Spreader Equipment for Anti-Icing

EDWARD J. FLEEGE AND ROBERT R. BLACKBURN

In the development of anti-icing technology, the need to apply a small amount of chemical in a very uniform pattern on the roadway surface was identified. All known manufacturers of spreader equipment were contacted to develop a master list of sources of application equipment and to learn about their testing procedures. It was determined that there are no procedures in the United States for evaluating highway spreader equipment under field conditions. The German government has standards for testing spreader equipment. Also, the European equipment manufacturers have testing procedures for evaluating their own equipment. A testing procedure will be of use to agencies who wish to evaluate available equipment to integrate anti-icing technology into their snow and ice control operations.

Limited experience of mainly European and Scandinavian countries has shown that applying a chemical freezing point depressant on a highway pavement before or very shortly after the start of frozen precipitation minimizes the formation of an ice-pavement bond. This anti-icing practice reduces the task of clearing the highway to bare pavement conditions and requires smaller chemical amounts than are generally required under conventional de-icing practices.

To accomplish anti-icing effectively, it is desirable to utilize spreader equipment that can meter a precise small quantity (such as 10 g/m^2 or 130 lb/lane mi) of applied chemical and spread it uniformly across the roadway.

Under SHRP Contact H–208 dealing with anti-icing technology, one of the objectives was to identify spreader equipment that can control the application rate and spreading pattern for solids, prewetted material, and liquid chemicals. The results of that portion of the study are reported in this paper.

In late summer of 1991, all potential American sources of spreader equipment used to apply de-icing chemicals were contacted. In addition, an effort was made to learn if and how U.S. highway spreader manufacturers tested their equipment's performance. This information was to be used to develop the necessary testing protocols for proposed American testing standards for winter maintenance spreaders. It was determined, however, that the highway spreader industry does not test its equipment's operating characteristics under actual field conditions. One exception was the Salt Institute, which has developed a procedure to measure the application rates of a spreader in a stationary mode. This standard was not useful to this study, however, because information was needed on spreader equipment tested in a dynamic mode.

The only standard test method found in spreader equipment literature from the United States was that developed by the American Society of Agricultural Engineers, ASAE Standard S341.2, Procedure For Measuring Distribution Uniformity and Calibrating Granular Broadcast Spreaders. However, this procedure is used with fertilizers, which have a narrow gradation band in comparison to salt. Furthermore, this standard does not pertain to application on a hard surface.

From the survey, it was evident that it would be necessary to develop a protocol that could be used to test and to evaluate spreader equipment. This standard would have to provide results that are accepted as valid by the spreader industry.

In developing a testing protocol for evaluating spreader capabilities, the researchers assigned fixed values to some of the test variables whereas other variables were measured and evaluated. A number of concepts were tested to evaluate the variables influencing material application rate and material distribution patterns.

First, the project team measured the application rates of some typical highway spreaders in a dynamic mode. Truck speeds of 24, 40, and 56 km/hr (15, 25, and 35 mi/hr) were selected as typical speeds used during salt application. Because the trucks usually travel in third or fourth gear at these speeds, it was first necessary to determine the respective engine rpm during actual operation. Next, the rear axle was lifted off the ground so that the drive wheels cleared the surface. The amount of material dispensed from the feed mechanism over a measured time and for a specific control setting was collected and weighed at each engine rpm to establish the material application rate (i.e., mass/unit time).

It was found that the material application rate varied substantially, both from spreader to spreader and from that specified by the spreader control manufacturer. Also, a number of the spreader vehicles had faulty hydraulic systems, which prevented the controls from providing accurate or repeatable results from setting to setting.

A series of spreader tests was performed to develop the most efficient method for measuring the material distribution pattern. A Schmidt spreader mounted on a Unimog truck was used for tests conducted during cold weather at an inactive truck weigh station along I–35 near Duluth, Minnesota. Three different methods of collecting salt spread during the tests were evaluated: hand sweeping, collection pans, and vacuuming of pavement strips. Dry rock salt meeting ASTM D632 Grade 1 was used.

