Evaluation of the Use of Salt Brine for Deicing Purposes

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The formation of snowpack and ice on roadways is of major concern during snow removal operations. The use of conventional methods requires substantial use of deicing chemicals and equipment. A new method for destroying snowpack and ice, which utilizes high-speed sodium chloride brine jet streams, is discussed herein. This report describes the prototype unit, its calibration and stationary facilities for making the brine solution. Data obtained from field testing the unit on Interstate 84 in Connecticut during the winters of 1977-78 and 1976-77 is contained herein. Application-rate data are compared for conventional methods and the salt brine concept for the past two winter seasons. Use of the prototype for special icing situations is also discussed.

Background

Environmental movements and tight operating budgets are compelling personnel responsible for highway ice and snow control to minimize the use of chloride deicers. Plowing is the primary method of removing loose bulk snow from a pavement. The snow remains after plowing is usually in a state of compaction and, on high-volume roadways is rapidly coated with an ice glaze caused by moving traffic. To reduce the formation of ice glaze and further snow adhesion to a pavement, chemical deicers are used.

A deicer applied in the dry form is embedded into the cover in either the solid or liquid form. The former is embedded for the most part by passing vehicles, whereas the latter is embedded as a brine which is formed on solution of the salt crystals. Regardless of which way the material enters the pavement cover, its transformation into an active deicer is time-consuming and dependent on both temperature and available moisture. The prime objective during ice and snow control operations, therefore, is to maintain or obtain an acceptable level of service by destroying an existing snow pack or ice glaze.

Prior to 1970, the Connecticut Department of Transportation, in keeping with a bare-pavement policy, called for application rates of 700 pounds of crystalline salt per two-lane mile. However, the 1970's have witnessed the rate of application drop from 700 pounds to the present 430 pounds per two-lane mile per application. During this time, a project was instituted to evaluate a unique concept involving the use of sodium chloride brine for pavement deicing. The use of both sodium and calcium brines in itself is not new. Brine has been used successfully in many areas.

Although the use of brine is not new, the method of applying it does differ from existing methods of application. The Department's first experience with brine occurred during the winter of 1971-72, when it was applied using a road oiler. During this period, it was reasoned that better results would ensue if certain modifications were made in the method of application. It was hypothesized that a 0-degree nozzle deployed at a very shallow angle to the pavement would destroy a portion of the pack or ice by mechanical action. Once the forward momentum of the jet had diminished, the solution would immediately initiate a chemical melt.

Prototype Design Considerations

The first consideration in advancing this hypothesis was to establish optimum nozzle parameters. It was reasoned that maximum mechanical efficiency would result if the nozzles were positioned as close to the pavement as possible and angled such that the path of the flow would be within a few degrees of being parallel to the pavement (See Fig.'s 1 and 2). With the nozzles positioned in this manner, the energy in the fluid stream, plus the forward speed of the truck would be better utilized. Also, it was hypothesized that with the nozzles deployed in this position, the fluid would destroy a portion of the pavement cover mechanically by a high-velocity stream directed at the packed snow or ice. It was reasoned that immediately after an application, the snow cover would be either partially or completely destroyed and the cover remaining on the pavement loosened sufficiently to allow removal by plowing. The remaining cover, permeated with an active deicer would either be destroyed chemically or would remain a mealy state. Under these conditions, the likelihood of the cover adhering to the pavement would also be substantially reduced.

Prior to constructing a full-scale prototype, laboratory tests were performed to determine the most suitable type of nozzle, spray angle, and fluid pressure to be used under field conditions. Commercially manufactured flat, narrow 15° (0.26 rad) and 20° (0.35 rad) fan nozzles seemed to be the most
promising and were used during the initial tests. The tests indicated that because of air resistance, the fan nozzles were unable to maintain a flat, narrow configuration at a test pressure of 150 psi (10.5 kg/cm$^2$).

