A STUDY OF ROTARY DISK SPREADERS TO IMPROVE WINTER SERVICEABILITY IN FRANCE

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1-Abstract
Rotary disk salt spreaders are the most commonly used machines on roads during winter in France. Given the high economic issues at stake and in reaction to pressure from the media, road network managers have increased the quantities of salt being spread. In order to control those quantities, the French Department of Roads and Highways (*Direction des Routes*) has developed a policy to improve winter serviceability. The policy, which focuses on staff training and on machinery techniques, has enabled the development of a measuring method for proportioning salt. The method developed and the type of appliance used enable salt spreaders to be quickly and precisely adjusted. A French standard formalises the service conditions and results for the method.

2-Introduction
France is a country with a highly diverse climate. Depending on the region or altitude, there are five types of climates: oceanic, modified oceanic, continental, Mediterranean and mountain.

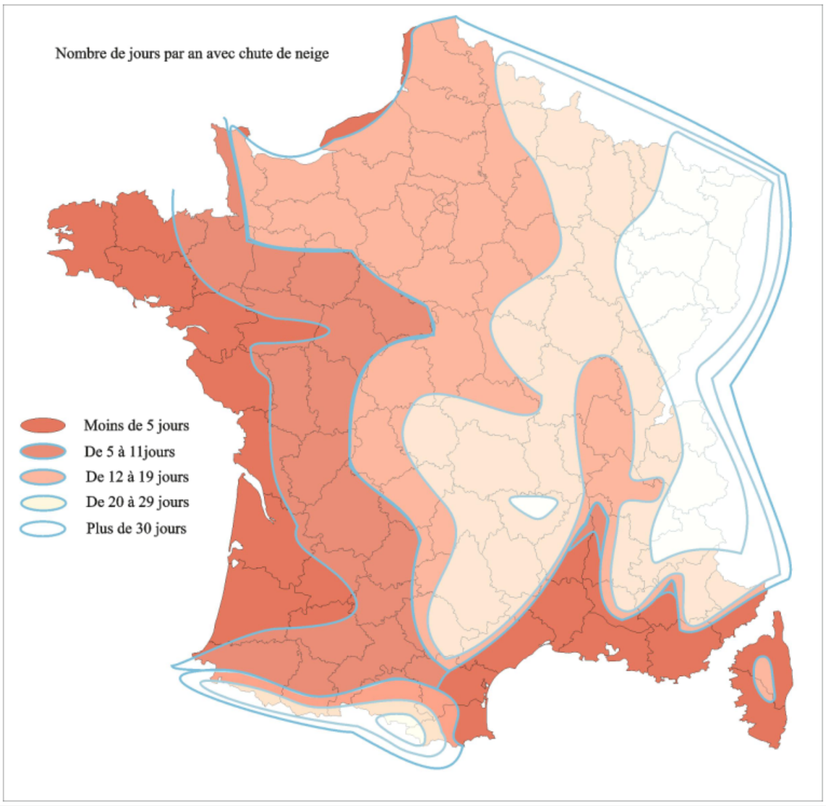

Fig. 1: Map of snowfalls in France.

Snowfalls and the formation of ice are linked in quantity and frequency to these climatic regions: for instance, snowfalls occur for more than thirty days per year in mountainous regions but less than 5 days along the coastline. The influence of the sea, which is felt deep inside the territory (from 200 to 400 km) by following the valleys of the major rivers, occasionally modulates the effects of altitude or exposure.

As a result, apart from the mountainous regions where snowfalls and negative temperatures are certain to occur, the remainder of the territory comprises a multitude of micro-regions in which the means and methods used to ensure winter serviceability vary to a considerable degree. To adjust to these variations in the climate, the principal machine for ensuring winter serviceability is a rotary disk salt spreader, used in addition to road scrapers or ploughs when the height of snow requires this type of treatment.

3-Finding

The machines are widespread and multipurpose, such that some 9,000 of the spreaders are used to ensure winter serviceability in France, but in so doing consume some 300,000 tons of de-icing agents during mild winters and up to 1,500,000 tons when winters are harsh. Because they are used in a wide variety of climatic situations during winter in France, rotary disk spreaders require different settings and operating conditions.

