BASIC CONCEPTS

OF

SNOW AND ICE CONTROL

PREPARED FOR

APWA NORTH AMERICAN SNOW CONFERENCE

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INTRODUCTION

This workbook will take the reader from why snow and ice control materials are applied to some of the operational "tricks of the trade". The intent is to identify key issues that agencies and others responsible for winter maintenance should address in their snow and ice control plans and operations. A list key references that will provide more detailed information is included in this workbook.

CHAPTER 1
PLAN, POLICY AND LEVEL OF SERVICE

PLAN AND POLICY

The backbone of any effective snow and ice control program is in a thoughtfully crafted written plan and policy. The people served by all levels of government and private industry, as well as the policy making institutions themselves benefit significantly from written policies that are reasonable and followed.

The best way to create local policy is to use a participative process. Road/facility users, police/security, fire, medical, business/merchants, elected officials, emergency management, media and a broad representation from within the agency should be part of the process. Items addressed should include: level of service to be provided, treatment sequence and timing, sidewalk and alley policy, parking during storm and clean-up operations, snow removal policy (hauling), materials storage and use policy, a complaint response and follow-up system, emergency response during unusually severe weather situations, property and mailbox damage, commercial/business/agency snow plowing, snow storage and snow disposal. A more complete list of topics to consider when creating written plans and policies is found in APPENDIX I.

LEVEL OF SERVICE

The most important policy issue in terms the application of snow and ice control materials is level of service. Here, the policy makers have to balance cost, environmental responsibility, the safety of the users of the facilities, and the safety of the people performing snow and ice control operations. If that policy is reasonable, and the agency follows that policy to the extent possible, there will be very little successful slippery road/facility litigation.

Level of service may be defined in a number of ways. The most common is to define the level of effort, sequence or priority of treatment, and type of treatment at various locations for particular storm types. Another common method is to define level of service in terms of results. This usually takes the form of particular surface conditions (bare, passable, snow covered, maximum snow accumulation, wheel track bare, plowed, sanded, etc.) at specified times during and after the storms. This method is less popular as it does not allow for the impact of severe weather conditions.

CHAPTER 2
SNOW AND ICE CONTROL EQUIPMENT

TRUCKS AND PLOWS

The most common pieces of snow and ice control equipment are trucks and plows. They should be chosen to meet the local need in terms of snowfall frequency, road structure, and road geometry. Oversized equipment may not be cost effective unless snow and ice control is incidental to its primary function. It may also be difficult to use in small areas and damaging to unstable areas. Undersized equipment is not cost effective and may not stand up to the rigors of plowing operations. In the real world some compromises have to be made in this area. In any event, plow trucks should have heavy duty components to withstand the weight and impacts associated with using plows and carrying heavy and undistributed loads.

Snow and ice trucks are acquired through purchase, leasing or rental (with or without operator). The choice is largely dependent on frequency of use, other program needs for the equipment, and fiscal resources. Whatever the acquisition method, a vigorous maintenance program will provide higher availability and up-time. Comprehensive pre and post operation inspections by operators and others can identify problems that are easily corrected early-on. Failing to detect and correct these small problems often leads to major repairs and downtime later.

SPECIAL PURPOSE EQUIPMENT

There are a number of special purpose pieces of equipment associated with snow and ice control operations. These include snow throwers (blowers), large loaders, motor graders, ice/snow melters, large trucks for hauling snow, sidewalk plows, brooms and others. The acquisition method depends on frequency of use and available fiscal resources. If there is significant “other” use or there is not an opportunity to rent or lease, ownership may be the only option. If there is only limited use potential and/or there is a favorable rental market, rental or leasing may be more cost effective. Another method gaining popularity is partnering. In this scenario, different agencies purchase different equipment and equitably share it with their partners.

EQUIPMENT AND STAFFING

The amount of available equipment and people necessary to provide satisfactory snow and ice control measures depends on:

1. local policy (level of service)
2. Production rate of the equipment
3. typical weather patterns
4. emergency and contingency considerations
5. other uses of the equipment

The level of service the agency chooses to provide is the most important consideration in determining the appropriate equipment and staffing levels (owned, leased, rental or in

partnership). Higher levels of service generally require more equipment for equivalent weather conditions.

The production rate of the equipment is important. Factors include highway geometry/grades, backing maneuvers, the frequency of traffic signals, traffic volume, routing and deadheading, equipment size/capacity, maintenance facility locations and operator skill level all need to be considered.

Typical weather patterns are important in determining equipment and staffing needs. Areas with little winter weather probably can get by with lower levels of service and less equipment. However, there should be contingency plans in place to deal with the occasional severe condition.

Emergency response capability considerations influence equipment and staffing levels. Locations that routinely experience severe weather (winter and other times) may want to have the capability of providing a timely response. That will necessarily require more resources (owned, rental, leased or contracted).

MATERIALS SPREADING EQUIPMENT

Materials spreading equipment is most efficient and effective when associated with plow trucks. Independent plowing and spreading operations require almost impossible coordination. By spreading chemicals on freshly plowed surfaces, the chemicals will dilute less and last longer. Most chemicals need time to work. Uncoordinated plowing that removes chemicals from the surface too soon is wasteful.

There are a variety of solid material spreader types that work well. These include: V-Box (slide-in or frame mount), Tailgate Replacement, Under Tailgate, Tailgate Slip-In, Foreword or Side dumping bodies with conveyors or augers, “permanent” conveyor dump bodies and the newer “0 velocity” systems.

Liquid chemicals may be distributed directly on the road, parking lot or walkway surface from a variety of tank systems mounted on trucks and other vehicles.

Liquid chemicals may be added to solid chemicals during the truck loading process or as the material leaves the truck hopper/body (prewetting).

Calibration

Whatever material distribution system is used, it must be calibrated. This will assure that the proper amount of material is bei*ng* applied. Over-application is wasteful and under-application will not achieve the desired results. Appendix II is the calibration procedure for solid chemicals found in “The Snowfighter’s Handbook” that is published by the Salt Institute. This is applicable to most truck mounted material spreaders. A back-up or manual calibration for automatic control systems is always a good idea.

Calibration procedures for liquid spreaders are similar except that the liquid is captured in a container and the time of discharge is recorded. This will yield a rate of discharge (volume or weight) that can be related to vehicle speed and area of coverage for calculating application rate.

For smaller and hand operated solid chemical spreaders, a band of material can be run across a plastic tarp. The area of that band on the tarp is measured and the amount of material on the tarp is weighed. The weight of material on the tarp divided by the area of material on the tarp is the application rate for those set of spreader conditions.

As speed, gate opening, type of material, and the speed of the discharge driving system change, the application rate will change. There has to be a separate calibration for each set of conditions. Automatic ground speed spreader controllers eliminate the speed variable and allow uniform application for a given gate opening.

Spread Pattern Control

Most commercial materials spreaders have the capacity of adjusting the spread pattern they deliver. The most common device for spreading solid materials is a vaned spinner plate. The distance material is cast is controlled by the speed of the spinner plate. The faster the spinner rotates the farther it will cast material.

The direction of cast from spinner plates is controlled by the direction of rotation and the location of the point where material drops on the spinner plate. Material dropped on one side of the spinner plate is generally discharged on the opposite side. Additional control is provided by deflectors or skirts that divert the cast material downward.

The proper spread pattern adjustments should be determined on the floor of the chemical storage facility. By pushing the discharged material into a windrow that runs parallel to the back of the spreader, a good indication of spread pattern can be obtained. Spread patterns determined by this method should be field verified by observing the distribution under actual operating conditions. The spread pattern for liquid distribution systems is usually done by adjusting the direction and spacing of nozzles. Observing the pattern is the best method to determine if it provides the desired distribution.

Maintenance Program for Material Spreaders

Materials spreaders will have a long service life if they are properly maintained. During the season of use they should be thoroughly washed after each period of usage. Periods of use may be as little as a few hours to almost continuous use for a month or more in some of the lake-effect areas. Prior to each operational shift they should be inspected for proper adjustments, loose or missing parts and lubricated per the manufacturer's recommendations.

After the end of each season, spreaders should be thoroughly checked by a mechanic and repaired as necessary. Protective coatings should be applied to moving parts and other areas should be painted as required prior to storage. Covered storage is preferable although it is not always available.

Prior to each season of use the spreaders should be hooked up and run to be sure everything is functioning properly. A calibration check should also be performed at this time.

CHAPTER 3
SNOW AND ICE CONTROL MATERIALS

There are a wide variety of materials used for snow and ice control. They are generally separated into two categories: chemicals and abrasives. There are only a few chemicals that are in general use for snow and ice control. These include: sodium chloride (rock salt) calcium chloride, magnesium chloride, potassium chloride, potassium acetate, urea, calcium magnesium acetate, and a variety of proprietary products that are by-products of organic refining operations. Sodium chloride is the most widely used chemical for snow and ice control.

