

Pre-wetting and Anti-icing — Techniques for Winter Road Maintenance

Maintaining safe roads during winter storm conditions requires skill and knowledge. Recent developments in the use of liquid chemicals offer new options to road maintenance agencies beyond what they can do with dry salt and sand. Chemicals other than salt are being used more and more. This publication describes these new options and gives basic information on pre-wetting and anti-icing.

Pre-wetting is a strategy of applying a liquid deicing chemical to a dry solid before or during its application to the pavement. When a liquid is applied to a rock salt particle, the particle absorbs a minor amount of the liquid which increases its density. The liquid also encapsulates, softens, and begins dissolving the salt particle. The wet salt stays on the road surface better, bouncing less and resisting traffic action.

Pre-wetting salt

Pre-wetting salt has been used since the late 1960s. It has several advantages:

- Reduced loss of salt from bounce and scatter. (Savings up to 30%. See Figure 1)
- Quicker melting.
- Better salt penetration into ice and snow pack.
- Melts at a lower temperature if wetted with other deicing chemicals.

Any deicing chemical can be used for pre-wetting. Liquid salt, calcium chloride, magnesium chloride, or blends are commonly used. Chemicals with lower eutectic temperatures (lowest temperature at which it can still cause melting) help extend salt effectiveness on lower temperature pavements. Figure 2 shows the difference between dry salt and salt pre-wetted with calcium chloride. Note that the melting effectiveness of both dry and pre-wetted salt decreases as road temperatures drop. Below 10° F there is almost no melting benefit.

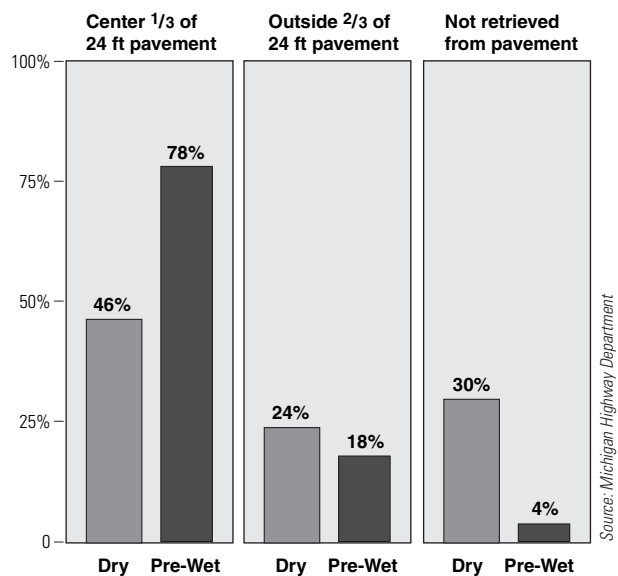


Figure 1: Salt retrieved from pavement surface

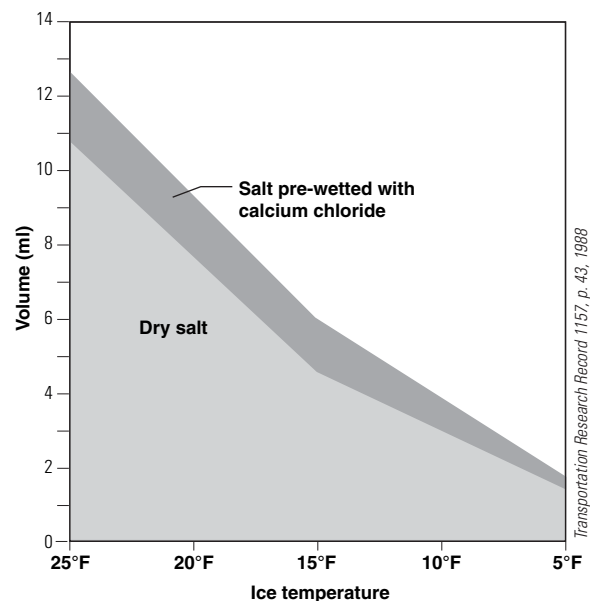
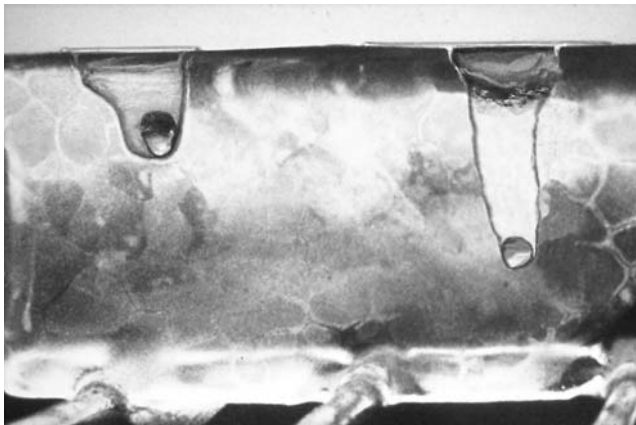


