is to be rejected:

a. If material fails initial inspection or testing reload the product and reject the load.

b. If reloading can't be done, (mixed with previous material) note the amount of product (liquid only) pumped into the tank and total product now present in the tank.

c. Circulate the tank and then pull two one-gallon (4 Liter) samples of the contaminated chemical material now in the tank

d. Check and record the specific gravity of the samples.

e. If testing is desired, send samples directly to a qualified Laboratory.

f. Immediately advise the supervisor of any ordering, delivery, storage, or product quality issues.

5. Price adjustments for deviations from specifications

Price adjustments will be assessed on product cost, excluding freight. Determination of a price adjustment to be applied will be based on MDOT testing procedures as outlined in the specification.

Field samples taken of the delivered liquid chemical products may be tested for the appropriate active ingredient concentration in percent according to Test Method 1. The test results will be compared to the bidder quoted concentration (BQC) of the chemical product. Any element or compound that is not specific to the product being bid will not count towards BQC.

Since this contract is awarded based on the lowest price per percent concentration of chemical product, a price adjustment structure is constructed to insure that the bidder quoted concentrations (BQC) are maintained. The percent values indicated below are percent concentration of total chloride. If the test results are out of specification, the contractor will be subject to a price adjustment based on the purchase price of the respective shipment as follows:

Price Adjustments for noncompliance of material to the Bidder Quoted Concentration (BQC):

BQC ± 1.5% but in no case below the stated minimum concentration limit of % total chloride (or other ingredients as applicable)--- No price adjustment.

Price adjustments for chemical products below the stated minimum concentration limit of % total chloride (or other ingredients as applicable) are as follows:

Concentration Ranges

-1.6 % to -2.0 % -- 50% Price adjustment

-2.1 % to -2.5 % -- 75% Price adjustment

> -2.5 % --- 100% Price adjustment

NOTE: In the case of a storm event, MDOT reserves the right to accept and use any concentration of product delivered and apply price adjustments as defined.

General Price Adjustments

Products which fail to meet any of the other specification requirements (outside of acceptable range), will result in a 50% price adjustment or total rejection as determined by MDOT. The contractor will be required to replace any rejected material plus any material that it contaminated at their cost. Any product that is rejected shall be removed by the contractor and replaced with product that meets the material specifications, including handling and transportation charges at no additional cost to MDOT. Removal includes the removal of all material contaminated by the non-specification material, if any. MDOT personnel will establish the amount of material contaminated. Two shipments per contract year of product found by purchaser to be beyond any acceptable range may result in contract termination.

6. Additional Requirements

NEWS RELEASES:

News releases pertaining to this CONTRACT or project to which it relates shall not be made without prior written MDOT approval, and then only in accordance with the explicit written instructions from MDOT. No results of the activities associated with this CONTRACT are to be released without prior written approval of MDOT and then only to persons designated.

CONTRACT DISTRIBUTION:

The Office of Purchasing shall retain the sole right of CONTRACT distribution to all state agencies and local units of government unless other arrangements are authorized by the purchasing office.

CONTRACT PERIOD:

This contract will be for a 1 (one) year period and will commence with the issuance of the CONTRACT(s). This will be approximately __________________through ______________. MDOT, at its option, reserves the right to negotiate an extension of the CONTRACT for up to 2 (two) additional years, in 1 (one) year increments.

DISCLOSURE:

Public Act No. 442 of 1976 known as the “Freedom of Information Act” provides for the complete disclosure of contracts and attachments hereto. Nothing in this section shall preclude the State of Michigan from disclosing information marked proprietary if the state is legally bound to do so.

TAXES:

The State of Michigan is exempt from Federal Excise Tax, State or Local Sales Tax. CONTRACT prices shall not include such taxes. Exemption Certificates for Federal excise Tax will be furnished upon request.

ASSIGNMENT:

The contractor is prohibited from assigning, transferring, conveying, subletting or otherwise disposing of any CONTRACT, of its rights, title or interest therein or its power to execute such agreement to any other person, company, corporation or entity without the previous written approval of MDOT. While MDOT may approve payment to be assigned to another party or may approve the issuance of two-party checks, MDOT assumes no liability for payment other than to the contractor.