HOW CHEMICALS WORK

All ice control chemicals work the same way - they depress the freezing point of water and melt ice. There are some differences among the chemicals in terms of working temperatures and ice melting rate.

The practical key to understanding how ice control chemicals work is to put it in terms of dilution of solution. Up to limits unique for each chemical, as solution concentration increases, the freezing point decreases. The object of the ice control program then becomes to provide enough chemical to keep the solution sufficiently concentrated to prevent freezing or melt ice for the surface temperature of the moment and surface temperatures expected before the next treatment.

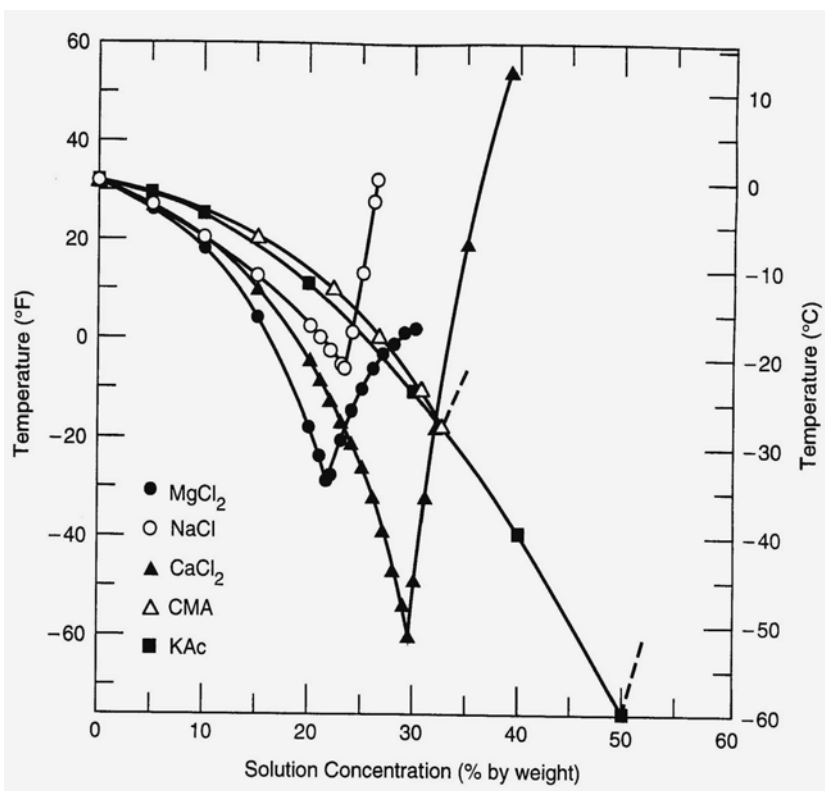


Figure 1 - Phase Diagrams for Common Ice Control Chemicals

The solution characteristics of chemicals are easily determined from graphical representations called phase diagrams. The phase diagrams for five common ice control chemicals appear as Figure 1. The vertical scale represents solution (pavement) temperature and the horizontal scale represents the solution concentration by weight. Any point on the curves represents the solution concentration and the corresponding temperature it will begin to freeze or solidify. Solution concentrations below the curve will solidify or freeze at or below the corresponding temperature. Solutions within the "V" of the curves will not freeze or solidify. The low point on each curve is called the eutectic temperature. This is the lowest temperature and maximum concentration that will not freeze or solidify. As the solution concentration increases beyond that point, the solidification temperature of the solution will actually increase. When using liquid chemicals at higher than the eutectic concentration, problems in the distribution system can occur.

As temperatures approach the eutectic temperature the melting rate slows correspondingly. Chemicals with lower eutectic temperatures generally exhibit faster melting rates in the range of 0°F to 32°F. Table 1 gives the relative melting abilities of common chloride chemicals at various temperatures.

Table 1: Melting Ability and Temperature for Chloride Chemicals

Temperature		Units of Ice Melted Per Unit of Chemical		
°F	°C	Calcium	Magnesium	Sodium
30	-1.1	31.1	47.8	46.3
25	-3.9	10.4	15.4	14.4
20	-6.7	6.8	10.0	8.6
15	-9.4	5.5	7.9	6.3
10	-12.2	4.8	6.8	4.9
5	-15.0	4.4	6.1	4.1
0	-17.8	4.0	5.5	3.7
-6	-21.1	3.7	5.0	3.2

The practical bottom line after understanding how chemicals work is translating that to application rate and frequency. In general, chemicals with lower eutectic temperatures can be used at lower temperatures. Application rates and treatment frequency for equivalent results will vary among the ice control chemicals. These are best developed locally, over time, using routine documentation of treatment, weather, road conditions and results.

SOLID CHEMICALS

Solid chemicals are the most often used form in ice control. Sodium chloride or rock salt in the solid form is the most used ice control chemical in the world.

Advantages of Solid Chemicals:

1. They are generally less costly as they are mostly chemical (no free water).
2. They generally handle and store well. However, hygroscopic (draws moisture from the air) chemicals like calcium chloride and magnesium chloride need to be purchased in impermeable bags and be covered during stockpile storage.
3. Solid chemicals dilute less rapidly than liquid chemicals as they are in a nearly 100% chemical state.
4. There are some abrasive or friction enhancing qualities associated with the larger particles of rock salt. Other chemicals depending on physical properties and gradation may not provide significant increases in friction.

Disadvantages of Solid Chemicals:

1. They need moisture to go into solutions and are generally not suitable for pre-treating.
2. The solution process takes time. This generally results in slower melting action, particularly in colder weather.

LIQUID CHEMICALS

Liquid chemicals are becoming increasingly popular as an ice control treatment.

Advantages of Liquid Chemicals:

1. As they are already in solution their action is nearly instant.
2. They are versatile in that they can be used directly on paved surfaces or they can be used to treat solid chemicals prior to application in order to speed melting action.

Disadvantages of Liquid Chemicals:

1. As they are mostly water, transportation changes per unit of chemical can be high.
2. They are not suitable for treating thick ice or snow pack. Doing so will create a very slippery condition and they may run off the sloping ice surface..
3. As a pavement treatment, they are usually limited to higher pavement temperature ranges (above 22°F).

COMBINATIONS OF CHEMICALS

Combinations of ice control chemicals are becoming very popular. Combinations of liquid and dry chemicals work fast and stick to the surface better than dry chemicals. This can result in increased effectiveness and reduced cost. Small amounts of corrosion inhibiting chemicals are being added to dry chemicals in order to reduce their corrosiveness. Various combinations of dry and liquid organic based chemicals exhibit less corrosion, less damage to concrete and less impact on vegetation in laboratory and limited field testing. There are a variety of these products in the marketplace that can assist with site specific concerns.

ABRASIVES (TEMPORARY FRICTION IMPROVEMENT)

Abrasives have always played a significant role in snow and ice control. Even with newer technologies, strategies and understanding, abrasives will continue to have a place in effective snow and ice control programs. That role is very narrow and very clear. They are typically used when it is too cold for chemicals to work, on low volume and unpaved roads that have a low level of service, and in areas where significant friction is always required to maintain traffic flow (steep hills, etc.).

There are a number of materials that are satisfactory for ice control abrasives. These include: natural sand, finely crushed rock or gravel, bottom ash, slag, ore tailings and cinders. Quality considerations include: hardness, particle shape, grain size distribution and limiting amounts of otherwise hazardous materials.

In order to maximize their effect, abrasives must stick to the ice surface. If they do not "stick", they will be quickly displaced by traffic and wind and effectiveness is lost. Methods of getting abrasives to "stick" include: mixing them with an ice control chemical in the stockpile, wetting the abrasives with an ice control chemical or warm water as they are distributed and heating the abrasives prior to distribution.

Abrasives, while initially inexpensive when compared with ice control chemicals, have hidden monetary and environmental costs that very often make them more expensive to use than chemicals. They are typically applied more frequently and at a rate of four or more times that of chemicals. In order to make abrasives flowable and stick to the ice, ice control chemicals are usually added. This brings up the cost and puts almost as much or more ice control chemical into the environment as using straight chemicals. In many areas of the country the per application cost of ice control chemicals and abrasives is about the same. When the cost of spring clean up and the more frequent applications associated with using abrasives are added, using abrasives where chemicals would otherwise work results in higher overall costs.

There are two significant environmental impacts associated with using large amounts of abrasives in snow and ice control programs. Siltation of water courses is a major problem in many areas of the country. This has profound negative impact on the water ecosystem. Abrasives are degraded by traffic and fine particles get into the air as dust. This is a significant problem in some of the western states and Japan.

