Paper No. 6246

Snow-clearance problems on Swiss roads†

by

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Discussion

Mr J. G. Taylor (Divisional Road Engineer, North-East Division, Ministry of Transport and Civil Aviation) asked the Author to give a more detailed description of what he meant in § 32(a) by "simple appliances and equipment", particularly the "equipment", since it was necessary to keep all industrial routes open to traffic in Great Britain and these seldom reached an altitude of 2,000 ft.

56. The Author had given a fascinating comparison between snow of various forms. One of the difficulties in the United Kingdom in the past had arisen from regarding snow as snow and not snow in the many forms in which it could be compacted by successive ploughings and various other operations.

57. Snow-falls such as the Paper described did occur to some extent in Great Britain. A brief glance at the record for 1946-47 would suffice to remove any doubts on that score. The following figures related only to the north-eastern area of England between the Rivers Humber and Tweed. During the period 6 January to 16 March, snow-falls had occurred on 41 days, aggregating in that period 60 in. level fall. The maximum individual falls had been of 12 in. on each of two occasions and 27 in. had fallen within 7 days. Severe frosts had preceded the snow by 8 days and continued for 8 weeks, with a minimum temperature of 2°F (30° of frost). High winds had blown throughout most of the period, varying from north-east to south-east in direction. Under such conditions, with snow falling on an already frozen ground surface, there was no absorption and in all areas ploughing operations had piled up snow on areas already deeply covered with snow.

58. Winter services in the north-eastern area during that winter had cost £2,250,000. (Today's equivalent would be about £3,750,000.) That had been on gritting and snow clearing, and when the winter was over, more money had had to be spent in restoring damage caused by frost and floods.

59. Although there had been no lack of snow-ploughs in the country at that time (1,600 had worked in north-east England), the eighty high-wing ploughs used had been far too few and the power of the propelling units insufficient to cope with deep snow-drifts which were numerous and recurring, reaching a depth of 26 ft on major roads in the Pennine area. Superhuman efforts had been necessary to try to keep roads open, but several important roads, including the Lancashire-Yorkshire trunk roads, had been completely blocked for periods of 2 to 6 days.

60. The winter of 1946-47 had clearly demonstrated that heavy V-ploughs alone were insufficient, even in England, for keeping roads permanently open, because solid walls of snow up to 12 ft in height were formed by successive ploughing of drifted snow and in many cases two-way traffic could be restored only by using mechanical shovels. Elsewhere it had been necessary to resort to manpower and 24,000 men had been employed to supplement the efforts of the highway authorities' personnel. The experience of that winter would long serve as a reminder of what could happen in Great Britain.

† Proc. Instn civ. Engrs, vol. 8, p. 199 (Nov. 1957).

61. Since that time a much stronger winter organization had been built up by most highway authorities.

62. Meteorological forecasts were now readily available at the modest annual cost of £10. The additional information which could be obtained on demand included the time when snow and frost were expected, the direction of the wind anticipated, and, what was so essential, its probable duration and velocity; this information was invaluable to highway authorities.

63. Despite the availability of all this advance information, a repetition of the worst conditions of the 1946-47 winter would necessitate round-the-clock working by teams operating high-wing ploughs followed by heavy-duty snow-blowing equipment such as had recently been acquired by the Ministry of Transport and Civil Aviation for location at strategic centres.

64. The motorways which had been planned would be provided with level hardened shoulders so that successive ploughing operations should keep the running-traffic lanes free from snow deeper than the 2 in. to 3 in. which, as the Author had said, was an inevitable result of the continuous passage of traffic consolidating the earliest snow-fall.

65. Several points had to be borne in mind, despite the comparative freedom from snow of those motorway carriageways after ploughing. Piled-up snow on the margins of any road sooner or later began to thaw, and if the thaw was continuous traffic hazards seldom occurred, except, of course, when a rapid thaw caused flooding of low-lying roads. If, however, a daytime thaw was succeeded by night frost, the freezing of the thin films of water from melting snow on super-elevated bends could cause really serious traffic hazards on roads designed for high-speed traffic, especially if this occurred when the carriageway was free from compacted snow or ice. The use of snow-blowers would do much to reduce such hazards by reducing the accumulations on the margins.

66. What were the Author's views on the relative values of temporary snow-fences and permanent shields of trees or stout hedges? In the North of England most of the deep snow-drifts occurred in sheep-raising country where farmers showed an unfortunate reluctance to permit temporary snow-fences to be erected in the late autumn on account of the alleged crippling of sheep by the stay wires supporting the fences. In designing motorways it might well prove a wise precaution to acquire areas of land adjacent to deep cuttings in open country on which permanent hedges, tree belts, or fences could be provided to prevent the deep drifting of snow in the most severe winters.

67. Mr Taylor then showed some lantern slides illustrating the points he had mentioned in his contribution. He also showed lantern slides illustrating points which would be made by Mr H. Foster in a written contribution.

Mr Stanley Mehew (County Surveyor, Derbyshire) said that he had been fortunate enough in the winter of 1955-56 to be sent by his council on a visit to Switzerland to study Swiss snow-clearance practice. To his surprise, he had thought that, without in any way endeavouring to belittle the very severe Swiss problems, the problems in Britain were in many senses more difficult. He was referring to the counties and the areas of the country in which heavy snow-fall was a fairly frequent occurrence. The snow conditions in Switzerland were more predictable and more stable. There were less very intensely trafficked roads of the industrial type carrying more than 6,000 tons/day, and, as mentioned in § 7, the side roads were comparatively little frequented by motor traffic, and therefore did not need much attention.

69. In industrial and agricultural counties such as Derbyshire and Durham, and in the West Riding of Yorkshire, and others, there were problems which made it important to snow-plough and grit nearly all the roads and to do the work quickly. In Derbyshire, for example, about 4,400 farms existed from which milk was collected every day, in accordance with a stated time schedule, and about 150,000 gal of milk had to be collected on a particular day; it could not be kept; if it was not collected, it had to be thrown away, which meant that in a county such as his about 3,000 miles of road must be ploughed more or less at the same time.

70. The result was very heavy expenditure. The Author had given an average

figure of £44/mile, but in Derbyshire the average cost of snow clearance and gritting for each of the 5 years 1951–56 had ranged from £136/mile for trunk roads, £145 for class I roads, and down to £41 for class III roads. The Author had referred to this work costing 10% of the total road expenditure. The figures which Mr Mehew had just quoted amounted to 12.4% of the total maintenance cost of trunk roads and 17.7% of the total maintenance cost of class I roads.

71. He was interested in the Author's remarks about snow bridges and ice bridges (§ 5), which were new terms to him. Would the Author explain these terms in more detail and also state if the milling-type cutter snow-plough shown in Fig. 14 would in fact deal with packed snow and ice, which was now really one of the most serious problems in Britain?

72. Winter gritting in Britain cost far more than snow clearance, probably three to five times more, though snow clearance was better known to the public because it was more spectacular and, when there was heavy snow, clearance was more essential. In a county like Derbyshire, about 33,000 tons of grit and 1,300 tons of salt were used in a reasonably hard winter. Picking up the grit afterwards was still a big problem, requiring increased mechanization, although the question of putting it down had been mastered. Could the Author make any suggestions on that matter?

73. Mr Taylor had asked what the Author meant by "simple methods" and Mr Mehew thought, from his own experience in Switzerland, that the inference was that the great majority of snow clearance was done by the economical and quick pusher-type of plough. The Author's remarks in § 42, about bigger clearance machines and large ploughs on caterpillar tracks confirmed Mr Mehew's theory that a big V-plough on a heavy tractor would be of great value in tackling work which it had been impossible previously to do quickly by any other method. He now had a plough, about 11 ft 6 in. wide and weighing 1 ton, on a D.8 tractor, and he was hoping to see if the plough would stand up to the efforts of the tractor. If it did, he was sure that it would be very effective in clearing deep drifts rapidly.

74. Most of the ploughs in Britain were run on skids, being kept down on the road surface by the weight of the snow, and he thought that the type used in Switzerland which was pushed down on the road (see § 35) was an important technical advance and a great improvement from the point of view of preventing choking. Northumberland County Council, and possibly others, had obtained such ploughs from abroad; but there were British ploughs now being manufactured on this principle.

75. Was frost damage to road surfaces and foundations a serious trouble in Switzerland? It was an increasing problem in Britain. Following the 1956 winter, which was not unduly severe, Derbyshire had spent £130,000 on frost-damage repairs, and it was a very interesting commentary on those who contended that the maintenance figures were excessively high, because the rate had worked out at £89/mile on Class I roads and only £34/mile on trunk roads, which carried heavier traffic. The comparison was surprising until it was remembered that more had been spent on maintaining the surfaces of the trunk roads, particularly on resurfacing work.

