DEVELOPMENT, IMPLEMENTATION AND EVALUATION OF REDUCED SALT SPREAD RATES

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ABSTRACT RÉSUMÉ

New pre-wetted salting vehicles and a programme of research has enabled the Highway Agency to reduce salt spread rates on the Strategic Road Network in England. The spreaders were required to satisfy performance to confirm that they could discharge and distribute salt accurately. The effect of trafficking on residual salt levels and the amount of water on road surfaces was investigated in road trials and a literature review. Spread rates were calculated using the sodium chloride – water phase diagram, taking into account the salt and water assumed to be present at the road surface after trafficking. The spread rates compared favourably with those used elsewhere in Europe for road surface temperatures above -4˚C, but they tended to be higher at lower temperatures. (Further research is recommended to determine if spread rates at lower temperatures can be reduced). Since January 2010 the new rates are estimated to have reduced usage by around 30% benefitting both the environment and the asset. The effectiveness of the reduced spread rates was assessed and no major safety concerns were identified. The same methodology has been used to determine spread rates for treatments in extreme cold when pre-wetting salt with alternatives to brine.

1. INTRODUCTION

The Highways Agency is an executive agency of the UK Department for Transport with responsibility for operating, maintaining and improving the strategic road network (SRN) in England on behalf of the secretary of state for transport. The SRN extends to 6,900km (4,300 miles) and is made up of motorways and the most significant 'A' roads, known as trunk roads [1].

Although representing only 2 per cent of all roads in England the SRN carries a third of all traffic by mileage. Two thirds of all heavy good vehicle mileage in England is on the SRN making it the economic backbone of the country. Operating and maintaining the SRN is therefore a key component to help support the sustainability of the UK's economy.

1.1. Winter Service Obligation and Delivery

Amendments to the Highways Act 1980 made by the Railways and Transport Safety Act (2003) [2] place a duty on UK highway authorities 'to ensure, so far as is reasonably practicable, that safe passage along a highway is not endangered by snow or ice'. Precautionary salt spreading treatments, using routes that cover every lane and link of the entire SRN, are carried out whenever there is a forecast that ice would otherwise form and in advance of forecast snow. Post treatments are carried out to aid the removal of ice, snow or hard packed snow. Spreading salt is the most cost effective way to fulfil this duty with research by others [3] claiming that every £1 spent on service provision brings £8 benefit to society due to reduced accidents and less traffic delay.

The provision of both routine and winter service is contracted to service providers with there being 12 main area contracts and several private finance initiative route contracts known as design, build, finance and operate (DBFO). Providing winter service to fulfil the above legal duty costs approximately £20M a year for the network of 35,000 lane-km.

The Highways Agency provides guidance to service providers on delivering winter service treatments including appropriate spread rates for various conditions. The service providers are responsible for deciding both when to deliver winter service and an appropriate treatment. Until winter 2009/10 dry salt spreading, using salt with a moisture content ranging from typically 2 to 4 per cent, was the norm using spread rates of 10, 20 or 40 g/m^2 that had been in use since the 1970s.

2. REDUCING ENVIRONMENTAL IMPACT & EFFICIENCY SAVINGS

2.1. Research Strategy

The Highways Agency carries out research to improve its operation and management of the SRN. From 2007 the focus for winter service research was that ‘roads are kept open and in a safe condition during winter, with minimal impact on the environment’. In terms of environmental aspects, the main aim was on reducing the amount of chlorides on the network, which the Environment Agency had also tasked the Highways Agency to do. Although spreading salt is a cost effective way of meeting the legal duty it is clearly not without its problems. As well as the environmental impacts of chlorides damaging roadside vegetation, soils, watercourses and aquatic life, salt is also damaging to the asset, especially causing corrosion of structural steelwork, steel reinforcement, street furniture as well as customers’ vehicles. Salt is also a natural resource that should not be wasted so there were also sustainability considerations. This became especially apparent in winter 2009/10 when stocks of indigenous rock salt in the UK came under threat during and following two exceptional winters when demand had been unprecedented. The two main Highways Agency suppliers, Winsford Mine in Cheshire and Boulby Mine in Cleveland, were unable to meet the demand for salt from UK highway authorities necessitating the import of significant quantities of salt from North and South America, the Middle East and Continental Europe at greatly increased cost. Any success in reducing the chlorides on the network would bring benefits in each of these areas as well as helping improve supply resilience.

There was high confidence that undertaking research to challenge historical salt spread rates would deliver results given anecdotal evidence that some European countries were using spread rates that were lower than those used by the Highways Agency. However, there might be entirely justifiable reasons (see Section 2.3).

2.2. Efficiency savings using pre-wetted salt spreading

Informed by the Highways Agency’s membership of the World Road Association (PIARC) and previous work [4] had confirmed the benefit case for the Highways Agency to replace its dated fleet of dry salt spreading vehicles, which were reaching the end of their economic lives, with new pre-wet capable vehicles. It has been widely accepted that pre-wetted spreading is a more effective precautionary treatment than spreading dry salt. The slight wetting of the salt by the brine helps control the finer salt particles, which might otherwise be lost due to trafficking and turbulence effects, resulting in less loss during trafficking, a more uniform spread distribution and hence greater potential to reduce spread rates.

Such benefit case was underpinned by saving salt spread, given that equivalent, i.e. same number, salt spread rates for dry and pre-wetted salt contain less chlorides for the former. Saving money by spreading less salt helps offset the additional costs associated with investing in brine saturators, purer brine salt and vehicles capable of combining the materials in the ratio 70 per cent dry salt to 30 per cent brine. By being able to more accurately control pre-wet spread rates there was potential for not only lower spread rates but also smaller spread rate increments, such that rates could be better tailored to the conditions rather than the coarse conservative spread rates that covered a range of conditions. It was estimated that the use of pre-wetted spreading further improved the overall benefit to cost for salting [3] to more than 10:1.

Although the Agency was working to replace its winter fleet, using a fleet-supply framework contract that would see the first vehicles operating from winter 2008/09, the last vehicle would not be retired until end of winter 2010/11. Plus, the Highways Agency does not make its winter fleet available to all service providers and some, especially DBFO contractors, intended to keep spreading dry salt beyond 2011/12. For these reasons any research into spread rates would need to consider both dry salt and pre-wetted salt.