CHAPTER 4
SNOW AND ICE CONTROL STRATEGIES

Treatment strategies for snow and ice conditions generally fall into five categories:

1. preventing an ice-pavement bond (anti-icing)
2. breaking an ice-pavement bond (de-icing)
3. temporary friction improvement
4. mechanical removal of snow and ice accumulation or packed snow and ice
5. doing nothing

ANTI-ICING

Anti-icing is a modern strategy that takes a systematic approach to preventing ice-pavement bond. This results in higher levels of service (available surface friction) for longer periods of time. The key to effective anti-icing is to get an ice control chemical on the surface before, or very soon after, precipitation or ice formation begins. While its highest benefits are on "important" roads and surfaces, "less important" facilities can also benefit. Anti-icing is not suitable for use on unpaved surfaces and areas where a low level of service is provided primarily by using abrasives. Figure 2 is a schematic of the anti-icing strategy.

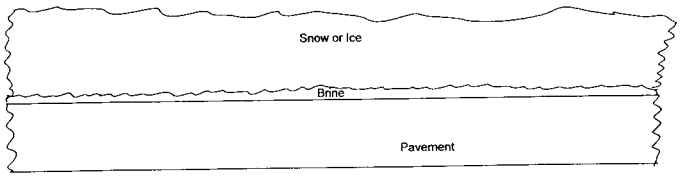


Figure 2 - Anti Icing

Elements of an Effective Anti-icing System

There are many elements that comprise an effective anti-icing system. Not all agencies will have all of the components identified. The important thing is to use whatever is available in a systematic way. You don't need all of the bells and whistles to have an effective anti-icing program.

Decision Making Elements

Having and using good information on the weather and surface conditions is the key to effective decision making. Current weather and forecast data are available from a

variety of sources including: local media, cable television (The Weather Channel), The National Weather Service (weather band radio), contract meteorologists, spotters, patrols, automated sensing systems, satellite data delivery systems and people

upstream in the storm path. Surface condition data is available from automated systems, observation and measurement, remote sensing points, and surrogate systems (data available from similar and proximate locations). Data on traffic volume and timing is also necessary in deciding the timing of treatments. By systematically using whatever data is available, informed decisions on anti-icing treatments can be made.

Plowing and Spreading Capability

Effectively removing accumulation of snow and ice on the surface and spreading the proper amounts of ice control chemicals in the right location at the right time is critical to effective anti-icing. To do this a sufficient quantity of materials spreaders and devices capable of timely removing almost all snow and ice on the surface must be available and used. The ability to "clean" the surface is important as it will require less ice control chemical to prevent the ice-pavement bond.

Solid Ice Control Chemicals

Solid ice control chemicals can be effective in anti-icing if they are used properly. Dry solid chemicals cannot be applied before a snow or ice event unless there is a reasonable chance they will stay on the surface. Vehicular traffic and wind can blow dry solid chemicals off paved surfaces. Wetting dry solid chemicals with water, or other liquid chemical solutions before they hit the paved surface makes them stick better and reduces "bounce and scatter" tendencies. Finer gradations of solid chemicals when heavily wet with a liquid will stand up to traffic and wind fairly well. Solid chemicals can be applied successfully to low volume/speed areas and to wet surfaces such as those just after a snow or ice event begins.

Liquid Ice Control Chemicals

Liquid ice control chemicals are very useful in an anti-icing program. Liquids can be applied to any paved surface prior to a snow or ice event and remain effective until it reaches critical dilution (the point where the solution will freeze). Liquids are not seriously displaced by traffic and the residue will remain effective for hours or even days in some conditions. Liquids are not very effective at pavement temperatures below about 22°F. Liquids should not be used on thick packed snow or ice surfaces as they will create a very slippery condition. Liquid ice control chemicals should be used only on very thin ice thickness.

Personnel

Skilled personnel at all levels within a maintenance organization are absolutely essential to a successful anti-icing program. Managers and supervisors need to be skilled at interpreting road and weather information. Operators need to be skilled in equipment operation, calibration, "reading the road" and common sense. These skills do not just happen - they are the result of comprehensive training programs. Well thought out call-out and stand-by procedures need to be in place in order to have people and equipment in the right place, at the right time to initiate anti-icing operations.

EVALUATIONS OF TREATMENT EFFECTIVENESS

The best guidance for effective anti-icing programs is developed at the local level. By systematically recording weather conditions, road conditions, treatments rendered and

results, an agency will have the data to develop its own treatment guidelines. Most likely there will be different treatments for the same weather and pavement conditions at different locations within the jurisdiction. This process has to be continuous - storm after storm, year after year in order to build a reliable data base.

DE-ICING

De-icing is a treatment strategy for dealing with snow or ice that has bonded to a paved surface. It may be necessitated by local treatment policy or when anti-icing treatments have failed (as they occasionally will). The most effective de-icing strategy is to place a coarse graded solid or pre-wet solid ice control chemical on the surface of the bonded snow or ice. The particles will melt through the ice and break the bond as the created chemical solution flows across the paved surface. Figure 3 is a schematic of the de-icing process. It is important to recognize that <u>for equivalent end results, a de-icing strategy for the same snow or ice event will generally require significantly more ice control chemical than an anti-icing strategy.</u>

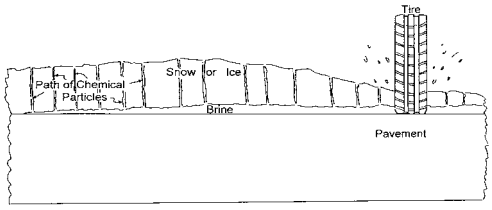


Figure 3 - Deicing

All of the elements that support anti-icing can be used to support effective de-icing. However, if technology and weather forecasting capability is acquired to support a routine de-icing strategy, it may not be cost effective.

TEMPORARY FRICTION IMPROVEMENT

The application of abrasives to snow and ice surfaces is a necessary treatment strategy in some circumstances. Abrasives are usually used in areas where a low level of service is provided and when the pavement surface is too cold for ice control chemicals to work. They can provide some surface friction until warmer temperatures allow effective de-icing or snow and ice removal.

Ice or snow-packed surfaces may be mechanically grooved, scarified or roughened to improve (slightly) friction and directional control. Any melting of the ice surface quickly eliminates the effectiveness of the treatment.

On unpaved and low volume roads, snow and ice is plowed to the extent possible and the remaining snow and ice surface is treated with abrasives (usually on hills, curves, and intersections). Ice control chemicals do not work efficiently on unpaved roads and they may adversely impact thin and porous paved surfaces. <u>Snow or ice surfaces that are treated with abrasives or are mechanically roughened have friction properties much lower than “bare” or “wet” paved surfaces.</u>

MECHANICAL REMOVAL OF SNOW AND ICE ACCUMULATIONS AND PACKED SNOW AND ICE

If there is traffic (vehicle or pedestrian) on a surface during a snow or ice event, periodic mechanical removal is necessary to keep the facility "passable". This is usually done with bladed equipment that has the capacity to displace snow and ice quickly. This mechanical removal may be done in conjunction with ice control chemical treatments designed to maintain surface friction and prevent or minimize ice-pavement bond.

When thick layers of packed snow or ice become bonded to the surface, specialized equipment is used to remove successive layers until the remaining layer can be successfully removed using a chemical de-icing technique. This is usually a very slow process. Motor graders and trucks with under body plows are usually used for this task. The combination of special ice blades and down-pressure enables this equipment to remove layers of ice. Newer mechanical impact devices that attach to motor graders do a good job of breaking up the ice prior to blade removal. Unless the pavement temperature is above 32°F, removal of the final layer of snow and ice on a paved surface will require an ice control chemical.

DOING NOTHING

Doing nothing can be an appropriate informed strategy in some circumstances. Typically pavement temperatures above 34°F associated with light frozen precipitation will not require treatment. Similarly light "dry" snow on a very cold paved surface (without any residual ice control chemical) may not require treatment. Vehicular traffic and/or wind will blow the snow off the surface.

CHAPTER 5
GUIDELINES FOR APPLYING SNOW AND ICE CONTROL MATERIALS

The application of snow and ice control materials should always be based on local policy and local level of service determinations. The recommendations found in Appendix's III, IV, and V are intended to produce a fairly high level of service at a modest cost. The recommended application rates listed are for Sodium Chloride ("salt" or "rock salt"). Application rates for other ice control chemicals will have to be adjusted to reflect the properties of the individual chemical. Before getting started, a definition of terms is in order. The glossary that follows is from PUBLICATION FHWA-RD-95-202 "Manual of Practice for an Effective Anti-Icing Program: A Guide for Highway Winter Maintenance Personnel" published by the Federal Highway Administration of the United States Department of Transportation and other sources. It should be noted that "black ice" and "frost" most often occurs in the absence of observable precipitation.

