A GUIDE FOR SELECTING ANTI-ICING CHEMICALS

VERSION 1.0

by

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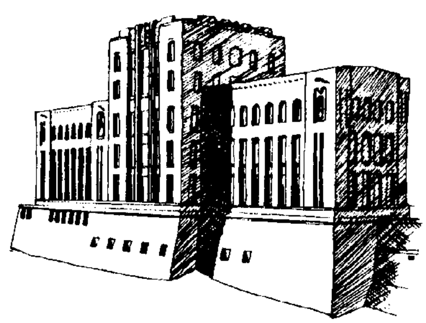

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CHAPTER 1: INTRODUCTION

The choice of the right chemical for anti-icing applications is dependent upon a number of factors. These would include the climatology of the area where the anti-icing would be done, the availability of chemicals in the given location, the extent to which the environment is a concern and so forth. The purpose of this guide is to provide assistance to those who must select anti-icing chemicals, by presenting various properties of such chemicals that might be considered by an agency that has to provide winter maintenance service. The relative importance of these properties can only be determined by a given agency, but for each property, different levels of performance have been defined. As demonstrated in chapter 4, these levels of performance can be used in several ways. A user may decide that a minimum level of performance is required for certain properties. Thus all chemicals that fail to meet those levels for the given properties would be disqualified from further consideration. Or, a user may choose to weight and score the given properties to develop a ranking of chemicals at the end of the process. The two methods could also be combined.

A secondary purpose of this approach is that it allows agencies to develop specifications relatively easily. If chemicals are not adequately specified then the selection of an anti-icing chemical will be determined solely by cost, rather than by the degree to which a given chemical meets the need of an agency. Of course, cost is important, but it should only be considered once the end-user is satisfied that the chemicals under consideration meet the performance required by the agency.

The overriding aim of this guide is to provide a tool to end users of anti-icing chemicals that allows them to select the best chemical for their specific anti-icing needs. To that end, this document is expected to develop over time, as a result of feedback from the user community. Such feedback is welcomed and can be addressed to the lead author of the guide (Wilfrid-nixon@uiowa.edu). The document will be made available primarily in electronic form, through the Guide's web site (http://www.anti-ice-guide.com/).

1.1: Inorganics vs. Organics

An interesting development in winter maintenance over the past decade has been the appearance of organic chemicals as de-icers, either in and of themselves, or as additives to inorganic de-icers often for the purpose of inhibiting corrosion. This development has both benefits and drawbacks. First, organic chemicals can be “designed” much more easily than inorganic chemicals to achieve certain goals (e.g. corrosion inhibition or freezing point depression). This raises the possibility of much more effective de-icing chemicals. However, the drawback of organic chemicals is that they tend to be less stable than inorganic chemicals, and thus require more careful storage, handling, and delivery. In short, the use of organic chemicals requires a more sophisticated approach (and thus improved training and superior equipment) from maintenance workers. Each agency has to decide whether the benefits afforded by organic chemicals outweigh the additional costs associated with them. One of the aims of this guide is to provide assistance in this regard.

1.2: By-products, Co-products, and Quality Control

The way in which organic chemicals are made can have a profound influence upon their utility in the field. Many organic products introduced as de-icing chemicals have been described as by-products of other chemical processes. In many ways, this is an excellent thing. By-products must either be used for something or disposed of, and if they can be useful in the area of winter maintenance then that is good. The drawback of by-products is that they are not directly produced. As their name implies, they develop by “accident” being essentially what is left over after the desired product is produced. This may raise some issues of quality and repeatability. A chemical refinement process will not be changed to ensure that a by-product meets certain specifications.

In contrast, a co-product is something that is deliberately created, during the creation of another product. Thus if a company is creating product A, and discovers that by adjusting their process slightly they can also create product B, then product B would be termed a co-product. A chemical refinement process may be changed to ensure that a co-product meets specifications.

