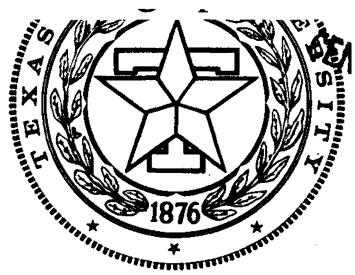

TEXAS TRANSPORTATION INSTITUTE

TEXAS HIGHWAY DEPARTMENT

COOPERATIVE RESEARCH

Heating of Roads and Bridges

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration
Bureau of Public Roads

BIBLIOGRAPHY 207

SURVEY OF LIBRARY FACILITIES PROJECT

HEATING OF ROADS AND BRIDGES

1. MANUAL ON SNOW REMOVAL AND ICE CONTROL IN URBAN AREAS. Snow and Ice Subcommittee, Associate Committee on Geotechnical Research, National Research Council (Ottawa, Canada), Tech. Memo. 93. Nov. 1967. (Recd. Nov. 1968). 135 pp. $1.50. HR Abstracts, April 1969.

The Manual is based on the experience accumulated over the years by a number of Canadian urban centers. It was not intended to be all inclusive in its coverage. Winter maintenance is not a static activity, but one which is in an active stage of development. Only now is there developing a general appreciation of the factors that have a significant influence upon it. As this appreciation grows, practices will be modified, and research and development will make available new concepts and methods. With this in mind, it was decided that the Manual should emphasize three important aspects of winter maintenance: preparation and conduct of operations, budgeting and records, and bylaws and regulations. It was also considered that it should cover the equally important subjects of use of chemicals for ice control, melting systems, and weather.

2. ICE-DETECTOR SYSTEM CAN PROTECT BRIDGES AND RUNWAYS. American City (757 Third Ave., New York, N.Y. 10017), Vol. 83, No. 12, pp. 76-77, Dec. 1968. HR Abstracts, June 1969.

A new ice-detection system warns of slippery, icy conditions before they actually occur. The system has been evaluated by the Michigan Department of Highways on the I-75 Flint River bridge. It incorporates humidity-transducing elements for detecting frost or ice conditions before they form during the presence of high humidity and low bridge, highway, or runway deck temperatures, and separate sensors for sensing ice formations resulting from precipitation. By comparing the differential temperatures, the system predicts when frost will appear on surfaces. By setting the electronic logic to take action when the relative humidity-to-saturation differential is slightly larger than the deck- to ambient-temperature differential, frost can be anticipated before it forms and an output signal will actuate a warning or de-icing system.

3. Carlson, John G. SNOW MELTER SAVES MONEY FOR THE NATION'S LARGEST TOWN. Public Works (200 S. Broad St., Ridgewood, N.J.), Vol 98, No. 8 , pp. 96-98, Aug. 1967. HR Abstracts, January 1968.

Brookline, Mass., experimented with a snow-melter unit to remove snow during the winter of 1964-65. The early part of the season was spent in discovering all the things which might go wrong both with the unit itself and with its operation. When the snags were ironed out, it was computed that the melter reduced the cost of snow removal from $2.26 per ton to $0.44 per ton. The winter of 1965-66 confirmed the estimate of savings. The melter can handle 135-150 tons of snow per hour operating either upgrade or downgrade. For practical purposes, and effort is made to run it upgrade, allowing the melted water to run down into the catch basins away from the work. The water is discharged at a temperature of 45 F, and the run-off is rapid enough so that it does not freeze in the gutters.

4. Sauer, Guenther. ON DAMAGES BY DE-ICING SALTS TO PLANTINGS ALONG THE FEDERAL HIGHWAYS. Nachrichtenblatt des Deutschen pflanzenschutzdientes (Verlag Eugen Ulmer, Stuttgart, Germany), Vol. 19, No. 6, June 1967 (In German). HR Abstracts, January 1968.

The use of deicing salts, especially NaCl, causes extensive damages to trees and shrubs along our highways by splashing the shoots above the ground with mixtures of melted snow and salt. The damages are manifested by dead buds and sprouts, brown leaves and needles on evergreen plants, and sometimes even the dying of plants entirely. The extent of damages is determined by numerous interacting factors, such as salt quantities, traffic patterns, weather and soil conditions and above all plant type and plant age. Investigations into the problems of making highway plants more salt resistant are currently under way.

5. Williamson, P. J. THE ESTIMATION OF HEAT OUTPUTS FOR ROAD HEATING INSTALLATIONS. Great Britain Road Research Laboratory. RRL Report LR 77. 1967. 33 pp. (Available from British Information Services, 845 Third Ave., New York, N. Y. 10022). HR Abstracts, June 1968.

Heat transfer coefficients relating heat losses from surfaces of heated roads to wind speed and the difference between air and surface temperatures have been derived from measurements made during icy conditions. The magnitude of the heat flow downwards from the heating grid is discussed and a method of calculating the extra heat output required for installations on elevated roads is given. Solutions of the equation of heat flow in a semi-infinite medium under simple boundary heat flux conditions are used to illustrate the effect of heater depth and output on the rate of response, snow melting capacity and thermal storage of the system. Operating conditions required to provide adequate thermal storage in off-peak installations are examined. The observed heat losses from existing installations and heater outputs required in different situations are estimated both for continuously available supply and for off-peak supply.

6. Butler, H. D. STUDY OF ELECTRICALLY HEATED BRIDGE DECKS FOR ICE PREVENTION. Texas Highway Department (Austin, Tex. 78701), Research Report No. 72-1-F. March 1968. 69 pp.

The design, construction, and study of three electrical heating systems is presented. The three Texas systems are as follows: Pierce Street overpass in Amarillo--this system is an anti-icing system for heavily traveled structures with deep approach grades and no frontage roads; Loop 289 overpass in Lubbock--this system consists of electric heating cables laid on top of the slab and covered with a polyester compound known as Terrazzite; City View Drive overpass in Wichita Falls--this system has provision for testing a variety of cable spacings and slab depths. Temperature data and visual observations were collected and analyzed. Results show that the use of electrical heating systems to prevent the formation of ice or accumulation of snow on bridge slabs is both feasible and effective. However, a more detailed study of the realtionships between slab thickness and heat distribution is needed before design criteria can be established

7. Willing-Deton, E. K. USE OF SLAT FOR WINTER MAINTENANCE OF ROADS IN GREAT BRITAIN. Imperial Chemical Industry Laboratory, England. Presented at the Highway Research Board meeting, January 1969.