GLOSSARY OF TERMS

RELATING TO PRECIPITATION, PAVEMENT CONDITION, AND OPERATIONAL PROCEDURES

1. Precipitation Definitions

Light Rain — Small liquid droplets falling at a rate such that individual drops are easily detectable splashing from a wet surface. Include drizzle in this category. (0.10 inches per hour or less)

Moderate Rain — Liquid drops falling are not clearly identifiable and spray from the falling drops is observable just above pavement or other hard surfaces. (0.11 – 0.30 inches per hour)

Heavy Rain — Rain seemingly falls in sheets; individual drops are not identifiable; heavy spray from falling rain can be observed several inches over hard surfaces. (Greater than 0.30 inches per hour)

Freezing Rain — When rain freezes upon impact and forms a glaze on the pavement or other exposed surfaces.

Sleet (ice pellets) — Precipitation of transparent or translucent pellets of ice, which are round or irregular in shape.

Light Sleet — Scattered pellets that do not completely cover an exposed surface regardless of duration. Visibility is

	not affected. (Less than 0.10 inches per hour of water equivalent)
Moderate Sleet	Slow accumulation on ground. Visibility reduced by ice pellets to less than 7 miles. (0.11 – 0.30 inches per hour of water equivalent)
Heavy Sleet	Rapid accumulation on ground. Visibility reduced by ice pellets to less than 3 miles. (Greater than 0.30 inches per hour of water equivalent)
Light Snow	Snow alone is falling and the visibility is greater than ½ mile (0.9 km). (Less than 0.50 inches per)
Moderate Snow	Snow alone is falling and the visibility is greater than ¼ mile (½ km) but less than or equal to ½ mile. (0.51 to 1.00 inches per hour)
Heavy Snow	Snow alone is falling and the visibility is less than or equal to ¼ mile. (Greater than 1.0 inches per hour)
Blowing Snow	When fallen snow is raised by the wind to a height of 6 feet. (1.8 m) or more and is transported across a road.
None	No precipitation or blowing snow.
Powder Snow	Loose, fluffy dry snow typically occurring below an air temperature of 22 °F
Ordinary Snow	More compact than powder snow typically occurring between 22 °F and 27 °F
Wet/Heavy Snow	Larger wet flakes typically occurring above 2 °F

2. Pavement Condition Definitions

Dry	No wetting of the pavement surface.
Damp	Light coating of moisture on the pavement resulting in slight darkening of concrete, and worn blacktop pavements, but with no visible water drops.
Wet	Road surface saturated with water from rain or melt water, whether or not resulting in puddling or run–off.

Slush Accumulation of snow on the pavement that is saturated with water. It will not support any weight when stepped or driven on but will “squish” until the base support is reached.

Loose Snow Unconsolidated snow that can be blown by the wind into drifts or off of a surface, or blown by traffic into non-traffic areas or off of a pavement.

Packed Snow The infamous “snow–pack”, “pack” or “compact” which results from compaction of wet snow by traffic or by alternate surface melting and refreezing of the water.

Frost Also called hoarfrost. Ice crystals in the form of white scales, needles, feathers, or fans deposited on pavement and other surfaces cooled by radiation or by other processes.

Thin Ice A very thin coating of clear, bubble–free, homogenous ice that forms on a pavement; sometimes called “black ice.”

Thick Ice A coating of ice thicker than so–called “black ice” and frost that is formed from freezing rain, or from freezing of ponded water or poorly drained melt water. It may be clear or milky in appearance, is generally smooth, though sometimes rough.

3. Operational Procedure Terms

Pre–treating Applying an ice control chemical (liquid or solid) to the road before a snow or ice event begins.

Pre–wetting Adding liquid ice control chemical or water to solid ice control chemicals or abrasives prior to distribution on the road.

Application Rate The amount (weight or volume) of ice control chemical applied per mile or lane–mile of highway. In the case of pre–wetting liquids, it is the number of gallons of liquid applied to a ton of solid ice control chemical, or abrasives.

FACTORS THAT INFLUENCE ICE CONTROL CHEMICAL'S EFFECTIVENESS AND TREATMENT LONGEVITY

The three primary factors that influence an ice control chemical's effect are pavement or surface temperature, chemical dilution, and traffic volume and speed. Understanding the relationship within and among them will lead to a better understanding of application guidelines. One also has to understand that occasionally there are snow and ice events so severe that we cannot reasonably apply enough chemical to make a significant difference.

Pavement or Surface Temperature

Pavement or surface temperature impacts how quickly an ice control chemical will melt ice and ultimately how much ice it will melt. As the surface temperature decreases so does the melting ability and melting rate of ice control chemicals. Table 1 gives an indication of the influence of surface temperature on the melting ability of Sodium Chloride, Magnesium Chloride and Calcium Chloride.

A number of factors influence pavement or surface temperature. Understanding their impact can aid in designing appropriate treatments.

Solar Radiation or Sunshine

Solar radiation warms surface temperature significantly above air temperature. The darker the surface, the more pronounced this effect will be. It is not uncommon to have surface temperatures 30°F to 40°F above air temperature early in the afternoon. As the angle of the sun above the horizon increases, solar warming increases. The lowest sun angles occur at the winter solstice and at sunrise and sunset of each day.

Clear Night Sky Radiation

Just as the sun warms surfaces through radiation, clear night skies with little or no wind, allows road surfaces to cool quickly. This often results in surface temperature being colder than the adjacent air temperature. This condition often allows black ice or frost to form on the surface.

Geo–Thermal Effects

Ground temperature influences surface temperature primarily through thermal conduction. In the fall, while the earth is still warm, short–term air temperature drops below freezing, without radiation effects, will probably not cause the surface to freeze. During the spring end of the season, surface temperatures will remain cold although the air temperature is warmer (absent radiation effects). Bridge decks cool quicker in the fall due to the lack of thermal conduction provided by the earth. However, in the spring, bridge decks warm more quickly than surrounding surfaces for the same reason.

Air Temperature and Wind

Absent radiation and geo–thermal effects, the surface temperature will always be moving toward the adjacent air temperature. The speed of temperature change is usually much slower than changes caused by radiation or geo–thermal effects.

However, with increasing wind speed, the rate of pavement temperature change due to air temperature will increase slightly.

Chemical Dilution:

Loose Snow or Ice and Water on the Surface

The dilution of the ice control chemical by loose snow or ice and water on the surface dictates how long the treatment will remain effective (for the same temperature) or how much melting it will do.

Ice or Water Content of the Event (Precipitation Type)

The ice content of snow and ice events varies dramatically. Light, fluffy “dry” snow has an ice content in the range of 10 percent. Wetter, “heavier” snow may be as high as 80 percent ice or water. Rain, sleet, and freezing rain all have nearly 100 percent ice or water. Higher ice content events will dilute ice control chemicals more rapidly.

Event Intensity or Precipitation Rate

The more intense the precipitation rate, the quicker it will dilute an ice control chemical. A high ice content event falling at a high rate of accumulation is about the worst–case scenario.

Cycle Time of Chemical Treatments

The longer the time between treatment cycles, the greater the opportunity for dilution. However, cycle times must be long enough to allow the chemicals to work.

Clearing Ability of Plows and Residual Snow and Ice on the Road

The more snow and ice mechanical equipment removes, the less dilution will occur in the following chemical treatment. Secondary rubber or slush blades do a good job of clearing the surface.

Bond of Snow or Ice to the Pavement

Snow or ice bonded to the pavement will require more ice control chemicals to achieve the bear/wet/un bonded condition than un bonded snow or ice.

Traffic

Traffic can have positive and negative effects on ice control chemicals. There is some small level of pavement warming that results from tire friction and the radiant effects of engine and exhaust systems. Mechanical agitation helps loosen snow and ice weakened by the ice control chemicals and keeps some potentially frozen brine solutions from actually freezing. Traffic can also remove ice control chemicals from the surface and consolidate snow to form pack. Vehicle–generated wind can displace solid chemicals and tire spray, and wind can cause airborne liquid chemicals to leave the pavement environment.

GUIDANCE FOR DESIGNING SNOW AND ICE CONTROL TREATMENTS

Guidance for applying snow and ice control materials can be found in a number of publications. “The Snowfighter’s Handbook” produced by the Salt Institute and the previously cited FHWA Manual of Practice contains excellent guidance and portions of those documents appear in the APPENDIX III and APPENDIX IV respectively.

APPENDIX V is an attempt to convey the latest available guidance. Here the factors that relate to pavement temperature and chemical dilution are identified, and. A methodology to design snow and ice material treatments is presented.