Appendix A. Bid submittal process

1. Bids must be accompanied by two each one gallon (4 liter) containers of the product and an analysis of the supplied samples. See "Product Sample Checklist" for complete instructions as to how to provide required samples and information. All samples must be marked with an easily distinguishable name and the associated paperwork must be clearly marked as such so that the samples and the submitted product information can be easily identified and matched up. Analysis must contain the following information for each type of product being bid, except for item (a) which is optional information. Failure to comply with this section may be cause for rejection of samples.

a. Corrosion test data obtained from an independent testing laboratory according to NACE Standard TM-01-69 (1976 rev.) as modified by PNS.

b. Analytical results, including pH, from an independent testing laboratory of all constituents for which limits have been set by these specifications (See Table 1).

c. Specific gravity chart must be supplied with correlating weight percentage and freeze point information presented in 1% increments beginning with a five percent solution. The chart must contain information up to, including, and exceeding, by 5% (or the solubility limits of the product) the concentration being submitted for evaluation.

d. Physical specifications including detailed information and minimum concentration of the corrosion inhibitor used in the product (if applicable) MUST be included with the bid document. Information must be sufficient in detail to address all specification requirements. Proprietary information must be included.

2. Bids must be accompanied with the most recent detailed product specification sheet, and Material Safety Data Sheet (MSDS). All documents must be clearly legible.

3. Product samples and required documentation shall be submitted in accordance with the "Product Sample Checklist." All samples and associated documents, including a copy of the completed checklist for each sample must be clearly labeled to facilitate easy identification of samples and associated documents.

4. All samples and product information must be received in a timely manner as noted on "Product Sample Checklist." Failure to supply the required samples and requested information in this section may be cause for disqualification. These samples will be used to establish a database for future fingerprinting of all approved products when delivered to any MDOT location and for future bid comparisons. Any products purchased in the future will be expected to meet specifications as established in the bid process. All test data that is submitted with each product sample is subject to verification by one or more laboratories. Results of the testing from the laboratories shall be verifiable and final. All bids and samples shall be delivered by the time and date of the bid opening. Bids and samples that are received late will be rejected and not tested.

Mark all samples submitted to the qualified contract Laboratory in large black lettering as "BID SAMPLES-TIME CRITICAL". Bids and all bid information will be mailed to the appropriate MDOT Region office or Transportation Service Center.

PLEASE USE BLACK INK OR TYPEWRITER WHEN PREPARING YOUR BID. BE SURE YOU HAVE INSERTED YOUR COMPANY'S NAME, PHONE NUMBER, AND NAME OF CONTACT PERSON IN THE BOX AT RIGHT.	**Bidder**

Category 1 – LIQUID CALCIUM CHLORIDE - Corrosion Inhibited with Agricultural Byproduct Residue

BIDDERS MAY BID ON ONE, SOME, OR ALL CATEGORIES.

Location of Storage Facility (City, State, County): ______________________

Garage	Price Per Gallon, Delivered FOB
Kalamazoo Maintenance Garage 5673 West Main Street Kalamazoo MI 49001	
Marshall Maintenance Garage 1242 South Kalamazoo Avenue P.O. Box 47 Marshall MI 49068	
Niles Maintenance Garage 2200 US-12 East Niles MI 49120	
Paw Paw Central Repair Facility 1003 East Michigan Avenue Paw Paw MI 49079	
Plainwell Maintenance Garage 596 11th Street Plainwell MI 49080	
Sawyer Maintenance Garage 5948 Sawyer Road P.O. Box 395 Sawyer MI 49125	

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Category 2 – LIQUID MAGNESIUM CHLORIDE - Corrosion Inhibited with Agricultural Byproduct Residue

BIDDERS MAY BID ON ONE, SOME, OR ALL CATEGORIES.

Location of Storage Facility (City, State, County): ______________________________

Garage	Price Per Gallon, Delivered FOB
Kalamazoo Maintenance Garage 5673 West Main Street Kalamazoo MI 49001	
Marshall Maintenance Garage 1242 South Kalamazoo Avenue P.O. Box 47 Marshall MI 49068	
Niles Maintenance Garage 2200 US-12 East Niles MI 49120	
Paw Paw Central Repair Facility 1003 East Michigan Avenue Paw Paw MI 49079	
Plainwell Maintenance Garage 596 11th Street Plainwell MI 49080	
Sawyer Maintenance Garage 5948 Sawyer Road P.O. Box 395 Sawyer MI 49125	

PLEASE USE BLACK INK OR TYPEWRITER WHEN PREPARING YOUR BID. BE SURE YOU HAVE INSERTED YOUR COMPANY'S NAME, PHONE NUMBER, AND NAME OF CONTACT PERSON IN THE BOX AT RIGHT.	**Bidder**

Category 3 – LIQUID ANTI-ICER - Corrosion Inhibited with Agricultural Byproduct Residue

BIDDERS MAY BID ON ONE, SOME, OR ALL CATEGORIES.