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.

Anti-caking treatment of rock salt from 1956 made large-scale pre-winter stocking of salt a practical proposition. 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 1/2 oz per sq yd for precautionary spreading before frost or snowfall, 2 oz on thin ice films, and 2 oz per sq yd, repeated as necessary, for snow treatment. In rural areas, plowing is normal when snow is about 2 in. deep to prevent accumulations due to drifting. On some main roads, considerably greater falls of snow than this are dealt with by the combined affects of salt and traffic.

Corrosion of vehicles has not restricted the use of salt on roads. No reliable and nontoxic corrosion inhibitor for road salt has yet been found. Atmospheric pollution is a source of corrosion agents of a magnitude similar to the quantities of road salt now used.

8. Ciemochowski, M. F. A FROST, SNOW AND ICE DETECTION SYSTEM FOR BRIDGES AND HIGHWAYS. Holley Carburetor Company. Presented at the Highway Research Board meeting, January 1969.

The twofold problem of detecting frost, ice and snow conditions on the deck areas of highway bridges and overpasses, and providing suitable warnings to motorists has become an increasingly important and critical highway safety problem on high-speed interstate highways. The author describes a system developed by Holley Carburetor Co. that detects both frost and ice and snow conditions through the use of a combination ambient air and relative humidity sensor on the bridge railing along with two other sensors buried in the bridge deck. The results of a 3 1/2-year evalutation program of a system that actuated a flashing sign on the Flint River bridge on U-75 near Flint, Michigan are described. A new Holley dual-channel frost, ice and snow detection system is introduced. This system splits the anticipatory frost and the snow and ice signals into two separate signals. The anticipatory signal can be relayed as an early warning to alert maintenance staffs to send an observer to examine the conditions first-hand and pass a judgment on the need for chemical application or sign actuation. The early warning signal can also be used to switch-on electric heaters embedded in the deck. The separate ice and snow signal can be used to actuate a warning flasher. Two new highway applications of the dual-channel system are announced, as well as the first application of a similar system on an airport runway.

9. SNOW MELTING. Civic Administration (481 University Ave., Toronto 2, Canada), Vol. 18, No. 8, pp. 24-26, Aug. 1966. HR Abstracts, May 1967.

The costs of snow removal are rising as suitable dump sites become scarce and haulage time and distance increase. Snow melters are becoming more appealing

to Canadian municipalities as an economical and effective means of snow removal. However, individual cities should investigate the problem before deciding to purchase a melter. A table compares the capacity, initial costs, operating costs, advantages and disadvantages of different types of stationary and mobile melting equipment.

10. Williams, G. P. ICE DUSTING EXPERIMENTS TO INCREASE ICE MELTING RATE. NRC 9349 Building Research News, No. 22, p. 6, April 1967. Available from publications Section, Division of Building Research, National Research Council of Canada, Ottawa, Canada. $0.75. HR Abstracts, October 1967.

The Snow and Ice Section of the Division of Building Research has undertaken a study of the use of dust to accelerate the melting of ice covers in various parts of Canada. The objective in applying a thin layer of suitable dust to snow or ice covers was to reduce the amount of short-wave radiation reflected from the surface and thus increase the heat absorbed. Almost any dark material applied to an ice surface will absorb radiation and, under favorable conditions, increase the rate of melt. The choice of material will depend largely on cost and local conditions. It was concluded from these studies that the success of any ice dusting technique will depend primarily on the weather conditions that prevail just prior to and during the natural melting period.

11. THE HEATING OF PAVEMENTS. Ceintrey and Bertoye. Revue Generale des Routes et des Aerodromes (3 Rue Alfred-Roll, Paris 17, France), Vol. 37, No. 420, pp. 81-85, April 1967. (In French). HR Abstracts, October 1967.

Heating of pavements is a new technique in France. In areas which are subject to freezing rains and the rapid formation of ice on the roads, such heating is a safety measure which should be tried. Methods of laying electric cables, placing the pavement over them, and the general operational control of the heating current are presented. It is felt that, while the operating costs are high at present, increased use of the technique will reduce the costs and that the extra margin of safety is worth the cost.

12. Minsk, L. David. ELECTRICALLY CONDUCTIVE ASPHALT FOR CONTROL OF SNOW AND ICE ACCUMULATION. U.S. Army Cold Regions Research and Engineering Laboratory. Presented at the Highway Research Board meeting, January 1968.

As asphaltic-concrete made electrically conductive by the addition of graphite was designed and tested in small test plots over two winter season. Power dissipation per unit surface area, P/A_s, in watts/ft^2, is

$$P/A_s = \left(\frac{E}{\ell}\right) \frac{t}{p}$$

where

E = applied potential difference, volts;
ℓ = conducting path length, ft;
t = thickness of conducting sheet, in.; and
p = resistivity of material, ohm-in.

From the design requirements of 20 watts/ft^2, 1/2-in. thickness, 30-volt potential drop between electrodes spaced 5 ft apart, the necessary resistivity was calculated to be 1 ohm-in. Laboratory studies to obtain this value were made, first using simulated asphaltic-concrete (paraffin as a binder) and then

asphalt-graphite-aggregate briquettes covering a wide range of mixtures. These studies led to the choice of a 25 percent graphite level, and six test sections were constructed at USA CRREL using this mix and three thicknesses and sizes of electrodes. Actual resistivities were 7 to 12 times design value. Mixing, placement and control are critical in achieving satisfactory electrical properties. The test sections performed satisfactorily over a two-winter observation period. The sections were not trafficked and measurements of resistivity showed increases of 21 to 83 percent over an 18-month period. Safety considerations would probably make necessary an overlay, since a steel form placed on one test section and loaded by standing on it resulted in a 40 percent current increase. Cost of a conductive asphalt with electrodes would be competitive with other methods of heating pavement surfaces.

13. THE USE AND EFFECTS OF HIGHWAY DE-ICING SALTS. Massachusetts Legislative Council (Room 236, State House, Boston, Mass.), Senate No. 2, Jan. 1965. 80 pp. HR Abstracts, January 1966.