![Fig. 1 Schematic Showing Proposed Design of Full Scale Prototype (Valve, Piping, Gages, Etc. Not Shown)](image)

Tests performed using straight or 0° fan nozzles showed that this type of nozzle produced a stream that was not substantially affected by air resistance. The resulting high-velocity stream had the ability to cut into the surface of the ice specimen on contact. Since the streams were cutting the ice at point locations, i.e., in the path of the flow, a corduroy effect resulted on the specimen surface. This problem was overcome by simply rotating the nozzles horizontally 10° (0.17 rad). This orientation change used the jet's abrasive qualities in a planing manner on the ice and the corduroy texture was substantially reduced.

A second project objective was to utilize the available energy in the jet stream to the maximum; therefore, it was required to optimize the incident angle of the jet stream to the pavement. The laboratory tests indicated that although an angle of less than 12° (0.21 rad) did not adversely alter the path of the stream, the optimum angle would have to be set in the field.

Prototype Brine Applicator

The full-scale prototype design was based on data obtained in the laboratory and from maintenance-operation requirements. Sufficient capacity was built into the unit to apply brine for ten miles at a rate of 75 gals (283.9 l) per minute at 300 psi (21.1 kg/cm$^2$) using a fully saturated solution; this amount is equivalent to 400 pounds (181.6 kg) per two-lane mile when applied at a travel speed of 30 mph (48.3 km/hr.). The prototype was fabricated and mounted on a standard maintenance nine-ton truck chassis (Fig. 3). The main components in the system consist of a positive-displacement pump, 25-horsepower engine, 1500-gallon (5,677 l) fiberglass tank, nozzle bar and necessary hoses, valves and fittings.

The distributor bar assembly (Fig. 4) consists of a 3-inch (7.6 cm) pipe 8 ft (2.4 m) long mounted on steel pads. 28 nozzles having an orifice diameter of .080 inch (2.0 mm), a pair of telescoping box beams, two 12-inch (30.5 cm) casters, and a pneumatic piston with necessary cables and pulleys for raising or lowering the unit.

The upper ends of the telescoping units are attached to the chassis directly in front of the rear wheels. The lower end of this unit was fabricated with slots through which the I-bars supporting the distributor bar are passed. The ends of the I-bars passing through the slots is attached to the box beam which is designed to lift the distributor bar off the pavement should an obstruction be encountered. When in the down or spray position, the nozzle elevation is fixed and maintained with respect to the pavement by
Brine Making Facilities

The stationary facilities consist of two steel tanks containing a total of 7,000 gal. (26,500 l), a fiberglass tank in which the salt is dissolved and an overhead hopper in which the crystalline salt is stored prior to entering the dissolver (Fig. 6). Although loose, free-flowing salt provides fully

the casters on which the unit rides. When the distributor bar is not in use, the entire assembly is raised pneumatically to approximately 9 inches (22.8 cm) above the pavement.

The piping system was designed to use the unit's pump for the dual role of filling the fiberglass tank and applying the brine to the roadway surface; therefore, auxiliary equipment is not required at the brine-making and storage facility.

The high-pressure system, which is used to apply the fluid, consists of high-pressure hoses, a pressure-relief valve, a 3-way valve, a distributor and an auxiliary by-pass line. In the spraying mode, the auxiliary by-pass is closed and the unit is pressurized to 300 psi (21.1 kg/cm²). When the system is operating, but not spraying, the auxiliary by-pass is open and a pressure of 230 psi (16.2 kg/cm²) is maintained.

The unit contains two safety devices consisting of a pressure-relief valve and fail-safe device capable of shutting off the system should pressure failure occur.