Fig.2: Salt spreaders ready to work

Road management in winter is made even more difficult by the following factors:

- Increasing demand from road users to have satisfactory driving conditions whatever the change in weather.
- The economic impact of closing parts of the road network, since this disrupts supply lines and the just-in-time operation of companies.
- Media pressure in the case of poor traffic conditions or blockage of the entire network (notably in the case of ring roads around large cities).

These difficulties have led network managers to over-increase the quantities of de-icing agent spread with each intervention, rather than look more closely at the quality of spreading and therefore the settings of spreaders.
The latter are capable of outputting large quantities of de-icing agent, but the use of small quantities, which are more difficult to control and adjust, is increasingly abandoned. Machines that are incorrectly set or poorly maintained are incapable of correctly functioning at low spreading rates, and as a result preventive treatment using these low levels is no longer applied.

Fig. 3: Road scraping and treatment on a suburban ring road

A reduction of 5 to 10% in the national consumption of de-icing agents can be obtained by:

- The systematic maintenance of machines before the winter serviceability period,
- Applying preventive treatment, which requires more precise machine settings and spreaders that are capable of working at low rates.

These potential savings therefore require:

- An improvement in the general operation of rotary disk spreaders.

  Users must ensure an adequate level of maintenance, and adjust the machines to obtain the programmed metering regularly and reliably.

  By means of technical innovations, manufacturers must provide rotary disks machines capable of spreading de-icing agents at low rates. The minimum spreading rate is 5 g/m²; the maximum can be limited to 40 g/m².

- A certain number of changes in winter serviceability operations.

  Increased awareness among end-customers about the use of preventive interventions at low spreading rates.

  Training courses for drivers about the new possibilities of their machines.

Fig. 4: Spreading de-icing agent on melting wet snow

Together these measures, i.e. savings in de-icing agent and improved machine settings, are also supportive of more ecological road management.

3-National policy

Based on this finding, the French Department of Roads and Highways has defined a general policy to improve the quality of winter serviceability.

This policy concerns the organisation of and materials for winter serviceability.
Various administrative departments have been entrusted with implementing this policy, each at their own level. The departments in question are:

- the roads and highways technical engineering department (SETRA).
- the civil engineering technical research centres (CETE) and their specialised centres.
- the central laboratory (LCPC) and the network of regional laboratories of the department of civil engineering (LRPC).
- the departmental roads and highways divisions and their motor pools.

The operations undertaken by these departments include:

- The development of intervention methods with remedial and pre-remedial treatment.
- Staff training courses.
- The development of decision-aid systems: weather report analysis, automated aid systems.
- Improvements in the quality of salt: provision, storage, compliance with standards.
- The quality of intervention equipment: upkeep and optimum settings before winter, capacity to spread at low rates with good distribution.

Representatives of these departments are taking part in the work of the standardisation committee for road maintenance equipment and products (MPER).
The tripartite committee (administration, equipment manufacturers, end-users) produces a coherent analysis of the areas of study and, when required, drafts the appropriate national standards.

4-From defining a measurement method to developing a national standard

The methods developed up until the present day are too difficult to apply: after spreading the de-icing agent on the ground, it is recovered in order to measure the quantity spread.
These methods require a large workforce, and the operation is long and tedious. Recovering the de-icing agent spread on the test ground is a delicate operation, in particular for low spreading rates, even when special receptacles are placed on the ground (tarpaulins or plates).
Retrieving the results using these methods is not immediate and the number of tests performed per day is low. The various operating parameters of the spreader cannot be studied in a single day.
The interaction between the ground and the de-icing agent at the time of spreading is specific to the test site used and to the nature of its surface. On the other hand, spreading the de-icing agent under real-life conditions is influenced by the effect of the wind and the turbulence at the rear of the spreader.
The only advantage of these methods is that they make it possible to measure the distribution of the de-icing agent across and along the road surface.