Having thus distinguished between by-products and co-products, it should be noted that this distinction is not enshrined in law, and the buyer should definitely beware. Just because a de-icer is termed a co-product does not mean that the process is managed to ensure it meets specifications. The buyer should be sure to ask (and should expect convincing evidence) about how the co-product is controlled for in the chemical production process.

The goal behind this is quality assurance. Any agency charged with providing winter maintenance on a road system needs to know what they are placing on the road. They need to know that this week's delivery will perform the same as next week's and as last week's. Products that cannot provide this level of quality are not useful products for winter maintenance.

1.3: Liquids vs. Solids

This guide will focus solely on liquid chemicals. While it is possible and appropriate under certain circumstances to use solid chemicals in an anti-icing mode, liquids are more commonly used. Further, there is a greater range of new liquid chemicals being made available. As agencies move to anti-icing, they are typically making the change from solid to liquid chemicals. This change affords them the opportunity to consider new chemicals. Depending on need, the guide may at some time in the future include a section on choosing solid chemicals.

CHAPTER 2: PROPERTIES OF ANTI-ICING CHEMICALS

This chapter presents the properties of anti-icing chemicals that might impact the extent to which a given chemical performs satisfactorily for a given end-user. At this time, eight (8) measurable properties have been identified: freezing point depression, consistency, environmental impact, stability, corrosion, handling, conductivity, and documentation. For each of these properties, the chapter will present an explanation of the property and the way in which performance in that property will be measured.

A ninth category of "future categories" is included to list possible categories that might in future be added to the category list. This includes properties that are important but for which at present widely used tests do not yet exist.

There is another category termed "other factors." This is a catch all for a variety of properties and concerns that may be very important in the choice of a given chemical, but are not necessarily easily measured. For example, the availability of a chemical may be critical in its choice, but is not an easily measured factor.

2.1: Freezing Point Depression

A fundamental characteristic of anti-icing chemicals is that when added to water, they reduce the freezing point of the mixture below the freezing point of water alone. This is most clearly seen through a phase diagram (Figure 2.1 shows the phase diagram for the water – sodium chloride system). As more salt is added, the freezing point of the mixture drops further until the eutectic point is reached. For salt this occurs at a mixture of 23.3% salt by weight and at a temperature of –21.1° C (-6.02° F). Freezing point can be determined in a number of fairly simple ways – see ASTM D1177 for an example.

While the eutectic temperature is a relatively easy point of comparison between chemicals, it is not a very realistic measure of performance. Most chemicals cease to be effective long before the eutectic temperature is reached. For example, salt is rarely used below 15° to 20° F. The guide proposes that two points on the eutectic curve measure freezing point depression. These two points would be: the freezing point of a solution that is 50% of the applied solution (for salt, which is applied at or close to a eutectic

