Use of Salt for Winter Maintenance of Roads in Great Britain

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This paper gives an account of developments in the use of salt without grit admixture for winter road treatment in Great Britain. Consumption of salt has risen tenfold in the past 12 years. Anticaking treatment of rock salt made large-scale prewinter stocking of salt a practical proposition since 1956. Most stocks are held as outdoor heaps without protection from rain, but there is a growing interest in covering such stockpiles with plastic sheeting.

The preferred grade of road salt contains both fine and coarse particles, and modern spreading equipment has been designed for such a grade. The rates of application generally used are ½ oz per square yard for precautionary spreading before frost or snowfall, 2 oz on thin ice films, and 2 oz per square yard, repeated as necessary, for snow treatment. In rural areas, plowing to prevent accumulations caused by drifting is normal when snow is about 2 in. deep. On some main roads, considerably greater falls of snow than this are dealt with by the combined effects of salt and traffic.

BRITISH CHILDREN have long been taught that their islands have a temperate climate because of the influence of the warm Gulf Stream and prevailing mild, wet, westerly winds from the Atlantic Ocean. True, there are a few well-sheltered spots in the west of the British Isles, including even the northwest coast of Scotland where palm trees and other semitropical plants have been induced to survive, but the belief that Britain has generally mild winters has, until very recent times, affected popular attitudes toward dealing with problems caused by winter weather. For example, the traditional British attitude toward domestic central heating was that it was not only unnecessary, but was also an unhealthy and faintly sinful self-indulgence. The truth is that in some winters practically the whole of Britain can have snowfalls and freezing temperatures when north or east winds blow for several days—or even weeks—at a time. Many areas of the country experience sharp frosts and snowfalls every winter, although they vary in duration and intensity from year to year. In an average British winter, we expect that from December to March most of the country will be subject to frequent icing conditions, especially at night, and that there will be about 12 days when the ground is covered in snow. About once in every 7 years we get a winter of unusual severity, and the average Briton adopts an attitude of surprise and disapproval.

This attitude had a strong influence on the approach to winter road maintenance. Until the middle 1950's, only very limited use was made of salt for winter road maintenance in Britain. The amount of salt held in stock in advance of winter by highway authorities was negligible.

DEVELOPMENT

In the 1950's, there began a rapid expansion in the number of commercial and private motor vehicles on British roads. In 1955, there were 6½ million vehicles in the country and 188,000 miles of highways. Today, there are 13 million vehicles and 201,000 miles

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of highways. This increase in traffic was accompanied by an increased public demand and economic need for a higher standard of winter road maintenance. The last 10 years or so has seen a very rapid increase in the use of salt for winter road treatment. In the 1940's and early 1950's, the consumption of salt for winter road maintenance in Great Britain ranged between 20,000 and 75,000 tons a year. The demand rose to half a million tons in 1962, and in 1968 it will be 1.3 million tons. In recent years, 60 percent of this salt has been taken by county authorities and 40 percent by urban authorities.

Of the 201,000 road-miles in Great Britain, about a third are regularly treated with salt in winter. The central government pays the entire cost of winter road treatment on all motorways and trunk roads, and also contributes to the costs incurred by county and urban authorities in treating other roads.

Two practical problems had to be overcome before salt could make its contribution to achieving a higher standard of winter road maintenance. First, salt in suitable condition for spreading had to be made available where and when it was needed. Second, the traditional practice of spreading the salt by manpower and shovel had to be replaced by rapid mechanical spreading of the salt in quantities appropriate to the conditions.

The basic technical solution to the first problem became available with the introduction of anticaking treatment by potassium ferrocyanide. In 1956, this treatment was applied to a grade of rock salt, developed by the Imperial Chemical Industries (ICI) for winter road treatment, that contained a balanced mixture of fine and coarse particles. This provided a salt that would not set hard, and that could be stored by local authorities for long periods with the confidence that, when needed, it would be in suitable condition for spreading effectively. The solution to the second problem called for the development and manufacture of motorized machines refined in design to spread salt evenly at rates between ½ and 4 oz per square yard, as required. These rates are equivalent to 365 lb and 2,950 lb per mile when spreading to a width of 20 ft.