Location of Storage Facility (City, State, County): ________________________________

Garage	Price Per Gallon, Delivered FOB
Kalamazoo Maintenance Garage 5673 West Main Street Kalamazoo MI 49001	
Marshall Maintenance Garage 1242 South Kalamazoo Avenue P.O. Box 47 Marshall MI 49068	
Niles Maintenance Garage 2200 US-12 East Niles MI 49120	
Paw Paw Central Repair Facility 1003 East Michigan Avenue Paw Paw MI 49079	
Plainwell Maintenance Garage 596 11th Street Plainwell MI 49080	
Sawyer Maintenance Garage 5948 Sawyer Road P.O. Box 395 Sawyer MI 49125	

PLEASE USE BLACK INK OR TYPEWRITER WHEN PREPARING YOUR BID. BE SURE YOU HAVE INSERTED YOUR COMPANY'S NAME, PHONE NUMBER, AND NAME OF CONTACT PERSON IN THE BOX AT RIGHT.	Bidder

PRODUCT SAMPLE CHECKLIST

FILL IN BLANKS WITH YES, NO, OR WHAT IS APPROPRIATE. IF SOMETHING DOES NOT APPLY, USE N/A. DO NOT LEAVE BLANKS. BLANKS WILL BE CONSIDERED MISSED INFORMATION AND WILL BE CAUSE FOR REJECTION. TYPE OR PRINT CLEARLY IN INK. ALL DOCUMENTS MUST BE CLEAR AND LEGIBLE. IF UNREADABLE, IT MAY BE REJECTED. EACH SAMPLE MUST BE SUBMITTED WITH A COMPLETE SET OF DOCUMENTATION INCLUDING A COPY OF THE COMPLETED "PRODUCT SAMPLE CHECKLIST."
The bidder is required to fill out the following information for each sample submitted. Failure to provide the following information is cause for rejection. If more than one sample is submitted, please make a copy of the required sheets and submit with the samples.

Product Information

Bidder's response to the following items will be considered representative of their product. During testing of the bid samples, submitted samples cannot deviate from the percent concentration by more than minus one and one-half (-1.5%) percent of the bidder quoted concentration as indicated below. If the bid samples exceed this deviation tolerance, that bid will be disqualified. If the bidder is bidding corrosion inhibitor product, they must indicate the Percent Effectiveness that their product qualified at for approval (Note: The submitted Percent Effectiveness will be compared to the approved product test results for verification. If different, the qualification results will be used to determine the "final best buy factor"). It is to the bidder's advantage to have the submitted sample match as exactly as possible to the Bidder Quoted Concentration and the Percent Effectiveness for liquids as applicable. At no time will any sample be allowed to be below the minimum concentration requirement for that product as stated in these specifications. Failure to supply any part of this information is cause for rejection.

1. The product being bid is sold under the brand name of

   ____

2. The product is manufactured by

   ____

3. The product has a concentration of __________ % Primary Constituent Chloride **

PLEASE USE BLACK INK OR TYPEWRITER WHEN PREPARING YOUR BID. BE SURE YOU HAVE INSERTED YOUR COMPANY'S NAME, PHONE NUMBER, AND NAME OF CONTACT PERSON IN THE BOX AT RIGHT.	Bidder

The product has a concentration of ___________ % Total Chloride **

The product has a concentration of ___________ % ABP **

**This is the Bidder Quoted Concentration. NO ranges please. If a range is used, the lowest bidder specified concentration will be used for cost analysis.

4. The approved product has a Percent Effectiveness (if applicable) of

_______________ %. Percent Effectiveness will be used to determine the "final best buy factor".

6. Does your product contain an organic matter based corrosion inhibitor (circle one)? If yes, complete the required information on the inhibitor as specified.