CHAPTER 6
APPLICATION TECHNIQUES FOR ICE CONTROL CHEMICALS

After the ice control treatment for prevailing conditions has been decided, the final step is to get the designed treatment in the right location at the right time. There are a number of techniques that can optimize treatment effectiveness:

TWO LANE, TWO WAY TRAFFIC HIGHWAYS (1 LANE EACH WAY)

The most effective way to treat this highway is to spread the ice control chemical in about the middle third of the highway. The slope of the highway and traffic will distribute the chemical fairly quickly across the entire pavement. When doing simultaneous plowing operations, care must be taken not to plow chemicals off too quickly. Set the spreader to spread only in the plowed path. If plowing is not anticipated, spread the entire middle third on the “out” run of an “out and return” route. Its okay to have a truck on the road not spreading if it is part of a planned strategy.

MULTI-LANE HIGHWAYS

Most agencies spread ice control chemicals on multi-lane highways as nearly full width as possible. Care must be taken not to spread beyond the pavement limits. Narrow bands of material near the high edge of each lane are also effective.

PARKING AREAS AND WALKWAYS

Spreading ice control chemicals as evenly as possible over the entire paved area is recommended for parking areas and walkways. These areas present a unique opportunity for anti-icing with solid chemicals as traffic will not displace them from the surface.

HILLS, CURVES AND INTERSECTIONS

Because of the higher friction requirements on hills, curves and intersections, many agencies use a higher application rate than on straight sections of highway. On lower level of service highways, these are sometimes the only areas that receive treatment. When doing special treatment at intersections, it is important to carry the treatment beyond the point where traffic normally backs up in snow and ice conditions.

BRIDGES AND ELEVATED STRUCTURES NOT RESTING ON EARTH

In the Fall and at other times when there is a rapid, severe, decrease in air temperature, elevated structures are likely to be colder than adjacent pavement on earth. It is appropriate to increase application rate on these structures so critical dilution will not occur or will occur at about the same time as the surrounding pavement. Toward Spring, when air temperatures are warming, structure temperatures are likely to be warmer than the surrounding pavement. Higher application rates are not necessary in this situation.

STRONG CROSS WINDS

When spreading in strong cross winds, try to keep the spreader upwind of the intended spread location. If the wind is too strong, spreading may not be appropriate.

BANKED OR ELEVATED CURVES

Try to keep the spread pattern on the high side of elevated curves. As the chemical works, chemical brine will migrate over the remainder of the pavement.

CHANGES IN MAINTENANCE JURISDICTION OR LEVEL OF SERVICE

Sometimes where maintenance jurisdiction or mandated level of service changes, there will be a dramatic change in the available pavement friction. This is a dangerous condition as it is usually unexpected. To alert motorists, appropriate signing or transitioning of the level of service treatment should be used. Having transitions occur at intersections is a good way to accomplish this.

THE WORST CASE SCENERIOS

The worst cases usually occur when the chemical treatment is quickly overwhelmed (diluted) by excessive amounts of water or ice. Blizzard conditions (intense snowfall, wind, very cold temperatures) quickly dilute ice control chemicals and render them virtually useless. If the pavement temperature going into and coming out of a blizzard is expected to be low, then plowing only is probably the best strategy. After the blizzard, if it is still very cold, use abrasives as necessary until warmer temperatures will allow chemical de-icing to work. If the pavement temperature throughout and after the blizzard is likely to be fairly warm, a treatment with an ice control chemical before or early in the storm followed by plowing only throughout the storm, will make de-icing at the end of the storm much quicker.

Rapidly accumulating freezing rain is another maintenance nightmare. The best strategy here is to apply solid ice control chemicals, at a high rate, in very narrow bands in the high side wheel path of each lane. With luck, there will be a location in each lane that will provide enough friction to allow vehicles to stop and steer.

In situations where falling and/or blowing snow make visibility near zero, it is a good idea to get snow and ice control vehicles well off the road. Operating in those conditions is a risk to everyone involved.

TYPICAL SPREAD PATTERNS FOR SOLID ICE CONTROL MATERIALS

Figure 4 (page 22) illustrates five typical general spread patterns and their use. This should strongly suggest that identifying spreader settings to achieve these patterns should be part of the calibration process. It is likely that optimum spread patterns will change before, during, and after winter weather events as weather and operational conditions are continually changing.

Most solid ice control materials spreaders have adjustment capability that will achieve these patterns. These include:

• spinner speed	This controls how far the material is cast
• deflectors	These limit the cast of the materials. Note: When there is deflector control, increasing spinner speed will not increase cast distance.
• Drop location on spinner	The bulk of the material discharged will be about 180° from the drop location
• Spinner direction	The direction of rotation can be changed by reversing the hydraulic hoses that drive the spinner motor

Achieving the desired spread patterns is largely a trial and error process. They can be established by observing the accumulation of material on the floor of the chemical storage facility. They should be verified by observing the pattern during field operations.

GETTING THE APPLICATION RATE RIGHT

Application rates for ice control chemicals are usually specified in pounds per lane mile or kilograms per lane kilometer. Spreaders are usually calibrated to deliver pounds per mile or kilograms per kilometer (the discharge rate). It is important to understand that relationship in order to be sure the proper application rate is being used. The application rate is the number of pounds or kilograms dispensed per mile or kilometer (the discharge rate) divided by the number of lanes being treated. Table 2 demonstrates that relationship:

TABLE 2 DISCHARGE RATE AND APPLICATION RATE

Discharge Rate	Application Rate, kilograms per lane kilometer Number of Lanes Being Treated		
(kilograms/kilometer)	1	2	3
28 (100)	28 (100)	14 (50)	9 (33)
56 (200)	56 (200)	28 (100)	19 (67)
84 (300)	84 (300)	42 (150)	28 (100)
112 (400)	112 (400)	56 (200)	37 (133)
140 (500)	140 (500)	70 (250)	47 (167)
168 (600)	168 (600)	84 (300)	56 (200)
196 (700)	196 (700)	98 (350)	65 (233)
224 (800)	224 (800)	112 (400)	75 (267)
(Pounds/Mile)	(Pounds per Lane Mile)		

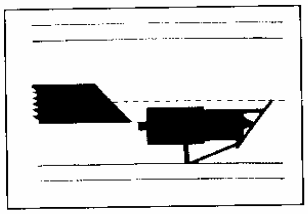
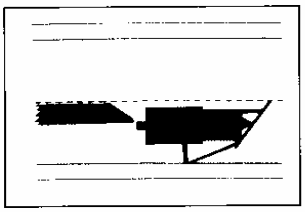
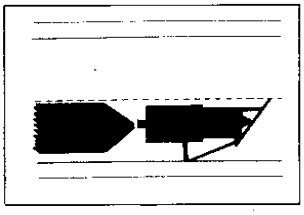
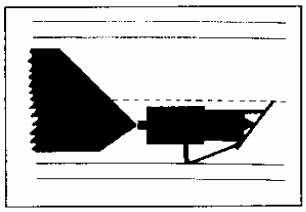
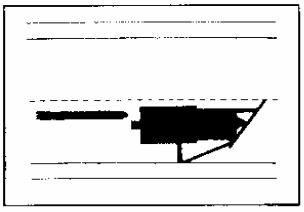
PATTERN	MATERIALS	USE
	• Chemicals	• Spread only on 2 lane- 2 way traffic or high points on multilane, one way traffic • Plow and spread on the "return" portion of an "out" and "return" segment
	• Chemicals	• Plow and spread if multi lane 1 way, apply to high side of lane (it could be to the far right in the lane)
	• Chemicals • Abrasives • Chemicals/ Abrasives Mix	• Plow and spread • Spread only
	• Chemicals • Abrasives • Chemicals/ Abrasives Mix	• Spread only thin ice or other slippery conditions where a quick response is required • Plow and spread on the "return" portion of an "out" and "return" segment
	• Chemicals	• Spread only – thick ice (heavy freezing rain) • Plow and spread in blizzard like conditions

Figure 4 - Typical Spread Patterns for Solid Materials and Their Uses

CHAPTER 7
SNOW PLOWING AND REMOVAL

Removal of accumulations of snow from highways and other transportation facilities by plowing usually is the necessary first step in restoring function. However, if the anti-icing strategy was successfully employed, it may be the last step.

VEHICLE MOUNTED PLOWS

Snowplows are most often mounted on a wide variety of truck types. Other vehicles including: motor graders, front-end loaders, ATV's, train engines and various tracked vehicles are often equipped with plows.

FRONT OR "NOSE" PLOWS

There are a variety of plow types that are mounted on the front of vehicles. The geometric characteristics of the plow dictate how well it will perform in various snow types, snow depths, operating speeds, wind conditions and directions of removal. Plow geometry should be chosen on the basis of the primary function of the plow. **NO SINGLE GEOMETRY WILL PERFORM ALL PLOW FUNCTIONS WELL.**

ONE WAY PLOWS

One way plows are designed to cast snow in one direction. They usually have significant curl and barreling that contain and discharged snow well at higher plowing speeds.