76. Could the Author give any indication of the method of assessing the danger of snow-slips at the sides of valleys. Occasionally in Derbyshire snow had to be blasted down. There had never been any certainty that it was quite necessary; some technical approach to that matter would be of great interest.

Mr E. W. H. Vallis (County Surveyor, Kent) agreed with Mr Mehew that, after comparing the predictability of snow conditions in Switzerland with the uncertainty in Britain, it seemed that British development was not inferior.

78. In Britain, where adjacent counties might have quite different conditions at the same time, the estimate of future expenditure had to be based on the average expenditure of the past few years. The result was reasonably accurate.

79. In Kent, over the 6 years from 1951 to 1957 the cost of snow clearance had averaged about 6.3% of the entire expenditure on maintenance work, ranging from 2.7% in 1951 to 11.15% in 1956. When comparing these figures with the 10% quoted

for Switzerland it should be remembered that the Kent figures included gritting, which could not easily be kept separate from the actual cost of snow clearing.

80. It seemed to Mr Vallis that, apart from maintenance, the problems in the two countries were in fact very similar and the methods adopted to deal with them were much the same. Snow clearance in Kent had to be part of the normal road-maintenance programme and it was incumbent upon local authorities to include in their duty of keeping the roads in a fit state to facilitate travel at all times and whatever the weather conditions a proper organization for snow clearance.

81. Mr Vallis did not understand § 18. It seemed to him surprising that one authority responsible for one class of road might compensate another responsible for a different class, and *vice versa*, resulting in overlapping the organization, which made the task difficult and increased costs. In Britain the organization was much easier and probably better. The county itself was the authority responsible for all the roads in the rural parts of the county, and there was only the county council, together with the overall authority of the Minister of Transport, to deal with the matter.

82. There was a reference in § 7 to roads in rural areas, which had to be maintained for sledges as well as for motor traffic. That problem did not exist in Britain, but there was a very real problem in keeping the minor roads free for the agricultural traffic which used them. In Kent a lot of the responsibility was placed on selected local land-owners and farmers, for whose use about 170 snow-ploughs were placed in strategic areas. They had come to an agreement by which they were expected in their own area to keep the minor roads open. This method saved the county a considerable amount of responsibility and since its introduction there had been very few complaints from the rural areas.

83. Snow-fences had been used in Kent since 1954—on a small scale at first. Now there were about 30 miles of snow-fences adjacent to roads in the worst part of the county. They were relatively inexpensive compared with the accumulative cost of snow clearance. The fences, which were of Kent chestnut and of simple construction, were taken down in the month of March, they were rolled up and stored until the next year, and the cost of erecting and re-erecting them was quite small.

84. For a very modest fee of £10 a year, meteorological reports were supplied to the head office and were at once disseminated to the nine divisions in the county. Sometimes, even earlier and very reliable advance weather information could be obtained by telephone from the local Air Force stations in the county. Possibly the problem of getting advance information was not quite as acute in Switzerland as it was in Britain, because they knew in Switzerland that once snow fell, perhaps in November, they would go on having snow all the time until the following March.

85. Section 30 referred to the interesting development of the equipment of bridges with a heating installation. This was new to him, but he had no doubt that more would be heard about it.

86. With regard to the use of salt, in Kent they did not use any neat salt; they used t mixed with abrasives in the proportion of about 1 to 10, which they had found to be quite effective.

Colonel S. M. Lovell (County Surveyor, West Riding of Yorkshire) said that the Paper was valuable because, among other things, it established data as to where slippery and bad road conditions were likely to occur, what types of pusher ploughs and of cleaning machinery to use, and where to use them. Such data would be useful when planning snow-clearing programmes in the future.

88. In § 42 it was stated that in Switzerland it was now necessary to keep routes open all the time. That had always been the case in the West Riding!

89. Colonel Lovell then described what it had been possible to do in the West Riding without any of the research that the Swiss had been able to undertake.

90. The West Riding had 4,500 miles of road to deal with, including ten trunk and class I roads crossing the top and both slopes of the Pennines. Anything could happen. For instance, lorries got stuck—once there had been more than fifty in a mile with

10–15 ft of snow on top of them. In those conditions it was impossible to plough. The first problem was, of course, to keep the industrial traffic routes open and keep the traffic moving. An effort was made to work down in descending order of classification, but of course milk deliveries and isolated farms had to be given some priority.

91. Insufficient credit was given to the actual man on the job and the appalling conditions in which he had to work. It was possible on the Pennines to get snow blowing horizontally so that one could hardly see the front end of a lorry in which one was riding, although the sun might be shining brightly overhead; those conditions could occur quickly and abruptly. He had known cases of men stuck to bulldozer seats having to be chipped off with pickaxes. Sometimes they had to rescue isolated travellers. In total, conditions could be really appalling. It would therefore be seen why, in those conditions, the welfare of the men in West Riding was considered to be of very great importance. Hot drinks and soup were supplied and lorries which went out on to the job were fitted with canteens for food and heat.

92. Colonel Lovell displayed two documents; the first was a lecture to foremen, setting out the whole procedure, and the second was the operation instructions. He went on to discuss some of the main points in the latter.

93. First, this was a written operation instructions incorporating all the experience built up over the years. It was felt that such written operation instructions were absolutely essential, to ensure correct and adequate procedure at every stage.

94. Control was built up from the bottom, in the first place from the police or the working foremen themselves, or even the roadmen, through the Highway Superintendent to the Divisional Surveyor (at this stage the depots were brought into permanent operation), then to the Assistant County Surveyor (this was most important), and finally to Headquarters. At all those stages, as conditions rendered it necessary, controls were manned, finishing up with Headquarters control. If conditions warranted it at any or all of the stages, all controls operated and were manned for 24 hours a day, 7 days a week, shift work then being operated from the staff right down to the workmen. The manning of each control depended on the situation report and at the Headquarters control, which was in the County Hall, Wakefield, decisions to operate were left to Colonel Lovell, his deputy, or the Chief Assistant County Surveyor.

95. When Headquarters control was in operation, the following was the procedure. Control room was responsible for: (a) priority of movement of Headquarters pool plant; (b) recording blocked roads and alternative routes; (c) keeping a log book with all messages and movements; (d) the movement and co-ordination of labour between all areas; and (e) the ironing-out of any other difficulties that might arise. Immediately Headquarters control came into operation, the following people were also informed: the West Riding Police, the B.B.C., the Lancashire County Council, the Cheshire County Council, the A.A., the R.A.C., and the Press.

96. At the Headquarters control room, the following information was available: the telephone list, including all County Council, local authority, and neighbouring authority's official numbers, as well as their private numbers in case they had to be called in the middle of the night; a list of all divisional offices and/or depots that would be manned, a list of Headquarters plant available for snow clearing, a list of hired plant available, and an up-to-date record of the labour available, location of stocks of hand tools held in the various depots, and any surpluses available.

97. Meteorological reports were received regularly from the Meteorological Office at Bawtry and were telephoned to the police. The police then forwarded them to specified people agreed with them, during the day or night; but there were always four alternatives so that if one person was not available the next one could be contacted. Those reports again started from the bottom upwards, i.e. direct to the man on the job and so on to higher formations. The meteorological report brought the stand-by arrangements into operation, and everything was put into a state of readiness. This really did work, and his assurances on this would have to be accepted, explanation of the details would be too lengthy. It had been arranged for the police to issue these reports for the simple reason that for 24 hours of every day of the year they had the control

room manned for their normal operational procedure, and they had accepted this forwarding of reports as an additional duty. They had done so without any hesitation.

98. Colonel Lovell then turned to the critical situation when snow actually started to fall during the night. In those circumstances the police patrol cars on duty anywhere in the Riding, *via* their own wireless to their own headquarters, *via* the chain of control for communications he had mentioned, brought into automatic operation all the standing arrangements and clearing operations commenced. During the day, of course, his own staff operated in a similar manner, according to conditions.

99. Situation reports were sent in at four specific times of the day: 09.00 hours, 12.00 hours, 17.00 hours, and 21.30 hours. They included roads blocked and cleared, diversions in operation, general conditions regarding frozen snow or pot-holing and locations, plant-location details, and the labour position. Most important, they also included details of roads still open and whether these were working for single- or double-line traffic.

100. At specific times certain information was passed to certain outside organizations: first to the B.B.C., who broadcast at least once a day the latest conditions as given to them, and to the Press, in time for the morning and evening papers. The police were given the details of each situation report; the D.R.E. got the information twice a day; the motoring organizations and private individuals got it on request.