In 1953, the British Road Research Laboratory published a report in which it summarized existing knowledge and experience of winter road treatment with salt (1). In 1954, highway authorities were made aware of the need to stock greater quantities of salt and the desirability of using salt by itself, free of sand or grit. There are very real advantages to be gained by using salt alone. Salt melts ice and snow, and clears the road surface; grit only provides an improvement in grip on icy surfaces, and even this effect is temporary because the grit is thrown off by traffic. Because a lower density of spreading is required for salt than that for salt with mixtures, a greater number of road-miles can be treated in a given time, and more efficient use is made of the spreaders' running time. Prompt treatment with salt alone results in a reduction of the amount of treatment necessary, and also a corresponding reduction in costs. Substantial savings are also made by eliminating the cost of grit, the cost of mixing, and the cost of removing grit from channels and drains.

From the early experience of those counties that tried using salt alone on a large scale, it was clear that salt spread lightly in advance of frost would not only prevent the formation of ice, but would also remain effective for up to 2 days under normal conditions. Salt spread somewhat more heavily before or during a moderate snowfall would prevent the snow from sticking to the road and would convert it to slush, which would in turn be dispersed by traffic.

This experience was especially valuable in a study of snow and ice removal that was made by the Ministry of Transport shortly before the opening of the first British motorways in 1958 and 1959. County authorities were to be responsible to the Ministry for maintaining sections of motorways within their boundaries, and they agreed to the following policy for winter maintenance of motorways:

1. Carriageways should be kept free from frost at all times.
2. Under the worst snow conditions, at least one lane of each carriageway should be kept open for traffic.
3. The basis of treatment to achieve these requirements is the use of ground rock salt without an admixture of grit.

To implement this policy, the Ministry cooperated with equipment manufacturers in improving the design of salt-spreading vehicles, and it established depots or maintenance compounds on the motorways at about 12-mile intervals to provide supplies of s-

rapid means of loading the vehicles, standby quarters for winter maintenance crews, and facilities for servicing and refueling the vehicles. These depots are built on sites of about 2 acres and have direct access to the motorway. Provision is made for the open-air storage of about 2,000 tons of salt at each depot, and usually there are twin 50-ton loading hoppers. Normally there is a 75-ft square garage area, together with messroom for up to 12 men, a bunk room with 4 beds for emergency use, several stores, and offices. Fuel and fuel pumps with 1,000-gallon tanks are provided. These depots are operated by the county councils, as agents for the Ministry of Transport. The county and urban authorities also have their own depots, on the appropriate scale, from which they carry out winter maintenance on their own roads.

STORAGE OF ROCK SALT

Prior to 1956, a serious obstacle to the use of salt for winter road maintenance was the difficulty of ensuring that the salt was available when required, because the caking problem did not allow stocks to be built up. With the introduction of anticaking treatment in 1956, the large-scale storage of rock salt became practicable. A trial showed that an outdoor heap of about 5,000 tons of treated rock salt did not cake but remained in a suitable condition for spreading even when the salt was not covered. This development was publicized in 1958, and since then the highway authorities have laid down prewinter stocks in ever-increasing quantities. By 1962, the highway authorities were holding prewinter stocks amounting to a quarter of a million tons throughout the country, and now such stocks amount to about one million tons. The highway authorities were given a rebate of about 7 percent to encourage the depots to take deliveries during the summer months, i.e., April to September.

The bulk of the rock salt is still stored without any protection from the weather, but there is now a growing interest in covering the heaps with waterproof sheets for two reasons. First, covering will prevent the so-called "freezing" of salt (actually a type of caking attributable to the crystallization of sodium chloride di-hydrate), which can cur if wet salt is subjected to very low temperatures for a long period of time. Second, it will prevent losses caused by rainfall. Such losses depend on the size and shape of the stockpile, the type of ground on which it is stacked, and the amount of rainfall.