TWO-WAY OR REVERSIBLE PLOWS

These plows are designed to cast snow right, left or straight ahead. They are adjusted either manually or hydraulically to the desired angle. These plows typically do not have much curl or barreling and they are near vertical in attitude. As a result, they allow a fair amount of snow to escape over the top of the plow during higher plowing speeds.

There are hybrid reversible plows in the marketplace that contains some curl and barreling on both ends. They do a better job of snow containment.

VARIABLE GEOMETRY PLOWS

Plows made of polymer materials and having the ability to adjust curl and barrel on both ends are available. They can be adjusted to perform most plowing tasks well.

"V" PLOWS

"V" shaped plows have been around for many years. They are designed to deal with deep snow and drifts. Their "V" shape casts snow in both directions simultaneously. They have limited value in routine highway and facility plowing operations. They are most often used on rail engines and in rural narrow road applications.

WING PLOWS

Wing plows are mounted on equipment to increase plowing width and provide benching and shelving capability. They are mounted on either or both sides anywhere from front

to rear axle and typically stow close to the vehicle. The extra plowing width usually makes them very cost effective when doing production plowing of streets and highways.

UNDER-BODY OR "BELLY" PLOWS

These plows are mounted under the vehicle, most often between the axles. They usually have provision for changing down-pressure, horizontal angle, vertical angle, left-right movement and vertical stowage. The down-pressure feature is particularly useful when removing pack and ice. They are sometimes equipped with a rubber blade to "squeegee" the surface in conjunction with conventional front steel plows.

BLADES OR CUTTING EDGES

Plow blades are usually made of steel. Other materials are sometimes used to satisfy site specific applications. Steel blades tends to wear quickly in the high-production environment. It is not unusual to have to change or reverse steel cutting blades every several hours. Steel blades with Tungsten carbide or ceramic inserts wear much slower and may have to be changed only once per season in a high-use environment. Mounting a regular steel cover blade in front of the Tungsten carbide blade can extend the life of these blades.

Rubber and polymer blades are used to "squeegee" the road and provide a "cushion" for frequent obstructions. Although these blades wear well, they do not cut and scrape compacted snow and ice very well. These blades are well suited to support a routine anti-icing strategy.

Plow blades are sometimes "shaped" to facilitate ice cutting, texturing ice surface or wear into a new "shape". These blades are most often used on plows that have down-pressure capability.

PLOW SHOES AND CASTER WHEELS

Plow shoes or caster wheels are sometimes used to minimize the blade from dropping into surface depressions. Unless these "depressions" are a "real" issue, there is little benefit to casters and shoes. Obstructions and depressions are most often accommodated by a "tripping" mechanism on the plow. There are several types. One is where only the blade or cutting edge "trips". A second type is where the whole plow "trips". Of the two, the blade or cutting edge "trip" seems to be preferred. A third type is where the whole plow "trips" on to the plow frame that is supported by shoes or casters. This seems to work quite well.

SNOW PLOWING PROCEDURES

Snow plowers use a variety of techniques that depend on highway configuration and environmental conditions. There are some general guidelines that apply:

- Try not to leave berms of snow on the traveled way for long periods of time.
- Maximize the use of right turns in routing.
- Where possible, cast snow downwind.
- Do not plow recently applied ice control chemicals off the road.
- Do not plow snow off bridges and overpasses.

- Use close echelon plowing (where the plows are close enough together that traffic cannot pass) to the extent possible on one-way (divided) highways having high traffic volume during plowing operations.
- Minimize backing maneuvers.
- Plow snow well beyond the high point on banked curves and other similar sections.
- Do not cast snow into traffic.
- Try to plow before peak traffic.
- When visibility is reduced to near zero by falling or blowing snow, get the plow vehicle safely well off the road and shut all lights off. Resume operations when visibility improves to a reasonably safe distance.

BENCHING AND SHELVING

Benching and shelving is usually accomplished with wing plows. It may be part of a pushing-back operation to provide additional snow storage, improve sight distance, or widen an existing plowed path. Here, the wing plow is near horizontal and several feet off the ground. This operation usually requires placing locking pins in the wing plow push arms. **These pins must be removed when performing normal plowing operations.**

SNOW REMOVAL

Snow removal operations usually require significant relocation of snow as opposed to simple displacement provided by plowing. Snow blowers and large wheel loaders are the primary pieces of equipment used for this purpose. Snow blowers can cast snow well away from the working location or deposit it into a truck for subsequent disposal. In the highway environment, try to cast snow downwind. This will minimize the snow cloud

and make the operation more visible to motorists. If it is calm, cast the snow into the direction of the prevailing wind. The resulting snow berm will act like snow fence and capture some blowing snow that would otherwise reach the highway. When using snow blowers, care must be exercised to avoid involvement with non-snow objects. Large loaders can also relocate snow into trucks or elsewhere in the immediate area. This is a slower operation, but it works.

SAFETY RESTORATION AND CLEAN-UP OPERATIONS

After snowplowing and the return of the pavement surface to the appropriate level of service, safety restoration and clean-up operations should commence. In general, safety related tasks should proceed mobility and commerce related tasks. The following list of clean-up operations that is in approximate priority order (Reference 8, APPENDIX VI):

1. Snow removal at locations that could melt and run onto the pavement (banked curves, super-elevated ramps, etc.).
2. Snow removal on bridges (do not cast snow on features below).
3. Snow removal in areas of reduced sight distance (intersections, curves, interchanges, etc.).
4. Snow removal around safety features (impact attenuators, guardrail, close median barriers, etc.).
5. Removal of accumulated snow that may be causing traffic to use other than intended pavement areas.
6. Snow removal in limited storage areas (narrow median, shoulders, gores, etc.)
7. Snow removal from recessed drainage features, culverts, channels, gutters, sag curves, etc. that may cause melt water to flow onto the pavement and freeze at night.
8. Snow removal from shallow cuts that may have drifted in.
9. Snow and ice removal at railroad crossings.
10. Snow removal on raised islands, medians, shoulders, gores, bridge sidewalks and guardrail support. Also rumble strips, curbs, raised pavement markings, buried delineator posts, etc.
11. Snow removal from buried or obscure signs.
12. Snow removal in restricted areas that may impact mobility.
13. Snow removal in business/commercial areas.

FINAL STATEMENT

This workbook has been designed to identify the major issues associated with snow and ice control programs. The references cited in APPENDIX VI contain much more detail and are highly recommended reading for snow and ice control practitioners.

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APPENDIX I

ITEMS TO CONSIDER IN A MUNICIPAL S&I CONTROL PLAN (In approximate Order of Importance)

1) Communications Issues
   A. Internal
      1. police
      2. fire
      3. other agency departments (parks, sewer, water, etc.)
      4. emergency medical services
      5. maintenance personnel (chain of command, organizational chart, mobilization procedures, responsibilities, etc.)
      6. emergency management team
      7. emergency operations center
      8. radio procedures
   B. External
      1. media/public
      2. other governmental agencies (resource sharing)
      3. emergency contractors and equipment rentals
      4. providers of snow removal and other emergency services (public and private)
         a. plowing, spreading and hauling
         b. towing
         c. shelter and food
         d. utilities
      5. customer complaint-follow-up, requests for service
   C. Weather and Pavement Condition Information
      1. sources
      2. distribution
      3. use

2) Level of Service (LOS) Issues
   A. General Statement of Objectives
   B. Definition of LOS characteristics
      1. frequency and time periods of treatment
      2. type of treatment
         a. chemical treatments
         b. plow only areas
         c. abrasives treatment
         d. seasonal road closure
      3. Priority of Treatments
         a. traffic and traffic generation considerations
         b. school bus and transit routes
         c. medical and other emergency facility locations
         d. school areas
         e. continuity of government
         f. hills, curves and intersections
         g. recurring problem areas

4. Goal pavement conditions at various points in time
5. Storm clean-up and safety restoration priorities, procedures, and timing
   a. loading and hauling warrants
   b. sidewalk, alley, fire hydrant and driveway clearing
6. how residents can help
7. safety tips
8. budget and resource data
9. disclaimers

3) Legal Issues
   A. Street Parking
      1. alternate side
      2. prohibited seasons/hours
      3. during snow storms, snow emergencies and clean-up
      4. abandoned vehicles
   B. Damage
      1. mailboxes
      2. turf
      3. other
   C. Enforcement Procedures
   D. Regulations and registrations relating to commercial plowers
   E. Regulations relative to the relocation of snow and ice from private drives and sidewalks
   F. Road Closures and Detours
   G. Vehicle Equipment Requirement (during certain time and storm periods)
      - Chain control
      - Snow tires, radial tires, etc.