101. The B.B.C. and the Press informed the general public that this control was in operation and that this service was available, giving the necessary telephone numbers for contact. It might be asked why his organization did this. They thought they were right in doing so, and experience had proved that it was so, for the following reasons: (a) they were responsible for clearing roads, and if they were to win the battle they must have the latest information—later than anyone else; (b) it prevented wrong information being given publicly, thereby misleading the public, and thus avoided complaints; (c) it gave the public the best possible routes and prevented delays and difficulties on their part. (Often, more than a hundred telephone calls in 24 hours were received from all the surrounding counties, and even from places up to 200 miles away.)

102. The operation instructions then dealt with the detailed movement of heavy Headquarters pool plant, i.e., bulldozers, and also with how to get additional outside plant if the lower formation was unable to get it. This procedure, again, worked from the bottom upwards. Similarly, with additional labour, i.e. inter-division, inter-area, or from outside resources such as the military, the Agricultural Committee, contractors, etc. Additional tools were dealt with in a similar manner.

103. Welfare details on what to do and how to do it were fully covered in the instructions.

104. The use of police patrol cars for specified routes was a recent innovation, but one which had been found to be absolutely essential on specified heavy industrial routes. Police patrol cars preceded snow-ploughs in order to keep traffic clear so that the ploughs could operate. In fact, what was done was similar to the practice for heavy indivisible loads. This was necessary because the volume of traffic on the heavy industrial roads rendered snow-ploughing at requisite speeds completely impossible, and the snow would soon be on top of them instead of they on top of the snow. This was operated through Headquarters control *via* radio communication.

105. Communications were fundamentally by radio from the forward positions through the depots and offices, divisions and areas, to Headquarters, all of which were on the net. It was supplemented by a normal telephone service, again laid as far forward as possible, or at the lowest level possible. It was felt that radio was indispensable, for any snow action depended for its success on the speed of action at the commencement of the emergency, and obviously radio was the quickest way of getting queries and, what was more to the point, getting those queries answered.

106. The foregoing was the briefest outline of the main points in the operational procedure in West Riding.

107. At this stage he wished to pay a particular tribute to the West Riding Police. His remarks had shown how much they co-operated; they had done this willingly, and

the whole system worked as smoothly as clockwork, and would be nothing like so effective without the unstinted co-operation of the police.

108. The available plant included 817 snow-ploughs, 464 gritters of all types, 11 Mack lorries with heavy V-ploughs and gritter bodies, a Bros snow-plough, a Rolba snow-plough, and approximately 40 pieces of heavy plant, including excavators, bulldozers, and building shovels. More than fifty farmers could attach ploughs to their own tractors for ploughing out from isolated farms and on milk delivery routes. In addition, and most important, there were coaches for the bulk transport of personnel.

109. For reinforcement, there was the Ministry of Transport depot at Pocklington with the latest heavy plant, and the contractors' plant within the Riding, of which there was a heavy concentration and of which they had lists. This plant could be obtained at short notice.

110. The total cost to the Riding for snow clearing and gritting could be anything between £100,000 and £400,000 yearly, depending on the severity of the winter.

111. There was little reference in the Paper to gritting. It was not usually realized how essential it was, and the gritting often cost two to three times as much as the actual cost of snow clearing. Therefore, if the cost of the winter's bad weather operations amounted to £400,000, one could see that gritting itself would be between £200,000 and £300,000. A feature very often overlooked was the extra cost of picking up the grit in the spring; this could cost as much as another 25% on the original cost.

112. In the winter of 1956-57 the experiment of spreading rock salt only had been tried in the West Riding and so far they had found it to be much more effective. There was no clearing up to do in the following spring, and the saving in cost had been up to 75% of the gritting operations. True, it was on a limited scale, but they were going to extend it this winter of 1957-58 on 1,000 miles of road; this could well save in a normal winter anything from £50,000 to £75,000, and for the county as a whole it might be from £200,000 to £250,000. It would be seen, therefore, that this experiment with rock salt only—and it was the only technically suitable material which they had found so far that was far better than normal soiled salt—could prove to be well worth while, and it might even get into the essential category.

113. What about the future? So far as he could see at the moment, the future lay along the following lines. First of all, snow-fences. There were up to 30 miles of them in the West Riding and they were being extended. It had been found that they collected as much as 35 cu. yd of snow per lineal yard of fence. Secondly, improvements to cuttings, the widening and sloping down of which did two things: prevented the collection of snow; and allowed the machinery, ploughs, etc., to operate. Thirdly, independent powered gritters. Traffic on the roads was so dense, and hence so slow that road wheels might not be rotating fast enough to spread the grit. It had been found essential to have the independent powered gritter which would spread grit at a requisite spread irrespective of the speed of the lorry. British manufacturers should look particularly into this point; they had done too little. Fourthly, the use of salt instead of grit—and he thought that this had a very marked and wonderful future. Fifthly, speedy action in improving their organization by the lessons learned each year.

114. In conclusion, snow clearing must be treated as a tremendous battle, but public money was being spent in that battle in an effort to keep industry going. Some of the brief outline that Colonel Lovell had been able to give might sound involved and complicated; he did not think it was; he thought it was merely an essential piece of organization and pre-organization to enable the battle to be fought.

Mr C. C. Toyne (Engineer, Ministry of Transport and Civil Aviation) referred to § 2 and asked the Author what numbers and types of ploughs were held, say, per mile or per kilometre in a typical Canton where snow was experienced each year. This would be very useful for purposes of comparison.

116. In § 6 the Author referred to the difficulty experienced in Switzerland in clearing compacted snow. Of course, there was that difficulty in Britain as well; but he had

been rather interested to hear some months ago that in Switzerland they had some ploughs of the type which were held against the road surface by pressure, which were capable of clearing compacted snow completely from the road surface. Mr Toyne felt that this was perhaps an exaggeration. Would the Author give more details?

117. The need to avoid compressing snow which was to be cleared was obvious, but it did not seem to be sufficiently comprehended by snow-plough drivers, many of whom treated their machines rather like bulldozers, trying to push the snow off the road rather than driving the plough so as to cut the snow away. He felt that more could be done in Britain to educate drivers on this point.

118. In § 35, the Author mentioned the question of ploughs which could be held against the road surface. Mr Toyne also had found that the suspended plough tended to ride up on the snow. As it did so, it left a thicker carpet behind the plough on which the propelling vehicle had to run, and because of that the effect was cumulative, and before very long the plough itself was running on a carpet of about 1 ft in depth although the initial setting was about 2 in.

119. Mr Toyne agreed with the Author regarding the desirability of having blade ploughs as light as possible (§ 39) and constructed so as to be as near to the propelling vehicle as possible in order to reduce stresses on the propelling vehicle. He had found also that with a shorter distance between the blade plough and the propelling vehicle there was less possibility of snow falling behind the plough blades and so causing a fish-hook barb effect when the plough had to be reversed between snow banks.

120. The Author's useful classification of machines in §§ 44 and 45 served to emphasize the importance of having the right size and the right type of plough for the particular job in hand. (That was often overlooked in Britain.) It also emphasized that the design of the propelling vehicle, for rotary snow-ploughs particularly, was just as important as the design of the plough itself.

121. Referring to the tests which had been carried out in Switzerland on snow and on snow-ploughs, had there been an effort to eliminate the human element in those tests? The skill and training of the operators, particularly of rotary ploughs, was very important, and if something had not been done to try to get some uniformity in the drivers during those tests, Mr Toyne felt that there would probably be some false results.

Mr M. M. Snow (Managing Director, British Rotary Snow Plough Co. Ltd) emphasized the importance of the characteristics of the vehicle or carrier on which a rotary snow-plough was mounted. The foremost aim was maximum adhesion and to that end all wheels must be driven. In the larger machines, the extra weight imposed by the plough being at the front of the vehicle raised unusual problems in the design of front axles, suspensions, etc. If, owing to its design, the plough-head was unduly far forward of the front axle of the vehicle, or if the front axle was not sufficiently strong to carry the weight of the plough-head, then additional wheels must be inserted in front of the driven wheels of the vehicle, to assist in taking the load, and the advantages of four-wheel drive were minimized. On the other hand, if the plough-head could be rigidly attached close to the vehicle, the full advantage of the driven front wheels was obtained (see Fig. 11). The Author emphasized this in § 35.

123. The Author had not mentioned—perhaps because it was self-evident—that the vehicle on which the rotary snow-plough was mounted should have a wide gear range and particularly “creeping” gears in the lower range. It was Mr Snow's own sincere belief that the rotary snow-plough had got off to a bad start in Britain soon after the 1939–45 war. During the war a large number of rotary snow-ploughs had been imported from America for airfield clearance. Unfortunately, owing to the exigencies of war, many of them had been mounted on four-wheel-drive trucks, which lacked some of the characteristics required for this particular duty, including adequate overall gear ratio. This fault might not have been quite so obvious on airfields, but directly they had been borrowed for road work and attempts had been made to clear deep drifts with them on inclines, it had become only too apparent. Not unnaturally, the rotary snow-

plough *per se* had been blamed for this, and it had earned a reputation for inefficiency—at least for conditions in Britain—which it did not truly merit. On large machines power-assisted steering was very desirable and, of course, attention must be paid to the comfort of the drivers and to adequate lights, heaters, and defrosters.