Yes No

pH of product

____

Percentage of organic matter in product

___________ %

7. Two each one gallon containers samples of the product included (circle one)?

Yes No

8. Chemical analysis of the supplied samples is included as required (circle one)?

Yes No

9. Corrosion test data available (circle one)?

Yes No

10. Specific gravity with correlating weight percentage and freeze point information (presented in 1% increments beginning with a 5 % solution) included (circle one)?

Yes No

PLEASE USE BLACK INK OR TYPEWRITER WHEN PREPARING YOUR BID. BE SURE YOU HAVE INSERTED YOUR COMPANY'S NAME, PHONE NUMBER, AND NAME OF CONTACT PERSON IN THE BOX AT RIGHT.	**Bidder**

11. All required information on the corrosion inhibitor included (circle one)?

Yes No

12. Proprietary information labeled as such (circle one)?

Yes No

13. Material Safety Data Sheet (MSDS) included (circle one)?

Yes No

14. Samples and associated paperwork submitted to the following address; Indicate month, day and year.

____

Appendix B. Bid evaluation process

1. Bid preferences for higher concentrations of active chemical ingredients.

STEP 1: Best buy (FOB delivery destination) based on percentage of active chemical in the product will be determined by the following formula. Bidder Quoted Concentrations (BQC) and price per gallon will be used for calculations. Delivered Price/Concentration Percentage equals the best buy factor (bbf) for this step of the process. (The bidder quoted concentration will be used in the calculation.)

Example: Active ingredient of $MgCl_2$ blended ABP.

product “a”, with 27% $MgCl_2$: 100 × $0.97 per gallon/0.27 = 359 bbf

product “b”, with 30% $MgCl_2$: 100 × $1.05 per gallon/0.30 = 350 bbf

Product "b" at the higher purchase price per gallon, with the higher concentration, and with the lower bbf would be selected if this were the final step.

2. BID PREFERENCES FOR SUPERIOR CORROSION INHIBITION

STEP 2: Bid preferences based on the corrosion inhibiting ability of a product as demonstrated by laboratory analysis and verified by field applications will be applied from the values as shown in Table 2 under “Effective Percentage Factor", and are used to reduce the best buy factor (see above) to arrive at the final determination.

Table 2. Corrosion inhibiting value adjustment factors.

CORROSION INHIBITING VALUE (PERCENT, NaCl = 100.0)	EFFECTIVE PERCENTAGE FACTOR
25.0 to 30.0	0
20.0 to 24.9	2
15.0 to 19.9	6
10.0 to 14.9	10
5.0 to 9.9	14
0 to 4.9	20

Example:

As noted above in step 1, based on concentration calculations, product "b" resulted in the lowest best buy factor. However, product "a" has a corrosion value of 1.5%, which equates to an effective percentage factor of 10, while product "b" displayed a corrosion value of 27.0%, which results in no added value.

Product “a”.   100 × $0.97 per gallon/0.27 = 359 bbf -20 = 339 the final best buy factor.

Product “b”.   100 × $1.05 per gallon/0.30 = 350 bbf - 0 = 350 the final best buy factor.

Product "a" with the lower concentration but with higher corrosion inhibiting value would be determined to be the best buy in the final step.

No manufacturer or contractor may submit a corrosion inhibited chemical product unless qualified by successfully completing the National Association of Corrosion Engineers (NACE) Standard TM-01-69 (1976 rev.) as modified by the PNS for chemical product testing.

> Note: The modified NACE Standard TM-01-69 (1976 rev.), requires the use of 30 milliliters of 3% solution per square inch of coupon surface for corrosion testing.

Acceptance of bids will be based on approved laboratory results.   Final determination of the liquid chemicals products will be based on the "final best buy factor" calculated from the combination of the lowest cost per percent concentration of liquid chemical and credit for corrosion inhibiting ability as specified in Steps 1 & 2. Bids will be awarded for the lowest "final best buy factor" for each category and to each designated location or zone.

Appendix C. Test methods

1. Percent Concentration of Active Ingredient In The Liquid (7a, 7b).

Atomic Absorption Spectrophotometry as described in "Standard Methods for the Examination of Water and Waste Water", APHA-AWWA-WPCF.

> Inductively Coupled Plasma Mass Spectrometry (ICP-MS) may also be used for this test. MDOT shall determine appropriateness of an analytical method used for evaluation and compliance, and such decision shall be final.
>
> Another test method for determining percent Calcium Chloride, ASTM E449, may be substituted as applicable for bid evaluation.