Figure 2: Ice melted in 20 minutes

Salt is usually pre-wetted with 8-12 gallons of liquid per ton of salt. Pre-wetting can be done in the stockpile; as spreader trucks are loaded; or by spraying the salt as it is spread on the road. Pre-wetting at the shop requires less equipment but reduces flexibility of use. Pre-wetting on board the truck allows better coverage and treatment as needed. On-board pre-wetting at the auger shows better coverage than spray at the spinner.

Savings are possible if operators reduce application rates when spreading pre-wetted salt to take advantage of its faster action and lower salt loss. Field research has documented equal or improved performance of 20% less pre-wetted salt compared to dry salt.



Faster melting action is the main benefit of pre-wetting salt. After 20 minutes the difference is significant. This photo shows two salt particles penetrating ice. The one on the right was pre-wetted.

Pre-wetting abrasives

Pre-wetting sand and other abrasives is done to hold them on the pavement. Pre-wetting at rates of 10-30 gallons of liquid chemical per ton of abrasives has proven effective. Agencies report that higher truck spreading speeds are possible with pre-wetted sand. Research on the use of very hot water (heated on-board) for pre-wetting is very promising.

Anti-icing

Anti-icing is a proactive snow and ice control strategy. A small amount of liquid chemical is applied to pavements and bridge decks before a storm to prevent ice from bonding with the surface. By contrast, the more commonly used strategy is *deicing*: applying chemical during or after a storm to break the ice/pavement bond so plows can clear the road.

Anti-icing is commonly used on pavements where the policy is to provide a high level of service or a bare pavement. It has proven very effective at preventing



Tanks for pre-wetting liquid: saddle-bags on a hopper spreader LEFT, and at the front of a dump body with a tailgate spreader RIGHT.

bridge deck and pavement frost. Specialized equipment is needed to apply small amounts of liquid chemicals. Detailed weather predictions are also helpful.

Benefits of anti-icing

An anti-icing strategy can produce significant benefits:

- Better pavement conditions (improved friction) can be achieved, reducing the number of crashes. (One study in Idaho reported 83% fewer crashes)
- Less chemical is required to prevent ice bonding than to remove ice after it has bonded to the pavement.
- Anti-icing applications are reported to last for several days, particularly in preventing frost on bridge decks.
- Clean-up after a storm may be easier with less ice bonded to pavement.
- Application can be made during regular working hours, reducing some overtime costs.
- Fixed liquid spray systems at bridges and intersections are possible.

A Michigan DOT report covering 1999-2002 found that anti-icing can reduce salt, reduce materials costs, and improve safety (Research Report R1418, 2002).

Costs and concerns about anti-icing

Implementing an anti-icing system involves costs for equipment, weather forecasting services, and training. Concerns about slippery roads and environmental effects must also be addressed.

New or better equipment for applying the anti-icing liquid to roads may be needed, including bulk storage tanks, on-board tanks, pumps, and spray applicators.

If your weather forecast is poor and a storm does not arrive, you may waste the resources; if the storm hits sooner than expected you may lose the opportunity. Most state DOTs have extensive Road Weather Information Systems (RWIS) that you may be able to tie into. Specialized weather forecast services are available that

provide improved storm timing and pavement temperature forecasts. Radar and additional forecast information from the National Weather Service is available through the Internet. The low tech approach is to call the agency that is “up-storm” from you and ask what’s happening.

Changing to any new system requires training. Fortunately, anti-icing has been in use quite a while now and many resources are available including manuals, online newsletters, and national and local workshops. Also, you can learn to use new equipment by practicing application and by taking advantage of vendor training.

When a crash occurs before the storm hits and the road has been sprayed, fingers quickly point at the liquid chemicals. This isn’t common, and many of the crashes blamed on anti-icing turn out to be situations where dilution and refreeze occurred, or even that the road wasn’t slippery at all. Some conditions, especially in early winter, do produce slipperiness; agencies using anti-icing learn to recognize and accommodate for them.