This report is concerned with the use and effects of the commonly used highway de-icing salts, sodium chloride and calcium chloride. Special attention is focused on the effects of these salts on public works, automobile bodies, vegetation, the public health, animal life and fish. The increasing use and the chemistry of de-icing salts are discussed. Notwithstanding the known acceleration of corrosion by highway chemicals, highway officials strongly defend their use because they believe any acceleration of damage is far outweighed by the substantial reduction in the duration and seriousness of hazardous driving periods, as well as by the obvious economic benefits that accrue to business, industry and the community from quickly opening up highways after storms.

Two studies from Massachusetts and New Hampshire deal with the problem of salt effects on vegetation; since the views disagree, the question of salts as a contributing factor in the demise of roadside trees is unresolved. Another study in New York City suggests that toxic gases from motor vehicle exhausts, rather than salts, are the real killers of trees.

14. Mellor, Malcolm. SNOW REMOVAL AND ICE CONTROL. U.S. Army Materiel Command, Cold Regions Research and Engineering Laboratory (Hanover, N.H.), DA Proj. IV025001A130, April 1965. 37 pp. HR Abstracts, February 1966.

This monograph summarizes current ideas and practice in snow removal and ice control as they affect means of transportation. The increasing demands for swift, high-capacity snow removal have been met chiefly by increasing the size of existing machines and supplying more powerful engines and tractive elements. Almost all machines now in use are based on long-established principles, and fundamental research on snow clearance appears to have been somewhat neglected. There is hope, however, that studies now being made in North America and Eruope will lead to radical improvement of techniques and equipment. Subjects for mechanical snow removal, snowplow design, ice control, melting chemicals and abrasion, thermal methods, snow clearing costs, and highway design considerations.

15. Schaerer, P. A. MELTING SNOW AND ICE BY HEATING PAVEMENTS. Building Research Note No. 5, National Research Council, Division of Building Research (Ottawa 2, Canada), Jan. 1966. 12 pp. HR Abstracts, August 1966.

Snow and ice removal by heating the pavement is a costly operation. Experience has shown that the capital cost of installation ranges from $1.00 to $6.00 per sq ft and operating costs from $0.15 to $0.30 per sq ft per winter, or $10.00 to $15.00 per ton of snow. The number of snow-melting systems installed during the past years, and frequent inquiries received by the National Research Council concerning them indicated a need for information concerning the design and cost benefit studies of such systems.

In response to this need, this paper has been prepared to: review and summarize the information available, indicate where information can be obtained, and point out where knowledge is still lacking and research is required. This paper considers only heating systems using buried pipes or electric cables. Heat for melting snow may be supplied also by infrared lamps. There is little technical information available, however, concerning the application of infrared heaters for snow melting, which indicates a need for research on this method.

The heat requirements for snow removal by heated pavements depend on the following influences: rate of snowfall, air temperature, wind speed, relative humidity of air (influence is small), heat transfer from the pavement into the ground, effect desired (bare pavement or snow cover allowed), warn-up time, idling time, area of pavement, and frequency of snowfalls and icing. With these data available, the design output in btu/sq ft/hr and the total heat required during one winter can be determined. With the costs of the energy known, the economics of a heating system may be assessed.

16. Hutchinson, F. E. RELATIONSHIP OF ROAD SALT APPLICATIONS TO SODIUM AND CHLORIDE ION LEVELS IN SOIL BORDERING MAJOR HIGHWAYS. University of Maine. Presented at the Highway Research Board meeting, January 1967.

Sodium and chloride levels in soils adjacent to salted highways were measured during July, October and April at 27 sites to determine the effect of salting for periods ranging from 0 to 18 years. Levels of both ions were raised as a result of this practice, with the effect greatest at the edge of the road embankment and also where salting had been practiced for the longest period of time. Salting increased sodium and chloride levels more at the 6-in. than at the 18-in. depth, and sodium levels were raised to a higher value than chloride levels. Although levels of these ions were highest at the edge of the highway, the levels were raised at a distance of 60 ft from the highway in some instances. Wells near some of the highways contained chloride levels in excess of the recommended maximum.

17. Minsk, L. D. SURVEY OF SNOW AND ICE REMOVAL TECHNIQUES. U.S. Army Material Command, Cold Regions Research and Engineering Laboratory (Hanover, N. H.), Tech. Rept. 128, Dec. 1964. 49 pp.

This report summarizes snow removal techniques, status of knowledge in this field as of 1960, and future considerations. During the winter of 1958-59, a comprehensive survey of snow and ice removal practices at eight Air Force bases, 13 state highway departments, and one RCA base in Canada was made. Between January and March 1960, a similar survey was made in six European countries. Mechanical, chemical, and thermal methods of snow removal are discussed and extensive data are given on various types of snow and ice removal equipment.

18. SYNTHETICS ENCASE HEATING SYSTEM. Engineering News-Record (330 W. 42nd St., New York, N.Y. 10036), Vol. 174, No. 15, pp. 50, 55, April 1965. HR Abstracts, August, 1965.

Austrian engineers have developed an electrical heating system for sidewalks, bridges and roads that is believed to be more efficient than previously used systems because heating is confined to the top 3/4 in. or less of the wearing surface. A newly developed heating cable is embedded in a multiple-layer pavement structure made up of various synthetics, glass fibers and fine quartz.

The system was installed on two ramps extending from the street to the basement garage of a new bank building in Vienna. It extends the full length (198 ft) of each ramp and over about 10 ft of the 12-ft width. The system lies on top of a reinforced concrete pavement with a rough surface. The five-man crew first etched the concrete with 20 percent solution of hydrochloric acid. They then sealed the concrete with a synthetic coating that penetrated about 1/2 in. into the surface. The sealing/bonding compound was a mixture of three commercial eposy-polymer compounds, phenol and pine oil. The next layer was a leveling course of cement mortar, about 2 in. thick, topped by the same compound. Atop the leveling course went a glass fiber mat, which was bonded in place with the same compound. The mat minimizes the effects of any cracks that may develop in the leveling course. As the pavement was being prepared, workmen assembled the heating mats (approximately 26 ft long and 10 ft wide) in the basement of the partially finished building. The basic unit is a black lattice nearly 12 in. square and injection molded from a plastic compound (polyamide-11).

The compacted surface has a load bearing capacity of at least 14,200 psi. Electrical capacity of the system ranges from 7 to 18 w/sq ft. For central Europe, heating time ranges from 70 to 150 hr/hr. A combination of a thermostat and a sensing triggering device performs switching operations automatically. The surface on the project cost about $3.20/sq ft. As normally installed, maximum heating level is 68 F, high enough to thaw ice or prevent its formation.