Recent work by the Road Research Laboratory (2) has led to the conclusion that, from large stockpiles of typical shape, the loss per year is about ⅛ percent of the initial weight of the pile for each inch of annual rainfall. Because the amount of salt dissolved from a heap is limited by the amount of rainfall and by the solubility of salt in water, the actual loss from any stockpile will depend only on its area. An obvious way of reducing the loss is thus to stack the salt to the maximum height possible.

At the rock salt mine in Winsford, Cheshire, the rock salt is stacked 20 to 25 ft high, but the more usual height of a stockpile at highway authority depots is about 12 ft. This is probably as high as it is safe and practicable to go, because of the risk of falls when recovering salt from the pile.

SPECIFICATION FOR WINTER MAINTENANCE SALT

In 1960, the general increase in the use of salt for winter highway maintenance, which had by then taken place, led the British Standards Institution to undertake the preparation of a specification for this product. The grade of noncaking rock salt developed by ICI—having been successfully used for about 5 years and amounting at that time to about 90 percent of the winter maintenance salt used—naturally formed the basis of the draft specification.

After trials and investigations, in which representatives of all the government departments and scientific and industrial organizations concerned took part, the Institute issued British Standard 3247, Part 1, that is given in Appendix A. The standard includes tests for certain of these properties and specifies the essential properties of a rock salt for winter maintenance. The main requirements of British Standard 3247, Part 1, refer to storing quality, grading, and chemical composition.

Three years later, British Standard 3247, Part 2 (Appendix B), was issued, covering salt other than rock salt. This specification is the same as British Standard 3247, Part in the storing quality and chemical composition requirements, but specifies different

gradings. Less than 5 percent of the total tonnage of salt used for winter maintenance is other than rock salt.

SALT SPREADING EQUIPMENT

There is also a British Standard specification for salt or grit spreading vehicles (British Standard 1622, 1960). This specification was originally issued in 1950, when gritting techniques were relatively undeveloped and salt was used mainly in combination with grit, sand, or ashes. A revision of this specification was necessary by 1960 because British manufacturers had developed more sophisticated spreading machines to match changing techniques in winter road maintenance. The important changes in technique were based on the use of salt alone, not only for the removal of snow and ice, but also for precautionary treatment in advance of such conditions. The economic use of salt called for gritters able to spread as little as 1 oz per square yard uniformly over wide carriageways at relatively high speeds between widely separated stockpiles. The machines also had to be able to operate with equal effectiveness at rates up to 4 oz per square yard for the treatment of snow. The revised specification divided winter spreaders into three classes, primarily based on spreading characteristics and speed of operation, and it included details of construction, performance, and testing for each class. The types of salt-spreading equipment most commonly used for winter road maintenance in Great Britain are described briefly in Appendix C.

PRESENT WINTER MAINTENANCE PRACTICE

Road Note 18 of the Road Research Laboratory, referred to previously (1), was revised in 1968 to take into account the developments in the salt treatment of snow and ice on roads that had taken place during the 15 years since it was issued. Recommendations for the use of salt are given, based on methods that have been found to be successful and economical.

Although the temperature at which any quantity of salt would fail to melt ice is -21 (-6 F), in practice salt is not often used in Great Britain at temperatures below -10 C (14 F). In fact, according to the Road Research Laboratory findings, most icing conditions and snowstorms experienced in Great Britain occur at temperatures above -3 C (27 F).

In the early days of the use of salt without grit admixture, attempts were made to estimate the severity of the conditions and to adjust the rate of application accordingly. Nowadays, because salt is applied at the earliest possible moment, and before the occurrence of frost or snow whenever possible, the practice is to apply salt at a standard rate sufficient for average conditions, and to repeat the application to the extent that it is necessary. These standard amounts are lower than the quantities formerly used, and this has the advantage of increasing the distance covered by each spreader-load of salt. The greater the mileage covered in the early stages, the better because the effect of traffic is to break down the snow once it has been salted; whereas on snow that has not been salted, the effect of traffic is to pack the snow into ice.