Of course everything that goes on the road is in the environment, so it is important to be careful what and how much you use whether it is traditional salt and sand or corrosive chemicals. If you implement anti-icing properly, you will use fewer chemicals than with deicing, and less abrasive material. This makes it anti-icing environmentally beneficial.

Guidelines for anti-icing

The Wisconsin Department of Transportation offers the following anti-icing guidelines to counties, which maintain all state highways.

When to anti-ice

- Anti-icing **should** be the first in a series of strategies considered for each winter storm.
- Anti-icing should be conducted prior to forecasted frost, freezing fog, or black ice events on bridge decks and pavement trouble spots as a minimum, assuming conditions in this guideline for anti-icing are met. Other areas (hills, curves, shaded areas, ramps, or intersections) may be treated as determined by the county, on an as-needed basis.
- Treatment for frost or black ice incidents can be made on a regular schedule; twice per week during the typical frost season (beginning and end of the winter months), or in accordance with weather forecast information. Applications in anticipation of a possible frost incident or snow event on a Saturday or Sunday may be made on the preceding Friday.



Typically anti-icing is a light application to dry pavement from streamer nozzles 12-18 hours before a predicted frost or snow event.

- Anti-icing should be done during normal, low traffic volume, non-overtime work hours. In the case of a county with normal overnight working hours, anti-icing could be done at night or other off peak traffic times. In counties where split shifts are not used, anti-icing should be done so as to minimize disruption to the traveling public. Applications should normally be made 12-18 hours prior to a predicted frost or snow event depending on the material used. Some anti-icing agents will last longer than others.
- When traffic volumes are high, use of a following vehicle for traffic control may be necessary. Due to high traffic volumes, additional application may be required if the anti-icing agent residue is worn off the bridge deck or pavement surface.
- Anti-icing may also be conducted prior to predicted *light* sleet and *light* (less than 0.5"/hr) or *moderate* (0.5"-1.0"/hr) snow events. If precipitation persists, additional anti-icing applications may be necessary to prevent refreeze due to dilution of the chemical or switching to deicing applications may be necessary.
- Anti-icing should be conducted when the pavement temperature is at or above 23° F or the pavement temperatures are forecast to rise or stay above 23° F.
- Liquid agents are the preferred material for anti-icing treatments. Although applying pre-wetted salt prior to an event can technically be considered anti-icing, liquid agents work more effectively than solids and there is also less waste with liquid applications.

When not to anti-ice

Liquid anti-icing should not be conducted:

- Prior to forecast of rain or freezing rain events.
- When winds are more than 15 MPH.
- When the anti-icing agents have the potential of causing snow to stick to the roadway under blowing and/or drifting snow conditions.
- When the pavement temperature is below 20° F or forecast to fall below 20° F.
- After the bond between the snow and the pavement has already occurred. Liquid should **never** be applied onto an icy or snow-packed surface.

Use discretion in applying anti-icing agents before heavy (over 1 inch per hour) snowfall events, due to limited experience. It may become a more viable option with greater experience.

Precautions

Calibration Liquid anti-icing application equipment should be calibrated at the beginning of every winter season. Application equipment that has been transferred to another truck, modified, or repaired should be recalibrated. Equipment should be monitored during use and recalibrated when performance appears questionable.

Drifting To minimize drifting of liquid anti-icing agents “drip” or “pencil” spray type nozzle heads are preferred over fan type nozzle heads. When truck speeds will exceed 25-30 MPH, consider adding drop rubber tubing extensions to drip or pencil spray nozzle heads to reach the surface.

Persistence If not diluted by rain or snow, residues of liquid anti-icing agents can remain on the surface for up to four days after application. When rain, snow, or moisture in the air dilutes the residual anti-icing agent on the surface, refreezing can occur. Reapplication may be needed.

Slipperiness Reduce application rates after dry spells, especially when pavement temperatures are warm (45°-50° F), when humidity is 45%-55%. Bridge decks and pavement surfaces where residues of oil products and/or rubber have built up may become slick when sprayed with an anti-icing liquid.

The precautions above were excerpted from the Wisconsin Department of Transportation, State Highway Maintenance Manual, Guideline 32:35, October 1, 2005.