19. Thomas, Lindsey Kay, Jr. ROAD SALT (SODIUM CHLORIDE) INJURY TO KENTUCKY BLUEGRASS. National Park Service. Presented at the Highway Research Board meeting, January 1966.

Most studies on salt injury to roadside vegetation are concerned with trees. Many of them involve quantitative analyses both of the chloride content of plant tissues and parts per million of soluble soil salts. This study, however, was on grass and shows that qualitative chemical analysis for chlorides in soil is a satisfactory, quick, and economical method for determining sodium chloride injury.

20. Minsk, L. David. SNOW AND ICE CONTROL PRACTICES IN EUROPE. U.S. Army Cold Regions Research and Engineering Laboratory. Presented at the Highway Research Board meeting, January 1966.

Snow and ice removal equipment and maintenance practices in Europe were surveyed between January and March 1960. Countries visited were Austria, England, France, Germany, Norway, Sweden, and Switzerland. Although snow removal is largely mechanized, considerable manual labor is used for cleanup, particularly in Switzerland.

Research on the mechanics of displacement plows and development of improved types of blades have been conducted in England, Germany, and Sweden. Rotary plows have been studied and development work carried on in Germany and Switzerland. Ice control by thermal (flame and electrical cable) means was investigated in England and Switzerland, and by chemical and abrasive methods in Sweden.

21. ANTI-ICING SYSTEM USES MI CABLE IN CONDUIT. Elec Construction & Maintenance v 62 n 12 Dec 1963 p 60-3.

Automatically controlled replaceable heating system is discussed, embedded in concrete of 1500 ft railroad overpass in Amarillo, Tex; MI cable, although suitable for direct burial in concrete, was given added protection of 1/2 in. electric metallic tubing to insure complete dependability in heating.

22. Sharples, J. T. ELECTRIC ROAD HEATING IN UNITED KINGDOM. Roads and Road Construction v 41 n 492 Dec 1963 p 381-5.

Particular features of road heating installations in Great Britain and types of heating systems are described; tests of mains voltage system in which insulated cable is applied at around 240 v and 1-v system in which uninsulated conductor is applied at up to about 30 v.

23. Tapley, W. P. DEVELOPMENT OF WINTER MAINTENANCE EQUIPMENT FOR MOTORWAYS AND TRUCK ROADS. Instn Highway Engrs--J v 11 n 1 Jan 1964 p 5-9.

Survey of motorway winter maintenance vehicles in Great Britain; survey includes salt hoppers and spreaders, Vee and angle blade snow plows, tractor-mounted rotary snow plows, electric road heating installations, and frost working devices.

24. SNOW MELTERS. Can Mun Utilities v 101 n 11 Nov 1963 p 37, 60.

Each of 2 stationary snow melters used in Westmount, Que, has total of 5 burners that consume some 56 gal of No. 2 fuel oil/hr with capacity to melt 360 tons of snow/hr; melting tank is connected to 30-in. sewer which is branched to 5-ft main; largest motors in melters are 250-hr diesels required to supply air to burners.

25. Kurtz, A. TORONTO TRIES SHIFTING SNOW WITH HEATED PAVEMENT. Eng & Contract Rec v 76 n 11 Nov 1963 p 55-8.

Experimental installation on 65-ft section of ramp of Toronto's Frederick G. Gardiner Expressway consists of 4 separate heating elements of welded steel mesh of different wire thickness, spacing and wattage; test results led to recommendations for installations to be made on 2 ramps of expressway, with experiments to be continued for another year.

26. WORLD'S LARGEST ROAD HEATING SCHEME. Heating & Vent Engr v 37 n 439 Feb 1964 p 438-41.

Description of prefabricated electric road-heating system to be installed in Chiswick viaduct section of M 4 motorway in Great Britain; over 280 mi of Pyrotenax mineral insulated heating cables, with total loading of 9000 kw will be used

to keep 5 mi of road surface and interchange ramps clear of frost, ice and snow; use of multistrand single-core resistance wire in cable that has unit load of 3 kw; heating cable mats will be laid on 3/4 in. mastic asphalt waterproof layer sprayed with adhesive or tack coat to assist in holding down mats.

27. Sharples, J. T. ELECTRIC ROAD HEATING. Electronics & Power v 10 June 1964 p 189-93.

Heating systems, installation procedure, costs and power supply are described of large schemes, with loadings of 100 kw or more, built in Great Britain for snow and ice control; transistorized bridge type recorder-controller in conjunction with moisture-- and snow-or-frost detectors, magnetic amplifier and associated circuitry are used to control heating automatically.

28. Edwards, H. M. STUDY OF EFFECTS OF CHEMICALS AND ABRASIVES IN SNOW AND ICE REMOVAL FROM HIGHWAYS. Queen's Univ--Ontario Joint Highway Research Programme--Report 17 Feb 1963 96 p.

Laboratory data were obtained concerning snow and ice melting capacity of chemicals, including coarse crushed rock salt, fine crushed rock salt, flake calcium chloride and pellet calcium chloride, and mixtures of these chemicals under various conditions of reaction time, temperature and chemical concentration; results of tests were used to develop mathematical relationships which related melting capacity with variables studied.

29. Henderson, D. J. EXPERIMENTAL ROADWAY HEATING PROJECT ON BRIDGE APPROACH. Nat Research Council--Highway Research Board--Research Record n 14 1963 p 14-23.

Methods and special equipment used for laying heating cable and various steps of entire operation; installation costs and complete design data are given including w/sq ft dissipation, total power required, conductor sizes, and electric circuitry; conclusions are given concerning suitability of materials and methods of construction.

30. Himmelman, B. F. ICE REMOVAL ON HIGHWAYS AND OUTDOOR STORAGE OF CHLORIDE SALTS. Nat Research Council--Highway Research Board--Research Record n 11 1963 p 1-22.

Study to determine comparative effectiveness of chloride salts and abrasive-chloride salt mixtures for ice removal; tests were run on 15 combinations of materials within 3 temperature ranges; data were collected on thickness of ice, actual quantity and location of chemical or abrasive applied, and periodic condition of ice with regard to amount of ice removed; outdoor storage characteristics of sodium chloride, calcium chloride, and mixtures of these materials.