2.3. Salt Dosage & Road Response Project

To investigate any possibilities to reduce salt spread rates the Highways Agency appointed Transport Research Laboratory (TRL) in February 2008 to carry out a research project titled Salt Dosage and Road Response. The aim of this was to determine appropriate precautionary treatment salt spread rates for the SRN that allowed the legal obligations to be safely discharged using lower spread rates, for both dry and pre-wetted salt.

A desktop literature review and worldwide consultation exercise, which focussed on countries that experience similar maritime climates to the UK was carried out. Highway authorities in Belgium, Denmark, France, Germany, The Netherlands, Norway and Sweden were all contacted. The findings confirmed that the salt spread rates used for precautionary treatments in parts of Europe, (which were mostly with pre-wetted salt though using a finer, purer and, in some cases, more uniformly graded salt than UK indigenous salt) tended to be lower than those used when dry salting the SRN [5]. For example to protect to -10˚C on a wet road the Highways Agency specified 40 g/m^2 whereas other European countries' equivalent rates were between 25 and 80 per cent lower. Few references were found in the literature or during the consultation to any fixed rules or procedures for deciding when and at what frequency to carry out treatments.

It was concluded that there was potential to reduce spread rates on the SRN, particularly given the high degree of spreading accuracy demonstrated by the new winter fleet. Despite the evidence obtained, it was thought that comparable lower dosage rates may not be entirely appropriate to adopt because of various differences in other countries. This may include:

- Legal requirements to keep roads free of ice and snow
- Driver behaviour in winter weather
- Use of winter tyres that are mandated in some European countries
- Different winter weather, for example more snow and less marginal, i.e. just freezing, conditions
- Road surface texture and air voids content
- De-icer type (including salt grading and purity)
- Traffic levels

- Treatment times and frequencies.

Therefore, further research was carried out to develop spread rates specifically for the SRN. It was considered that whether ice forms on a road surface is dependent on three main factors:

- The road surface temperature
- The amount of de-icer at the road surface – particularly the amount remaining after trafficking
- The amount of water at the road surface – particularly for the worst case scenario after rainfall.

A number of other factors were considered in the study but the effect of trafficking on residual salt levels and the amount of water at the road surface were of particular interest.

3. PERFORMANCE SPECIFICATION FOR SPREADERS

As part of the fleet-supply framework contract, the Highways Agency specified stringent performance requirements for the new pre-wetted spreaders with suppliers required to undertake a series of tests to demonstrate that the amount of salt discharged was on target, with minimal over- or under-spreading. One spreader of each type supplied was tested for each year of production with 6.3 mm dry, pre-wetted and treated salt (dry salt treated with an additive 3 per cent by weight). The amount of salt discharged over a distance of 2 km was required to be within 6 per cent of the target amount at spread widths of 9, 11 and 13 m and spread rates of 10 and 20 g/m^2 with the hopper full and 10 per cent full.

Distribution trials were carried out to prove that the salt distribution was sufficiently uniform and wastage was minimal. For the distribution trials, the spreader travelled across a trial site to replicate the spreading of a three-lane motorway and hard shoulder when the spreader was travelling in lane 2 at 64 km/h. The trial site was marked out for the collection of salt from panels within three strips, the positions of which are shown in Figure 1.

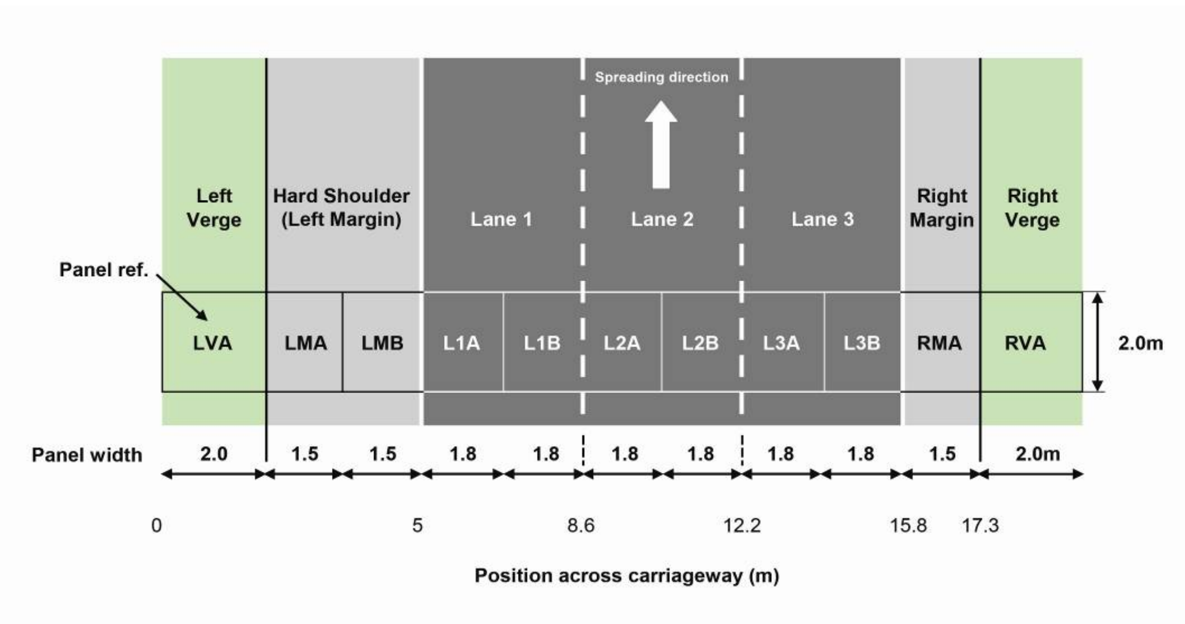

Figure 1 – Distribution trial salt collection position of panels

The specification allowed a small range within which test strips were allowed with fleet-supply framework contractors choosing different spacing, namely 10 m for Aebi-Schmidt and 14 m for Romaquip. The amount of salt collected by wet-wash vacuuming (see Photograph 1) from each panel was determined from conductivity analysis of the saline solutions collected.