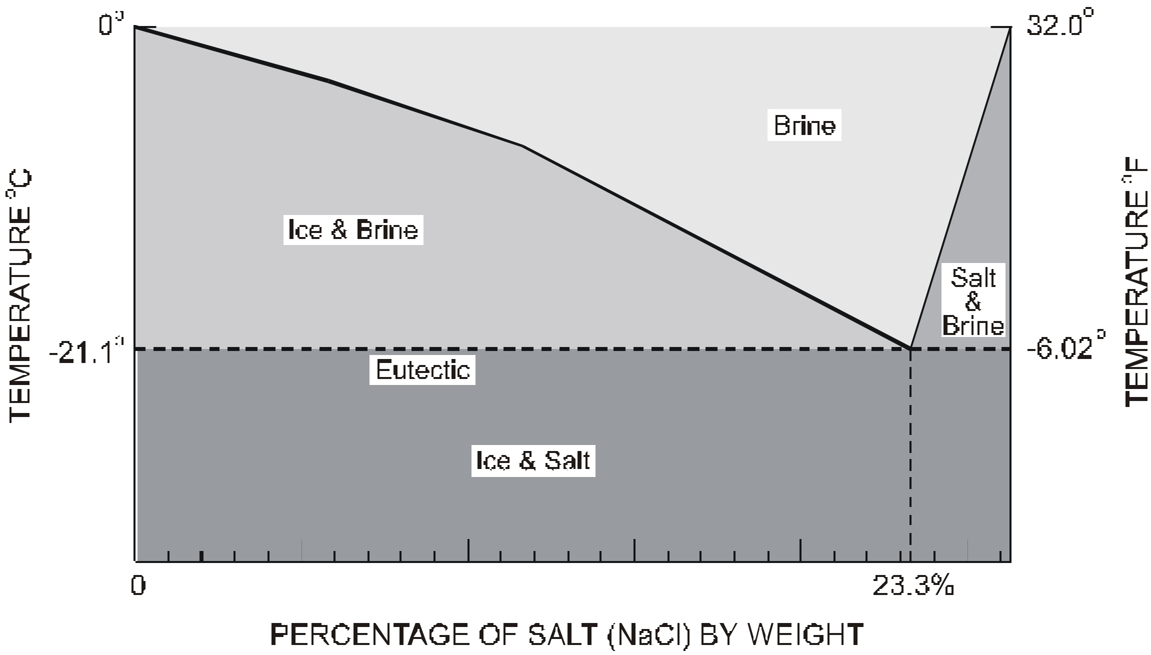

Figure 2.1. Phase Diagram for the Salt-Water System.

solution, that would be a mixture that is 11.65% salt by weight – it occurs at 18° F) and the freezing point of a solution that is 25% of the applied solution (for salt that is 5.825% salt by weight – it occurs at 26° F). These values give a better measure of the real world performance of a given chemical.

There are a variety of additional properties that could be considered in this regard. The Strategic Highway research program identified a number of tests for de-icing chemicals. However, these tests are not regularly used or reported and thus at this point in time it does not seem appropriate to use them in the guide.

2.2: Consistency

It is extremely important operationally that an anti-icing chemical should perform consistently from batch to batch and over time. In the ideal, each batch of chemical delivered would be tested for all properties specified herein that are deemed important by the purchasing agency. In practice, this is not feasible (although we strongly urge that a comprehensive quality control program should be implemented by all agencies). As an alternative, two properties in particular should be consistent. These are viscosity and specific gravity. These two properties are relatively simple to measure, and may be indicative of other variations in performance. It should be noted that absolute values of these two properties are not at issue here. The measurements are to determine that the values of these properties are within proscribed limits from a specified value.

2.2.1 Viscosity

Viscosity can be measured simply using an efflux cup, which times how long it takes a liquid to flow through a funnel with a certain diameter opening. See for example ASTM Standard D5125.

2.2.2 Specific gravity

Specific gravity can be easily measured using a hydrometer (see ASTM D891). Variations in specific gravity may indicate that a liquid has not been supplied at the correct concentration. This could have critical impact on anti-icing operations. If operators believe they are placing a eutectic mixture of salt brine on the road, but in fact that mixture is only a 15% salt solution, refreeze will occur much sooner and a dangerous situation may develop quite unexpectedly.

2.3: Environmental Impact

There are increasing concerns about the effect of "classical" de-icing chemicals on the environment. These concerns include the effect such chemicals may have on local groundwater, on roadside vegetation, and on nearby streams and rivers. However, these concerns are not uniform, and while for one district environmental restrictions might be extremely strict, for others they may be of only secondary concern.

Environmental impact can be measured in a number of ways. These include: levels of heavy metals (and other chemicals) present in the anti-icing liquid; the toxicity of the liquid, the amount of nitrogen available in the liquid, the Biological Oxygen Demand (BOD) of the liquid and the Chemical Oxygen Demand (COD) of the liquid. In the ideal, all five of these factors should be known for any anti-icing liquid applied to the road. However, at present there are only limited data available for toxicity, Nitrogen, BOD, and COD for anti-icing liquids. We urge that they be conducted for all anti-icing chemicals but at this time levels of these measures are not included in the properties considered in the guide.