The highway authorities make use of a service provided by the Meteorological Office for a small annual fee, and obtain warnings of expected icy conditions or snowfalls. These warnings are provided from local meteorological stations. The forecasts are not invariably correct, but the view is generally held that, although salt may be wasted occasionally on unnecessary operations, this is much outweighed by the savings made by prompt spreading where snow or ice actually occurs. In addition to these forecasts, several highway authorities have installed detector systems. These signal to a highway depot or to a foreman's home when icing conditions are likely to occur at the sites where the detectors are installed. They operate by measurement of humidity and temperature, and the more recent models also measure the presence of salt on the road, canceling the warning if there is salt remaining that will prevent ice film formation.

For precautionary spreading, a rate of application as low as ½ oz per square yard (365 lb per mile) is sometimes used. Some engineers prefer to use higher minimum rates to ensure that no blockage of the spreaders occurs. On some machines, when

preading on narrow roads, only a very narrow opening of the feed-gate is required at the lowest rate of application. Should a blockage occur, this could remain undetected when salting at night, and a dangerous situation would arise if a length of road were left unsalted.

Thin ice films on the road surface are usually less than 0.01 in. thick, and this amounts to about ½ lb of ice per square yard. Because the temperature is usually above -3 C (27 F), only ½ oz of salt per square yard (365 lb per mile) is needed to melt this weight of ice completely. Therefore, only ½ oz of salt per square yard is used for precautionary spreading to prevent the formation of these thin films of ice, or to prevent snow from adhering to road surfaces. If, however, ice has already formed, salt is used at the rate of about 2 oz per square yard (1,475 lb per mile) to ensure that the ice is speedily removed.

A normal density of fresh snow is about 6 lb per cubic foot, so that a 1-in. depth of snow weighs about 4½ lb per square yard. It has been found in practice that half the quantity of salt required for complete melting will reduce the snow to a slush that is dispersed by traffic, and, to get this condition, about ½ oz of salt per square yard (365 lb per mile) is required per in. of fresh snow per degree Centigrade that the air temperature is below freezing point. One or two applications of salt at 2 oz per square yard (1,475 lb per mile) are found to clear the average snowfall.

If snowfall continues, the salting is repeated, and snowfalls of as much as 10 in. have been cleared in urban areas solely by the use of salt. It is more usual, however, to commence plowing when the depth of snow reaches 2 in. or so, and to spread salt at the rate of 1½ to 2 oz per square yard (1,100 to 1,475 lb per mile) after each passage of the plow. The salt prevents snow layers from bonding to the surfaces of the roads, thus making plowing easier and preventing the formation of packed snow layers.