Three test series were conducted. The arrangement shown in Figure 1 was used first. (Note that the vehicle wheel tracks are located between Sampling Locations 4 and 5 and Locations 6 and 7.) The amount of material collected by two different types of collection pans (i.e., one plastic and one aluminum) was compared with the hand sweeping of the equivalent area of the pavement at Sampling Location 5 along Line AB. Tests were conducted at actual vehicle speeds of 23, 32, and 40 km/hr (14, 20, and 25 mi/hr), with three passes made at each speed. A hand-held radar unit was used to measure the truck speeds.

The material distribution patterns for truck speeds of 23, 32, and 40 km/hr (14, 20, and 25 mph) as determined by hand sweeping are shown in Figure 2. Figure 3 shows a comparison of hand sweeping and pan collection at Sampling Location 5 (i.e., the area directly beneath the spinner), the center of which is 5.2 m (17.3 ft) from the left edge of Sampling Location 1. As indicated by the hand sweep-

E.J. Fleege, Minnesota Department of Transportation, Transportation District One, 1123 Mesaba Avenue, Duluth, Minn. 55811-2798. R.R. Blackburn, Blackburn & Associates, 1709 East Aloe Drive, Fountain Hills, Ariz. 85268-2963.

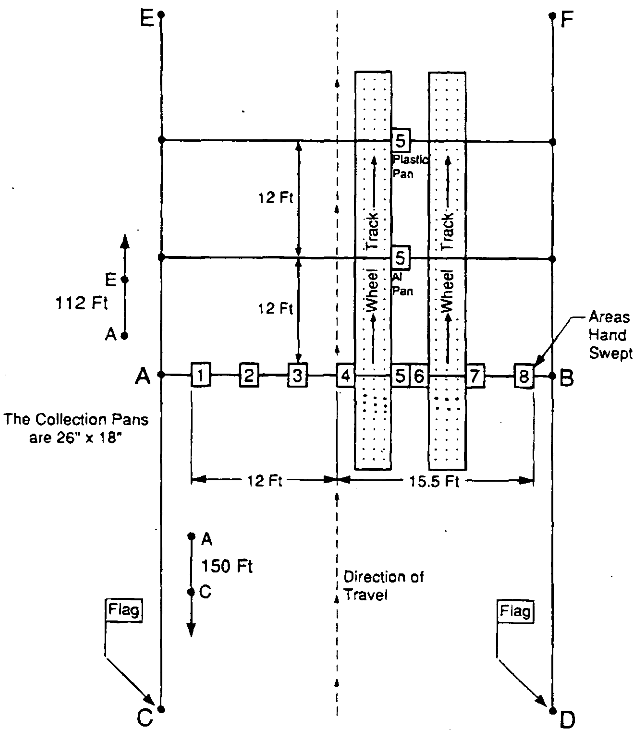

FIGURE 1 Experimental arrangement for first series of spreader tests (1 ft = 0.305 m).

ing data (Figure 2), the amount of material applied by the spreader varies with both vehicle speed and sample location.

The second test series was performed with the same vehicle but using hand sweeping, two different types of collection pans, and vacuuming of 15 m by 0.4 m (50 ft by 1.35 ft) strips of pavement using an industrial vacuum cleaner (Figure 4). Again, three passes were made during each test at vehicle speeds of 23 and 32 km/hr (14 and 25 mi/hr). The data obtained by vacuuming were compared to those obtained by hand sweeping and pan collection at selected locations.

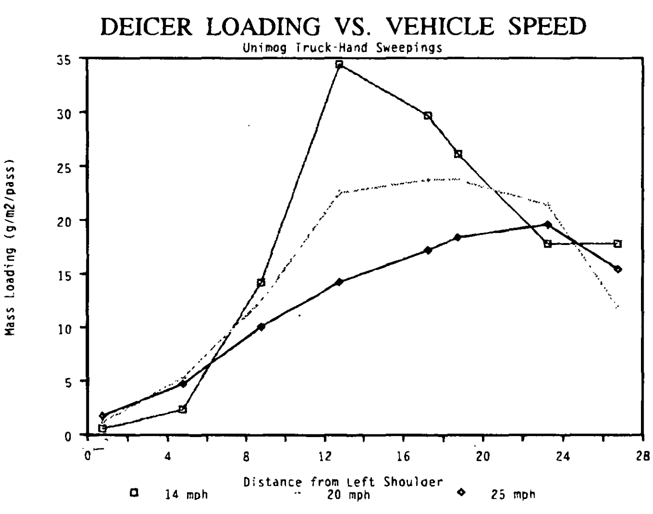

FIGURE 2 Deicer distribution patterns determined by hand sweeping (March 17, 1992).