Standard tests for all five of these factors are readily available. Toxicity can be measured in a number of ways. SHRP recommended a range of toxicity tests, of which the tests on Fathead Minnows (EPA/600/4-85/013) and on seed germination (EPA/560/6-82/002) are the most relevant and should be used at least initially. To measure Nitrogen content, the standard test is Kjeldahl Method (see Standard Methods for the Examination of Water and Wastewater, published jointly by the American Public Health Association, the American Water Works Association, and the Water Environment Federation, 1992). BOD and COD test methods are described in the same publication.

The Pacific Northwest Snowfighters (PNS) require[1] testing for a number of elements, which are shown listed in table 2.1. Table 2.1 shows the required maximum levels for these chemical elements, as well as the required maximum levels as specified by the

[1] See http://www.wsdot.wa.gov/fossc/maint/pns/

Environmental Protection Agency (EPA) for drinking water. It can be seen that for some chemicals the PNS specification is stricter than drinking water standards.

Table 2.1 Allowable Levels of Various Elements

METAL	PNS Requirements (ppm)	Drinking Water Standards (ppm)
Phosphorus	25.00[2]	NA
Cyanide	0.20	0.20
Arsenic	5.00	0.05
Copper	0.20	1.3
Lead	1.00	0.015
Mercury	0.05	0.002
Chromium	0.50	0.1
Cadmium	0.20	0.005
Barium	10.00	2.0
Selenium	5.00	0.05
Zinc	10.00	5.0

2.4: Stability

Once a chemical is received by an agency it is a reasonable assumption that the chemical will not change. However, especially with organic liquids, this is not necessarily the case. At the very least, stratification may occur. In other circumstances the liquid may be either chemically or biologically active and may thus degrade over time.

To get a true measure of the stability of an anti-icing liquid over time, it would be necessary to test all properties on a regular basis. This is overly burdensome. Therefore, it is recommended that the property of stability be measured in terms of the manufacturer's willingness to warrant the product for a specified period of time. The warranty may include certain requirements (for example, it may require that storage tanks be fitted with agitators that are used regularly, according to a specified schedule). However, this requirement reduces the issue of stability to being the responsibility of the supplier and the manufacturer.

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[2] This test is actually conducted with a dilute solution that has 1% by weight of the anti-icing liquid mixed with distilled water – see the PNS web site at: http://www.wsdot.wa.gov/fossc/maint/pns/deicespec/99DeicerSpecs.htm

2.5: Corrosion

There is considerable concern about the corrosive effect of inorganic de-icing chemicals. This concern has two primary aspects: chemicals may corrode exposed equipment, such as crash barriers, trucks, and signs; chemicals may also infiltrate concrete and corrode reinforcing steel (re-bar) within the concrete. Of the two problems, the latter is much more serious because relatively little can be done to stop it. Exposed metal surfaces can be washed with water. Re-bar cannot.

The corrosion of re-bar is problematic in other ways. The conditions that exist (from a corrosion viewpoint) in and around re-bar in concrete are very complex. No simple test exists to measure how much corrosion of re-bar a given chemical causes (although the Strategic Highway Research Program proposed a test – SHRP H-205.12 – it is lengthy, requiring several months to conduct, and is not in common usage).

In addition to being hard to measure, the corrosion of re-bar poses further difficulties. Many chemicals attempt to limit corrosion by adding corrosion inhibitors to the de-icing chemicals. However, it is unknown how well these corrosion inhibitors penetrate to the re-bar. It is also unknown how long these inhibitors persist. Unfortunately, chlorides persist for a long time and so it is possible that corrosion inhibitors merely delay the corrosion of re-bar, rather than providing complete protection. Clearly, further work is needed in this area.

That said, the suggested method for measuring corrosion potential of different anti-icing chemicals is that developed by PNS, which is based upon the National Association of Corrosion Engineers standard NACE-TM-01-69 (revised, 1976). This involves immersion in the liquid and then air exposure for metal coupons over a specified cycle time and duration, followed by a measurement of weight loss (or gain). PNS expresses their results as a comparison with losses experienced in a eutectic salt brine, thus corrosion for them is measured as a percentage (with salt brine scoring 100%).