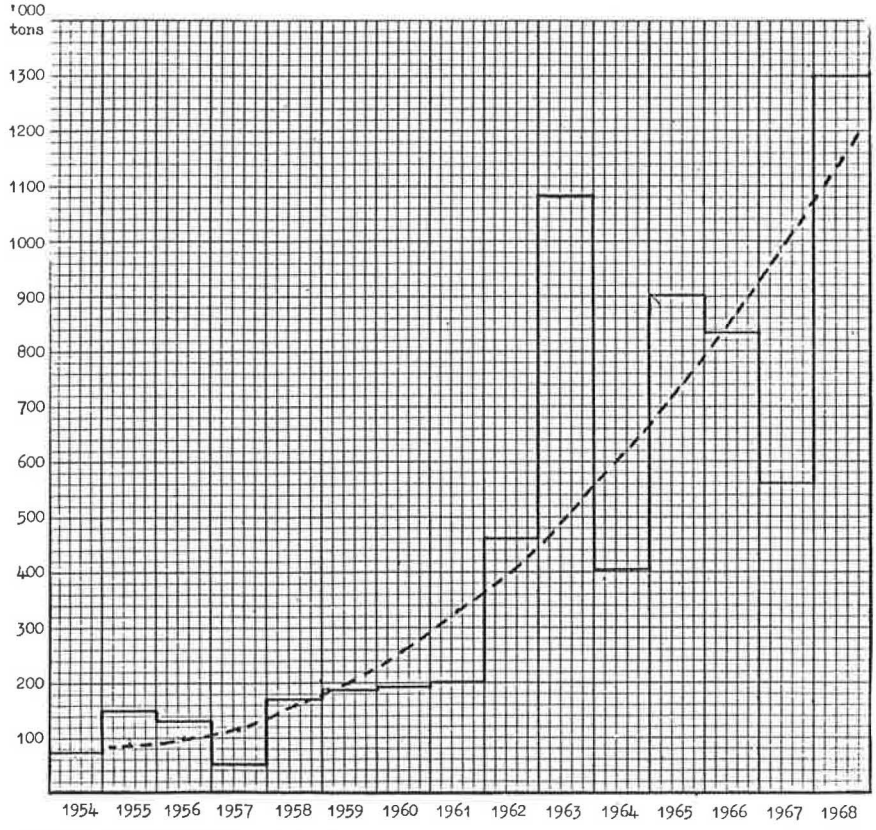

Figure 1. Estimated sales of salt for winter road treatment in Great Britain with averaged growth curve.

If hard-packed snow layers have been allowed to form, they are often removed by the use of very heavy applications of salt, assisted by the traffic. Alternatively, abrasives such as grit, ashes, or sand may be used to provide adhesion for vehicle wheels. These materials are also sometimes used on steep gradients, but present practice in Great Britain is to keep their use down to the minimum.

GROWTH IN THE USE OF SALT FOR WINTER ROAD TREATMENT

The estimated annual sales of salt for winter road treatment in Great Britain over the last 15 years are shown in Figure 1. Currently, the use of salt on Britain's roads in an average winter appears to be increasing at about 150,000 tons a year, based on a relatively simple analysis of meteorological records, but attempts are being made to verify this by a more detailed statistical analysis. An investigation is also being made to try to forecast how the rate of growth in demand might change in the future, and what the consumption of salt for roads might be for an average winter in 10 to 15 years. Solution of the latter problems depends on many factors, including questions of how closely all highway authorities are already approaching optimum use of salt in existing conditions, how much these conditions will change as new roads are developed, and how soon treatment will be extended to minor roads that carry little traffic at present but that might have to carry increasing volumes to feed main routes in the future.

REFERENCES

1. Salt Treatment of Snow and Ice on Roads. Road Research Laboratory, Crowthorne, Berkshire, England, Road Note 18, 1968.
2. L. E. Hogbin. Loss of Salt Due to Rainfall on Stockpiles Used for Winter Road Maintenance. Road Research Laboratory, Harmondsworth, England, Rept. 30, 1966.

Appendix A

BRITISH STANDARD 3247—1960

SPECIFICATION FOR SALT FOR SPREADING ON HIGHWAYS FOR WINTER MAINTENANCE PART 1. ROCK SALT

The main requirements are as follows:

Chemical Composition (calculated on a moisture-free basis)

Sodium chloride, NaCl (including $MgCl_2$ and $CaCl_2$ expressed as sodium chloride)	not less than 92 percent
Soluble sulphate compounds expressed as $CaSO_4$	not more than 1.5 percent
Material insoluble in water	not more than 6 percent

Grading

British Standard Sieve	Percentage Passing
⅜ in.	100
No. 7	30 to 70
No. 52	0 to 20

Storing Quality

The bulk of the salt shall be in a loose and usable condition after open storage for 18 months in an unprotected stockpile at least 4 ft high with sides inclined at the angle of repose of the salt.

Under these conditions any nonfriable crust formed shall not exceed 3 in. in thickness.