Photograph 1 - Salt recovery using wet-wash method

The performance requirements can be summarised as follows:

- Total salt collected 90 to 110% of target amount
- Lane coverage 70 to 130% of target spread rate
- Hard shoulder coverage ≥25% of target spread rate for lanes
- Wastage to left and right verges ≤5% of total salt collected
- Strip to strip variation 80 to 120% of mean for strips
- Panel coverage (pre-wetted salt) 50 to 160% of target spread rate

It should be noted that the performance requirements and any trial result are presented as amount of salt collected whilst spread rates are quoted as the rate for dry salt and brine (assumed 23 per cent salt concentration) combined in the ratio 70:30 respectively. For example, 10 g/m^2 of pre-wetted material contains 7 g/m^2 of salt from the dry component and 0.7 g/m^2 from the brine totalling 7.7 g/m^2.

Figure 2 shows averaged normalised salt distributions from two trials carried out by Aebi-Schmidt (Trials 1 and 2) when 6.3 mm pre-wetted salt was spread at a target rate of 10 g/m^2 in Lanes 1 to 3 and 5 g/m^2 for the hard shoulder. The target amount of salt in the lanes and hard shoulder is shown in the figure by the horizontal lines across the lanes, equating to 7·7 g/m^2 and 3·8 g/m^2, respectively. The distributions in each trial were normalised (for the purposes of this paper) by scaling the total salt collected so it equalled the target amount. The distributions in Figure 2 were calculated by averaging the normalised distributions for the three strips in both trials. Both Aebi-Schmidt and Romaquip were able to demonstrate that all types of vehicles supplied complied with the performance requirements using this type of trial. The spreader setting that satisfied the performance requirements were adopted across the fleet for spreading 6.3 mm salt.

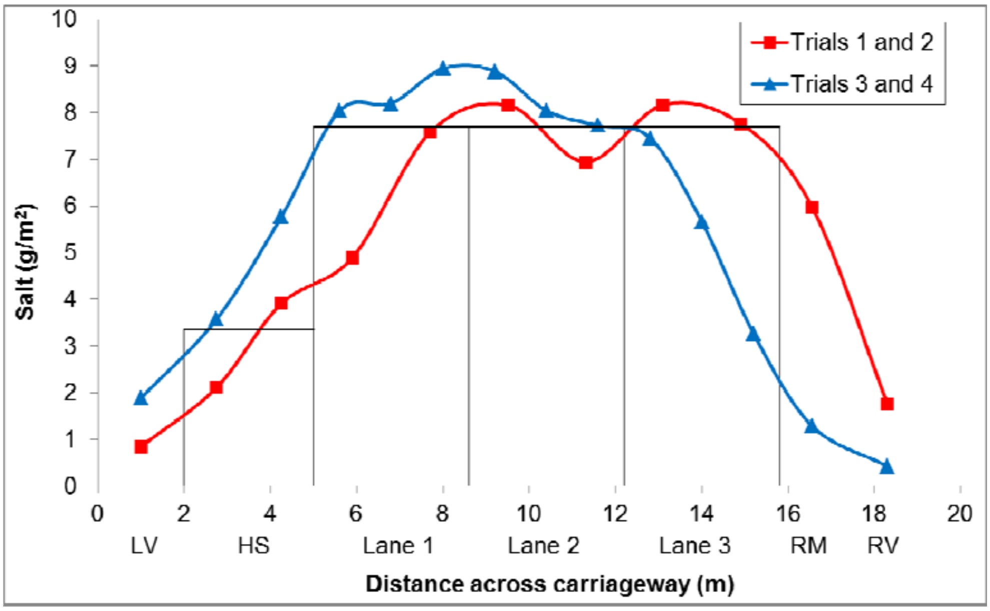

Figure 2 – Average normalised salt distributions from trial carried out by AEBI Schmidt (Trials 1 and 2) and TRL (Trials 1 and 2)

Further distribution trials were carried out by TRL to determine the salt distribution immediately after spreading so that the loss due to trafficking could be determined. The original intention was to carry out these trials on the same site as to be used for the road trials (see Section 4) but due to inclement weather it was necessary to carry out the distribution trials (Trials 3 and 4 in Figure 4) using an indoor facility in a disused aircraft hangar at Aston Down (Gloucestershire). Figure 2 also shows averaged normalised salt distributions from two trials carried out by TRL (Trials 3 and 4) when 6.3 mm pre-wetted salt was spread at the same target rate using the same spreader settings as in Trials 1 and 2 (see Section 4). However, the salt was collected from three panels per lane in Trials 3 and 4 compared to two panels per lane in Trials 1 and 2.

Figure 3 shows the grading of the 6.3 mm salt spread in the four trials. Different sieve sizes were used for the salt tested by Aebi-Schmidt and TRL. The figure includes the upper and lower limits for the grading that are specified in British Standard BS 3247: 2011 [6]. Also shown is the mean grading of 6.3 mm salt that has been spread in many trials by TRL.

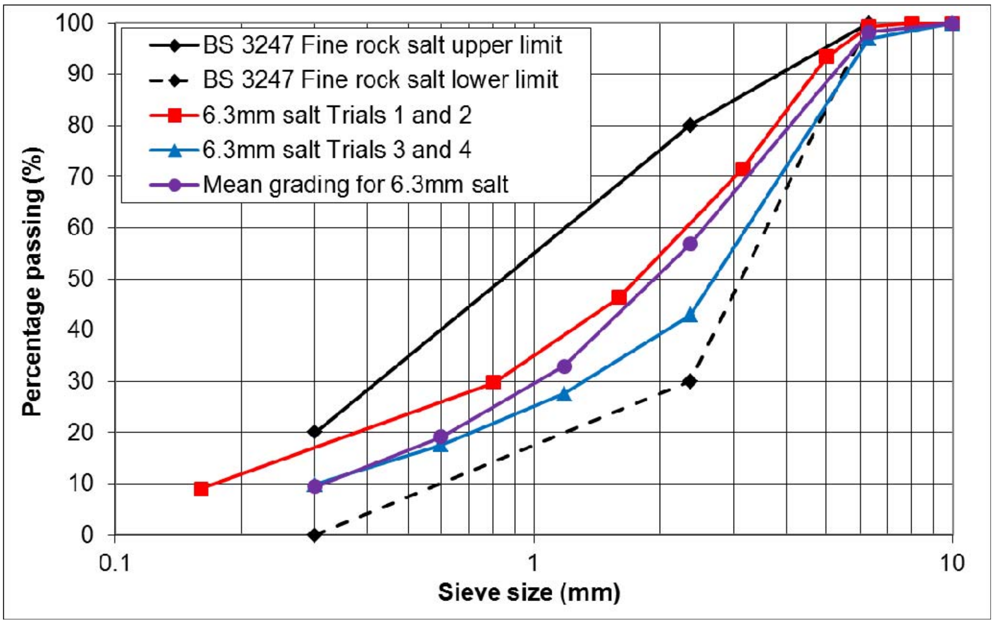

Figure 3 – Grading of 6.3 mm used in Trial 1 to 4 and mean grading from other trials