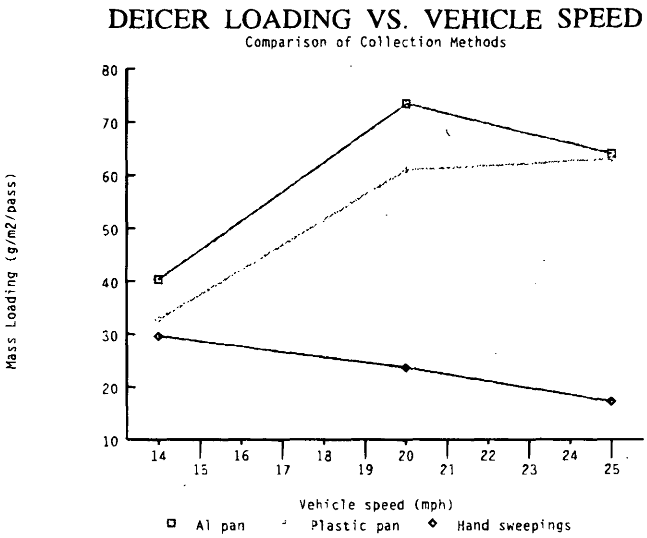

FIGURE 3 Deicer loadings determined by hand sweeping compared with those determined by collection pans (March 17, 1992).

The material distribution pattern is shown in Figure 5 for truck speeds of 23 and 40 km/hr (14 and 25 mi/hr) as determined by vacuum sweeping. Although material loading does vary somewhat with transverse distance and vehicle speed, the vacuuming data show a relatively consistent distribution pattern from one speed to another. This indicates that the distributor control system may be operating in the "ground-oriented" manner intended by the manufacturer. Comparing the various collection techniques in the aforementioned tests (see Figures 6, 7, and 8) suggests that hand sweeping and vacuuming are relatively comparable at the boundary of the distribution pattern where loadings are low, but they are not comparable at higher loadings close to the spinner (i.e., center of pattern).

In the last set of experiments, material distribution data were obtained from an array of plastic collection pans and compared with equivalent vacuum sweeping data using the arrangement shown in Figure 9. The same vehicle was driven at speeds of 23, 32, and 40 km/hr (14, 25, and 35 mi/hr). Three passes were made at each speed.

The material loadings obtained from the collection pans during the last set of tests (Figure 10) are substantially higher than those obtained by vacuuming for truck speeds of 23, 40, and 56 km/hr (14, 25, and 35 mi/hr). In addition, no consistent relationship could be found between the collection pan results and those results obtained by vacuuming. These findings indicate that additional work is needed to establish the most appropriate collection method to evaluate spreader patterns.

Therefore, numerous foreign sources were contacted by letters to obtain information on various types of anti-icing equipment that is used and their testing procedures. Follow-up interviews were held with a number of users and manufacturers in the various European and Scandinavian countries. It appears that most of the research and development on spreader equipment has been conducted in Europe. In the discussion with users and manufacturers, it was clear that there is a great interest in the development and utilization of spreader equipment that dispenses very small amounts of salt during snow and ice control operations. This interest comes from the great concern European and Scandinavian countries have regarding the protection of their surface groundwater from winter maintenance operations.