31. DE-ICER FASTER THAN SALT. Surveyor (42 Russel Sq., London, W.C.1) Vol. 122, No. 3726, p. 1372, Nov. 2, 1963. HR Abstracts, February 1964.

A new non-corrosive chemical de-icing compound, X-73, has been introduced by Wilson's (Ruislip), Ltd., Kern House, Breakspear Road, Ruislip, Middlesex, and is claimed to be not only cheaper but also faster in action than salt or calcium chloride when used to thaw ice on road and footpath surfaces, railway installations

sewers, drains, gutters, downspouts, etc. It is also applicable for unfreezing big areas of turf, such as in playing fields, sports grounds, and the like. The compound, in pellet form, contains "Phosite" rust inhibitor and heat-retaining agent which protects metal during de-icing, and which is of particular value for finishing off a snow-clearance operation which may leave heat-encrusted base-ice. The compound melts snow and ice by exothermic (heat generation) action and is applied by sprinkling at a rate of 1.5 to 2 oz per sq yd either by hand or from a mechanical spreader. Such application will break up ice 1/2 in. to 3/4 in. thick in approximately 4 to 6 hr, and if a surface if treated prior to frost of snowfall, will retard ice formation or settling. Deterioration in storage does not occur, and the compound is stated not to affect vegetation, tires, shoes, etc.

32. Skorik, I. L. UTILIZATION OF CERTAIN SUBSTANCES FOR THE ACCELERATION OF THE MELTING OF ICE. Translated by V. N. Pavloff. From Trudy Arkticheskogo 1 Antarkticheskogo Nauchno Issledovatel'skogo Intituta, 218:200-208, 1960. National Research Council of Canada (Ottawa, Canada), Technical Translation 1067, 1963. 13 pp. HR Abstracts, May 1964.

This translation describes results obtained from a Russian study on the effectiveness of various dusting materials for advancing the breakup of an ice cover. Conclusions reached indicate that dusting of the ice surface with hard insoluble finely-dispersed materials promotes the thawing and destruction of the ice.

The rate of thawing the destruction of the ice cover depends on the nature and degree of subdividion of the dispersed material as well as on the density of dusting of the ice surface with this substance.

Dyeing of natural sand with Prussian blue and aniline black (0.5, 1 and 2 g per 400 g sand) promotes its destructive effect on the ice, although to a lesser extent than could be expected on the basis of the separate effects of sand and its components. On dyeing the sand, the dye sticks to the sand particles (thereby increasing the color intensity and radiation absorbed) and also forms dye films on the sand particles which results in decreasing the dispersity of the dye (thereby reducing the effectiveness of the dye for increasing absorption of solar radiation of the dye).

The action of coal dust (particle size less than 0.5 mm) on ice has several features distinguishing it from other dust-like materials: 500 g and even 250 g of coal dust spread over an ice surface area of 25 m^2 destroyed the ice cover more effectively than did 10 kg of sand; the coal dust penetrated the ice to a depth of 47 cm in spite of the 10-15 thick layer of water.

In the course of the experiment, the dye Prussian blue which was applied directly on the ice, as well as that used for dyeing sand, gradually changed color from blue to green and even rust-brown. The dye aniline black did not change its color throughout the entire experiment. Prussian blue was twice as effective in the destruction of ice than was aniline black when each was applied directly to the ice surface.

33. Brohm, D. R. SNOW AND ICE CONTROL ON THE PROVINCIAL HIGHWAY SYSTEM OF ONTARIO. Ontario Dept. of Highways (Toronto, Ont.), Materials and Research Div., Rept. No. 45, 1964. 22 pp. + Apps. HR Abstracts, November 1964.

This paper describes the winter maintenance administration, operations and equipment of the Ontario Department of Highways.

Factors determining the standard of service provided are reviewed and design features affecting winter maintenance are enumerated.

The need for prompt remedial action is stressed and the value of two-way radio communication is emphasized. Examples are given of typical action taken under various storm conditions.

Specifications for abrasives and chemicals for winter use are provided and details of the standard items of snow-clearing equipment are given.

Safety and developments in equipment in Ontario are discussed briefly.

Some suggestions for future research are made before concluding with comments on the cost of winter maintenance.

34. George, J. D. SNOW AND ICE REMOVAL FROM ROAD SURFACES BY ELECTRIC HEATING. Metropolitan Toronto Department of Roads. Presented at the Highway Research Board meeting, January 1965.

In the development of street, expressway and highway systems, the most important factors, after proper design and construction, are efficiency and economics of operation. One of the biggest problems is the removal of snow and ice from driving surfaces, especially in the critical areas of a facility where operation of the usual snow removal machinery is not practical for different reasons. One method is the use of electric heat. An experiment was started 3 yr ago to melt snow and ice automatically on the "on" and "off" ramps of the F. G. Gardiner Expressway in Metropolitan Toronto, Canada. The purpose of the experiment wss to establish technical and economical feasibility, before larger financial commitments were made. The experiment was carried out on site under actual traffic conditions. Electric heat was generated by means of iron wire mesh mats embedded under the pavement surface using between 20 and 30 v. Electricity was turned on and off automatically by temperature and weather detection instruments. Manual means were also provided to save on power when possible. Each year the area of the experiment was progressively increased as technical and economic data accumulated. In the last year of operation, during the winter of 1963-1964, two complete ramps, one "off" and one "on," were operating under traffic conditions and were kept under constant observation.

Between 30 and 40 w/sq ft of area is required to keep the driving surface free of snow and ice in this area which averages approximately 55 in. of snow per winter. Capital cost for a good complete installation is assessed at $3.40/ sq ft. Operation costs $0.32/sw ft of heated area per winter. Both costs may be considerably reduced in the future. The method is practical, but due to its high costs should be used judiciously.

35. Graham, Malcolm D. EFFECT OF BRIDGE DECK INSULATION ON ICING CONDITIONS. New York State Department of Public Works. Presented at the Highway Research Board meeting, January 1965.

The effectiveness of urethane foam sprayed on the underside of bridge decks as insulation to reduce icing was evaluated. A tri-level interchange in Rochester, N. Y., was selected for the experimental installation. Surface temperatures of the upper and lower decks and the approach pavements were measured continuously before and after application of the urethane foam. Supplementary information included precipitation records, visual observations of icing, traffic studies, and an examination of a previously insulated bridge.