Calibration of the unit is easily performed by collecting and measuring a volume of water dispensed over a given period of time and at an observed pressure. Two methods have been used for collecting the water. One method, shown in Fig. 5, involves the use of four 55-gal. (208 l) drums in which all the water is collected and measured. The second method consists of collecting the water by placing four 2.5-gal. (9.5 l) containers under individual nozzles and again measuring the volume collected. The sequence is twice repeated using four different nozzles each time. The recirculation pressure prior to calibration and application pressure are noted. Of the two methods, the second

Fig. 7 Tanks used to store brine with brine-making unit in background
saturated solutions (100 percent saturation), caked salt can be efficiently disposed of in the dissolver when due care is exercised; in the latter case, however, saturation drops off to approximately 90 percent, and on occasion, to as low as 85 percent. An 85 percent solution has a freezing point of minus 3.7°F (-19.8°C); therefore, with ambient storm temperatures normally ranging in the high twenties and thirties, there is no need to increase the saturation to 100 percent.

Description of Experimental Section

The experimental section was located on I-84 in the Towns of Southington and Cheshire. It was selected so as to include a long continuous grade over Southington mountain; here, the road rises 320 ft (97.5 m) over a distance of 1.8 miles (2.9 km). In terms of elevation, this area is the highest of the entire run, and was considered by Maintenance personnel to be the most severe problem location under their jurisdiction (See Fig. 8 and 9).

Fig. 8 Map of Connecticut showing location of test site

In the final layout, the test section on which the brine was applied ran from Rt 229 (West St) in Southington to Rt 70 in Cheshire and included only the westbound roadway; the entire test section encompassed approximately 15.9 lane-miles (25.6 lane-km), including the truck-climbing lane. The control section in the eastbound roadway not only ran concurrent with the westbound test section, but also continued beyond it in both roadways for approximately 47.8 lane-miles (76.9 lane-km). To facilitate record keeping for amounts of crystalline salt applied, however, the remaining section of I-84 from Rt 229 to Rt 72 in New Britain (both roadways) was incorporated into the control section, since the trucks spreading the salt were responsible for the entire run from Rt 70 to Rt 72, and metering of the output of salt would be less complex if it were done over the entire run. In this case, the total lane-miles monitored for amounts of salt used was 61.9 lane-miles (99.7 lane-km).

All operations involving the experimental brine program operations originated from the Southington Maintenance garage where the brine-making apparatus and prototype unit were housed. This garage is also responsible for the maintenance of the entire experimental and control sections on I-84 from Rt 72 to Rt 70.

Storm Description for Winter 1977-78

Maintenance personnel were called out for storm duty a total of eighteen times. The following is a description of all storms experienced during the winter season:

<table>
<thead>
<tr>
<th>No. of Storms</th>
<th>Snow Accumulation</th>
<th>Average Storm Temperatures</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>1&quot; or less (5 with a trace)</td>
<td>20°F or less</td>
</tr>
<tr>
<td>5</td>
<td>1.25&quot; - 3&quot;</td>
<td>25°F - 30°F</td>
</tr>
<tr>
<td>2</td>
<td>3.125 - 6&quot;</td>
<td>over 30°F</td>
</tr>
</tbody>
</table>

Of the eighteen storms, nine did not warrant the prototype's use. The nine storms in question either lacked an appreciable amount of snow or occurred during warm (above 30°F) temperatures. During five of the remaining eight storms, difficulties were experienced with the truck or pump engine.

Field Operations

Prior to the winter of 1977-78, the prototype was fully operational. During the first storm it was noted that the nozzle bar tended to rotate downward to an angle of 7.75 degrees (0.14 rad) to the pavement from the desired angle of 3 degrees (0.05 rad). It was determined that since the casters, which set the height of the nozzles, act independently, a torque is developed in the bar as each caster attempts to conform to the snow-covered pavement surface. This nonuniform vertical movement caused the bar to rotate. The bar's clamping system was redesigned to overcome the rotation problem.

Since it was not known to what degree the concept would meet with success, the prototype was mounted on an older truck. Also, the engine for driving the pump was one used previously on a salt spreader. The truck and pump engines required many hours of repair, therefore, the prototype was not used for the duration of a number of storms making comparisons impossible. Tables 1 and 2 summarize the results of tests not only for the winter of 1977-78, but also for the previous snow season.