The suppliers of the salt aim to provide salt with a grading that corresponds as closely as possible to the mean of the upper and lower limits permitted within BS3247. It can be seen that the mean grading was consistent with this aim. The gradings of the other salts were close to the mean of the upper and lower limits. However, the salt used for Trials 1 and 2 was slightly finer and the salt used for Trials 3 and 4 was coarser.

It was concluded that the small differences in the grading were responsible for the differences in the salt distributions shown in Figure 2. The distribution with the finer salt was offset slightly to the right (Trials 1 and 2) and the distribution with the coarser salt was offset slightly to the left (Trials 3 and 4). Similar offsets have been observed in trials with other salts which were coarser than the mean grading.

The spreader settings used in the performance trials that satisfied the performance requirements were adopted across the new winter fleet for spreading UK 6.3 mm rock salt. The results from Trials 1 to 4 have demonstrated the sensitivity of the salt distribution to the grading. However, they gave assurance that salt with a grading close to the mean of the upper and lower limits would provide a good distribution. Although not tested with the appropriate spreader settings, it is likely that salt with the mean grading would provide a distribution with less offset than that shown in Figure 2. With such a good distribution, the scope to reduce spread rates with the change from dry to pre-wetted salting was maximised.

4. ROAD TRIALS

Road trials were carried out on the M180 (North Lincolnshire) to measure how much salt remained after two and 25 hours of trafficking. In order to be representative of winter humidity conditions the road trials were scheduled during winter 2008/09 though not on a night when freezing was forecast (which would have resulted in standard precautionary treatments being delivered too). The two hour time was chosen to represent the maximum amount of loss expected prior to forecast.

The layout of the M180 site is shown in Figure 4. The trial site was a 700 m long section of the three-lane eastbound carriageway between the exit and entry slip roads at Junction 2, which facilitated an easy diversion route for traffic while the trial site was closed for recovery of salt. The surfacing material was a negatively-textured thin surfacing system.

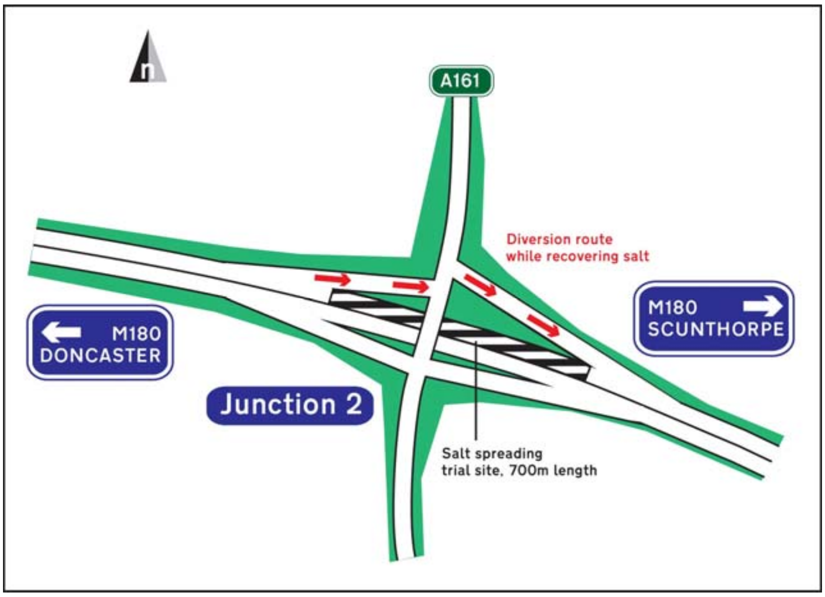

Figure 4 – M180 Trial Site

Pre-wetted salt was spread at 10 g/m^2 using a pre-wet spreader from the Highways Agency's new winter fleet, with the trial site open to traffic, at about 1830 hrs. Traffic levels were relatively light and no traffic was adjacent to the spreader during spreading (which could have had an adverse effect on the distribution of the salt across the entire carriageway). On the first night of each trial (Night 1) the trial site was closed to traffic 2 hours after spreading (927 vehicle passes) and the positions where salt was to be collected were marked on the carriageway. On each night of the trial, the salt was collected by wet-wash vacuuming from three or four test strips spaced 50 m apart. Each strip comprised 11 panels, of dimension 1 m long x 1.2 m wide, with two panels in the hard shoulder and three in each lane. On completion of the salt recovery, the site was re-opened to traffic (at about 0100 hrs) to allow unrestricted traffic flow (15,600 vehicle passes) until the following evening.

A 50m length of carriageway at the start of the trial site was left unsalted to allow measurements of the background salt level to be made within two panels in each lane and one in the hard shoulder.

On the second night of each trial (Night 2) the site was closed to traffic about twenty-five hours after spreading and the residual salt collected from another four strips that were identical in size to those used on the previous night, but were offset 10m in advance of the Night 1 positions.

4.1. Loss of salt due to trafficking

Figure 5 shows the average residual salt distributions for Lanes 1 to 3 with the background levels subtracted, i.e. they represent what remained of the salt that was spread after 2 and 25 hours. The horizontal bars above the running lanes and hard shoulder represent the target salt spread rates (cf. Figure 2).