124. The Author had shown that for different types (or hardnesses) of snow the best results were obtained by the employment, depending on the hardness, of two different designs of rotary snow-plough, one of which he termed the milling type and one the centrifuge type. From Fig. 19 it appeared that, on the formula adopted by the Winter Service Commission, the milling type was effective over a wider range than the centrifuge type. This was interesting, but one must not assume that at the high altitudes in the Alps there was a greater proportion of hard snow than would be found in the United Kingdom, except during an exceptional winter.

125. It would be interesting to know if the wet snow of high density so often encountered in Britain had a high measure of cohesion. This seemed to follow from § 20.

126. The Author had emphasized the need for early action, since the fresher the snow the easier it was to handle, though he admitted the difficulties in the way of doing this. It was to be supposed that the “traffic hardening” to which the Author referred presented one of the worst headaches to the engineers concerned in Britain, especially in urban and suburban areas. What success had been obtained in Switzerland with the milling type of machine in dealing with this condition?

127. Medium and large rotary snow-ploughs involved considerable capital expenditure, and the economics must therefore be carefully assessed, as well as the selection of the most suitable types for the various conditions. Such machines did not lend themselves to production for stock, and they were bound to take some time to manufacture, and on this account also it was important to plan ahead.

Mr W. P. Tapley (Senior Engineer, Ministry of Transport and Civil Aviation) referred to the prevention of snow-drifts and ice on roads and suggested that there were still some parts of Britain where this aspect of the snow problem did not receive the attention it deserved.

129. Where he had been living in Scotland, 20 miles from the nearest railway station, there was snow every winter and the roads were icebound for long periods. It was noticeable that the roads always tended to be blocked or become difficult at roughly the same places every year, and that the drifts, although they sometimes successfully blocked a road, were confined to a very small proportion of the whole length affected by the snow. It took a lot of undrifted snow to stop traffic. In fact, with timely action it need seldom cause much trouble, except in certain places and in exceptional years.

130. In §§ 28, 29, and 31 of the Paper, the Author had indicated some of the features that should be avoided, from a snow point of view, where practicable, in new road projects. In §§ 29 and 30 the Author referred to the tendency for the roadway on bridges to cool more quickly than on other parts of its course, and mentioned a possibility of equipping bridges with heating installations. It would be interesting to have details of the form and extent of the heating employed, and the length of time during which it was anticipated that the heat would have to be applied before icing was expected to take place.

131. Snow-fences were mentioned in § 33. It would be helpful to have more details of their effectiveness, and their construction and siting in relation to the road.

132. Last winter had generally been regarded as mild and snowless in Britain. Nevertheless, on a road journey from London to Cornwall on 27 December he had been held up for many hours by snow on Salisbury Plain, and others whom he had met had had to spend the night there. The drifting which had caused the blockage extended over a relatively short length of road in one place only, and could have been readily cleared by a large blade plough if it could have been put to work before the road was blocked by traffic. This could have been prevented by “timely action”, two words which Mr Tapley considered to be the most significant in the Paper. If the road had

been slightly above the level of the surrounding countryside, instead of below it, or if suitable snow-fences had been in position, the road might not have been blocked at all in those normal, or almost subnormal, conditions.

Mr W. I. J. Price (Principal Scientific Officer, Road Research Laboratory, D.S.I.R.) confined his remarks to the research aspect of the Paper. Much of the early fundamental work on snow properties had been done by Swiss investigators. Clearly that work was continuing and was now being applied intensively to the mechanics of snow removal. This was not only the case in Switzerland; notably in the United States of America there had been a rapid development in this field during the past few years. He had tried snow testing at various times in the past 7 or 8 years and he rather envied the Author his deep snow conditions which permitted the use of a shear box 1 sq. dm in area; the best that Mr Price could manage very often was a few square inches, and even then the sample was remoulded.

134. He was not sure that he shared the views of the Author on the importance of compressibility in snow-clearing work. Croce, in Germany, had computed the work done to achieve a given change in density of a certain unit mass of snow which had been laterally confined and, using some of those figures, he (Mr Price) had found from experiments on this subject that on average only about 1 or 2% of the work done by the plough was contributed by compressibility. He thought that one had to look to other features, mainly the gravitational and inertia forces, the frictional forces and the shearing forces in the material, to account for the large draughts that one could experience on conventional blade ploughs. He thought that this also would apply to rotary snow-ploughs.

135. He agreed with the Author's general remarks on the formation of ice being more likely on bridge sections than elsewhere. However, he thought that the Author would probably agree that this was just one aspect of a complicated problem, because the general conditions under which ice formed were related very closely to the prevailing weather conditions and to the type of ice which eventually formed. The Author had mentioned the particular example of conditions of a bridge section as being due to the fact that the bridge cooled more readily than the remainder of the road. This conformed with the general trend Mr Price had observed in his experiments, i.e. that ice was more frequently experienced on roads with lower values of thermal conductivity, specific heat, and density. There were, nevertheless, rather rare conditions of weather when the opposite of this could be true, and this was the case with what was known in Britain as a type of glazed frost—the equivalent of the German *glatteis*—where there was a sudden change from a prolonged cold period to a relatively warmer one; in a case like that the bridge section would be less icy, since it would be warmed up more quickly because of its smaller thermal mass.

136. The Author had mentioned road heating as one form of remedy for ice formation. On that matter, research in Britain was probably ahead of Switzerland. One or two full-scale experiments in road heating had been carried out in Britain and, for comparison, he would like to have some details of the scheme which the Author had in mind. Mr Price thought he was right in assuming that it referred to a by-pass where they employed power outputs of the order of 8 to 14 watt/sq. ft. This was a little in excess of what would normally be employed in Britain, where it was found that a power output of 8 to 10 watt/sq. ft was of the right order. This was about what was required to balance the flow of heat radiated from the surface on a clear frosty night.

137. The use of salt was also fairly well-known in Britain, and very often it constituted the only snow-removing technique which was used. The experience was that the quantity of salt should be adjusted to the weather conditions more precisely than the quantities which the Author gave. One needed about four times what the Author recommended for dealing effectively with 3 to 4 in. of snow under 3 or 4° of frost, whereas for dealing with icy conditions in the early morning one might need only one-tenth of what the Author recommended. With regard to the Author's remarks concerning the effectiveness of chemical treatment at low temperatures, the obvious

alternative was calcium chloride in some form rather than magnesium chloride; the latter was rather troublesome from the point of view of chemical damage to concrete.

138. He was dubious about the claim that front-mounted blade ploughs could deal with packed ice without damage to the road. He felt that the most effective existing equipment that had been tried for dealing with this condition was a blade grader. It had a blade mounted in a position on the machine where the maximum vertical pressure could be exerted, and also there was a very delicate control on the level of the blade, which was very necessary in this kind of work if extensive damage to the road was to be avoided. One had to get on to the packed snow as soon as possible.

139. Mr Price showed some slides illustrating a heating grid which had been laid near West Drayton, Middlesex. It was of the low voltage type. The grid itself consisted of expanded metal, standard mesh, and could be fed with up to 55 V, which was usually considered as being safe. This particular one was supplied at voltages up to 30. It covered an experimental area of about 2,000 sq. ft. There had not yet been really severe enough conditions to test it, but it had been found that the running costs were fairly modest. The winter of 1957, of course, had been exceptionally mild, so that the costs had been exceptionally low. The total running cost for 4,000 sq. ft (two grids) had been less than £20.

140. There was also a high-voltage heating grid installed near West Drayton (which he thought was one of the first of its kind), with maximum power output of the order of 6 watt/sq. ft. Both grids were controlled so as to be switched on when the temperature of the road had fallen below a certain value, usually 2 or 3°C above freezing point, if the road was wet. If it was dry, they were not switched on until the road temperature fell below that of the air.

Mr R. A. Lovell (Deputy Chief Engineer, Ministry of Transport and Civil Aviation, Traffic and Mechanical Engineering Branch) said that in snow clearance in Britain the main weight of the burden fell on the highway authorities, with a certain amount of help from the central Government in the provision of equipment; but the requirements were somewhat more intermittent than in Switzerland, in spite of the fact that there was generally a fair amount of snow.

142. Because the needs were intermittent, it was found generally more economical to use the bladed type of plough attached to a vehicle which at other times could be used for normal purposes. For instance, such a plough could be attached to a lorry which at other times could be used for gritting. Had that sort of dual-purpose arrangement any real place in the system in Switzerland? Because this type of plough was used extensively, experience of the single-purpose rotary type of plough in Britain was limited.