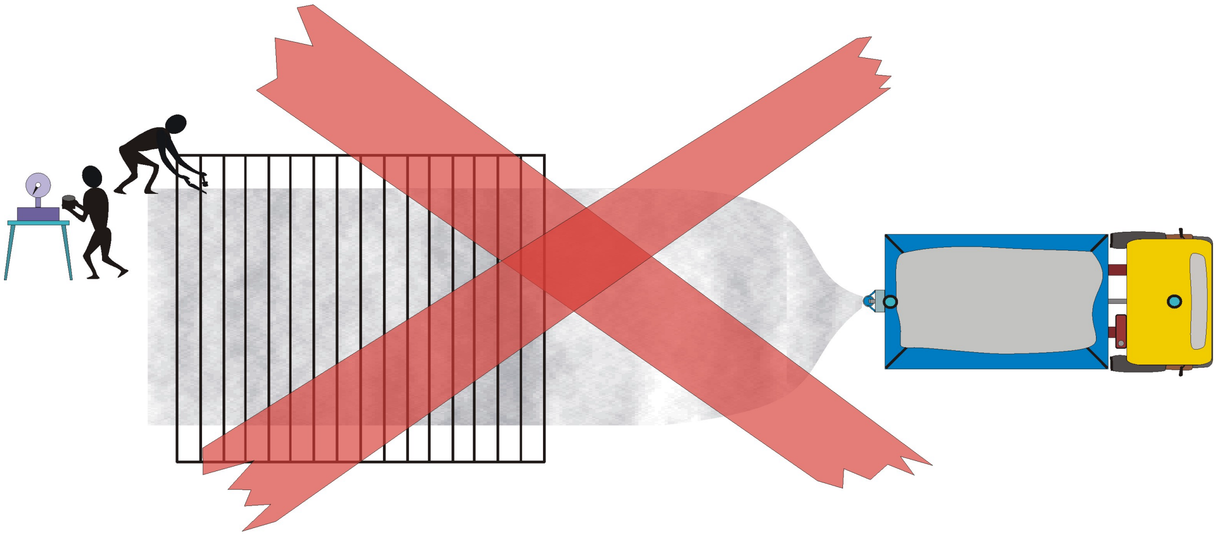

Fig. 5: Methods involving the recovery of the de-icing agent from the ground have not been adopted.

4.1-**Fixed station measurement method**

The purpose of the present method is to make it possible to **verify** both the operation and **quickly adjust** salt spreaders before winter sets in.
A group of experts comprising equipment manufacturers, machine users, network managers and measurement specialists defined the basic points and conditions of the method:

- it had to be simple and reliable,
- the results had to be immediately retrievable,
- it had to enable verification of the main operating parameters of the machine.

The group of experts also defined the parameters that were to be verified and results that were to be restored.
The parameters that were to be verified were:

- the speed of the spreader,
- the width of spreading,
- the operation of the components in the de-icing agent proportioning system.

The results that were to be output were:

- The spreading rate, i.e. the weight of de-icing agent on the ground per unit of surface area (in g/m^2),
- the regularity of the spreading rate (distribution) over a distance of 200 m.

The length of time required to verify the operation of a salt spreader was not to exceed one normal working day and the retrieval of the results for each test had to be automatic and immediate.

Given these conditions, it seemed clear that the testing of a salt spreader had to be performed when the vehicle was stationary.
The advantage of a "stationary" test is that the test equipment can be installed in special premises and is not hindered by weather conditions. The method is therefore reproducible and enables the machines to be adjusted under identical conditions.

To calculate the de-icing agent spreading rate (g/m^2), the quantity spread by the machine had to be measured. The solution adopted was to collect and immediately weigh the de-icing agent after its ejection by the disk of the spreader.

The time measured (**t**) in relation to the theoretical speed (**v**) during the test determined the fictional distance (**d**) covered by the machine (**d = v** x **t**). The test distance adopted was 200m. The fictional surface area treated by the machine was therefore obtained by multiplying distance **d** by the width of spreading.
To assess the regularity of the de-icing agent spreading rate, the surface area treated had to be cut up into a regular series of zones in order to create a sample population. The distance **d** was cut up in 200 samples 1 metre long, the surface area (**s**) of each sample therefore being the product of the width of spreading by its length of 1m (**s = spreading width x 1 meter**).

The de-icing agent spreading rate **x** was determined for each sample, then the average spreading rate $\overline{X}$ was calculated for the 200 spreading rates **x**. then the scattering (or standard deviation) σ of the spreading rate for the 200 samples was calculated .

Nota : $\sigma = \sqrt{\frac{\Sigma(X-\overline{X})^2}{n-1}}$

The regularity of the de-icing agent spreading rate over the surface area covered is expressed by the longitudinal variation coefficient "**cvl**",

$$\text{cvl} = \frac{\sigma}{\overline{X}}$$

The series of samples 1 metre long can be illustrated as a fictional grid (Fig.6) in which each slot would be filled by the spreader if it were to move. The grid is represented by the series of weight measurements whose rate is such that the length between each measurement simulates a displacement of 1 meter of the salt spreader.