2.6: Handling

As agencies make the change from de-icing to anti-icing as their primary winter maintenance strategy, they need to address a variety of issues associated with handling liquid chemicals, rather than solid materials. In so far as possible, the handling of liquids should be as simple as possible.

Two aspects are of concern in regard to handling. First, how easily can the liquid be used? Does it require special pumps and nozzles, or can gravity flow be used? This does not mean gravity flow must be used, but handling is a great deal simpler if a liquid can be moved by gravity flow alone rather than requiring special pumps.

The second concern is how easily the liquid can be stored. Liquids with high specific gravities may require containers that are strengthened in comparison with standard liquid containers. This is by no means a debilitating issue, but users need to be aware if there are special storage concerns.

2.7: Conductivity

Conductivity determines how easily an electric current can flow through a material. Some liquids have very high conductivity and may thus pose hazards for any roadside electronics. This is more of a concern in the winter maintenance of airport runways, as opposed to highways but is included as a category because for some end users it may be important, and it is very simple to measure.

2.8: Documentation

From the point of view of an end user, documentation of a liquid chemical is critically important. Two aspects of documentation are of particular import. First, the extent to which a liquid can be chemically defined is in some degree a measure of the quality control of that liquid. De-icing materials can be categorized according to the percentages of given chemicals present in the material. Thus, for example, a given supply of road salt might be characterized as: NaCl 98.1%, $CaCl_2$ 0.8%, Other 1.1%. The guide proposes that chemicals be categorized according to the percentage of the chemical termed "other." The justification for this is that the category termed "other" can in fact be anything at all – it is not in anyway controlled. Thus, the less "other" there is in a given material, the more confidence there is that the material will do as it is supposed to do.

The other aspect of documentation relates to the simple presentation of sufficient information to the end user to allow them to make an informed decision. The guide proposes that all anti-icing materials should be required to provide information in all categories as specified in sections 2.1 through 2.8. A given agency does not need to consider all these categories, and thus may not require information in all categories, but the collection and presentation of this information should be standard practice in the anti-icing industry.

2.9 Future Categories

There are two properties that would be very helpful to winter maintenance agencies but have not yet been included in the guide because they are not measured with sufficient frequency at this time. These are: friction characteristics, and recommended usage levels. A test exists for measuring friction characteristics, SHRP H-205.10, which uses the British Pendulum Tester. This could easily be introduced as a category for the guide, if it were in common enough usage. There is some interest at present in the effect of liquid chemicals on road surface friction and it may be that this develops to the point where suppliers regularly conduct measurements of friction characteristics, but at present that is not the case.

The issue of recommended usage levels is more complex. Clearly a liquid chemical is most useful to a winter maintenance agency if recommendations are provided for how much should be used under certain circumstances. However, such information is not readily available, and the issue always arises as to what conditions should be considered. Clearly certain winter storms require different levels of chemical application than others.

To this end, it would be useful if there existed a collection of "standard storms" for which a supplier could specify usage levels. A start at such a collection was made in the FHWA Manual of Practice for an Effective Anti-Icing Program[3], in Appendix C of that report, which specifies six winter storm events, with recommended actions for each. The authors of the guide encourage suppliers of liquid anti-icing chemicals to recommend usage levels of their products for each of these six "standard" storm events.

[3] Publication number FHWA-RD-95-202, available on the internet at: http://www.fhwa.dot.gov/reports/mopeap/eapcov.htm

2.10 Other Factors

The choice of an anti-icing chemical will not rest on the categories above alone. One obvious factor that has not yet been considered is cost. Availability, levels of technical support and customer service, and a host of other considerations may be important for agencies as they make their choice of an anti-icing chemical. The purpose of the guide is not to ignore these other factors, but rather to provide a method for agencies to ensure that they are considering chemicals that will meet their needs, rather than simply choosing the cheapest chemical, regardless of whether it does the job. Chapter 4 of the guide details how the categories can be used to rank and qualify available chemicals, and thus hopefully lead to a better choice of chemicals for an agency.