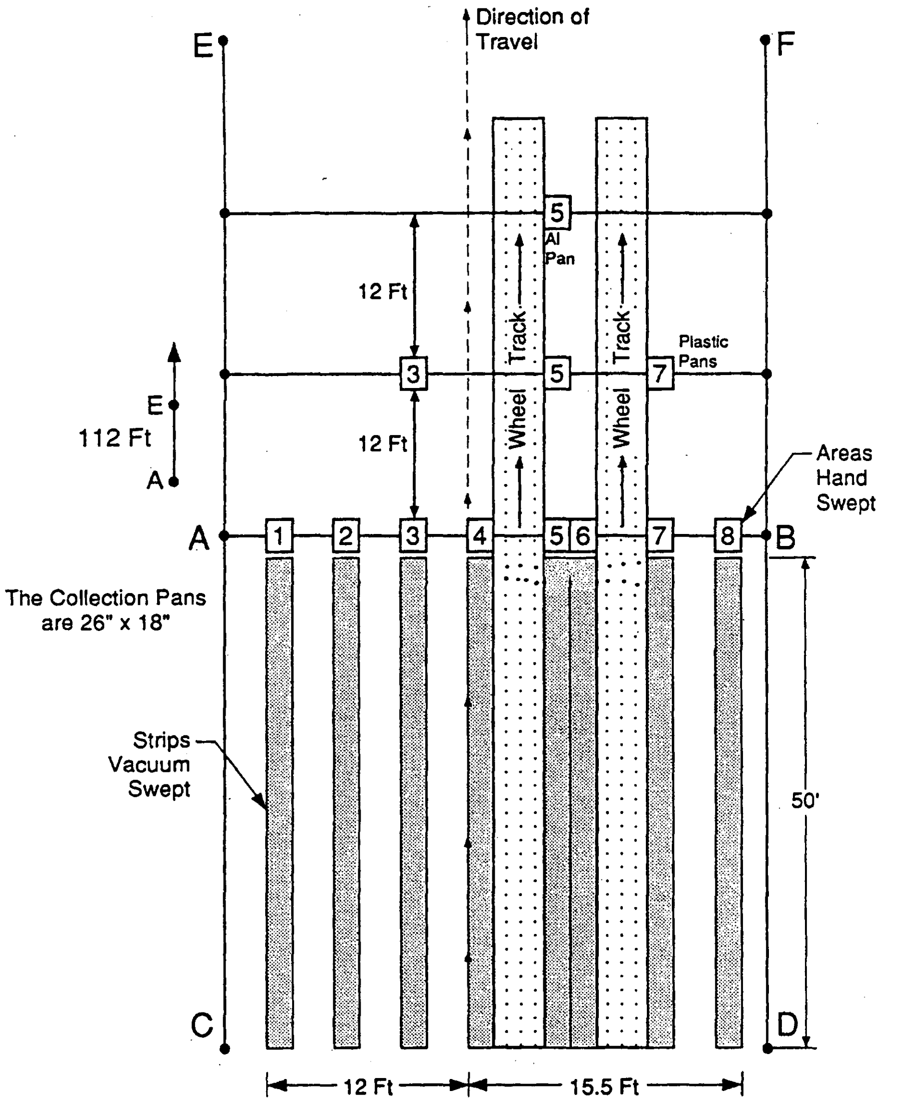

FIGURE 4 Experimental arrangement for spreader tests involving collection pans, areas, and strips (1 ft = 0.305 m).

A number of European governments require spreader equipment manufacturers to demonstrate that their equipment controls and monitors the application rate and spread pattern before the equipment can be commercially marketed in those countries.

The German government has prepared technical specifications and standards for winter spreader equipment used by its Road Maintenance and Traffic Department. These standards address such factors as technical data for equipment position, equipment height, spreader attachments, safety protection, and spread-material output. Within the spread-material output standard, requirements and testing procedures are detailed for mass loading rate, spread pattern, and speed. The German test protocol pertains specifically to the spread of dry material (salt and abrasives).

A version of the test protocol for prewetted salt is available currently only in draft form. However, German equipment manufacturers evaluate their equipment by testing spread pattern for prewetted salt in a stationary position. The wetted salt is spread from a stationary position for 2 min with the control setting at 40 g/m^2 (520 lb/lane mi) and a spreading width of 6 m (19.7 ft). Then the wetted salt is shoveled longitudinally into a row that is transverse to the center line of the spreader. This row is subdivided from the spinner location. Each subdivision of wetted salt is then collected and weighed.

The German spread pattern test for dry salt is conducted at a speed of 20 km/hr (12 mi/hr) with control settings of a spread width of 4 m (13 ft) and a spread density of 20 g/m^2 (260 lb/lane mi). With its hopper loaded to approximately half capacity, the spreader is driven over a marked grid system spreading salt. The salt samples are vacuumed into paper filters from the surface of the grid system. The mass of the salt vacuumed from each sampling rectangle is weighed to an accuracy of 0.1 g (0.04 oz) and then recorded. The data are analyzed to show the characteristics of the distribution overall, both longitudinally and transversely.