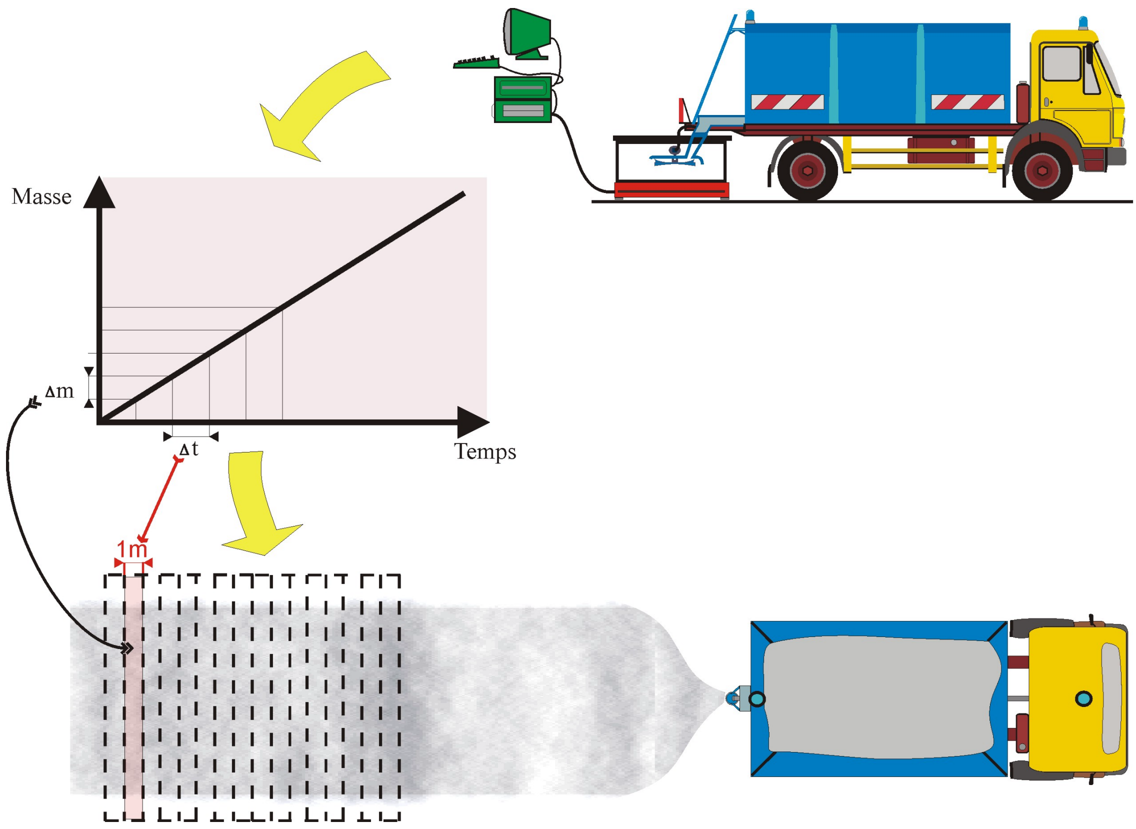

Fig. 6: Diagram of the stationary measurement method

This method does not enable measurement of the transversal variations in the de-icing agent spreading rate; another method, currently under study, is required to analyse these variations.

4.2-Equipment for spreader adjustment

In parallel to the analyses of the measurement method, the S.EM.R.* has developed an initial experimental device to validate the various technical options.
This initial appliance, modest in construction but precise in operation, could not be used as such on salt spreaders by maintenance personnel. It was therefore necessary to design an appliance that would meet the requirements of the method (precision, speed of data acquisition) that could be used by the staff in the operating centres (ease of use, human engineering).
The C.E.C.P * * Rouen was entrusted with designing this new device, nicknamed DORSA (a French acronym for Device to Optimise the Regulation of Salt Appliances) (Fig.7).

The DORSA device is based on a weighbridge fitted with a receptacle that collects the de-icing agent output by the spreader disk on the machine.

Fig. 7: DORSA

The spreader is stationary, i.e. it does not move. If the wheels have to be rotated to test the speed control, the machine is installed on a home trainer.