The uninsulated decks were only slightly more susceptible to icing than the approaches. The temperature-stabilizing effect of the urethane increased the potential for icing during most of the winter. In addition, evidence that the insulation had trapped water suggested that the concrete deck and structural steel could be adversely affected. The only benefit derived from the insulation was a significant reduction of freeze-thaw cycles. This advantage is considered to be secondary, compared to the effect on the potential for icing. Further use of insulation should be discontinued and insulation should be removed from the experimental bridges.

36. Whiffin, A. C. and Williamson, P. J. ELECTRICAL HEATING OF ROADS TO PREVENT FORMATION OF ICE AND FROST. Heating v 25 n 206 Feb 1963 p 41-7.

Methods of heating limited lengths of road at sites where icy conditions are particularly dangerous; heating experiments by road research laboratory; heating systems at present in use in Great Britain; automatic control of heating.

37 HIGHWAY SNOW MELTING. Elec Construction & Maintenance v 62 n 6 June 1963 p 96-8, 179.

Experimental roadway snow-melting installation in Newark, NJ is described using embedded mineral insulated cable to show that such project can be included in resurfacing operation on major highway without serious delay or disturbance to paving work; proof of economic feasibility requires more severe test.

38. Booth, R. L. STRAIGHT CHEMICALS KEEP CONNECTICUT HIGHWAYS CLEAR. Pub Works v 94 n 9 Sept 1963 p 106-8.

Salt and sand mixture is applied to all hills and curves on Connecticut Highways to keep traffic rolling and avoid tie-ups during snow storms; as snow accumulates to 1-2 in., straight sodium chloride is applied at rate of 500 to 800 lb/mi in windrow along center line of pavement; on all nonaccess, high-speed highways, mixture of 1/3 calcium chloride and 2/3 rock salt is used when temperature is below 26 F; policy on use of chlorides for snow and ice control is given.

39. Brohm, D. R. USE OF CHEMICALS IN WINTER MAINTENANCE. Can Mun Utilities v 101 n 8 Aug 1963 p 21-4.

Study designed to provide data concerning role of chemicals, and mixtures of chemicals and abrasives, in snow removal and ice control; chemicals tested were sodium chloride and calcium chloride; investigation was confined to effects of time of reaction, temperature of ice or snow, and concentration of chemical application; application of research findings to winter maintenance.

40. TECHNICAL ANALYSIS OF SALT (SODIUM CHLORIDE) FOR ICE AND SNOW REMOVAL. A Critical Review of Laboratory and Field Data to Assist in Achieving Maximum Highway Safety. Salt Institute (33 N. LaSalle St., Chicago 2, Ill.), (1962?), 59 pp. HR Abstracts, June 1963.

In this booklet, the Salt Institute has presented technical data that will permit highway engineers to obtain the maximum efficiency from salt in maintaining pavement free of ice and snow. Characteristics of salt are thoroughly examined.

Salt's early application prevents ice formation. During lengthy storms when ice or hard packed snow does form, salt's fast boring action quickly penetrates the snow and ice cover and forms brine to eliminate bonding of snow or ice to the road surface. As salt's under cutting action breaks the bond to the road surface, normal traffic or snow plows readily break up and throw aside ice and snow. The salt then recrystallizes to leave a bare dry pavement.

Its minimal melting temperature of -6 F makes it ideal for combating storms in the northern States and Canada. Subjects discussed include: mechanism of chemical de-icing with salt; results of skid-tests on treated pavements; methods and benefits; procedures recommended by highway departments on how to remove snow and ice under various conditions in city and rural areas; storage of salt, outdoor storage characteristics of salt, as compared with mixtures; corrosion of automotive vehicles, including corrosion of lacquered surfaces; effect of de-icing chemicals on concrete and asphalt pavement; corrosion of steel in bridges, bridge decks, and reinforcing steel; effect of salt on vegetation, textiles and leather; and winter temperatures and snowfall temperatures in States and Canadian Provinces.

41. Conrardy, W. P. CHEMICAL DEICING OF AIRCRAFT RUNWAYS. Wright-Patterson Air Force Base. Presented at the Highway Research Board meeting, January 1964.

Although snow accumulations can be adequately removed from airfield pavements by a variety of mechanical means, safe removal of thin layers of ice, which cause difficulty with respect to aircraft braking action, is still inadequate. In addition to the usual requirements that ice control chemicals cause minimum damage to the pavement to which applied, the U.S. Air Force has imposed some quite rigid requirements with respect to stress corrosion. The very-high-strength aluminum and low-alloy steels used in advanced aircraft systems are particularly susceptible to catastrophic stress corrosion cracking, a mode of failure greatly accelerated when the structures involved are contaminated by such conventional ice control agents as sodium chloride and calcium chloride. This paper discusses an evaluation of several candidate deicing formulations with respect to their increasing the stress corrosion susceptibility of high-strength metals. Specimen preparation, conditions for exposure, methods of applying stress, and data for a number of deicing materials are presented.

42. Lang, C. H. SNOW AND ICE CONTROL WITH CHEMICAL MIXES AND ABRASIVES. New York State Thruway Authority. Presented at the Highway Rssearch Board meeting, January 1964.

During the winter of 1958-59 the New York State Thruway Authority, in conjunction with the Calcium Chloride Institute, conducted a research program on the use of chemical mixes of calcium chloride and rock salt with or without abrasives in winter maintenance. The report of this first year's study was published in HRB Bull. 252.

Results of the one-year research program on a 32-mi test section were promising enough to justify a second one-year study, which was basically the same but with emphasis on the refinement of application which would result in the most economical use of chemical mixtures. The anticipated results of the second-year tests were confirmed and the Authority adopted the findings on a Thruway-wide basis beginning in the winter of 1960-61. For the next three winter seasons, the mixtures were used as a general policy. This paper reports on experiences over this period. An outline of winter conditions, analysis of the economic benefits

to be derived from use of chemical mixtures, and general observations and recommendations for snow and ice control procedures are included in the paper.

43. Price, W. I. J. MODERN TRENDS IN WINTER ROAD MAINTENANCE. Journal Institution of Highway Engineers (47 Victoria St., London, S.W.1), Vol. 7, No. 4, pp. 319-326, 1960. Road Abstracts, Vol. 28, No. 5, p. 108, May 1961. HR Abstracts, January 1962.