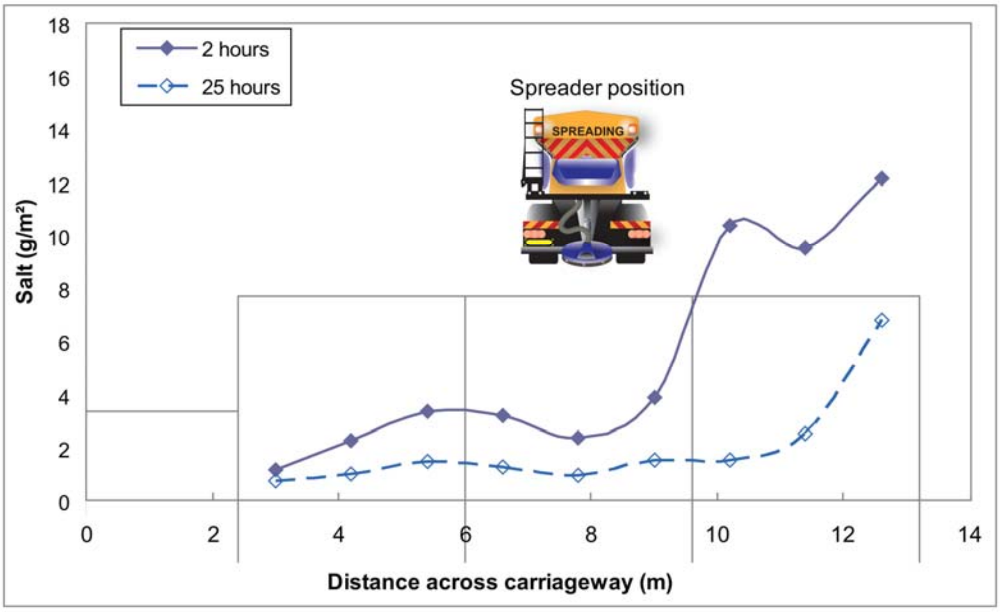

Figure 5 – Road Trial: 6.3mm salt distributions 2 and 25 hours after spreading - background levels subtracted

By comparing the results in Figure 5 with the amount of salt spread, it was estimated that after 2 hours of trafficking, 48 per cent of the salt spread to Lanes 1 to 3 was lost and 68 per cent of the salt spread to the most heavily trafficked lanes, Lanes 1 and 2, was lost. The equivalent losses after 25 hours were 85 and 86 per cent, respectively.

The results from a total of three trials on the M180 and the results from other trials, also conducted by TRL, on behalf of the National Winter Service Research Group (NWSRG) which is a sub-group to the UK Roads Board and part of the UK Roads Liaison Group (UKRLG), were analysed. It was noted that the salt loss on the M180 (as shown in Figure 5) was higher than in the NWSRG trials most likely as a result of spreading when the road surface was drier than the damp / wet conditions more typical of when spreading would occur and because there was a reasonable level of traffic immediately after spreading before dissolution. Salt loss is known to be highest before it forms a brine [7]. Taking all trial results into account it was concluded that a 50 per cent salt loss after 2 hours was appropriate for calculating spread rates for pre-wetted salting on the Highways Agency's network. Further trials indicated that losses of 60 and 50 per cent were appropriate for dry and treated salt, respectively.

5. AMOUNT OF WATER AT THE ROAD SURFACE

A key part of the research concerned estimating the amount of water at the road surface. Sufficient salt would need to be available at the surface which when diluted with any water present remained sufficiently concentrated to prevent freezing. The worst case scenario would be when salting is carried out after rainfall, so water film thicknesses in this event were explored.

The literature review identified a number of studies that included estimates of the amount of water at road surfaces. Whereas water films of thickness 1mm or greater are common during heavy rain, normally much less water is present in frost conditions. This is because drainage and trafficking has had time to disperse water after the end of rainfall and before freezing conditions occur. Also, relatively small amounts of water are normally deposited on roads when the dew point is below the road surface temperature, i.e. conditions for frost to form.

5.1. Tests to determine water film thickness

To tailor the research to the SRN tests were carried out to measure water film thickness on a heavily trafficked part, the A329(M), after rainfall. Measurements of texture depth confirmed that the surfacing at the test site was representative of the negatively-textured thin surfacing on the SRN. Measurements were made using a non-contact device, a Vaisala DSC111 Spectro. It should be noted that the DSC111 can only measure what is visible at the surface so does not take into account any water present within the surface macro-texture (as reported by Livet [8]). Measurements made in this project were made in the hard shoulder and the wheel tracks and centre of each lane with a single DSC111.

Figure 6 shows the variation in the water film thickness immediately after a period of approximately 2 hours light/medium rainfall. The road surface was clearly wet, with a shiny appearance, although there was no significant pooling of surface water. The measured water film thickness decreased from 0.07 mm to 0.0 mm (not measurable) in 50 minutes. Traffic very quickly dissipated water to film thicknesses of less that 0.01 mm within around 30 minutes.

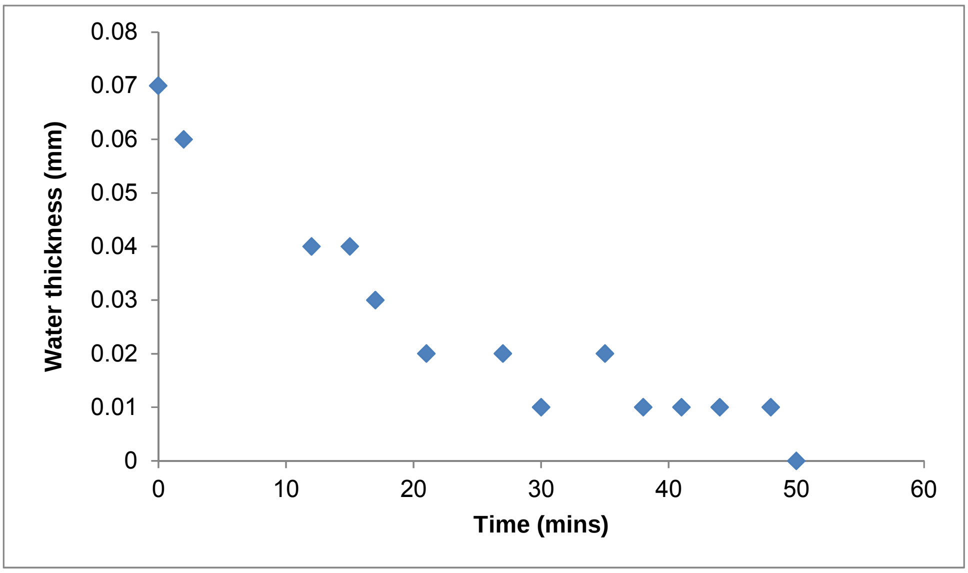

Figure 6 – Variation of water film thickness with time after rainfall

Data from a further six Spectros, mounted on weather stations forming part of the Highways Agency's road weather information system (RWIS), were analysed from which it was possible to estimate the amount of water present at road surfaces in winter conditions. For a well trafficked, well drained, damp road the water film thickness was estimated to be no greater than 0.03 mm. Even for a wet road, at least an hour after being well trafficked following rainfall, the maximum water film thickness was estimated to be barely thicker at 0.05 mm. This is considered a minimum thickness for vehicles to trigger a spray [9]. Much higher water film thicknesses were considered possible after rainfall at some lightly trafficked sites, but a water film thickness of 0.1 mm was considered the maximum for this scenario. Lower salt losses due to trafficking were also considered for lightly trafficked roads. Of course, water film thicknesses can be much higher at poorly drained locations or where water drains onto the carriageway from adjacent land.