*S.E.M.R.: (Experimental station for road equipment). A technical department of the French ministry of civil engineering that studies the operation of all construction and road servicing equipment.

* *C.E.C.P.: (Prototype design and construction centre). A technical department of the French ministry of civil engineering that designs and constructs special equipment for use on roads and in earth-moving applications.

Fig. 8: Spreading rate measurement with DORSA

All the functions of the machine are then operational and can be checked. The tests carried out with DORSA define the de-icing agent spreading rate (g/m²) applied by the machine and the longitudinal regularity of the spreading rate. The de-icing agent output by the spreader is weighed dynamically, i.e. continuously, the time interval between each weighing (sampling) depending on the programmed speed of advance of the machine. The speeds of the various components involved in the spreading rate are measured synchronously with the weighings.
The weighbridge is linked to a special electronic card capable of carrying out the high number of measurements required for mathematical processing and precision.

Frequency of electronic card	500 Hz
Maximum sampling frequency	50 measurements per second
Precision of mass measurements	±0.5g
Precision of measured spreading rate	From 3 to 0.3%

A software system provides the interface with the user and manages all of these measurements, it checks the data acquisition, it carries out the processing, stores the data and finally calculates the de-icing agent spreading rate as well as its longitudinal regularity.

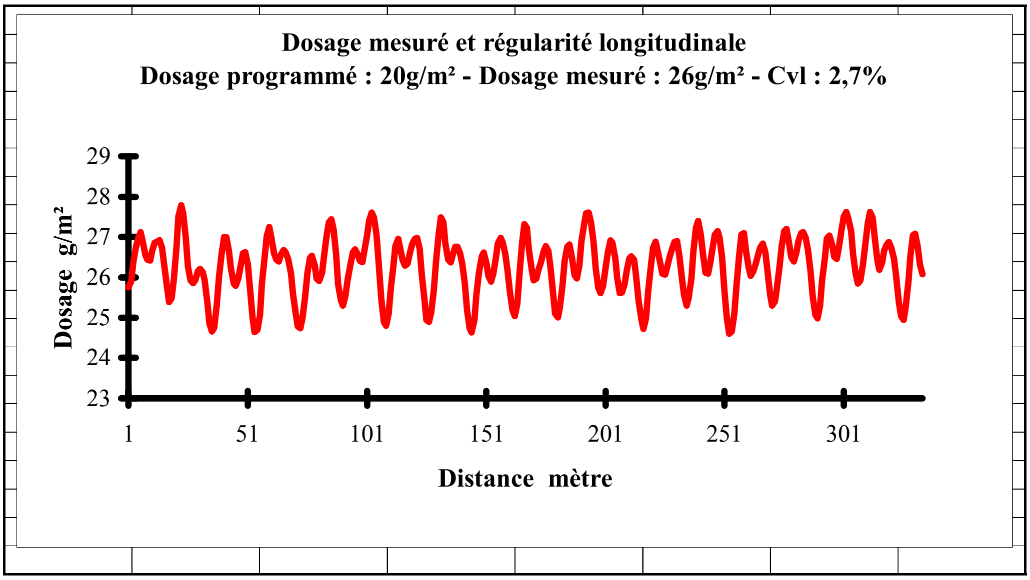

Fig. 9: Results obtained with DORSA: spreading rate and longitudinal regularity.

On figure 9, it can be seen that the de-icing agent output by the spreader has a spreading rate on the ground of 26g/m² for a programmed spreading rate of 20g/m², i.e. a deviation of 30% in surplus de-icing agent. Adjustment of the rotation speeds and control of the various spreader components enable this large-scale deviation to be corrected.

4.3-A French standard for rotary disk spreaders

In order to harmonise the methods used, the standardisation committee for road maintenance equipment and products (MPER), with the support of the French Department of Roads and Highways (*Direction des Routes*), has drafted a standard for adjusting salt spreaders. The standard, jointly drafted by manufacturers, road network managers and French government design and engineering departments, has been ratified by the AFNOR (the French Standardisation Association) under reference no. NFP 98-797. It is based on the principles of the method previously described and relates them to test equipment of DORSA type.

The parameters to be checked on salt spreaders are described as well as the results that should be obtained. All the functions affecting spreading and the method for controlling them are defined.