CHAPTER 3: DEFINING CATEGORY LEVELS

For each of the eight defined categories identified in Chapter 2, levels of performance must be defined. Chapter 3 describes how these levels are defined, and what the different levels are. As the guide is a living document, it is to be expected that these levels will adjust over time.

3.1: The Four-level System

In six of the eight categories, a four level classification system has been used, grading chemicals with a letter grade of A, B, C, or D. In general, a chemical that scores an A grade in a given category will be among the best performers available in that category.

In two cases, a somewhat different scoring approach has been used. In the category of handling, for reasons described below, only two levels have been used, termed A or B. In the category of Documentation (completeness) a simple pass/fail decision is suggested.

3.2: Properties for Each Level

Table 3.1 presents levels for each of the eight categories identified. It should be noted that some of these are currently undefined and remain to be determined (indicated by TBD on Table 3.1).

3.2.1 Freezing point depression

As described in section 2.1, the effectiveness of a liquid anti-icer at depressing the freezing point is measured in terms of the freezing point at 25% and 50% of the eutectic concentration. Table 3.1 shows the four levels chosen for this category. By way of a reference, sodium chloride receives a grade of D in this category. Some chemicals (for example Calcium Magnesium Acetate) would not even achieve a grade of D.

3.2.2 Consistency

Consistency is expressed in terms of the maximum allowable variation from a specified value. The four grades, shown in Table 3.1, range from ± 1% to ± 10%. Salt brine, if made correctly, is a very consistent product and would thus likely achieve a grade of A in this category.

Table 3.1 Proposed Levels for Categories

<table>
<tr><th colspan="17">PROPERTIES</th></tr>
<tr><th rowspan="2">CATEGORY</th><th colspan="2">FREEZING POINT DEPRESSION</th><th rowspan="2">CONSISTENCY</th><th colspan="5">ENVIRONMENTAL IMPACT</th><th rowspan="2">STABILITY</th><th>CORROSION</th><th colspan="2">HANDLING</th><th rowspan="2">CONDUCTIVITY</th><th colspan="2">DOCUMENTATION</th></tr>
<tr><th>25%</th><th>50%</th><th>Nitrogen</th><th>BOD</th><th>COD</th><th>Toxicity</th><th>Heavy Metals</th><th>PNS (MMPY)</th><th>Ease of Use</th><th>Storage</th><th>Unspecified composition</th><th>Complete-ness</th></tr>
<tr><td>A</td><td>16.5°</td><td>0°</td><td>< ± 1%</td><td colspan="4" rowspan="4">T.B.D.</td><td>1:1</td><td>2 years</td><td>0</td><td rowspan="2">A</td><td rowspan="2">A</td><td rowspan="4">T.B.D.</td><td>< 2%</td><td rowspan="4">PASS / FAIL DECISION</td></tr>
<tr><td>B</td><td>20°</td><td>7°</td><td>< ± 2%</td><td>2:1</td><td>1 year</td><td>10</td><td>< 5%</td></tr>
<tr><td>C</td><td>24°</td><td>10°</td><td>< ± 5%</td><td>10:1</td><td>6 months</td><td>25</td><td rowspan="2">B</td><td rowspan="2">B</td><td>< 10%</td></tr>
<tr><td>D</td><td>26°</td><td>18°</td><td>< ± 10%</td><td>100:1</td><td>1 month</td><td>50</td><td>> 10%</td></tr>
</table>

3.2.3 Environmental impact

As noted in section 2.3, liquid anti-icing chemicals are not routinely tested for BOD, COD or toxicity at this time. Accordingly, while these are included as sub-categories, levels have not yet been determined.