5.2. Assumed maximum water film thicknesses

The following water film thicknesses were adopted (as representative of well trafficked dry / damp and wet roads and lightly trafficked wet roads) to help determine precautionary spread rates:

Dry / damp road (well trafficked)	≤ 0.03 mm
Wet (well trafficked road) / damp (lightly trafficked road)	≤ 0.05 mm
Wet (lightly trafficked road)	≤ 0.1 mm

These maximum amounts of water film thickness were used to determine brine concentrations and by implication the amount of salt to spread.

6. SPREAD RATES DERIVED

Precautionary spread rates were calculated using the estimates of the salt loss due to trafficking, water film thicknesses in winter conditions (see 5.2), the salt distribution profile immediately after spreading (the minimum dosage across the running lanes), the sodium chloride content of the salt spread and the phase diagram for sodium chloride and water (Figure 7).

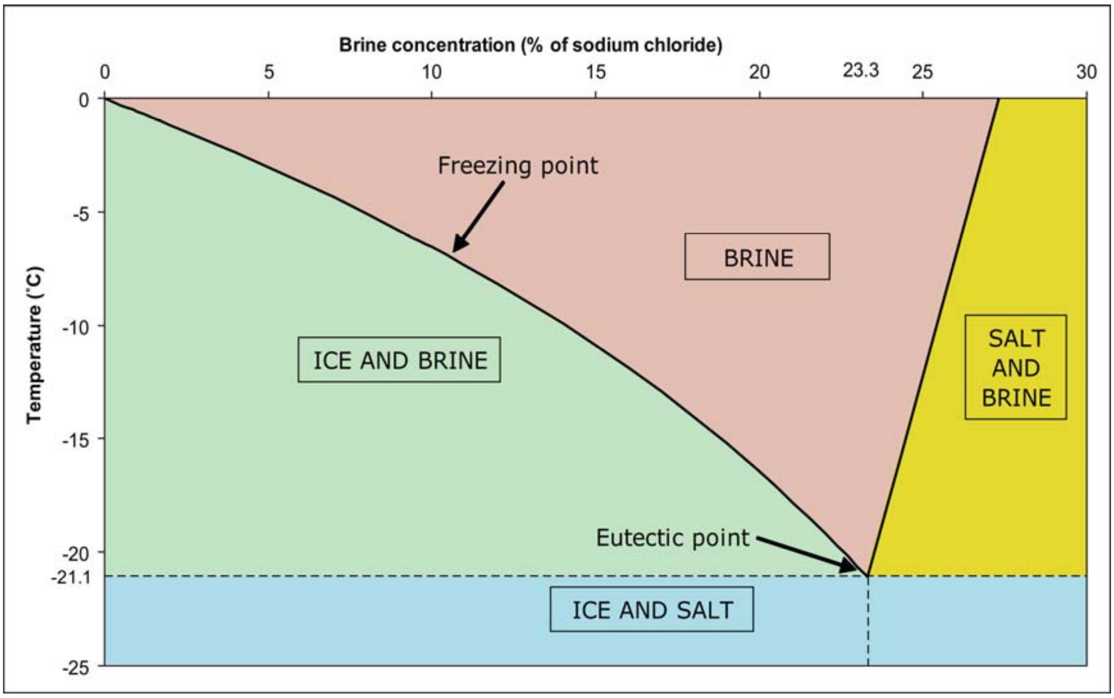

Figure 7 – Phase diagram for sodium chloride and water

The phase diagram indicates the temperature at which brines of different concentration would freeze. Provided the brine concentration and temperature are such that the conditions fall within the ‘brine’ section of the diagram, ice would not be formed. For example, the diagram shows that a solution of concentration 5 per cent would not freeze if the temperature was not less than -3˚C. Clearly, salt usage can be lower the closer the conditions are to the freezing point line (i.e. the brine concentration is just sufficient to prevent ice formation).

6.1. Theoretical Spread Rates

Theoretical spread rates were calculated using the phase diagram for both pre-wetted salting (Figure 8) and dry salting (Figure 9) for the categories of trafficking and 'wetness' considered.