Using liquid chemicals

Winter maintenance liquids are solutions of water with one or more chemicals such as road salt (sodium chloride, NaCl), calcium chloride (CaCl₂), or magnesium chloride (MgCl₂). Ordering, handling and applying liquid chemicals requires special knowledge. However, their action on the roadway is similar to solid deicing chemicals since solid chemicals must first be dissolved into solution before they can begin their melting action.

Advantages of using liquid chemicals include:

- They are already in solution; their melting action is nearly instantaneous.
- They can be used to both pre-wet solid chemicals and anti-ice pavements.
- Liquid salt (NaCl) can be made at local highway shops and cost is low (5 cents/gal).
- They can be applied at lower rates than solids and adhere better to the pavement.
- Vendors offer corrosion inhibitor additives.

Disadvantages of using liquid chemicals are:

- They will become diluted (and may refreeze) more quickly than solid salt during heavy snow or ice storms.
- Transporting chemicals that are mostly water (68%-78%) can be costly.
- They cannot be used for anti-icing when freezing rain, glare ice, or snow pack conditions exist.
- Their anti-icing use is generally limited to pavement temperatures above 20° F.
- They require special equipment for liquid storage, pumping, and application.

Application

Application rates in the range of 25-50 gallons per lane mile are being used. This is equivalent to 60 to 120 pounds per lane mile of dry chemical. Even smaller applications of 15 gallons per lane mile have been reported effective in anti-icing for frost.

The actual liquid chemical application will depend on the choice of chemical, air and pavement temperatures, and storm conditions. Figure 3 gives a comparison of equivalent application rates for calcium chloride and

Temperature Degrees F	Salt		Calcium Chloride		Magnesium Chloride	
	Solid lb/lane mile	Liquid gal/lane mile	Solid lb/lane mile	Liquid gal/lane mile	Solid lb/lane mile	Liquid gal/lane mile
31	100	44	111	32	94	33
25	100	44	102	29	86	30
21	100	44	89	25	74	26

Figure 3: Equivalent application rates

Source: Snow Removal and Ice Control Technology, Transportation Research Circular E-C063, page 48.

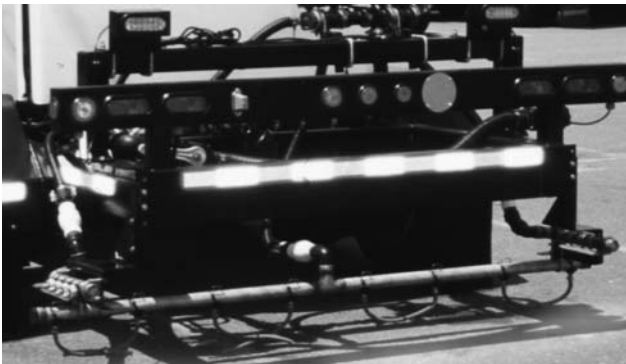


Often anti-icing programs start small with tanks on the back of a patrol truck LEFT. A large tanker RIGHT is more efficient for anti-icing a larger road system.



magnesium chloride to salt. At lower road temperatures the application rates for calcium chloride and magnesium chloride become less compared to salt.

Special spreading equipment is required for low volume liquid applications. Streamer nozzles ($\frac{1}{8}$ " to $\frac{3}{8}$ ") are preferred to fan spray nozzles. Applications can be made at 25 MPH to 55 MPH. Equipment that allows applications in more than one lane and ground-oriented (computer-controlled) equipment are useful. They are necessary to ensure that you gain the full cost savings of the anti-icing strategy.



Spray bar with hose extensions on nozzles, shown here tied up for transport. During application hoses drag on road.

Concentration and freezing point

Like salt and other solid chemicals, liquids work by depressing the freezing point on the pavement. Choosing which specific chemical or blend of chemicals to use depends on the characteristics of the chemical, temperature and weather conditions, available moisture, and cost. In order to make this choice, you need to understand the characteristics of each chemical.

Phase diagrams

The lowest point at which a specific chemical suppresses freezing depends on temperature and concentration. Figure 4 helps illustrate this. This diagram shows the temperature at which various concentrations stop thawing or change "phase" for salt.

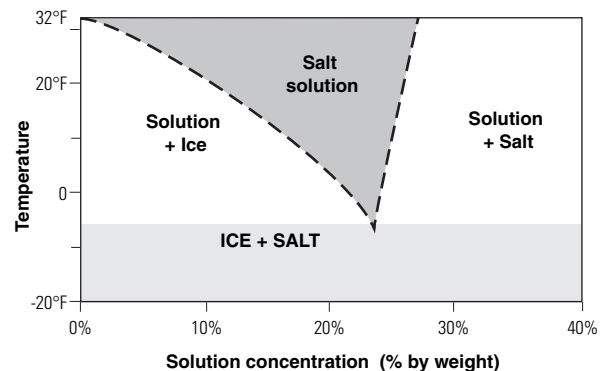


Figure 4: Phase diagram of salt.