3.2.3.1 Nitrogen levels

While Nitrogen Level (as measured by the Kjeldahl Method) is an important measure of the environmental impact of chemicals, levels have not yet been determined.

3.2.3.2 BOD

While BOD is an important measure of the environmental impact of chemicals, levels have not yet been determined.

3.2.3.3 COD

While COD is an important measure of the environmental impact of chemicals, levels have not yet been determined.

3.2.3.4 Toxicity

While toxicity is an important measure of the environmental impact of chemicals, levels have not yet been determined.

3.2.3.5 Heavy metals

Table 2.1 listed the maximum allowable levels for various elements (primarily heavy metals) as specified by the PNS. The four levels for heavy metals listed in table 3.1 are based upon these maximum allowable levels, with a dilution factor included. Thus, to achieve a grade of A, a given chemical must satisfy these levels in undiluted form. A grade of C requires that a sample of chemical, diluted in ten parts of distilled water, achieve the specified levels, and so forth. Typically salt does not have much in the way of metals present (although this depends on the source) thus a grade of A would be most likely for sodium chloride in this category.

3.2.4 Stability

The levels in the category of stability are determined by the willingness of the chemical supplier to warranty their product. The four levels are shown in Table 3.1. Typically, a salt brine would be stable with minimal agitation for periods in excess of two years, thus salt would achieve a grade of A in this category.

3.2.5 Corrosion

Corrosion will be measured according to the specified PNS method, which is based upon the NACE standard TM-01-69. The PNS test results in a reading of mils per year, which are then modified by subtracting from this value the mils per year that the test coupons would loose if placed in distilled water (this value is 6 mils per year). Thus it is possible, using the PNS method, to have a chemical that produces a negative value of corrosion. Table 3.1 presents results in terms of modified mils per year (i.e. having the 6 mils per year subtracted). Thus to achieve a grade of A, a chemical would have to be no more corrosive than distilled water. Salt would score a grade of D in this category.

3.2.6 Handling

Handling is described by two sub-categories: ease of use and storage. For both sub-categories, only two levels are provided, termed A and B.

3.2.6.1 Ease of use

Ease of use relates to whether special equipment is required to pump and transfer the liquid, or whether it can be treated as if it were water. To receive a grade of A in this sub-category, a liquid must be able to be easily used with equipment (pumps, nozzles etc.) that can handle flowing water. If a liquid requires special pumps, or special nozzles, to avoid blockages and similar problems, then it receives a grade of B. Salt brine would typically get an A grade.

3.2.6.2 Storage

As for ease of use above, storage refers to whether a special accommodation must be made in storing the liquid chemical. This may be the case if the chemical has a very high specific gravity (requiring storage tanks to be reinforced). To receive a grade of A in this sub-category, a liquid must be able to be stored as if it were water. Salt brine would typically get an A grade.

3.2.7 Conductivity

Conductivity may be a factor that limits the use of certain chemicals. However, at this time levels for the four grades have not been assigned.

3.2.8 Documentation

Documentation is described by two sub-categories: Unspecified composition and completeness of information. The unspecified composition sub-category uses the standard four levels of grading. However, completeness of information is graded simply on a pass/fail system. Chemicals for which complete information is not supplied are deemed to have failed the process.

3.2.8.1 Unspecified composition

Any liquid anti-icer will include a description of components. This will present a list of primary constituents, each with a percentage (normally given by weight, but occasionally by volume). Included on the list is a component termed "other." This sub-category differentiates between chemicals on the basis of the amount of chemical in the unspecified or "other" category in the supplier provided composition. If the "other" category is less than 2% an A grade is received. The other levels are defined in Table 3.1. Typically salt brine would receive a grade of A in this sub-category.

3.2.8.2 Completeness

The requirement for completeness is simply that any supplier of anti-icing chemicals should be required to provide as generally available information all the data required by the guide. If a supplier does not do this, then the guide assigns a failing grade in this sub-category.