This is a summary of a lecture dealing with recent developments in methods for removing snow and ice from road surfaces by treatment with common salt or by electrical heating; these developments are largely the result of work carried out at the Road Research Laboratory, Harmondsworth. The factors affecting the amount and frequency of ice formation are discussed and mention is made of a road experiment in which the influence of some of these factors was investigated; it was found that the highest values of sideway force coefficient in icy conditions were given by a bitumen macadam to B.S. 1621 using a 1/2-in. quartzite aggregate. Experiments in electrical heating, carried out by the Laboratory in cooperation with the Ministry of Transport and many highway authorities, are reviewed. At Harmondsworth, it has been found that an output of 10 $\pm$ 2W/sq ft is required in a normal road to prevent freezing of a wet surface on the formation of hoar-frost; this output will also melt snow at the rate of about 1 in./hr under moderate traffic and melt a layer of glazed frost within a few minutes. The two main large-scale heating systems are (a) a mains voltage system in which an insulated hearing cable is supplied with current at a potential of 240 v and (b) a system in which an uninsulated heating cable is supplied at a potential of 30 v or less by means of an extra low-voltage transformer.

44. Schneider, T. R. THE CALCULATION OF THE AMOUNT OF SALT REQUIRED TO MELT ICE AND SNOW ON HIGHWAYS. Translated by D. A. Sinclair from Eidgenossisches Institut fur Schnee- und Lawinenforschung Weissfluhjoch-Davos, Interner Bericht nr. 328. 1960 27 pp. National Research Council of Canada (Ottawa 2, Canada), Tech. Translation TT-1004, 1962. 42 pp.

A comprehensive study of snow and ice removal from highways was recently undertaken by the society of Swiss Highway Experts. The Swiss Snow and Avalanche Research Institute, under the directorship of Dr. M. de Quervain, undertook for this society a series of investigations on methods for removing snow and ice or controlling their disposition. This report contains the results of a preliminary theoretical investigation of the action of salts on ice crusts. Because of its preliminary nature it should not be considered as the final answer to the practical problem.

45. AUTOMATIC CONTROLS FOR DE-ICING SYSTEMS PREVENT COSTLY SHUTDOWNS. Aminco Lab News (American Instrument Co., 8030 Georgia Ave., Silver Spring, Md.), Vol. 17 No. 3, p. 10, September 1961. HR Abstracts, June 1962.

Last year, the fuel to operate heating elements that keep three East Coast pedestrian bridges free of snow and ice, cost $1,100 during the month of February. Heaters are controlled by a thermostat which senses only changes in temperature. During the period, the temperature was almost constantly below 32 F, however, there were only three days during the month when ice or snow accumulated.

By replacing the thermostat control with an automatic Hygrodynamics Snow/Ice Control System (which actuates the heaters only when snow or ice conditions exist), the corresponding power cost would be approximately $110. The $990

one-month saving in this case is considerably greater than the cost of a new Hygrodynamics Controller.

According to the manufacturer, the new system offers inexpensive protection for radio, TV, radar antennae; bridges; parking lots and loading ramps; sidewalks; gas storage tanks; gas-line pumping stations; telephone power lines; and railroad switches. The Sleet and Ice Control Systems consist of: (1) a detector unit installed on the facility being monitored; and (2) a controller installed indoors at distances up to 2,000 ft from the detecting unit. The detector incorporates both an adjustable thermostat, and a plug-in precipitation element so that auxiliary equipment is actuated only when icing conditions (low temperature and precipitation in any form) exist.

46. SNOW AND ICE REMOVAL. Frontier, Armour Research Foundation of Illinois Institute of Technology (10 W. 35th St., Chicago 16, Ill.), Vol. 23, No. 3, p. 14, Winter 1962. HR Abstracts, October 1962.

The removal of ice and snow presents serious problems to airport officials and traffic engineers. Relatively small amounts of snow can shut down an airport and tie up normal traffic flow. For certain jet aircraft, one-quarter to one-half inch of slush on the runway requires an appreciable amount of extra power for take off and also makes landing extremely hazardous.

The most common method of snow removal, such as bulldozing, brushing, and then carting it off in trucks, is generally considered to be inefficient and expensive. Accordingly, scientists at ARF have contemplated a project to develop a better method.

The project is centered around developing a liquefying device to melt the snow and a system for removing the water. Since the physical volume of material is greatly reduced when snow is melted, the problem of removing the waste is simplified. Used to remove snow from streets or highways, the system could dispose of water through existing sewers.

The proposed ARF liquefying device is not a new innovation; a number of prototype models have already been developed both here and abroad. But the method under study involves several additional factors. Feasibility studies of the method are expected to begin shortly.

7. Axon, E. O. and Couch, R. W. PROGRESS REPORT OF EFFECT OF INSULATING THE UNDERSIDE OF A BRIDGE DECK. Missouri State Highway Department. HR Record No. 14.

The described investigation was designed to determine the merit of insulating the underside of a bridge deck in: (a) preventing formation of ice on a bridge deck prior to such formation on the abutting pavement, and (b) decreasing the number of freeze-thaw cycles and salt applications.

Information is presented regarding application and bonding performance of the urethane foam, instrumentation, and collection and analysis of data for the periods of December 1, 1961 to April 29, 1962; and October 1, 1962 to November 30, 1962.

Present data are considered insufficient to establish the merit of the insulation but indicate that the effects tend to be beneficial.

3. Henderson, D. J. EXPERIMENTAL ROADWAY HEATING PROJECT. New Jersey State Highway Department. Presented at the Highway Research Board meeting, Jan. 1963.

During October 1961, electric heating cables for snow removal and ice control were installed in connection with a bituminous concrete resurfacing operation on the approach to a State Highway Drawbridge in Newark, New Jersey. The cables were installed in an 840-ft length of two lanes of the bridge approach roadway. This approach ascends at a three percent grade and was the scene of major traffic delays during the heavy snowstorms of the previous winter. The installation was made under emergency conditions on a very heavily traveled highway and the work of laying the cable was designed so as to produce minimum delay or interference with resurfacing operations.

The article describes methods and special equipment used for laying the heating cable and the various steps of the entire operation. Installation costs and complete design data are given including watts per square foot dissipation, total power required, conductor sizes and electric circuitry. The winter of 1961-62 in the area was very mild with little snow accumulation. This condition precluded the gathering of firm data on performance. Conclusions are given concerning suitability of materials and methods of construction, together with a brief analysis of electric power costs as related to the rate structure of the utility company. Photographs of several steps in the construction are included.