2. Weight Per Gallon

Specific Gravity by ASTM D 1429, Test Method D - Hydrometer (corrected to 60˚ F).

3. Corrosion Control Inhibitor Presence and Concentration

The qualified contract Laboratory may use the test procedures provided by the bidder or manufacturer for testing quantitative concentrations of additives. These same tests can then be used to verify that materials being delivered are the same as those previously tested and approved in the bid process.

4. pH

ASTM D 1293, except a dilution shall be made of 1 part chemical product to 4 parts distilled water before attempting a reading.

5. Total Phosphorus

Total Phosphorous as described in "Standard Methods for the Examination of Water and Waste Water." Total phosphorus shall be determined upon a 1% test solution. The Total Phosphorus value determined from the 1% solution is the value to be reported without adjustment for dilution. The test solution should be prepared by placing 10 mL of sample into 500 mL of ASTM D 1193 Type II distilled water contained in a 1 L volumetric flask to which 2.5 mL 1:1 sulfuric acid has been added. Swirl the contents and make up to 1000 mL with distilled water.

6. Total Cyanide

Total Cyanide as described in "Standard Methods for the Examination of Water and Waste Water."

7. Total Arsenic, Barium, Cadmium, Chromium, Copper, Lead, Selenium and Zinc.

Atomic Absorption Spectrophotometry or ICP-MS as described in "Standard Methods for the Examination of Water and Waste Water."

8. Total Mercury

Cold Vapor Atomic Absorption Spectrophotometry as described in "Standard Methods for the Examination of Water and Waste Water."

9. Visual Inspection and Field Observations.

Visual inspection and field observations to assure that the material remains clean and free of extraneous matter, free from hard caking, does not segregate, and remains suitable for the intended purpose and as otherwise outlined in section d. MDOT may use laboratory testing as appropriate to verify conclusions from visual inspections.

10. Corrosion Rate as conducted from the NACE Standard TM-01-69 (1976 Revision) as modified by the PNS.

The corrosion inhibited chemical product must prove to have a corrosion value of at least 70% less than Sodium Chloride (salt) to be acceptable. PNS has modified this procedure so that the test procedure uses 30 mL of a 3% chemical product solution per square inch of coupon surface area for the corrosion test.

11. Percent Total Settleable Solids and Percent Solids Passing a No. 10 Sieve.

This test method is used to determine the amount of total settleable solids and the percent solids passing on the No. 10 sieve that are generated from a liquid chemical product when stored at a specified cold temperature without agitation. Settleable solids are typically formed from chemical precipitation, chemical crystallization, or by the dense settlement of any other components of the anti-icing product.

Chemical precipitates are formed when specific chemical constituents within the liquid product react to form insoluble products and settle out of solution.

Chemical crystallization begins to form when a solution is cooled below its chemical saturation point. Crystallization is the physical characteristic by which a liquid begins to turn to a solid. This physical characteristic is typically used to identify the freezing point of a liquid. This test will determine if the deicing solution can maintain its liquid state at the supplied concentration and at the specified testing temperature with no agitation. The settlement or separation of additional component(s) (i.e. inhibitors) of the product will be examined for the formation of a dense solid layer and the ability of the chemical product to maintain a non-stratified suspension without agitation. Total settleable solids will consist of all described parameters excluding soft settling stratification as outlined in the test methodology.

Percent Solids Passing on the No. 10 Sieve will be measured by subtracting the volume of solids retained on the sieve from the total sample volume.

I. Equipment

1-Liter Graduated Imhoff Cone	ASTM E11 No. 10 sieve	Rubber policeman
Graduated cylinder	Watch glass	

II. Test Method

Place 1000 mL of a well-mixed (non-diluted) liquid chemical product into a graduated one-Liter Imhoff cone. Place this sample into a freezer, that has been precalibrated and stabilized to -17.8° C +/- 1° C (0° F +/- 2° F). Cover the sample with a watch glass. The sample shall remain in the freezer unagitated for a period of 168 hours. Record the temperature of the freezer daily to assure proper testing temperature. After 168 hours the sample is carefully removed from the freezer for testing.