143. For the winter of 1957-58 the Ministry of Transport were setting up five or six emergency snow-plough depots throughout Britain, and these would be equipped with heavy lorries with blade ploughs and also with some of the more specialized types, such as rotary ploughs, so that they would be available whenever highway authorities felt that they were in trouble and had need of more equipment than they possessed themselves. The Government would provide the equipment, but the idea was that the highway authorities themselves would provide the crews and send them to the depots when they wanted the machinery taken out. It was intended to provide proper training for drivers so that the best skill available could be used on this comparatively expensive equipment.

144. What powers were there in Switzerland to close roads so that the snow-clearing equipment was not hampered, as it was so often in Britain, by having to work while traffic was running, thus suffering from the obstinacy of many people who would insist on trying to get through at all costs. As the highway authorities and the police knew, this caused a lot of trouble and wasted a lot of time.

145. He did not think that sufficient attention was paid to the fact that even the best type of "non-corrosive" salt could cause much trouble to vehicles. In the winter of 1946-47, for example, London Transport had had a very large number of vehicles taken

out of service merely because salt had got into the mechanism underneath affecting particularly the braking system and especially the rubber hoses of hydraulic brakes. This was a serious problem in city streets, where there were numbers of public-service vehicles in operation. Another point to remember in this connexion was that the snow-ploughs themselves could suffer, and it was very important that after use they should be brought in and thoroughly cleaned down.

146. During the past few years in Britain there had been considerable progress in the development of bulk gritters using mechanical means of spreading grit. However, the question of loading was important, and was now being considered. A device was being developed for the mechanical loading of grit, and he felt that, if this fulfilled present expectations, there would be a very efficient and adequate means of gritting roads mechanically and filling the lorries when necessary without the use of the manpower that was so very difficult to get.

Mr Neville Borg (Deputy City Engineer and Surveyor, Birmingham) said that, for a great part of England, and certainly in the case of Birmingham, the problem was not so often the disposal of heavy falls but more usually the attempt to get rid quickly of relatively small falls before they became hardened by the traffic. In an industrial city the effect of traffic delays and of accidents was costly and painful and the fundamental problem in snowy conditions was to try to retain in the surfaces of the highways those running and non-skid characteristics for which they had been designed. Experience had shown that in normal weather conditions the number of vehicle accidents in which there was personal injury was about one-third of the whole. During heavy snow the proportion involving personal injury was much smaller, but that involving damage to vehicles and other property was much higher, although the average damage per accident was less because of the lower average speed.

148. Those conditions applied also on icy roads, but depending on weather conditions—which might camouflage the dangerous condition of the road—the accidents tended to be more serious. It was also interesting to note that the results of the Road Research Laboratory's studies showed that rubber-tired vehicles travelling at low speeds were more liable to skid on ice than when travelling at higher speeds. If skids occurred at the higher speeds, however, damage per accident would be greater, and it appeared that the community, by travelling slowly in slippery conditions, was probably accepting the lesser of two evils and incurring a larger number of less serious and sometimes relatively trifling accidents.

149. As other speakers had said, the urban highway engineer had to concentrate on reducing the time-lag between the first warning action on snow clearance and the actual commencement of large-scale operations, and on the accumulation of sufficient reserves of men, machines, and materials to accomplish that reduction.

150. In Birmingham a system of weather warnings from the local observatory had been in force for many years and was transmitted by code day and night to the district surveyors so that advance warnings from the central control, giving approximate forecasts, were followed (usually at diminishing intervals) by more precise forecasts, and finally by an instruction to put into action those resources that had been brought into readiness during the period of warning.

151. Since the cost of dealing with snow and ice was a factor which had to be considered in setting out to produce savings to traffic and to people, there was a limit to the state of readiness into which any large organization could be placed; therefore, the preparation for action was separated into three stages. First, during the summer, stocks of salt and grit were assembled separately in the many depots throughout the city. Snow-ploughs and gritting machines were overhauled and the system of warnings and of action messages were considered and improved, if necessary, in the light of any changes in conditions. Provisional arrangements were made with employment exchanges, contractors, and haulage firms so that extra men and machines could be found. The second stage of readiness was to prepare ready-mixed stocks of salt and grit at certain buffer depots, and to have loading shovels available at those depots day and night from

about the beginning of December. By the end of December other main depots were brought into line with loaders and, depending upon the length of time that it would take to call out drivers and men to particular depots, sleeping arrangements were made for some of them so that skeleton crews were on the spot.

152. There was co-operation between the Public Works Department and the City Transport Department. Traditionally the resources of the City Transport Department had been used for snow clearance. In the days when there were trams, those heavy vehicles with a plough fixed underneath were most efficient in clearing a path along the main roads, even if only over the tram track. With their disappearance, however, the buses had acted instead as involuntary spreaders of salt and grit. The work of clearing bus routes had been divided between the two departments so that the resources in men and vehicles of the City Transport Department should not lie idle during emergency. Atkinson gritters were supplied by the Public Works Department and operated over certain bus routes by the Transport Department, and those gritters were loaded at the Public Works depots from the stocks of ready-mixed grit and salt. There were no large stocks of salt and grit held at any City Transport depots, the Public Works Department being responsible for its supply as needed, and it was for this reason that it was vital to have stand-by crews and machines at the buffer depots to feed not only Public Works gritters but also those operated by the City Transport, whose activities in the matter were limited to dealing with a large proportion of the bus routes but none of the other roads.

153. A period of $1\frac{1}{2}$ hour had been laid down as the maximum allowable between the issue of the "action" message bringing all teams into full operation and the action itself. In those cases where crews were kept at the depots, action would be quicker than that; some districts might have anticipated the message, since, subject to an over-riding obligation to meet the $1\frac{1}{2}$ -hour period, the district surveyors had complete latitude to act earlier according to conditions in their particular areas. This was given because it was essential, first, to meet the variety of conditions that might be found within the compass of the city, which was about 13 miles from south to north and 9 miles from west to east. (Great variations both of temperature and of snow-fall were common.) Secondly, it was necessary to avoid a too inflexible system tending to reduce personal initiative. Winter gritting and dealing with various phases of frost and minor snow-falls, etc., were dealt with, of course, as a matter of routine.

154. The cost of the arrangements for producing a state of readiness of $1\frac{1}{2}$ hour was of the order of £300 per week, and this might be regarded as a very small insurance premium for what was, after all, a very short part of the year—usually about 4 to 6 weeks.

155. Would the Author give an outline of the system in Switzerland and an indication of the state of readiness which they tried to achieve?

156. During the winter of 1955–56, when Birmingham had shared with Frankfurt the distinction of being the coldest place in Europe, and when conditions had been the most severe since 1947, the total average snow-fall over the city had been only 25 in. and much of it had never been "removed" in the sense of being ploughed or collected in its loose state. The intense urban traffic, while having the advantage in certain conditions of assisting in the dispersal of snow through its mixing action with the melting agents that had been spread, was a disadvantage, of course, under severe conditions, since it compacted the snow into a thin skin of ice before removal had been possible, and it was in dealing with this condition that high costs had been incurred during that year—£4,000 per inch of snow. However, when the mileage of road (1,000) and the population (1,100,000) were considered, the unit costs per mile of road (£100) and per head of population (2s 0d) looked very much more favourable. It might be most interesting, if difficult, to take as a yardstick in future, in cities, either the cost per vehicle-mile of keeping traffic on time, or the cost of keeping accidents down to the normal rates.

157. In the Paper emphasis had been laid on the physical characteristics of snow and the design of machines able to dig it and throw it under various stages of compaction. He had no doubt that those scientific studies, on which the Swiss service was to be

congratulated, would commend themselves to those highway engineers in the north of the British Isles who had a frequent need to remove heavy falls that would justify the retention of expensive plant. For the urban conditions in England, however, where the weather varied so greatly from year to year, it seemed uneconomic to concentrate on the accumulation of expensive and specialized plant, and wiser rather to spend the insurance premium in having men, light machines, and supplies of salt in a high state of readiness in order to meet the Author's primary condition, i.e. to get the snow on the move before it was compacted. It would be interesting to have information on whether in Switzerland there was any use of burners for melting the last skin of ice.

158. The comment about preparing the roads for a snow-fall by the spreading of salt beforehand was interesting; at many times of the day this would not be effective in Britain because the intense traffic worked anything that was on the surface into the channels in a very short time, but this comment certainly drew attention again to the possible merits of dealing with falls that were predicted during the late night or early morning in that way. It was, again, a question of relative cost, but examination might show it to be practicable and well worth while to organize a rapid drenching of roads at such times. Certainly the Paper had made this amongst other very valuable points, including the consideration of heating bridges, which would become important, particularly in grade-separated roads in cities where the gradients would often be difficult. It would be interesting to know what was the Swiss practice in this respect.