The total mass of material collected on any one transverse strip should not differ from the mean mass collected on the three strips by more than ±30 percent. The total mass of material collected on either overspread strip (U_l, U_T) should not exceed 5 percent of the total mass collected. The mass of material collected on either side strip (R_l, R_T) should not be less than 5 percent of the total mass col-

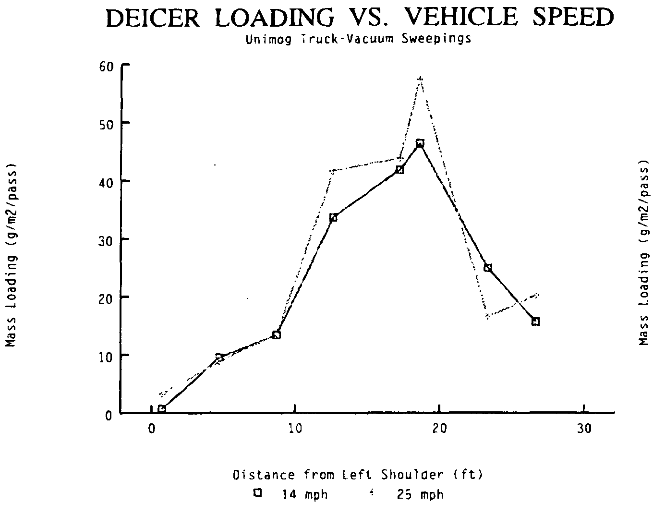

FIGURE 5 Deicer distribution pattern determined by vacuum sweeping (March 18, 1992).

lected. The allowed deviation of the computed spread density (SD) for the inner lengthwise strips between the side strips from the average SD of all the rectangles in the grid system should not be less than 90 percent nor greater than 50 percent.

The mass loading rate test addresses the amount of material released from the spreader in a unit of time. The amount depends on the spread density SD (g/m²), spread width b (in meters) over which the material is to be dispersed, and on the speed v of the spreader vehicle (km/hr).

Using the lower and the upper limits of these variables, a three-dimensional operational space is described within which all possible operating points must lie.

The requirements for mass loading exactness are related to the deviation between the measured and control setting value for SD. This deviation, ΔSD, must be within $\pm$6 percent. The mass loading rate of the spread material should be regulated so that the selected

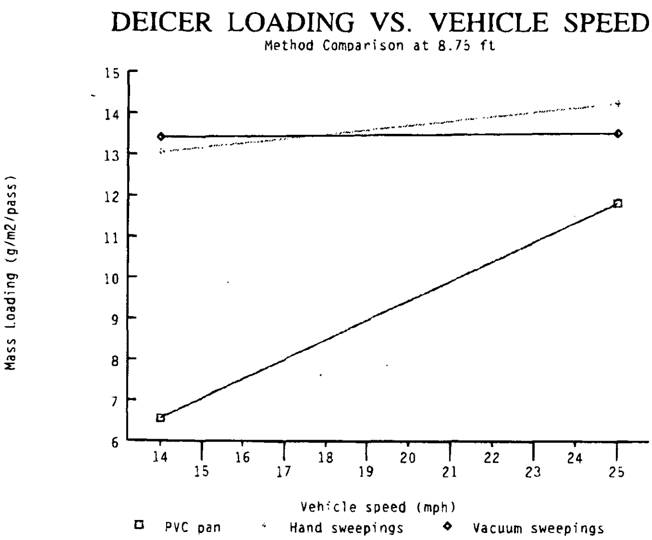

FIGURE 6 Comparison of deicer loadings for three different collection methods at Sampling Location 3 (March 18, 1992).