At 20° F, salt will melt ice at an 11% solution. At 10° F, it must be at 18% solution. The freezing point continues to decrease with higher concentrations until the maximum freezing point, or "eutectic" point is reached. Salt brine stops working at about -6° F and 23% concentration (23% salt, 77% water by weight). At 23% solution there is 2.256 lbs of salt per gallon. The total weighs about 10.6 lbs per gallon. Notice that at higher concentrations (25%), the freezing point of the liquid chemical *increases sharply*.

It is important to understand the concept of phase change in order to use liquid chemicals effectively and

avoid waste. The curved lines on the diagram separate the phases of the solution:

- Above the curve—all liquid solution; melting action.
- Below the curve—mixture of solution and ice or salt; refreezing action.
- Below the eutectic point—solid ice.

Thus, the diagram describes the freezing point of salt brine as a *function* of the solution's concentration. Note particularly that the freezing point of the brine solution is lowered (has more melting capability) as the concentration increases, until the eutectic point is reached. Beyond the eutectic point the freezing point will increase (has less melting capability) as the concentration increases.

In snow and ice control operations, and particularly during anti-icing treatments, it is important to know what chemical concentrations you are applying. In addition, it is important to monitor the pavement conditions after it is applied to watch for conditions where refreezing may occur.

Refreezing

The phase diagram shows how deicing and refreezing can occur on a pavement. When a liquid chemical is applied, snow or ice on the pavement will melt as long as the temperature on the roadway is above the freezing temperature for the concentration of the chemical.

As ice is melted the water combine with the solution already on the pavement, causing dilution. Dilution lowers the concentration, meaning that the freezing point goes up. Melting and dilution continue until either all of the ice is melted or the solution is too diluted to work. Snow, rain or freezing rain after application will also cause dilution.

Refreezing will occur if the chemical concentration is not adequate to produce melting at the actual pavement temperatures. For snow and ice control:

- Adjust initial application rates depending on both pavement temperature and the amount of snow and ice on the road.
- Monitor the dilution process by tracking pavement temperature, melting, and additional precipitation.
- If solution concentration on the pavement decreases into the pavement's freezing temperature range before the pavement is clear, refreeze will take place. Additional applications, a different chemical or blend of chemicals, or other winter maintenance treatment will be needed.

Cost and quality control

Liquid salt is the least expensive product but it has the normal temperature use limitations. Liquid calcium chloride, magnesium chloride and potassium acetate with corrosion inhibiting additives are significantly more expensive but can be used at lower temperatures. Figure 5 shows the phase diagrams for commonly used chemicals.

When purchasing liquid chemicals or producing your own liquid chemicals from dry products, be aware of the percentage solution that is being delivered. Liquid magnesium chloride products may vary between 23% and 30%. At 30% solution there is 2.36 lbs of magnesium chloride per gallon, weighing 10.7 lbs per gallon total. Higher chemical concentrations allow vendors to ship more material at less cost. The cost effectiveness of liquid chemicals must also take into account the percentage concentration to determine the best value.

Liquid chemicals usually contain some degree of impurities. They are not directly a concern for effectiveness, but they can settle out and clog nozzles and pumps. Different chemicals settle or coagulate at different temperatures. In addition, the viscosity of a chemical changes with temperature. At very low temperatures the chemical may not freeze, but may become too thick for pumps and applicators to work.