159. So sensitive had the traffic system of highly industrialized Britain become that the mere maintenance of contract might be taken for granted. It was the maintenance of normal running conditions that was now set as the highway engineer's standard.

Mr F. B. Avery (Chief Assistant Engineer, Wandsworth Borough Council) described the procedure followed during snow and icy conditions in what he called a typical Metropolitan borough.

161. For a period of approximately 4 weeks before Christmas and a further 8 weeks after, gangs comprising a driver and two men reported to each of the main depots at 6.30 a.m. The gangs then loaded the lorries or attached the bulk-supply trailer gritters which were kept in the depots ready-loaded. In particularly inclement weather, however, the lorries were loaded overnight. In addition, gritting was also carried out, using spinner- and flyer-type machines, which required to be hand fed, and in extreme cases gritting was done by hand from the lorry. The gritting was carried out on a beat system dealing first with the hilly sections of major traffic routes, particularly those used by public-service vehicles, and the remainder of classified roads, totalling about 65 miles, according to traffic use. Thereafter gritting would, if necessary, continue throughout the day, reloading being carried out at the nearest depot or from strategically placed grit-bins. In Wandsworth this left a further 180 miles of other roads which might ultimately require attention. These were, again, dealt with on a priority basis, e.g. hilly roads being treated first and thence according to a prearranged rota.

162. It would be seen that this procedure was automatic in its initial operation, and could be adjusted by the District Works Superintendents according to the severity of conditions. At the end of the working day, if it was anticipated that conditions might warrant it, personnel were detailed to continue gritting work or warned to report later for this purpose. In specific cases of an emergency call from the police to a depot, for example, late evening or early morning, the snowball arrangement for calling out the gangs was operated, and the appropriate roads were then dealt with. If, however, the call should be of a general nature, all available drivers and men would be called out by the same system, and would follow the procedure for gritting and clearing which he had outlined already.

163. From experience, it had been found to be beneficial for snow clearing to use a mixture of salt and shingle, the proportions being adjusted according to the severity of conditions and, with the aid of traffic, this was normally sufficient for the snow to thaw and drain off in the usual way.

164. The clearing of footpaths was mainly confined to shopping areas, and the

snow was placed in the carriageway clear of channels and gullies for collection by lorries and disposal, by arrangement with the County Council, into the main sewers.

165. Considerable thought had been given to the use of snow-ploughs and blowers. With regard to ploughs, however, it was felt that in the Metropolitan area greater disadvantages resulted from their use owing to the compaction which they caused and the subsequent disposal of the snow, which must necessarily remain on the carriageway pending removal. Snow-blowers were not considered to be suitable for use in built-up areas.

The following contributions were submitted in writing.

Mr Henry Foster (City Engineer and Surveyor, Sheffield) observed that the Paper was an interesting combination of theory and practice as applied to snow clearing in Switzerland. He proposed to confine his observations to some of the practical aspects of snow clearing, for he thought that in Sheffield—indeed, throughout Great Britain—there was little purpose in making calculations on the properties of snow when in any case a large variety of plant was not available and when climatic conditions (and in consequence snow conditions) might change from hour to hour, day and night.

167. He agreed entirely with the Author that the best and most economical snow clearance was secured by the plough. This was their basic weapon in Sheffield. They had a complement as followed:—

Thirteen Harberrry ploughs. This was the best plough they had for general utility. It was spring loaded, had a strong light blade, and it had a great advantage in being easy to fix and did not require any heavy undercarriage.

Twelve "Canadian"-type ploughs, made in their own workshops for heavy work. This type of plough had a disadvantage of requiring a heavy undercarriage which had to be fixed to the lorry in advance and which therefore had to be carried about all winter ready for any snow emergency.

Twelve "Dutch"-type sectional ploughs. This was a light plough but it had been found, in use, to be easily damaged, and was therefore being abandoned.

Fifteen Fordson tractors, each fitted with dozer blade. These were very manoeuvrable in congested city streets and were useful in clearing secondary-street ends which had been blocked by the bigger ploughs ploughing the principal routes.

Twenty farm ploughs—as referred to later.

Two Bros snow-blowers. These were fitted to the front of Fordson tractors and had been very useful in widening a single line clearance in rural areas, but they were not very successful in city streets where the snow, being wet and salted, tended to choke the chute.

One Aveling-Austin Grader—power bladed.

168. The total of adopted roads in the city of Sheffield was 701 miles. The average annual cost of snow clearing and gritting was about £55,000, though in one year it had exceeded £106,000.

169. In 1947 they had had a total depth of snow-fall near the city centre of 4 ft 4 in. In 1955 they had had falls of 15 in. and 22 in.; in 1956 falls of 6 in., 6 in., and 12 in.; in 1957 of 8 in. (6 in. in 4 hours) and of 7 in. (6 in. in 7 hours). The depth of fall was not the major factor in creating difficulties; a light fall which was dry and powdery, with a light wind, could create serious drifting. This, he thought, was the major problem for road designers to have in mind.

170. No attempt was made in Sheffield to clear all the highways in the early stages of a heavy snow-fall. Priority was given to the immediate city centre (about $\frac{3}{4}$ mile dia.) and to bus and tram routes (about 173 miles). This would include practically all classified roads. After this (and after the successive ploughings of them if continued snow-falls made it necessary), secondary routes were cleared. All this work in the early stages was by plough of one form or another.

171. The problem in Sheffield was unusually difficult because it presented a combination of town and country conditions. They had many miles of roads across moorlands

at altitudes up to 1,300 ft above Ordnance Datum and they had a great part of the city at about 100 ft above O.D. In consequence, heavy blizzards might be occurring over one area of the city while the main depot and the remainder of the city had no snow at all. Or again, the upland snow might remain hard with frost for weeks or thaw slightly during the day to freeze again at night, giving very slippery conditions, while the snow in the lower areas (if any had fallen at all) might have been softened by the salting and have melted away. This called for frequent inspections and variations in the method of attack from district to district and hour to hour. The maximum use was made of forecasts both by their local weather man and the Air Ministry, but in very many cases experience alone could decide whether to continue to plough or whether to salt and leave it to nature.

172. Thus, flexibility was the essence of the Sheffield organization. The whole organization must be such that it could swing into operation at any time of the night or day. Every winter a full stand-by for salting and gritting was maintained during non-normal working hours. This was the first line of attack on snow, for prior salting was invaluable if and when ploughing had to be done. This stand-by consisted of five "Atkinson" gritters, twelve Sheffield-designed gritters, with sixteen "Glotrac" gritters in reserve. It was capable of salting and gritting about 200 miles of road in a few hours. In the case of frost likely to cause icing during the night or early morning, gritting and salting the roads was immediately begun on predetermined priority routes. The action taken was based on the weather reports, and on actual conditions as reported by the police, motoring organizations, the City Transport Department, district foremen, and others. If conditions changed during the night and snow began to fall to an extent that made further gritting useless, a change-over was ordered from gritting to snow-ploughing; and the night foreman prepared additional ploughs for the day men to take over. During normal working hours the whole of the department's direct labour organization, about 1,300 men, and plant, would become operative if necessary, dependent on conditions.

173. If the storm continued, ploughs were worked continuously and might be employed during the night, though night ploughing was avoided as far as possible because it was a dangerous business, especially in outlying areas or poorly lighted streets, where ploughs were liable to damage with more loss of time than gain. Day-light ploughing was by far the most satisfactory.

174. The main aim of the night organization was to aid snow clearance by salting and to achieve as much snow clearance as possible in the early morning before the traffic began to pad the snow down; for once it was padded down, removal became very difficult.

175. The Author had pointed out that the plough must be rigidly connected with the vehicle pushing it forward so that its vertical motion in relation to the roadway was not affected by variable resistances in the snow; experience in Sheffield fully confirmed that view. The most effective type of plough in use in Sheffield for heavy and packed snow-falls was the power-bladed Aveling-Austin grader; it was so effective for this type of work that serious consideration was being given to the possibility of designing a blade which could be rapidly fitted to an ordinary motor lorry in front of the driving wheels, but behind the front wheels, hydraulically operated from the hydraulic tipping gear. It was not economic to keep more graders than could be used normally merely to be available for snow conditions.

176. In Sheffield it was extremely uncommon to call upon the assistance of public contractors for snow clearing, since the department had a large direct-labour organization, but experience through the years had proved the effectiveness in the outlying areas of the Sheffield practice of using farmers' own tractors fitted with snow-ploughs. Under this system the department provided the farmer with a plough which he kept on the farm and which could be very easily fitted to the usual farm tractor; he was shown how to fix it, and he was then given a route which he was expected to plough immediately snow began to settle, without waiting for further instructions, and he was paid for the hours he worked. Arrangements were made for him to be contacted during those

operations so that if necessary he could be moved to adjoining or more important routes. This system had worked very well during the past 10 years; many routes which would be most troublesome and difficult to deal with if left till the snow padded or accumulated were effectively ploughed by the farmers often in the early morning before traffic began.