The preliminary tests for any spreading rate measurement enable the following items to be checked:
- the correspondence between the programmed forward speed and the real forward speed of the vehicle.
- the correspondence between the programmed spreading width and the real spreading width.

The performance tests with different operating parameters are used to determine:
- the overall de-icing agent spreading rate.
- the longitudinal regularity of spreading rate.
- the repeatability of the spreading rate.
- the operation of the closed-loop control system for spreaders that control the de-icing agent output according to the speed and width of spreading.

Additional tests can be used to characterise:
- the start tests, to measure the variations in salt spreading rates during machine shutdown and start-up phases.
- measurement of the spreader drain rate.

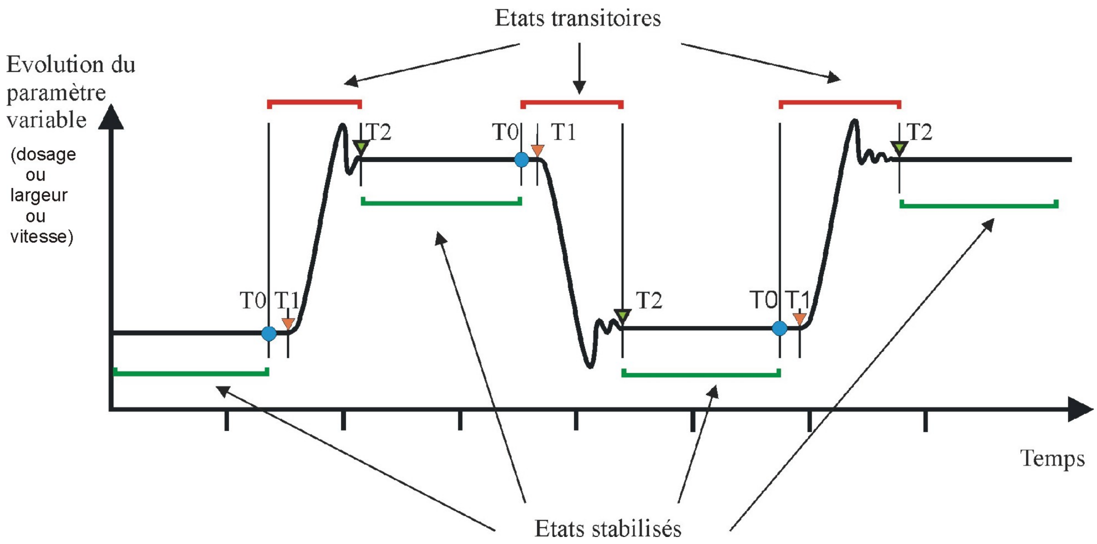

Fig.10: excerpt from French standard NFP 98-797, diagram of closed-loop control analysis.

A test report concludes this evaluation standard for the performance of salt spreaders.

5-From today to tomorrow

The surveys undertaken up to the present date are mainly concerned with controlling the output of salt spreaders, to obtain better control of the quantities of de-icing agent spread during the winter period.

Output alone can not ensure the spreader works efficiently; it is equally important that the transversal distribution of de-icing agent is satisfactory. Studies on salt spreaders are currently under way to develop a method for measuring the transversal distribution of spreading. Experiments have shown that de-icing agents are not always ideally spread and are partially lost by being spread directly onto the shoulder.

An apparatus capable of rapidly evaluating the distribution of spreading according to the breadth of the road surface is currently being developed. These two complementary appliances (Dorsa and the measurement of transversal distribution) will be essential instruments for setting-up and adjusting salt spreaders.

The spreading of salt in grains was the first topic for research; it is now time to undertake studies on the operation of combined machines using the slush technique (i.e. simultaneously spreading salt and brine).

6-Conclusion

Studies on the operation of rotary disk salt spreaders have shown how necessary it is to correctly adjust the machines before the winter period. Through the initiative of the government departments in charge of the road network, equipment users and manufacturers, a common, active approach has resulted in the definition of a measurement method for the de-icing agent spreading rate. The method has been applied using the appropriate equipment and the global approach has been formalised by drafting a national standard. Because the machines are better calibrated, the end-customers' instructions can be more easily obeyed, the user's safety is maintained by machines working more efficiently; and in so doing, they help to preserve the environment by reducing the quantities of de-icing agent that need to be spread.