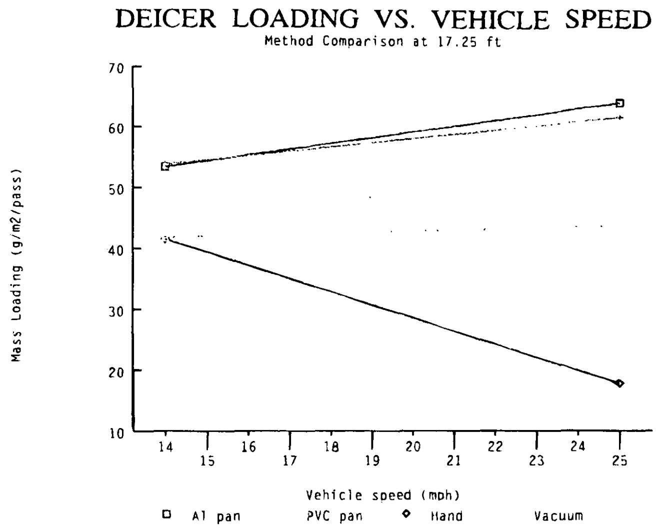

FIGURE 7 Comparison of deicer loadings for four different collection methods at Sampling Location 5 (March 18, 1992).

SD remains constant when the vehicle is operated at speeds that range between 10 and 40 km/hr (6.2 and 24.8 mph). The SD also cannot change with adjustments of the spread width between 3 and 8 m (9.8 and 26.2 ft).

EQUIPMENT DESCRIPTION

All the various major European spreader manufacturers conform to the standards for spreading dry salt through the use of patented equipment. All the manufacturers supply hopper boxes for use by highway agencies. The capacity of these hoppers will vary from 6 m³ up to 9 m³. The spreaders can be demountable or chassis mounted. Because most of the countries hire rental trucks in the winter for snow and ice control operation, a large percentage of the

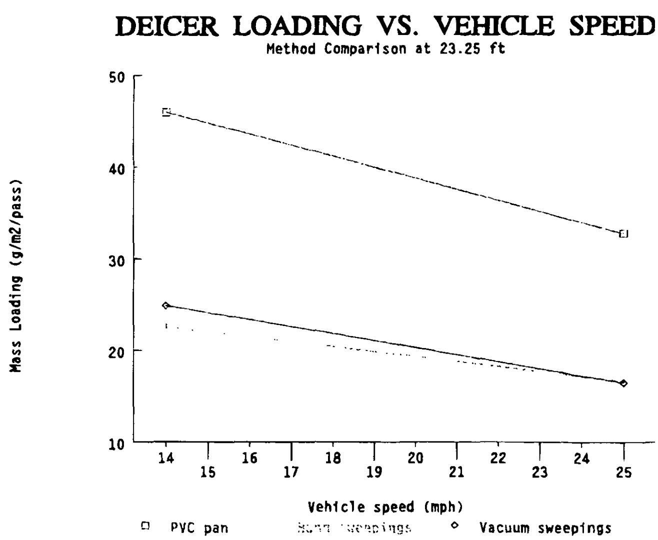

FIGURE 8 Comparison of deicer loadings for three different collection methods at Sampling Location 7 (March 18, 1992).