Under normal operating procedures, a plow mounted on the prototype would remove the bulk of the loose snow on the pavement to expose compacted snow or ice glaze. When ice glaze exists on a pavement, it is removed on contact by the high-velocity jet streams. Any compacted snow remaining on the road surface after passage of the plow will be penetrated and loosened to some extent by the mechanical action of the high-velocity brine jet, and will be converted to a mealy mass. Compacted snow covers of 0.25 inches (0.6 cm) or less in depth are readily penetrated by the brine and can be immediately removed by a trailing plow. Where the depth of the residual cover exceeds 1/4 inch (0.6 cm), however, the mechanical action of the brine is insufficient to loosen the entire pack, but penetration of the brine will precipitate an immediate chemical action that continues to destroy the pack, and ultimately the bond at the pack-pavement interface.
Table 1 Summary of Test Results for Two Winters

<table>
<thead>
<tr>
<th>Storm No.</th>
<th>Total Precipitation</th>
<th>Roadway Cover</th>
<th>Brine Applied (Gal.)</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>3&quot; Snow</td>
<td>Mealy Snow</td>
<td>2,250</td>
<td>Pavement Wetted</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thin Pack</td>
<td></td>
<td>Pack Broken</td>
</tr>
<tr>
<td>11</td>
<td>1&quot; Snow</td>
<td>Thin Pack</td>
<td>1,350</td>
<td>Pavement Wet</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>with Slush</td>
</tr>
<tr>
<td>14</td>
<td>8.8&quot; Snow</td>
<td>Mealy Snow</td>
<td>2,250</td>
<td>Pavement Wet</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>and Clean</td>
</tr>
<tr>
<td>23</td>
<td>0</td>
<td>Ice</td>
<td>750</td>
<td>Ice removed on</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>contact</td>
</tr>
<tr>
<td>11A(e)</td>
<td>0.4&quot; Snow</td>
<td>Thin Pack</td>
<td>2,250</td>
<td>Pavement Wet</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>with Slush</td>
</tr>
<tr>
<td>18(a)</td>
<td>18&quot; Snow</td>
<td>.25&quot; Pack</td>
<td>3,700(c)</td>
<td>Pack Loosened</td>
</tr>
<tr>
<td>21(b)</td>
<td>6.0&quot; Snow</td>
<td>Thin Pack</td>
<td>800(d)</td>
<td>Wet</td>
</tr>
</tbody>
</table>

(a) 85% Brine Solution  
(b) 65% Brine Solution  
(c) Deicers used only for cleanup operations  
(d) 90% Brine Solution  
(e) Winter of 1977-78

Table 2 Comparison of Crystalline Salt vs Brine Used for Two Winters in ton per lane mile per storm

<table>
<thead>
<tr>
<th>Storm No.</th>
<th>Crystalline Salt</th>
<th>Salt Brine</th>
</tr>
</thead>
<tbody>
<tr>
<td>10(a)</td>
<td>0.89</td>
<td>0.19</td>
</tr>
<tr>
<td>11(a)</td>
<td>0.73</td>
<td>0.11</td>
</tr>
<tr>
<td>14(a)</td>
<td>0.89</td>
<td>0.16</td>
</tr>
<tr>
<td>23(a)</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>11A(b)</td>
<td>0.61</td>
<td>0.21</td>
</tr>
<tr>
<td>18(b)</td>
<td>1.19</td>
<td>0.35</td>
</tr>
<tr>
<td>21(b)</td>
<td>0.98</td>
<td>0.17</td>
</tr>
</tbody>
</table>

(a) Winter of 1976-1977  
(b) Winter of 1977-1978

On January 9, (Storm 11A) two applications of brine were made on dry, dense, thin pack. After each application, the pack was converted to a light slush cover. During this storm, a total of 2250 gallons (8516 l) of 96.5 percent saturated solution equivalent to 2.87 tons (2.61 mt) of crystalline salt was used. On a per lane-mile basis, this amounted to 0.21 ton (0.19 mc) of salt for the brine application, and 0.61 ton (0.55 mc) for the dry crystalline application. The storm temperature was 22°F (-6C) with a total 0.4 inches (1.0 cm) of snow.