CHAPTER 4: COMPILING AN OVERALL SCORE FOR A GIVEN CHEMICAL

The purpose of the guide is to allow agencies to differentiate between different chemicals and choose the anti-icing chemical that best meets their needs. This differentiation requires a number of steps. First, the agency must determine which of the categories is most important to their needs, through a weighting process (section 4.1). The agency may also determine that in certain categories a minimum grade of performance is required. This may have the effect of "disqualifying" certain chemicals, and thus limiting the number of choices. This process is described in section 4.2.

Once categories are weighted and limited to describe an agency's needs and priorities, then data for various chemicals can be "fed" into the screening table, and scores can be developed for each chemical. This simple process is described in 4.3. Once scores are available, they chemicals can be ranked (section 4.4).

4.1: Weighting Each Property

Each agency must determine the relative importance of each category to its own specific needs. For example, an agency in the lower mid-west of the US may not experience much in the way of cold winter weather. This means that the first category (freezing point depression) is not very important to it. Conversely, an agency close to the Canadian border may experience some very cold weather and may thus weight freezing point depression very highly. It is recommended that agencies use rankings between 0 and 4, with 0 being not important at all (i.e. performance in that category will not effect final rankings at all) and 4 being most important.

Table 4.1 shows how a hypothetical agency might weight the categories. For this agency, the most critical factor is corrosion. The agency is located in the mid to Northern part of the mid-west, and thus often experiences some fairly cold temperatures, even during and after snow storms, so freezing point depression is critical. The supervisor feels that consistency and documentation are important things to have in any product. A lot of people in the agency's district fish and so there are some (currently muted) concerns about the environment. Finally, while stability and handling are not very important to the agency, they are a factor and are thus included.

Table 4.1 Hypothetical Weighting of Categories

Category	Assigned Weight
Freezing Point Depression	3
Consistency	2
Environmental Impact	2
Stability	1
Corrosion	4
Handling	1
Documentation	2

4.2: Limiting of Properties

An agency may decide that certain categories require a minimum grade to be acceptable in performance. For example, in the above example, the agency may decide that corrosion is such an important category for them that they are unwilling to consider any chemical that doesn't score at least a B grade on corrosion. Any C or D grades in this category would be "disqualified" for the agency.

4.3: Calculating a "score"

To calculate a score for each chemical, the grade in each category is assigned a numerical value. For categories with four grades (A, B, C, and D) the scores are 4, 3, 2, and 1 respectively. For categories with only two grades (A and B) the scores are 2 and 1 respectively. Where a category has two or more sub-categories, the grade scores are averaged. The score for a given chemical is found by taking the grade point value in each category, multiplying it by the weight, and adding the totals thus generated. This is shown in Table 4.2 for two hypothetical chemicals, termed "Iceblaster" and "Sno-b-gone."

Table 4.2 Scores for Hypothetical Chemicals

Category	Assigned Weight	Iceblaster		Sno-b-gone	
		Grades	Scores	Grades	Scores
Freezing Point Depression	3	A	12	B	9
Consistency	2	D	2	B	6
Environmental Impact	2	D	2	B	6
Stability	1	C	2	B	3
Corrosion	4	B	12	A	16
Handling	1	B	3	A	4
Documentation	2	D	2	B	6

In this case, the score for Iceblaster is 35, while that for Sno-b-gone is 50.

4.4: Ranking Available Chemicals

Table 4.2 shows a hypothetical score for two chemicals, Iceblaster and Sno-b-gone. A simple ranking suggests that Sno-b-gone, with its score of 50, will perform better than Iceblaster (score of 35). However, other factors such as cost and availability may influence the final choice. Nonetheless, this guide provides a simple and effective way to differentiate between chemicals based on an agency's performance needs.

CHAPTER 5: CONCLUSIONS

This document presents a method for differentiating between various anti-icing chemicals on the basis of performance in a number of categories. The intent of the guide is to be continuously changing, so as to meet the needs of the winter maintenance community more effectively. Comments are always welcomed and are actively sought at the dedicated web site for the guide.