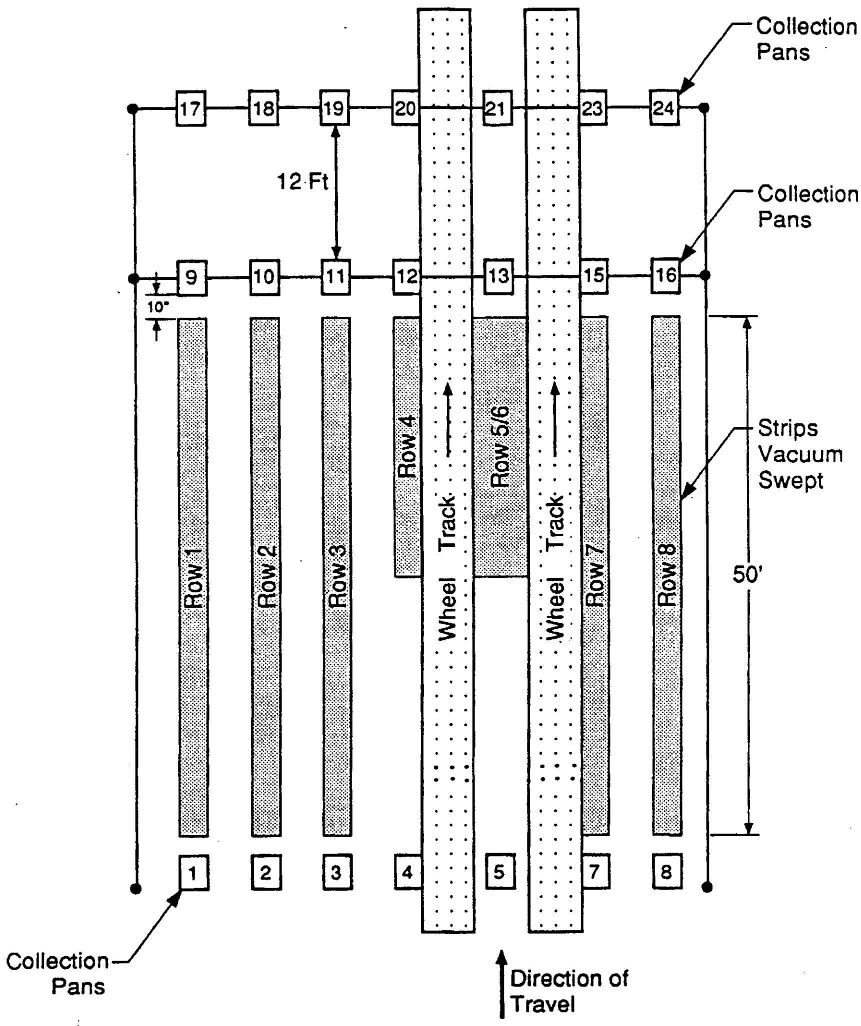

FIGURE 9 Experimental arrangement for final series of spreader tests (1 ft = 0.305 m).

spreaders that are marketed are demountable. It takes about 15 min to load or unload a spreader from a truck.

The method of conveying the material from the hopper box to the spinner varies depending on the manufacturer. One method utilizes a large auger that runs the length of the box. The auger is either a solid or an open type. In addition, a number of manufacturers incorporated a parallel shaft with fingers, which were used to break up lumps of material before being augured out of the hopper. A second method used a smooth belt conveyor or one with raised herringbone ridges to convey the material from the hopper.

The material transported from the hopper is dropped through a closed chute and onto a specially designed disk spinner. All the manufacturers utilized curved fins. The design of the curvature and the number of fins will vary with the patent. Generally all the disks were slightly concave and constructed of stainless steel. A number of the spinners utilize a fluted hub.

Depending on the manufacturer, the diameter of the spinner will vary from 500 mm to 800 mm. One manufacturer has a uniquely designed disk spinner. The patented spinner has a series of three different radii by which the disk acquires an almost triangular configuration. This shape provides for variant lengths of curved vanes or fins on the disk.

There are two methods of controlling spread distribution patterns (symmetrical or asymmetrical) on the roadway. One method is to control the position where the material lands on the spinner. The second method is to control where the location is changed by rotating the whole spinner assembly to change the direction of the pattern.

When the spreader equipment is designed for prewetting salt at the spinner, the liquid is pumped with a positive displacement pump and through a check valve just above the spinner. The liquid is discharged either directly onto the spinner near the center or through an overflow chamber and then onto the spinner. The dry material and brine become mixed as they travel along the curved vanes.

The system controls for all spreader equipment utilizes a microprocessing unit to control the density of the application, spreader width, and percentage of prewetting. Some of the controls are programmable, which provide the user with enhanced flexibility over the control settings. Some companies use digital indications, and others use knob settings on the control box.

The digital controls have the following capabilities:

- Density—has a range of 0 to 40 g/m^2 for salt with increments of 1 g/m^2.