4. Operating Procedures (This could be a separate document depending on the level of detail)
   A. Human Resource Issue
      1. training
      2. call-outs
      3. overtime/shifts/scheduling
      4. temporary personnel
      5. union agreement
   B. Materials Management Issues
      1. types
      2. storage
      3. controls
      4. environmental responsibility issues (disposal of cleaned up abrasives and snow, chemical storage, NPDES II requirements and ice control chemical storage
   C. Equipment Management Issues
      1. inventory
      2. outsourcing
      3. partnerships

4. inspection/safe operating procedures
5. criteria for “downing” equipment
6. maintenance requirements
    a. pre-season
    b. in-season
    c. post-season
7. calibration
8. fueling procedures

D. Strategies & Tactics
1. response to various types of storms
2. priority/sequences of treatment
3. treatments provided at various locations

E. Operations
1. specific beats/routes for various storm conditions
2. chemical/abrasives application rates
3. plowing and materials spreading procedures
4. road closure/procedures
5. beat maps
6. known “trouble” or “sensitive” spots
7. post-storm safety and drainage restoration priorities, procedures and timing
8. abrasives clean-up, turf repair, etc.
9. loading and hauling – criteria and procedures
10. snow disposal (ordinary and contaminated)
11. non-highway snow and ice control locations and procedures
12. policy on “private” facilities
13. periodic inspection of highways and facilities

F. Reporting and De-Briefing
1. record keeping requirements
2. storm reports (weather and road conditions, accidents)
3. storm and seasonal debriefings
4. storm and seasonal resource use reports

5) “Living” Document Provisions
A. update requirements
B. participative procedures

6) Appendices
A. copies of local laws
B. diagrams and maps

An example of a well crafted plan and policy can be found at :

HTTP://www.twp.cranberry.pa.us/publicworks/SNOWANDICECONTROL04.pdf

APPENDIX II:

SPREADER CALIBRATION PROCEDURE

Calibration of spreaders is simply calculating the pounds per mile discharged at various spreader control settings and truck speeds by first counting the number of auger or conveyor shaft revolutions per minute, measuring the material discharged in one revolution, then multiplying the two and finally multiplying the discharge rate by the minutes it takes to travel one mile.

With hopper-type spreaders, specific gate openings must be calibrated. Measure from floor of conveyor to bottom edge of gate.

Each spreader must be calibrated individually; even the same models can vary widely at the same setting.

Equipment needed:

1. Scale for weighing.
2. Canvas or bucket/collection device.
3. Chalk, crayon or other marker.
4. Watch with second hand.

Calibration steps

1. Warm truck's hydraulic oil to normal operating temperature with spreader system running.
2. Put partial load of salt on truck.
3. Mark shaft end of auger or conveyor.
4. Dump salt on auger or conveyor.
5. Rev truck engine to operating RPM (at least 2000 RPM).
6. Count number of shaft revolutions per minute at each spreader control setting, and record.
7. Collect salt for one revolution & weigh, deducting weight of container. (For greater accuracy, collect salt for several revolutions and divide by this number of turns to get the weight for one revolution.) This can be accomplished at idle or very low engine RPM.
8. Multiply shaft RPM (Column A) by discharge per revolution (Column B) to get discharge rate in pounds per minute (Column C), then multiply discharge rate by minutes to travel one mile at various truck speeds to get pounds discharged per mile.

**For example, at 20 MPH with 30 Shaft RPM and 7 lbs. discharge- 30 x 7 = 210 x 3.00 = 630 lbs. per mile*

Calibrating Automatic Controls

Automatic controls come with factory calibration cards that indicate the proper rate of spread for each setting. However, when there is a need to calibrate, use the following steps:

1. Remove or turn off spinner.
2. Set auger on given number, such as No. 2.
3. Tie sack or heavy canvas under discharge chute.
4. Mark specific distance, such as 100 or 1,000 feet.
5. Drive that distance with spreader operating.
6. Weigh salt collected in sack or canvas.
7. Multiply weight of salt by 5.2 (in case of 1,000 feet) or 52.8 (in case of 100 feet).

This will be the amount of salt discharged per mile, which remains constant regardless of speed, but calibration must be done for each control setting.

NOTE ; THE ACTUAL APPLICATION RATE ON THE ROAD IS THE AMOUNT DISCHARGED PER MILE DIVIDED BY THE NUMBER OF LANES BEING TREATED

CALIBRATION CHART

Agency: _____

Location: _____

Truck No.: _____ Spreader No.: _____

Date: _____ By: _____

GATE OPENING (HOPPER TYPE SPREADER)				POUNDS DISCHARGED PER MILE								
	A	B	C	MINUTES TO TRAVEL ONE MILE								
Control Setting	Shaft RPM (Loaded)	Discharge Per Revolution (Pounds)	Discharge Rate (Lbs/Min)	5 mph x 12.00	10 mph x 6.00	15 mph x 4.00	20 mph x 3.00	25 mph x 2.40	30 mph x 2.00	35 mph x 1.71	40 mph x 1.50	45 mph x 1.33
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

APPENDIX III
STORMFIGHTING GUIDELINES

The following chart is a guideline to combat various types of storms.
Local conditions and policies will be the final determining factor.

Condition 1 **Temperature** Near 30 **Precipitation** Snow, sleet or freezing rain' **Road Surface** Wet	If snow or sleet, apply salt at 500 lbs. per two-lane mile. If snow or sleet continues and accumulates, plow and salt simultaneously. If freezing rain, apply salt at 200 lbs. per two-lane mile. If rain continues to freeze, re-apply salt at 200 lbs. per two-lane mile. Consider anti-icing procedures.
Condition 2 **Temperature** Below 30 or falling **Precipitation** Snow, sleet or freezing rain **Road Surface** Wet or Sticky	Apply salt at 300-800 lbs. per two-lane mile, depending on accumulation rate. As snowfall continues and accumulates, plow and repeat salt application. If freezing rain, apply salt at 200-400 lbs. per two-lane mile. Consider anti-icing and de-icing procedures as warranted.
Condition 3 **Temperature** Below 20 and falling **Precipitation** Dry Snow **Road Surface** Dry	Plow as soon as possible. Do not apply salt. Continue to plow and patrol to check for wet, packed or icy spots; treat them with heavy salt applications.
Condition 4 **Temperature** Below 20 **Precipitation** Snow, sleet or freezing rain **Road Surface** Wet	Apply salt at 600-800 lbs. per two-lane mile, as required. If snow or sleet continues and accumulates, plow and salt simultaneously. If temperature starts to rise, apply salt at 500-600 lbs. per two-lane mile, wait for salt to react before plowing. Continue until safe pavement is obtained.
Condition 5 **Temperature** Below 10 **Precipitation** Snow or freezing rain **Road Surface** Accumulation of packed snow or ice	Apply salt at rate of 800 lbs. per two-lane mile or salt-treated abrasives at rate of 1500 to 2000 lbs. per two-lane mile. When snow or ice becomes mealy or slushy, plow. Repeat application and plowing as necessary.

Note: The light, 200-lb. application called for in Condition 1 and 2 must be repeated often for the duration of the condition.

APPENDIX IV
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:

- Light Snow Storm
- Light Snow Storm with Period(s) of Moderate or Heavy Snow
- Moderate or Heavy Snow Storm
- Frost or Black Ice
- Freezing Rain Storm
- 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.
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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; *ALSO* **-4 to 0°C (25 to 32°F)**, remaining in range	Dry	Apply liquid or prewetted solid chemical	28 (100)	28 (100)	Plow as needed; reapply liquid or solid chemical when needed	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 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
	Wet, slush, or light snow cover	Apply liquid or solid chemical	28 (100)	28 (100)						
-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; *ALSO* **-1 to 0°C (30 to 32°F)**, remaining in range	Dry	Apply liquid or prewetted solid chemical	28 (100)	28 (100)	Plow accumulation and reapply liquid or solid chemical as needed	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 2) Do not apply liquid chemical onto heavy snow accumulation or packed snow
	Wet, slush, or light snow cover	Apply liquid or solid chemical	28 (100)	28 (100)				
-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 liquid or solid chemical as needed	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 operational cycles 2) Do not apply liquid chemical onto heavy snow accumulation or packed snow
	Wet, slush, or light snow cover	Apply liquid or solid chemical	55 (200)	42-55 (150-200)				
-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

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 (32°F) or below, *and* equal to or below dew point	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 that the pavement can not be seen
	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)	
-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

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

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 V
DESIGNING SNOW AND ICE CONTROL MATERIAL TREATMENTS

A recommended step-by-step procedure taken from NCHRP Report 526, “Snow and Ice Control : Guidelines for Materials and Methods”, October, 2004 follows that winter maintenance field personnel can follow in determining an appropriate snow and ice control chemical treatment action to take in response to a variety of conditions. Appropriate application rates for solid, prewetted solid, and liquid NaCl are given as a function of pavement temperature range, adjusted dilution potential level, and the presence or absence of ice/pavement bond. The adjusted dilution potential level accounts for precipitation type and rate, snow and ice conditions on the road, and treatment cycle time and traffic volume conditions. The recommended snow and ice control material application rates depend on atmospheric and pavement conditions at the time of treatment and on how these conditions are expected to change over the time window prior to the next anticipated treatment.
Implicit in the treatment guidelines is the requirement that plowing, if needed, should be performed before chemical applications are made. This is necessary so that any excess snow, slush, or ice is removed and the pavement surface is wet, slushy, or lightly snow covered when treated.