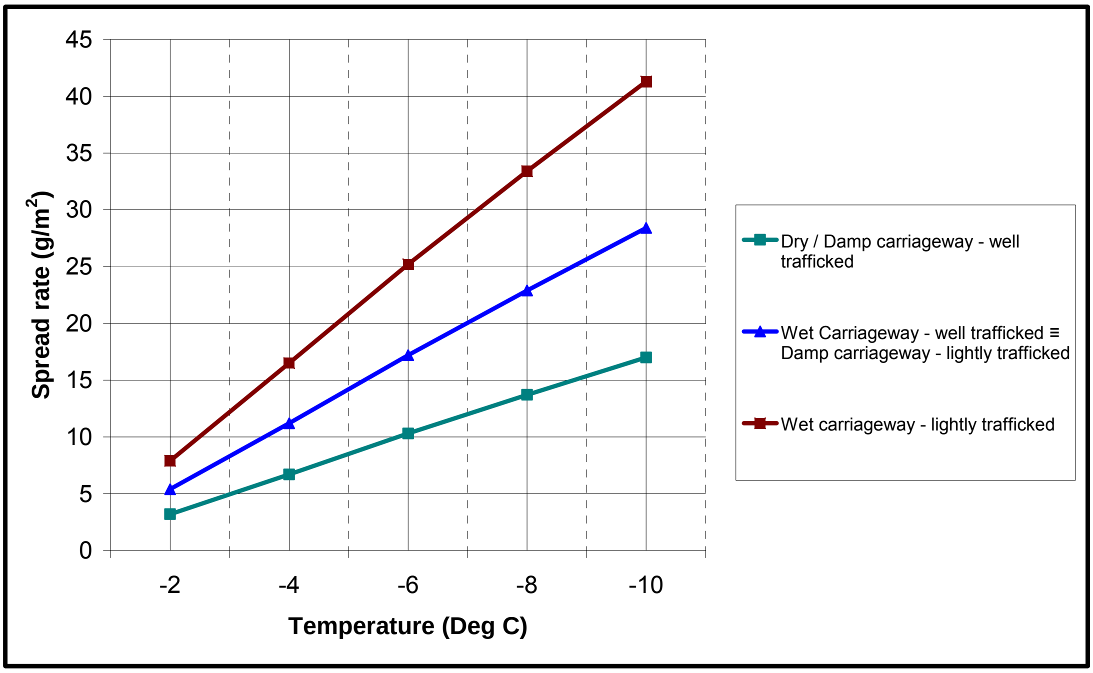

Figure 8 –Theoretical pre-wetted salt spread rates

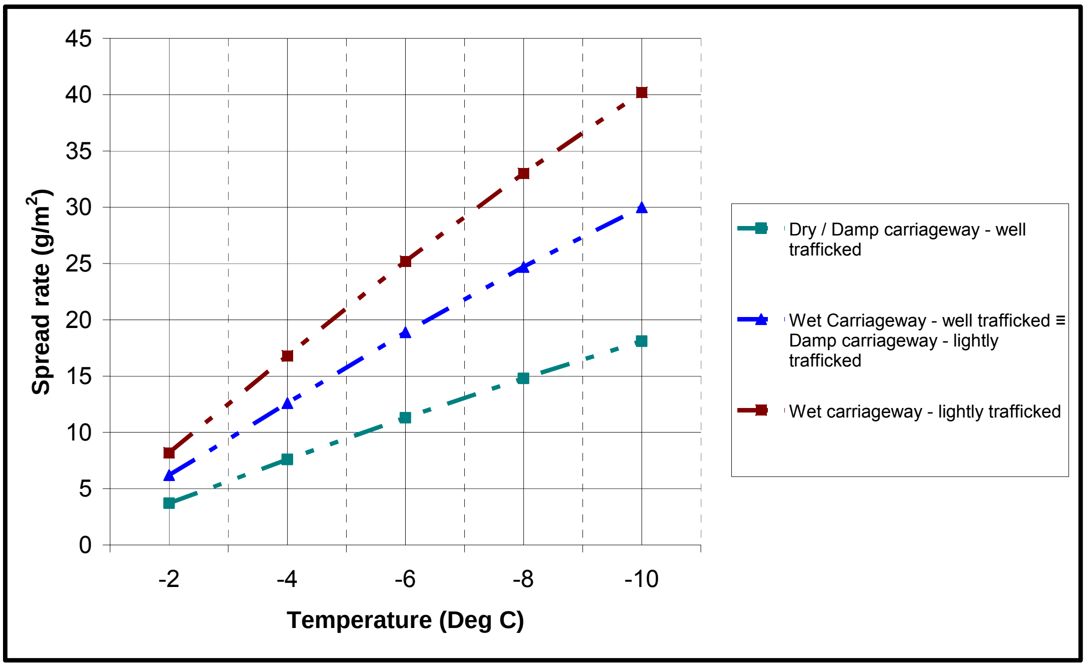

Figure 9 –Theoretical dry salt spread rates

6.2. Presenting New Spread Rates

The Highways Agency's existing treatment matrix guide, then included within the Network Management Manual, was modified to present the new spread rates. It was expected that service providers would find this easy to understand rather than developing an entirely new matrix. The same temperature bands were retained though wet road conditions were fully differentiated from dry / damp by the insertion of an additional row. This ensured spread rates were targeted to the conditions and helped maximise salt saving. A minimum spread rate of 8 g/m^2, for both pre-wetted and dry salting, was set owing to concerns about the uniformity of the distribution of the granular material at very low spread rates, even though the theoretical rates were somewhat lower. Undertaking research to investigate if this minimum spread rate could be safely reduced might be something the Highways Agency considers in future.

Spread rates have been rounded up to the next integer to give a small factor of safety in addition to any factor of safety associated with the conservative water film thicknesses. Although the research took into account the effect of trafficking, particularly at dissipating water from the road surface, this had not been previously accounted for within the matrix. To address this, additional notes were added referencing lightly trafficked roads especially when at the coldest end of the temperature bands. The resulting precautionary target treatment matrix guide, annotated to show the amount of salt saved compared with previous rates, is presented at Table 1.

Table 1 - Extract from Target Treatment Matrix Guide showing only precautionary spread rates

Weather Conditions **Road Surface Conditions** **Road Surface Temperature (RST)**	**Treatment**	
	Dry Salting (g/m^2) **[change compared with 09/10]**	**Pre-wetted Salting (g/m^2) (see Note 1)** **[change compared with 09/10]**
Frost or forecast frost RST at or above -2°C	**8 [-20%]**	**8 [-11%]**
Frost or forecast frost RST below - 2°C and above - 5°C and dry or damp road conditions (see Note 3 if damp and lightly trafficked)	**10 [-50%]**	**9 [-50%]**
Frost or forecast frost RST below - 2°C and above - 5°C and wet road conditions (see Note 3 if lightly trafficked)	**16 [-20%]**	**15 [-16%]**
Frost or forecast frost RST at or below - 5°C and above -10°C and dry or damp road conditions (see Note 3 if damp and lightly trafficked)	**18 [-10%]**	**18 [-]**
Frost or forecast frost RST at or below - 5°C and above -10°C and wet road conditions (existing or anticipated) (see Note 3 if lightly trafficked)	**30 [-25%]**	**30 [-17%]**
Rate of spread for precautionary treatments may be adjusted to take account of residual salt or surface moisture unless stated otherwise within NMM 5.6.4.		
Notes: ***1. Spread rates for pre-wetted salt is the combined weight of dry rock salt and brine combined at 70:30 proportion by weight respectively with a maximum brine concentration of 23% salt.*** ***2. When ice has formed or snow is lying dry salting is the preferred treatment unless the road is closed to traffic when pre-wetted salting may be used. Pre-wetted salting is the preferred treatment in advance of such conditions.*** ***3. Treatments should be carried out, whenever possible, after traffic has dispersed standing water. Successive half rate treatments (for both pre-wet and dry salt operations) should be considered for lightly trafficked roads at the lower end of temperature bands indicated.***		