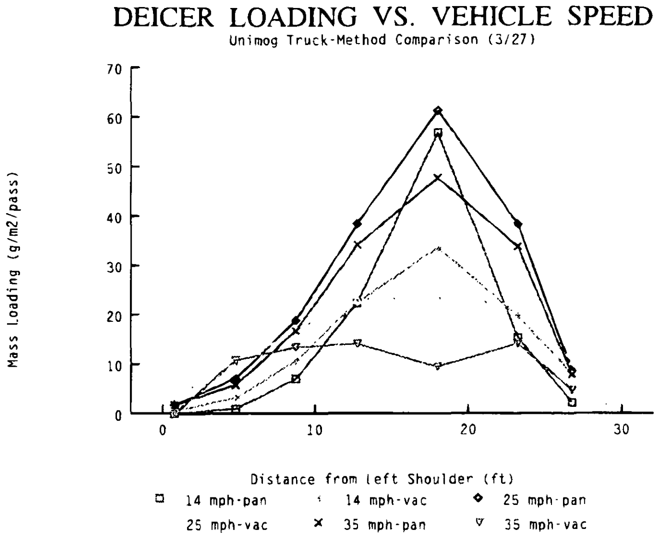

FIGURE 10 Comparison of deicer distribution patterns for two different collection methods (March 27, 1992).

- Percentage of prewetting—has a range of 5 to 40 percent with increments of 1 percent.
- Spreader width—has a range of 2 to 8 m with increments of 0.1 m.

The knob controls have the following capabilities:

- Density—has a range of 5 to 40 g/m^2 for salt with increments of 2.5 g/m^2 up to 20 g/m^2 and with increments 5 g/m^2 from 20 g/m^2 to 40 g/m^2.
- Percentage of prewetting—has settings of 10, 20, and 30 percent. One company has only 30 percent.
- Spreader width—has a range of 2 to 8 m with increments of 1 m.

The control units for prewetting salt are similar to those used for the dry salt controls. The amount of liquid brine being added is controlled by using a percentage of the total prewetted material. As the amount of prewetting liquid application is increased, the amount of dry material is decreased proportionally so that the desired density remains a constant.

A number of the controls also have the capability to download information on spreading and plowing operations. The information provided is the density of application (g/m^2), percentage of prewetting, spreader width, speed, distance traveled while spreading at a given setting, distance traveled while plowing, total distance traveled, and time of day. The printouts also provide a summary of the total kilograms of material spread and kilometers traveled.

In observing the action of salt during spreading operations in Minnesota, turbulent air flow behind the truck is an important factor in the resultant distribution pattern of salt. One manufacturer has addressed this issue by developing an air deflector which is mounted just behind the hopper box and projects above the box. The idea is for the air deflector to force the material down on the roadway. The Motor Research Industry Association of the United Kingdom has been conducting testing on this concept also.

Due to the practice of applying liquid salt to the roadways in Scandinavian countries, a number of companies have designed and manufactured liquid spreaders. There are two basic types of liquid spreaders: one incorporates spray nozzles, and the other uses a dish spinner(s).

DISCUSSION OF RESULTS AND RECOMMENDATIONS

To integrate anti-icing technology into an agency's snow and ice control operations, it will be necessary to use spreader equipment that can effectively dispense small amounts of material in a uniform pattern on the roadway. A preliminary procedure has been developed to measure the ability of the spreader to control the distribution pattern and the application rate of spread material. The distribution pattern should be evaluated at speeds of 20 km/hr (12 mph) and 40 km/hr (25 mph) with control setting values delivering 20 g/m^2 (260 lb/lane mi) of spread material over a 6 m (19.7 ft) width. The spreader should be driven over a marked grid system during spreading of the dry salt. The application rate test should measure the accuracy of the spread material released in accordance with the normal operational range of the spreader. In addition to controlling the dispensing of material, the American manufacturers should investigate ways of obtaining consistent application rates from truck to truck. The presently available spinner design used on U.S. manufacturer spreader equipment also needs to be evaluated.

American manufacturers are working to develop microprocessing units that can control the dispensing of small quantities of material. (However, these controls were not tested in this research project.) In addition to controlling the dispensing of the material, the hydraulic systems, spinner design, and prewetting systems on spreader equipment presently available on the domestic market need to be upgraded.

The experience of the authors indicated there is a lack of testing procedures for spreader equipment. This may be one factor inhibiting the development of precision equipment essential to anti-icing operations. The European governments require spreader equipment manufacturers to demonstrate that their equipment can control and monitor the spreading of material.

ACKNOWLEDGMENTS

The work reported herein was conducted under Contract SHRP-90-H208. L. David Minsk was the SHRP Research Manager for the contract. Funds for the study were provided by the SHRP, National Research Council, National Academy of Sciences.

Publication of this paper sponsored by Committee on Winter Maintenance.