The first step in the procedure is to determine the pavement temperature at the time of treatment and the temperature trend after treatment. A judgment, either estimated or predicted by modeling techniques, of what the pavement temperature will be in the near term (1 to 2 hours after treatment) is necessary. This is one aspect of what is commonly called “nowcasting.” This will result in the determination of the “pavement temperature and trend.”
The next step is to establish the dilution potential that a chemical treatment must: endure before another treatment is made during a winter weather event, or produce a satisfactory result in the absence of precipitation at the end of an event. The establishment of the dilution potential for each treatment includes consideration of precipitation type and rate (including none), precipitation trend, the presence of various wheel path area conditions, treatment cycle time, and traffic speed and volume.

The dilution potential for the precipitation at the time of treatment and its anticipated trend in the short-term is determined from Table A. The level of precipitation dilution potential will be either low, medium, or high. The definitions of the different types and rates of snowfall are given elsewhere. In the absence of precipitation, the dilution potential is determined from the wheel path area condition and is also shown in Table A
.
In the next step, an adjustment to the precipitation dilution potential shown in Table A may have to be made for various wheel path area conditions. These adjustments are given in Table A as well

Next, an additional adjustment to the precipitation dilution potential may have to be made for treatment cycle time. This is the time between anticipated successive treatment passes. In the case of pretreating, it is the time between the onset of precipitation and the next anticipated treatment. These adjustments are given in Table A.

Finally, an adjustment to the precipitation dilution potential may have to be made for traffic speeds greater than 35 mph and traffic volume greater than 125 vph. These adjustments are also given in Table A. No adjustment is made for traffic volume when traffic speeds are 35 mph or below.

When making additional level adjustments to the precipitation dilution potential, an adjustment level of 1 would change a low level to a medium level or a medium level to a high level. An adjustment level of 2 would change a low level to a high level. The end result of adding various factor adjustment levels to the precipitation dilution potential is termed “adjusted dilution potential.” The final adjusted dilution potential level cannot exceed “high.”

The final step in the procedure is to make a judgment of whether an ice/pavement bond condition exists. This determination (yes or no) is made based on field observations or sensor data.

The appropriate application rates for solid, prewetted solid, and liquid NaCl can then be determined from Table B using the results from the previously described steps.

Some agencies choose not to consider some of the variables that comprise adjusted dilution potential as they are essentially constant in their operations.

TABLE A: Precipitation Dilution Potential and Its Adjustments

	Precipitation type	Precipitation rate: Light	Moderate	Heavy	Unknown
1.	Snow (powder)	Low	Low	Medium	Low
2.	Snow (ordinary)	Low	Medium	High	Medium
3.	Snow (wet/heavy)	Medium	High	High	High
4.	Snow (unknown)	–	Medium	–	–
5.	Rain	Low	Medium	High	Medium
6.	Freezing rain	Low	Medium	High	Medium
7.	Sleet	Low	Medium	High	Medium
8.	Blowing snow	–	Medium	–	–
9.	Snow with blowing snow		(Same as type of snow)		
10.	Freezing rain with sleet	Low	Medium	High	Medium
11.	None				
	If wheel path area condition is:		Not applicable		
	– Dry or damp		Low		
	– Wet		Low		
	– Frost or black ice (thin ice)		Medium		
	– Slush or loose snow		High		
	– Packed snow or thick ice				

Adjustments to Precipitation Dilution Potential

a) Wheel path area condition when precipitation is present	Increase precipitation dilution potential above by number of levels
Bare	0
Frost or thin ice	0
Slush, loose snow, packed snow, or thick ice	1

b) Cycle time	
0 - 1.5 hrs	0
1.6 - 3.0 hrs	1
Over 3.0 hrs	2

c) Traffic volume at traffic speeds > 35 mph	
Less than 125 vph	0
More than 125 vph	1

TABLE B: Application Rates for Solid, Prewetted Solid, and Liquid Sodium Chloride

Pavement Temperature (°F)	Adjusted dilution potential	Ice pavement bond	Application rate	
			Solid (1) lb/L-M	Liquid (2) gal/L-M
Over 32	Low	No	90 (3)	40 (3)
		Yes	200	NR (4)
	Medium	No	100 (3)	44 (3)
		Yes	225	NR (4)
	High	No	110 (3)	48 (3)
		Yes	250	NR (4)
30 to 32	Low	No	130	57
		Yes	275	NR (4)
	Medium	No	150	66
		Yes	300	NR (4)
	High	No	160	70
		Yes	325	NR (4)
25 to 30	Low	No	170	74
		Yes	350	NR (4)
	Medium	No	180	79
		Yes	375	NR (4)
	High	No	190	83
		Yes	400	NR (4)
20 to 25	Low	No	200	87
		Yes	425	NR (4)
	Medium	No	210	92
		Yes	450	NR (4)
	High	No	220	96
		Yes	475	NR
15 to 20	Low	No	230	NR
		Yes	500	NR
	Medium	No	240	NR
		Yes	525	NR
	High	No	250	NR
		Yes	550	NR
10 to 15	Low	No	260	NR
		Yes	575	NR
	Medium	No	270	NR
		Yes	600	NR
	High	No	280	NR
		Yes	625	NR
Below 10°F	A. If unbonded, try mechanical removal without chemical. B. If bonded, apply chemical at 700 lb/L-M. Plow when slushy. Repeat as necessary. C. Apply abrasives as necessary.			

NR = Not recommended.

Specific Notes:

1. Values for “solid” also apply to prewet solid and include the equivalent dry chemical weight in prewetting solutions.
2. Liquid values are shown for the 23-percent concentration solution.
3. In unbonded, try mechanical removal without applying chemicals. If pretreating, use this application rate.
4. If very thin ice, liquids may be applied at the unbonded rates.

General Notes:

5. These application rates are starting points. Local experience should refine these recommendations.
6. Prewetting chemicals should allow application rates to be reduced by up to about 20% depending on such primary factors as spread pattern and spreading speed.
7. Application rates for chemicals other than sodium chloride will need to be adjusted using the guidance in APPENDIX VI.

Before applying any ice control chemical, the surface should be cleared of as much snow and ice as possible.

APPENDIX VI
RECOMMENDED REFERENCE MATERIALS

1. Ketcham, Stephen, A., Minsk, L. David, Blackburn, Robert, R., Fleege, Ed, J. "Manual of Practice for an Effective Anti-icing Program: A Guide for Winter Maintenance Personnel" Publication No. FHWA-RD-95-202, Federal Highway Administration, U. S. Department of Transportation, (June, 1996).

2. "The Snowfighter's Handbook," The Salt Institute, Alexandria, VA (1991).

3. Boselly, S. E., and Ernst, D., "Road Weather Information Systems, Volume 2, Implementation Guide." Report SHRP-H-351, Strategic Highway Research Program, National Research Council, Washington, DC, (1993).

4. Special Report 235 "Highway Deicing - Comparing Salt and Calcium Magnesium Acetate" Transportation Research Board, National Research Council, Washington, DC (1991)

5. Transportation Research Record 1157 "Deicing Chemicals and Snow Control" Transportation Research Board, National Research Council, Washington, DC (1988);

6. "Snow and Ice Control - A Best Practices Review" Office of the Legislative Auditor, State of Minnesota, Saint Paul, MN (May, 1995).

7. "Highway Maintenance Guidelines - Snow and Ice Control" New York State Department of Transportation, Albany, NY (December, 1993).

8. Migletz, L., Graham, J. L., and Blackburn, R. R., "Safety Restoration During Snow Removal - Guidelines" Publication No. FHWA-TS-90-036, Federal Highway Administration, U. S. Department of Transportation, McLean, Virginia (February, 1991).

9. Kuemmel, David E., "Synthesis of Highway Practice 207 - Managing Roadway Snow and Ice Control Operations" National Cooperative Highway Research Program, Transportation Research Board, National Research Council, Washington, DC (1994).

10. Minsk, L. David, "Snow and Ice Control for Transportation Facilities" McGraw-Hill, 1998.

11. "Guide For Snow and Ice Control", American Association of State Highway Officials, 1999.

12. "Snow and Ice Control : Guidelines for Materials and Methods", NCHRP Report 526, Transportation Research Board, October, 2004