49. Kallas, B. F. PERFORMANCE OF ASPHALT PAVEMENTS SUBJECTED TO DE-ICING SALTS. The Asphalt Institute, College Park, Maryland. Presented at the Highway Research Board meeting, January 1963.

The widespresd use of sodium and calcium chloride salts for ice and snow control has caused increasing concern over the effects of these salts on pavements. This paper describes a laboratory investigation on the performance of asphalt pavement subjected to the common de-icing salts.

Laboratory-prepared asphalt pavement specimens of sheet asphalt and dense-graded asphalt concrete were subjected to repetitive daily test cycles designed to simulate field conditions existing when de-icing salts are applied to pavements. Similar specimens of each mix type were divided into three groups and all exposed to the same daily cycles of freezing at 20 F and thawing at 50 F in a temperature cabinet. Specimens in two of the groups were fitted with watertight rubber collars and during the freezing cycle water was placed on their surfaces. A mixture of sodium and calcium chloride salt was applied to the ice on the surfaces of specimens in one of the groups during each daily test cycle. Ice on the surface of the other group was permitted to thaw without the addition of de-icing salts. The third group was subjected only to freezing and thawing and was not contacted by the salts or water.

Various tests were made on the specimens immediately after they were prepared and after 10, 50 and 100 daily test cycles. Comparisons of the test results indicated that the repetitive daily applications of the de-icing salts to melt ice from the surfaces of specimens had no significant effects on specimen stabilities, or on the penetration, softening point or duciility of asphalt recovered from the specimens. No loss of aggregate from any specimens occurred during the tests.

No detrimental effects of the de-icing salts on the asphalt pavement specimens subjected to the testing conditions used for the investigation were indicated by the test results. The study offers evidence that well-designed and constructed asphalt pavements are not damaged by sodium and calcium chloride salts used for ice and snow control.

50. McGovern, E. W. PROTECTION OF PORTLAND CEMENT CONCRETE FROM DELETERIOUS EFFECTS OF ICE REMOVAL CHEMICALS. Koppers Company, Inc. Presented at the Highway Research Board meeting, January 1963.

This paper describes field and laboratory experience over a 5-yr period on the effectiveness of a coal-tar coating to prevent deterioration of concrete from the effects of ice removal chemicals.

The laboratory experience covers observations made on samples of concrete sealed with a coal-tar coating and immersed in solutions of calcium chloride and sodium chloride and subjected to repeated cycles of immersion and evaporation--and also repeated cycles of freezing and thawing.

The field experience describes observations made in New York State, Ohio, Pennsylvania, and Connecticut on the effect of a coal-tar coating in preventing deterioration of concrete on bridges, highways, and gutters due to the action of ice removal chemicals.

51. Murchie, J. A. ICE REMOVAL ON HIGHWAYS AND STORAGE OF BULK AND PACKAGED CHLORIDE SALTS. Minnesota Department of Highways. Presented at the Highway Research Board meeting, January 1963.

The first part of this report covers a field study to determine the comparative effectiveness of chloride salts and abrasive-chloride salt mixtures in the removal of ice from highways. Tests were conducted within three temperature ranges of 10-20 F, and 20-30 F, using a controlled amount of vehicular traffic.

The second part of the study covers the outdoor storage characteristics of sodium chloride, calcium chloride and mixtures of these chemicals, both in bulk and packaged quantities.

52. INSTITUTE STUDYING EFFECTS OF SALTS ON APPHALT PAVING. Michigan Contractor and Builder (1040 W. Fort St., Detroit 26, Mich.), Vol. 54, No. 28, p. 86, October 15, 1960. HR Abstracts, January 1961.

A laboratory investigation to determine the effects, if any, of de-icing salts on asphalt pavement has been launched at College Park, Md., by the Asphalt Institute.

The Institute plans to extend its study over a period of about a year, simulating field exposure of asphalt pavements to repeated wetting with de-icing salt solutions. Initial studies have been limited to two dense-grade mixes having different types of coarse aggregate--one a limestone and the other a glacial gravel, both used in combination with a natural quartz sand fine aggregate and a commercial limestone dust mineral filler. All laboratory specimens are typical of in-service asphalt pavements. These specimens are subjected to repeated weekly cycles of immersion (for 3 days) in concentrated solutions of sodium chloride and calcium chloride, and drying (for 4 days) at room temperature.

53. Miller, Lawrence. CALCIUM CHLORIDE-SALT SNOW AND ICE CONTROL TEST, WINTER 1960-61. Highway General Foreman, Connecticut State Highway Department. Highway Research Board Proceedings, 1962, p. 321.

The Connecticut State Highway Department for many years has endeavored to maintain bare pavements throughout the winter. It is extremely difficult and in

some areas impossible to accomplish the desired results using sand-salt mixture or salt alone.

A further consideration was the conservation of sand. In many areas of Connecticut sand deposits have been depleted or zoned out of existence, resulting in the necessity of importing sand. The resulting increase in the cost of sand tends to make chemical control of snow and ice more attractive from an economic point of view.

The results obtained by the use of calcium chloride-salt mixtures on the New York Thruway were cited to gain permission to conduct a test of chemical control of snow and ice on a section of Conn. 15 in the towns of Willington, Ashford, and Union during the winter of 1960-61. This report covers the test in considerable detail.

As pointed out in the report, mechanical failures and unfamiliarity with procedures resulted in higher costs than would normally be expected. Nevertheless, the cost appears to be substantially the same as standard methods of snow and ice control.

54. Whiffin, A. C. and Price, W. I. J. ELECTRICAL HEATING OR ROADS. Roads & Road Construction v 38 n 449 May 1960 p 144-5.

Experiments, made by Road Research Laboratory studying use of electrical heating to prevent ice and frost forming at danger spots on roads showed that ice can be prevented by employing 9 to 12 w/sq ft of road surface; elements should be about 1 1/2 in. below surface; method of control; three experimental applications and results obtained.

55. HEATING METHODS FOR SAFER ROADS IN ICY WEATHER. Surveyor v 118 n 3512 Sept 26 1959 p 281-2.

Heating of road sections with bad accident records in icy weather; trials by British Road Research Laboratory; two systems can be used, 240 v from three phase supply and low voltage system employing insulated wire mesh and maximum potential of 55 v above earth potential; advantages of both systems; automatic control system.