177. Where routes of importance ran from the area of one local authority to that of another, it was essential for co-ordination to be arranged between the two local authorities so that each could help the other, especially in hilly districts like those of Sheffield and its neighbours, and where uphill ploughing could be extremely difficult. Usually the authority with the plough at the top of the hill agreed to proceed downhill in the area of the adjoining authority until contact with neighbouring ploughs was made.

178. It was felt that most of the foregoing considerations with regard to snow clearing would be well known to those who were accustomed to dealing with this problem. The main consideration which he thought should be in mind in a study of the snow problem was as to how it was possible in designing the new main highway system for the country to avoid the worst consequence of heavy snow-falls. This consequence usually arose not directly from the fall of snow itself but from drifting consequent on wind. In Sheffield the maximum depth of a single snow-fall was about 22 in.; usually it was between 6 in. and 12 in. If such snow fell without wind (a rare occurrence) it was relatively easy to deal with, provided a quick start could be made before traffic had padded the snow down.

179. But the major problem was that of drifting. Almost invariably a snow-fall was accompanied by wind, and a 6-in. fall in those circumstances could lead to serious drifting. This consideration had been brought home to him very strongly in looking at a deep cutting on the new Preston By-pass where a long cutting, about 50 ft deep and 250 ft wide, was in process of construction. Such a cutting, particularly if at right angles to the wind direction, would certainly cause a reduction in wind velocity and (in snow country) a consequent deposition of wind-blown snow. The drifting would be particularly bad if the storm had been preceded by a light fall which had thawed slightly and then frozen. These conditions provided a glazed sliding surface across which fresh powdery snow blew like a white dust-storm, with all the snow piling into cuttings or against buildings. Therefore the provision of snow-fences as a temporary preventive of such drifting until tree barriers could be planted and grown seemed to be essential at cuttings on new motorways in snow country. The snow-fences in Sheffield had proved very effective indeed. It was considered that tree barriers should consist of a wide band of trees, possibly 30-40 yards deep. The distance back from the cutting would depend on experience of the district and the lie of the road. The type of tree would also probably depend upon the district. In the Sheffield area Scotch firs with beech, poplar, sycamore, and larch inter-planted would probably be best. It was felt that with proper advice, perhaps from the Forestry Commission, the planting of suitable trees might be made to show a profit and a useful addition to the national timber resources. Rhododendron of the hardy type and thorn bushes intermingled with the trees would also seem to be necessary. Where the routes of future national motorways were known and deep cuttings were to be expected, it would seem worth while to consider the planting of those tree belts now in advance of the execution of the work.

180. It was difficult for those not accustomed to snow conditions such as were experienced in Sheffield to appreciate that in some parts of the country even really big cuttings could be completely filled with snow where the snow was dry and a steady wind was blowing. Such a state of affairs might well be an annual occurrence and would prove very difficult of clearing with the type of equipment at present available in England. The rotary-blower type as described by the Author would probably be the solution, though with really deep cuttings and with the snow becoming wet and soft, as one often got it in Britain, even the blower would be in difficulty. It also seemed important, therefore, in planning new motorways to ensure that an easy exit from them on to the secondary highways was available near the really deep cuttings. Such exits could perhaps be designed to be opened during times of snow. It seemed also that great

attention should be paid to drainage, with adequate soakaways to prevent flooding during rapid thaws of large accumulations of snow, since the normal gully outlets would be covered by snow during most of the thaw.

181. It seemed that in Switzerland a considerable quantity of expensive specialized equipment was used every winter, and no doubt used to good effect, but in Britain that would be regarded as extravagant, at least until there was a system of motorways. Perhaps to continue snow clearing with inferior tools was being "penny-wise, pound-foolish", having regard to the amount spent each year on snow clearing. But if, in Britain, more was to be spent he thought that it should be on the grader type rather than the blower type. At present it was the practice to have dual-purpose equipment, with the result that the ploughs in the main were fitted to lorries which, except in times of snow, were on normal departmental work. One of the difficult decisions which had to be taken when snow began to fall was whether or not ploughing would become necessary, for fixing ploughs and then unfixing was wasteful of time and money if ploughing did not prove necessary.

182. Without Government aid, most local authorities in Britain at the present time would not be in a position to buy the specialist equipment which the Author mentioned, with the possibility of such plant standing idle for perhaps 11 months of the year, and in some years not being used at all. Where storms were continuous and work must be carried on for days or weeks, the welfare of personnel was most important and arrangements were made in the Sheffield organization for the supply of hot drinks and meals where necessary. It was also important for supervisory staff to share and to be seen to share the conditions of cold and hardship which the men endured. They were very fortunate in that a great proportion of their men turned out, often in appalling conditions, and at off-duty times, to fulfil the duty of snow clearance; for even after the ploughs had done their best, work by shovel was often necessary—to widen deep drifts, to clear gullies and soakaways (especially in places liable to flooding), and sometimes to dig out the ploughs!

Mr G. F. Garnett (County Surveyor, Northumberland) thought that the Paper inevitably gave rise to the comparison between the problems in Switzerland and in Great Britain and the methods of dealing with them. In some parts of this country there was some snow every year, but there was a tremendous variation in the conditions that could prevail in different years. No doubt it was this variation that had prevented the adoption of the same approach to the problem as in Switzerland and the development and provision on an adequate scale of plant specially designed for snow clearing.

184. The idea behind the organization of the Winter Service was admirable and he felt that some original research on the properties of the types of snow met with in Britain would be of great benefit and would lead to a better understanding of the problems and to the achievement of a better design of plant for its removal.

185. He noticed the importance placed on compressibility and was sure that the Swiss research and development based on the avoidance of undue compression was correct; this was borne out by the performance of their machines.

186. It was interesting to note the application of salts before the frost or snow occurred and this would be of value in assisting the clearance right down to the road surface, a standard of clearance for which there was an ever-increasing demand. Here again the great variation in conditions in Britain from winter to winter and during any one winter made this practice impracticable. Probably the best that could be done was to start gritting with a salt mixture as soon as possible after the snow started to fall.

187. As the Author had stated, the most economical clearance was achieved by means of the plough, and no doubt the plough would always be the main tool. But when continued drifting occurred conditions worsened after each clearance by plough. The depth to be cleared increased as the higher snow-walls filled up, there was no space available to which the snow could be pushed and complete blockage could result. In the case of a sunken road the problem became extremely difficult and in an area where

the boundaries were dry stone walls a serious amount of damage could be done. In these conditions equipment of the milling-centrifuging type would be invaluable.

188. Two years ago Mr Garnett's deputy visited Switzerland to examine the performance of various kinds of plant and, as a result, his council acquired some small Rolba machines and some Peitl ploughs, but the real need was for an adequate number of the larger machines.

189. It was very important to bear in mind that practically all the plant used in Britain for snow clearance was improvised. Ploughs were fitted to lorries primarily designed for load carrying not for snow clearing, while bulldozers were primarily for earth moving on site.

190. When severe snow conditions occurred then the demand from all sections of the public was for immediate clearance, but the public memory was also short and the really severe conditions did not occur with sufficient regularity for there to be a demand for proper provision of the means for dealing with them.

191. If snow clearing in Britain was to be treated seriously and to be carried out to the standard demanded by the public when the actual emergency arose, then what was really required was the provision of equipment designed primarily and essentially for that purpose to an adequate scale, a scale which had not so far been envisaged by the authorities.

Mr W. E. Weisflog (British Representative of Rolba Company Limited, specialists in snow-clearing equipment, Zurich) remarked that in § 2 the Author gave figures of the cost of the Winter Roads Communication Service in Switzerland, and in the discussion Mr Mehew and Mr Vallis had given comparative figures for their counties in Great Britain. The latter showed that in certain years the cost of a winter service in English counties had been about the same proportion of the total cost of road upkeep as in the Swiss Cantons. It would now be interesting to know how much of the cost could be attributed to mechanically operated snow-ploughs and how much to manual labour. From what he had seen, the standard of the snow-clearing organization in Britain was high and probably equal to Swiss standards; but snow clearance by manual labour and outdated or unsuitable equipment such as bulldozers, excavators, etc., still played a large part in Britain. Accordingly, large sums were spent on snow clearing, as high as £500,000 in one county in a bad year, and he wondered if some of this money would have been saved if a bigger proportion of it had been spent on modern plant. A number of British authorities had recently acquired some of the smaller types of snow-clearing machines (rotary snow-ploughs) but on the whole it seemed that British engineers were hesitant about making use of the mechanical devices which were now available. This was rather surprising since the modern plough made it much easier and quicker to deal with heavy snow conditions.