A. Total Settleable Solids

This test method will be used to determine if the liquid chemical product is usable and if it requires agitation. It will determine the detrimental amount of settlement formed from chemical precipitation, chemical crystallization, or by the dense settlement of any other component(s) of the deicing product.

The formation of chemical precipitation and/or chemical crystallization above the prescribed limit is cause for rejection. These characteristics are observed by a dense formation of precipitate and/or crystals in the cone. Various levels of crystallization may be present if the chemical product concentration is at or near its freezing point.

The settlement of other chemical product components that produce a dense solid layer above the prescribed limit will be cause for rejection. Stratification of material exhibited by phase separation or exhibiting a soft settlement is not to be interpreted as a dense solid layer. This type of separation is a result of the chemical product not staying homogenous through the test conditions. Samples submitted that exhibit stratification but pass all other specifications will be passed and will be categorized as "Requires Agitation".

The time used to evaluate each sample should be kept to a minimum because as the deicing solutions warm, the physical characteristics within the solution change.

Remove the sample contained in the Imhoff cone from the freezer. Determine readings as soon as possible because sample temperature begins to rise immediately after being removed. Measure and record the volume of settleable solids using the calibrated gradations on the cone. (Note: If the settled matter contains pockets of liquid between large settled particles, estimate the volume of these and subtract them from the volume of settled solids.) For transparent liquids the determinations are easily determined by directly reading the volume of the settleable solids in the bottom of the cone. For liquids that are not clear due to hazy, cloudy or opaque solutions or to indefinite stratified zones use the following method.

Place the sample in a room with no light. Then using a light capable of producing a concentrated beam, such as a flashlight with adjustable light features back light the sample. With this procedure determine the amount of settlement in the bottom of the cone and the phase separation interfaces. Record the settlement value and the stratification interface volumes if present.

To determine if this settlement is a dense formation or soft settling due to a phase separation use an eight-millimeter diameter solid glass rod of sufficient length to reach the bottom of the cone. The rod diameter should allow the rod to be inserted to the bottom of the cone and large enough so as to be able to determine the slightest resistance. Gently insert the rod into the chemical product and gradually lower the rod to the bottom of the cone. If resistance is felt, mark the rod level at the top of the cone and remove. Place the rod on the outside of the cone with the mark even with the top of the cone. Read and record the volume where resistance was felt from the gradations on the cone that correspond to the tip of the rod. This volume reading is to be interpreted as a dense settlement and must not exceed the specification limit. If the rod goes completely to the bottom of the cone with no resistance record that no dense settlement was found.

If stratification is present, hand stir the chemical product in a clockwise direction for 45 revolutions in one minute to see if the sample will re-homogenize. Examine the chemical product again, with the light if necessary, to determine phase stratification interface levels remaining, if any. Record new levels if present. If no levels are detectable and the solution is returned to a homogenous state exhibiting no stratified layers the chemical product will be marked "Requires Agitation". If levels of stratification are still present, mark as "Requires Extreme Agitation."

The total settleable solids volume shall consist of the accumulated amounts of chemical precipitation, chemical crystallization, and the dense portion of any other constituents. The total settleable solids are reported in percent based upon the volume to volume (V/V) ratio of the settleable solids to the initial sample size.

B. Percent Solids Passing the No. 10 Sieve

This procedure must be conducted as fast as possible after determining the total settleable solids so that any frozen chemical crystalline materials are adequately evaluated.

Immediately after determining the total settleable solids, invert the cone (or remove the tip on some models) and pour the sample through an ASTM E 11 certified Number 10 sieve. The sieve should be kept in a mixture of ice and water to keep it cold before using and between samples. Rinse the sieve with water to remove any traces of the previous sample prior to placing in the ice bath. Before using the sieve briefly shake excess water from the sieve. The sample should be poured through one-quarter section of the sieve if possible to reduce the surface area from which the sample must be retrieved. The sample on the sieve is not rinsed or pushed through the sieve by any means. All material not flowing through the sieve is rubber policed from the sieve into a graduated cylinder and the volume measured and recorded. Rubber police only the side of the sieve the material was placed on to pass through. Material that is trapped in the mesh of the sieve and does not come loose on the face of the sieve is considered passing and is not included. This volume is subtracted from the total volume of the sample to calculate the sample volume passing. The solids passing the No. 10 sieve are reported in percent based upon the volume to volume (V/V) ratio of sample volume passing to the initial sample size.