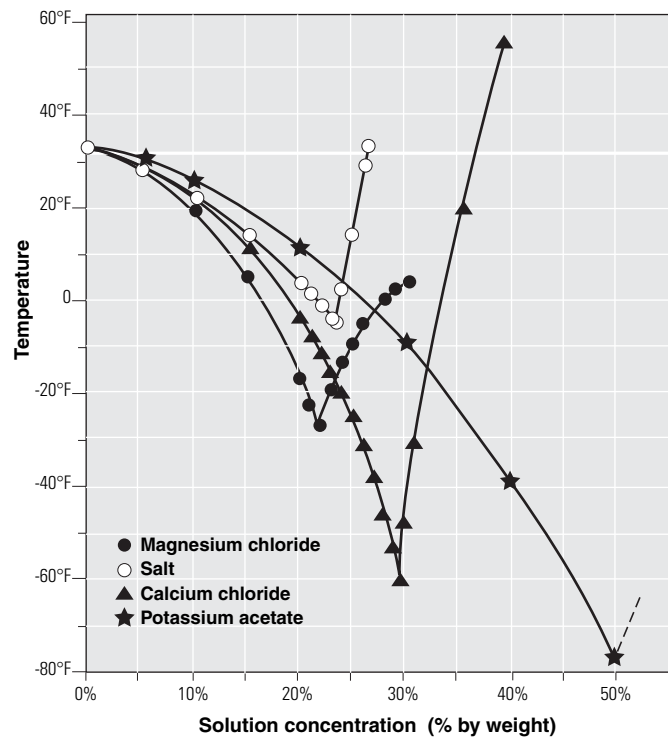


Figure 5: Phase diagrams of four chemical solutions

Quality control is important when purchasing and using liquid chemicals. Hydrometers can be used to field check the specific gravity of the chemical. Readings



must be adjusted for the actual temperature of the liquid. This test will determine if the delivered chemical is in the allowable range of concentration.

Storage and handling procedures for liquid chemicals must comply with state regulations. Tanks must be designed to handle liquids heavier than water. Agitation or recirculation may be necessary. Check for storage and pumping recommendations from your supplier.

Preparations and precautions

Before you send out the anti-icing equipment, let the public know about it. Include it in pre-storm announcements along with other reminders about driving near winter equipment. Signs on the back of trucks are also helpful.



Use the most accurate weather predictions you can get to avoid applying chemicals when no storm occurs. Low temperatures, below 20° F,

strong winds, and heavy snowfall or freezing rain conditions all make anti-icing problematic or ineffective.

Slippery pavements may develop with anti-icing due to refreezing or to “chemical” slipperiness. Refreezing can occur if the chemical is diluted, temperatures drop, or blowing snow is trapped. Warm temperatures and high humidity can dilute chemicals with calcium or magnesium because of their high attraction for moisture.

Pavements wet with deicing chemicals have slightly less friction than pavements wet with water. Some chemicals also go through a “slurry” stage when they either dry out and return to a solid state or then hydrate and go from solid to liquid state. This “slurry” stage is very temporary but causes an additional drop in friction (15%) on the pavement. This so-called “chemical” slipperiness is not usually enough by itself to cause loss-of-control problems for highway traffic. However, when

pavement temperatures are warm (45°-50° F) and dirt and oil come to the surface of the pavement, slippery conditions may develop for a short time, leading to claims of chemical slipperiness. Very few cases of slipperiness have been reported where salt brine was used.

Follow-up

Winter storms are notoriously variable. The treatment used early in a storm may have to be modified as it proceeds, especially if light snowfall is interspersed with periods of heavy snowfall. Continue monitoring weather conditions to determine your actions.

Consider snow buildup on road edges, time of day or night, temperature trends, traffic volumes and when rush hour may begin, and predictions from weather services. Re-application may be needed or you may transition into plowing and normal deicing. Snow pack may still develop and a bond may form between the pack and pavement even when anti-icing was successful. Usually the bond will not be as strong.

After the storm, when operations are normal, take time to review the anti-icing operation. You may identify potential improvements in operations or equipment. Involve all levels of maintenance personnel from district level supervisors to equipment operators. Many times a supervisor and an operator will see different things during a storm and both perspectives are useful. Consider how you measure effectiveness or success in your winter maintenance operation, and review costs and results for both traditional plowing/deicing and anti-icing strategies.

When learning to use liquid chemicals, evaluation of field performance is critical. Some agencies have found a TAPER form useful in this evaluation. It provides an organized way to collect data on conditions and materials applied. The key is to collect actual roadway performance information which allows your agency to develop its own future guidelines. TAPER stands for Temperature, Application, Product, Event, Results. Sample TAPER forms are available from the TIC Web site publications page, <http://tic.engr.wisc.edu>

Summary

Pre-wetting and anti-icing practices are a means for maintaining roads in the best condition possible during a winter storm. They are also a way to do so efficiently. However, do not assume that they will automatically result in reduced overall costs. Use operator training, sprayer calibration, ground oriented spreader controls, pavement temperature sensors, and accurate weather information to keep liquid chemical use at the lowest effective amount. Review and evaluate your operations and keep up to date with improvements.

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