7. IMPLEMENTATION

To mitigate the small risk that the new rates were not effective, the intention had been to reduce the spread rates over time until the target spread rates presented at Table 1 were achieved. After each reduction and operation over a winter season their effectiveness would be carefully monitored, using existing lessons learned procedures after incidents, to confirm that they performed as intended before making any further incremental reduction. This approach would also give service providers comfort especially given some target rates were reduced significantly, e.g. rates were halved for some temperatures. The first incremental reduction was made with the issue of pre-wetted salt spread rates in September 2009. At the same time a note for decision makers to consider when carrying out dry salting was also added to recognise the problems of water on the road surface. Indeed, for lightly trafficked carriageways, especially towards the coldest end of temperature bands in the treatment matrix, the historical spread rates may have needed to be increased for those specific situations. The research revealed this safety issue as well as the overall opportunity to reduce salt spread rates. However, it was noted that the new rates at the lowest temperatures tended to be higher than those used in some other countries

Nationwide problems with the supply of salt during the challenging winter of 2009/10 resulted in the UK Government issuing strong guidance to highway authorities to reduce their salt usage by 25 per cent to conserve stocks. Rather than adopt a phased implementation the Highways Agency chose to immediately implement the target treatment rates as one of the methods in support of reducing salt usage.

8. BENEFIT CONFIRMATION AND CONCLUSIONS

Initial feedback from service providers was that the treatment rates were entirely effective and as a result they were issued in July 2010 as standard treatment rates for winter 2010/11, which turned out to be another challenging winter. After two further seasons use, and once more data on their use was available, the Highways Agency considered it appropriate to formally review the performance of the rates and their use to confirm that they are as effective for all conditions as initially thought. Key to this was looking to see if there was a statistically significant change in incident rates for dry salting using the original spread rates and the previous dry salting vehicles compared with pre-wetted salting using the new reduced salt spread rates and the new winter fleet. The results of that further analysis are detailed in [10] and summarised below.

Analysis of winter service records confirmed that service providers had used virtually all treatments available within the treatment matrix guide and that they had selected an appropriate treatment for the recorded conditions. This suggested that the treatment matrix guide was understood well. The only treatment not used was the 30 g/m^2 treatment, which would be delivered as two consecutive 15 g/m^2 treatments. The analysis suggested that service providers were conservative when considering the wetness of the road given there was an equal split for ‘dry / damp’ and ‘wet’ treatments rather than a tendency to ‘dry /damp’ as might be expected from typical winter conditions. Such conservatism was sensible given a lack of data on actual water film thicknesses, although more accurate date on surface wetness could give service providers confidence to use the lower ‘dry / damp’ spread rates rather than err on the side of caution.

In their responses to questionnaires service providers expressed concern about the effectiveness of the precautionary spread rates for some specific, limited, scenarios. The Highways Agency are keen to develop further guidance for them to address such concerns for dealing with freezing soon after rainfall, treating hoar frosts, treatments on porous thin surfacing (which are not prevalent on the SRN) and when traffic flows are low.

An attempt was made to compare accident statistics before and after the new spread rates were introduced using national injury accident records (STATS19), that are compiled by the Police. Although this provided an overall check that there are no obvious issues with the new spread rates, it has not been possible to identify particular conditions or spread rates that are not effective or confirm that there has been no effect on the likelihood of incidents.

Service providers have reported salt savings of around 30 per cent as a consequence of using the new spread rates, in addition to the savings due to the introduction of pre-wetted salting. It is estimated that overall as a result of this research between 60,000 and 120,000 tonnes of salt have been saved annually by the Highways Agency bringing salt purchase savings of between £1.5M - £3M per annum. Additionally, this helped improved resilience (for not just the Highways Agency but all UK highway authorities) when the pressure on salt stocks was at its greatest.

9. FURTHER WORK

The Highways Agency's original research has been further developed for the NWSRG to enable spread rates to be calculated for spreaders with different spreading capability when spreading dry, pre-wetted and treated salt. This recognises that other, especially older, spreaders used by other highway authorities in the UK do not spread salt as accurately as the Highways Agency's new winter fleet can spread pre-wetted salt. The derived spread rates were issued to NWSRG members together with guidance on salt storage and spreader calibration. This included guidance on how to assess the salt distribution and, therefore, determine the appropriate spread rates to use. The NWSRG spread rates and associated guidance have subsequently been incorporated into 'Well-maintained Highways', the Code of Practice for Highway Maintenance Management. This Code is overseen by the UKRLG and applicable to all highway authorities within the UK.

In 2012 the Highways Agency appointed TRL to carry out laboratory testing of the effectiveness of alternative treatment materials when used in conjunction with rock salt as part of a pre-wetted delivery method in extreme cold [11]. Testing was carried out of ice melting, rate of dissolution and freezing point suppression at extreme cold temperatures below -7˚C. The testing demonstrated the benefits of the alternative de-icers and enabled spread rates to be derived for treatments at extreme cold temperatures which were lower than those when pre-wetting with sodium chloride brine

Recently research has been reported regarding the friction behaviour of icy road surfaces resulting from the freezing of salt solutions. It has been shown that when a salt solution freezes, a composite structure of brine solution pockets in porous ice is formed. The research has suggested that the ice structure formed is softer and more brittle under braking action than clean ice formed without de-icer. Consequently fairly high friction readings can be achieved at lower concentrations of salt than suggested by the sodium chloride-water phase diagram. It was suggested by the authors [12] that the fairly high friction at fairly low concentrations of salt opens up interesting opportunities for winter maintenance. Since the practical amounts of water or ice in slippery conditions on maintained highways are typically about 0.1 mm or less, the required amount of salt is only a few grams per square meter even at lowest temperatures. This research would warrant further investigation and may provide further opportunity to reduce spread rates, especially at temperatures from -4 to -10˚C.

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