Appendix B

BRITISH STANDARD SPECIFICATION 3247—1963

SPECIFICATION FOR
SALT FOR SPREADING ON HIGHWAYS FOR WINTER MAINTENANCE
PART 2. SALT OTHER THAN ROCK SALT

The requirements are the same as those for rock salt in Standard 3247, Part 1, except those for grading, which are as follows:

Salt	Passing British Standard Sieve	Percentage by Weight
Coarse	⅜ in.	100
	No. 14	80 maximum
	No. 100	0 to 10
Fine	No. 14	100
	No. 100	0 to 30

Appendix C

SALT-SPREADING EQUIPMENT IN GREAT BRITAIN

The automatic spreading vehicles most extensively used in Great Britain have a hopper body with moving floor belt delivering beneath an adjustable gate onto spinner discs. The vehicles designed for use on the motorways have a capacity of 8 cubic yards and can travel at speeds up to 50 mph. Their purpose-built chassis have 173-hp engines, driven through a 6-speed gearbox to 6 wheels. The body is made of sheet metal on a steel frame. The moving floor belt is driven from the power takeoff, and can be run in either direction, with the vehicle either moving or stationary. The salt spinners are located in front of the rear wheels, so that the salt that is being spread provides adhesion and the crew can monitor the flow of salt. The outlet gate is at the front of the hopper body, and can be adjusted to give a delivery of salt varying between ½ and 4 oz per square yard of 36-ft or 24-ft carriageway, i.e., ranging from 440 to 5,280 lb per mile. The outlet gate is divided into two parts, and either half can be closed by the driver from the cab. As one half is lowered, the other half is correspondingly raised to maintain the same total rate of salt discharge, but to either the offside or the nearside as required. The salt delivered through the gate is carried by augers, driven by power takeoff, to the offside, nearside, or both sides of the vehicle, and fed onto spinner discs. The speed of rotation of the discs must remain constant and independent of the road speed to ensure a constant width of spread. This is achieved by driving them hydraulically, directly from the vehicle engine, their speed being governed by a control valve in the driver's cab. Because the speed of the moving floor belt is directly related to the vehicle speed through the power takeoff, the rate of delivery of salt is automatically correlated to changing vehicle speeds caused by traffic or other conditions.

These vehicles, in addition to being equipped for salt-spreading, are fitted with heavy subframes and standard mountings to take large V-plows or reversible high-speed angle-blade plows. Salt-spreading vehicles of this type, although generally of rather smaller capacity and less elaborately equipped, are used by virtually all highway authorities in Great Britain.

A more recent development by the manufacturers is a demountable bulk spreader body with automatic control of spreading rate, which can be used on a flat truck or tipper lorry. The conveyor belt floor of the hopper body is driven hydraulically, the speed of the conveyor being controlled by a drive from the periphery of the vehicle's rear wheel. The single spinner is also driven hydraulically, and its speed can be set

by control valve to give a width of spread from 6 to 30 ft. The hydraulic pump is driv by a built-in fuel or diesel engine. Salt can be spread to the offside, to the nearside, or symmetrically, the adjustment being made by movement of the chute feeding the spinner. These bulk spreaders usually have a salt capacity of 5 to 6½ tons. Trailer spreaders with a capacity of about 2 tons, operating on the same principles, are also used, but their popularity is waning.

In addition, there are spreading attachments that are mounted beneath the body of a vehicle, and are fed through an opening on the body floor. The salt falls through a chute and an adjustable feeder valve onto a spinner disc. The machine is driven from the rear wheel of the vehicle, to which it is attached. In this case, the width of spread is controlled by the speed of the vehicle, and is approximately 20 ft at the normal spreading speed of 8 mph.

As well as equipment utilizing spinners to spread the salt, there are also in use in Great Britain spreading machines that discharge salt directly onto the road, over their own width. A typical machine of this class is a 2-wheeled hopper trailer about 8 ft wide with a transverse slot in its base. This slot has rubber flaps with spring supports, and there is a roller (gear-driven from the trailer wheels) between the rubber flaps. For spreading salt at low rates, a roller spirally wound with wire is used to feed the salt, the rate of spreading being controlled by adjustment of the pressure on the rubber flap by hydraulic or mechanical means. There is a toothed impeller shaft mounted a few inches above and parallel to the feed roller to prevent arching, and to break up caked material. The hopper capacities range from about 1 to 3 tons of salt. These machines are designed to be drawn by tipper lorry (from which they can be refilled directly), or they may be towed by tractor.