During the blizzard of February 6 and 7th, (Storm 18) deicers were not used. On February 8th after the blizzard had stopped, maintenance personnel made a brine application, which removed the still remaining snow cover consisting of 1/4 in. (0.6 cm) of extremely tight pack. Approximately 48 hours of snowplowing had elapsed since the beginning of the storm. Personnel at the site stated that "immediately after application of the brine, either bare pavement resulted or the pack was loosened sufficiently to permit removal by plowing." A total of 3700 gallons were used for clean-up operations. On a per lane-mile basis, 0.35 ton (0.32 mc) of salt as brine was used compared to 1.19 tons (1.08 mt) of crystalline salt. Total snowfall prior to deicer applications amounted to 18.0 inches (45.7 cm). During the brine application, the ambient temperature was 21°F (-6C).

During the storm of March 3 (storm 21), brine was applied only to the grade ascending Southington.
Mountain (Fig. 9). This section of roadway is 1.8 miles (2.9 km) long and consists of two travel lanes plus a truck-climbing lane. On two occasions, this section was covered with a thin, extremely slippery, wet, compacted snow. The pavement surface receiving the brine was immediately exposed after the application (Figs. 10, 11, 12). A total of 800 gallons (3028 l) of 90% saturated solution equivalent to 0.17 ton (0.15 mt) per lane-mile was used. A total of 60 tons, or 0.98 ton (0.89 mt) per lane-mile of salt were used outside the test section. The storm temperature was 24°F (-4°C) with a total of 4.4 inches (11.2 cm) of snow.

Fig. 10 Pavement prior to brine application

Fig. 11 Brine being applied to pavement

Fig. 12 Pavement 5 minutes after brine application

Special Icing Situations
Bridges having open steel grid decks, especially when coated with ice, are extremely hazardous to the motorist and are a difficult problem to maintenance personnel. Application of either deicers or abrasives are of little or no value on bridge decks of this type. Since the grid has steel studs which protrude above the grid's surface, plowing is both difficult and ineffective (Figs. 13 and 14).

An icing condition occurred on such a bridge deck over 1800 ft (546.6 m) in length during the winter of 1977-78. Having spent approximately two hours attempting to remove an ice accumulation from the four-lane divided deck and having exhausted all other avenues, maintenance personnel requested the services of the prototype brine truck. An application of a 90% brine solution was made in each of the four lanes at a speed of approximately 10 mph (16 kmph) and a pressure of 300 psi (21.1 kg/cm²). This amounted to approximately 1460 pounds (662.8 kg) of crystalline salt. Once the applications were completed, the deck, except for a few isolated spots, was bare of ice. The ice remaining on the deck had been weakened sufficiently to allow removal by traffic. The film
of brine remaining on the deck acted as an anti-icing agent, preventing further ice formation.

**Fig. 13** Close-up view of open steel grid bridge deck showing studs

**Fig. 14** Overall view of open steel grid bridge decks

Ice formation often occurs on shoulders especially under overpasses. Since the ice is shaded from sunlight, it can remain in these locations for extended periods of time. Crystalline salt frequently embeds itself into the ice forming deep narrow cavities where the crystals come to rest leaving the remainder of the ice intact. Brine applied on ice of this type fills the existing cavities resulting in a rapid breakdown of the ice.

**CONCLUSIONS**

The second year's testing of the prototype produced results similar to those obtained during the preceding year. The high-velocity jet streams combined with the brine's deicing characteristics were capable of destroying packed snow normally encountered during snow removal operations. Sufficient melting had occurred in the path of the brine applications within moments of application, during most storms, to cause splash up by passing vehicles. The lowest ambient temperature during a brine application was 21°F (-6°C).

The prototype proved its ability to overcome difficult icing situations such as bridges having steel open-grid bridge decks. All operational problems encountered during the winter season can be assigned to mechanical difficulties with the pump and truck engines. All components of the prototype functioned as designed.

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**REFERENCES**