193. In §§ 20-26 the Author dealt with the properties of snow. These were indeed of the greatest importance with regard to snow-clearing machinery (rotary snow-ploughs) and the Author's statement that compression "should be avoided as much as possible" (§ 20) could be fully endorsed. Especially in Britain, the "wetness-of-snow" factor (§ 24) was the crucial factor. By making enquiries from engineers who had already tried out the type of machine in question, engineers who wanted to purchase machines could make sure that they were able to deal with wet snow.

194. In §§ 35-39, the use and construction of blade ploughs was discussed. In Great Britain, it was, of course, necessary to remove the snow completely from the carriageway, especially compacted snow, and, as the Author had said, it was essential that the blade ploughs were rigidly connected to the propelling vehicle. In the case of Continental blade ploughs recently acquired by Northumberland County Council, the connecting plate, into which the hydraulic gear fitted, was welded to the vehicle chassis. This made it possible for the blade plough to be pressed hydraulically on to the road surface. These ploughs, which weighed approximately 3,300 lb. (including hydraulic lifting and lowering gear) were fitted to Mack lorries, an ideal type of vehicle for this type of blade plough.

195. Sections 40–53 dealt with the rotary snow-ploughs (“clearing machines”). Here the requirements clearly differed in the two countries. Snow depths of 10–15 m (30–40 ft) were, of course, extremely rare in Britain and it would appear that a depth-capacity in a rotary snow-plough of 3–4 ft was quite sufficient for British snow conditions in average winters. Large-sized caterpillar equipment was, therefore, not normally needed. If the snow depth exceeded 3–4 ft on relatively short stretches of road, this could easily be cleared by a pedestrian-operated machine (hand machine) with caterpillar wheels.

196. Larger snow-clearance machines (rotary snow-ploughs) on heavier four-wheel-drive trucks (up to 180 h.p.) had been developed but these ploughs were very expensive and their use was limited to wide roads without sharp bends and to roads the gradients of which were not too steep, or to use on aerodromes.

197. In § 44, snow-clearance machines were classified into:

- (a) hand machines;
- (b) medium-heavy machines; and
- (c) heavy machines.

198. In Britain excellent results had been achieved from a close-co-operation between hand machines and V-ploughs (double-sided ploughs). The hand machines were used for making a cut into the snow-drifts for the blade ploughs to follow.

199. The medium-heavy machines (approximately 100 h.p.) seemed to be the ideal size of rotary snow-plough for clearing a large mileage of roads under British snow conditions.

200. Heavy machines, especially heavy machines on caterpillar tracks, were not justified in Britain.

201. Referring to the classification (§ 45) into: (a) centrifuges, (b) milling-centrifuges, and (c) millers, Mr Weisflog thought that type (a) was, as the Author stated, a machine for very soft snow—he would rather call it dry powdery snow—and was not designed to cope with the wet snow got in Britain. Type (b) was the type manufactured by his own company. Type (c) was a special tool for removing old hard snow (as was found when opening Alpine Passes in the spring), which was seldom experienced in Britain. The intake of type (c) was very limited, since the cutters were fixed on a horizontally mounted closed drum (see Fig. 14). Types (a) and (c) might be useful in special snow conditions, but, in his opinion, the best machine for Britain was one which would deal efficiently with all types of snow.

The Author, in reply to Mr Taylor, said that by “simple equipment” he meant snow-ploughs and possibly manually operated tools. On highways in the country the snow may be cleared all through the winter with the snow-ploughs. In the larger towns hand tools were also required, to load the snow on to lorries when there were not enough mechanical excavators available. Such “simple equipment” was not sufficient to keep roads at high altitudes open all through the winter.

203. Turning to Mr Taylor’s question on snow fences (§ 66) the Author said that where circumstances allowed, permanent structures to deal with snow-drifts were preferred to mobile equipment, because, once erected, camps were not required and maintenance costs were much less. In Switzerland protective structures against snow-drifts were never more than 2.5 m (8½ ft) high. For permanent snow-fences hedges and rows of low bushes were considered suitable, and were planted at appropriate distances from the edge of the road. In farming districts permanent installations were not in general use and they were built mostly in places where there was a constant tendency for drifts to be built up from the same direction. High trees were not suitable.

204. Mr Mehew and others had asked the meaning of the term “snow-bridge”. It was unfortunately the only possible translation of the word “Schneebrücke” and as such did not express the usually intended meaning, even when a single meaning was intended. The Author, when using the word was referring to the layer of compressed and compacted snow created by the traffic. This layer of snow was often converted by the

traffic, and also by the weather, into a layer of ice, an "ice-bridge". The term was disputable and the Author felt that its use could be discontinued.

205. The rotary plough "Peter", shown in Fig. 14, was particularly suitable for removing hard snow. It was possible, for example in deep layers of snow, for fairly thin ice-crusts, or ice-lenses, to be formed and these were easily dealt with by the machine. Frozen ridges left by snow-ploughs along the outer edge of the swept track were effectively removed by the machine. However, the general principle followed in Switzerland was that snow must be cleared before it freezes or turns into ice. When this machine was used in the spring-time clearing of roads in the high mountains, there was usually a layer of ice, about 10 to 15 cm thick. The machine *could* remove it, but that was not what was actually done. To begin with it would be very expensive, and the road surface might suffer damage. Moreover, that layer of ice had usually melted away by the time the work was finished. The ice on the road was sometimes thawed out by the application of salt, but it was better practice to clear the snow before the ice formed. The removal of ice with the machine would be an extremely expensive process.

206. The problem of recovering the grit (§ 72) had not yet been solved in Switzerland. Usually it was washed away by the road supervisors. In towns the street-washing machine was used. So far as the Author knew there were no special machines for this purpose in operation in Switzerland.

207. Damage by frost (§ 75) was a serious problem in Switzerland, as elsewhere. In the spring of 1957 alone the damage amounted to about 200,000 francs on a 40-km length of road in the Author's own district. The causes, in this case, had been frequent precipitation and temperature changes (thawing and freezing), and also the porosity of the road surface (old and porous surfaces), as well as the ever increasing use made of the roads in winter. He believed that the principle cause was the porosity of the surface. Where the same surface had been treated, in previous years, with a bituminous material, the damage had not occurred. In other cases damage had occurred where sunshine and air movement were lacking, that was to say, in afforested areas. Such areas were also at a disadvantage in winter because of the earlier and later formation of sheet-ice.

208. For protection against avalanches and snow-slides off the slopes (§ 76), protective fences or avalanche galleries were built. The fences were built either to keep small slides off the road, or to prevent the slides from starting at all. In the latter case the fences were built right into the area where the slides originated, placed next to each other and behind each other over the whole area. In that way the snow was held in place and prevented from beginning to slide. The foresters engaged in building them referred to them as "snow-bridges"—another meaning of the term discussed in § 204. A Code of Standards for this work was in course of development but could not be more than a guide, because dimensions must depend on local data such as height of snow, steepness of slopes, nature of drainage basin, and so on.

209. In answer to Mr Vallis (§ 81), the problem of service in winter had been given proper attention only since the 1939-45 war. Owing to the diversity of authorities concerned, cantons, boroughs, and so on, the organization of winter service was not yet fully developed in all respects. Also, the problems in town and country were so different that an integrated organization would not be practicable.

210. The Author could not tell Mr Toyne (§ 115) the average number of kilometers that a snow-plough had to deal with in Switzerland. In Canton Uri, where snow clearance was an important problem, the figure was at present 18 km. That was excessive and 8 to 10 km would be more satisfactory. In the case of towns and the larger villages the best holding known to the Author was one plough to 4 km. The single-bladed type was the most commonly used; the symmetrical prow-type was used only to deal with deep snow at high altitudes.

211. The new types of plough (§ 116) had blades which could be raised and lowered hydraulically, and did not rest on rollers. These blades could be pressed to some extent against the road surface and would remove hard-packed snow. In formulating a Code of Standards, the Winter Service Commission intended to include in their specifications

for standard snow-ploughs that the blades must be capable of being pressed against the road surface in this way.

212. With regard to Mr Toyne's comment in § 121, there was a shortage of labour in Switzerland and so snow clearing was mechanized so far as possible.

213. Every possible effort was made to prevent "traffic hardening" (§ 126) by starting to plough as soon as the snowfall began. In the towns good results had been achieved by spreading salt *before* the snowfall, to prevent the snow freezing on to the surface. The snow stayed soft and could easily be removed. Once the layer of snow had become compressed and hard, it did not pay to remove it with machinery. There were machines, called "snow-planers", with which it could be done.

214. So far, only one bridge had had a heating system installed (§ 130). The matter was at present in the experimental stage and no data were available.

215. For the design of snow-screens (against drifts) and snow-fences (against snow-slides) (§ 131), standards were at present being developed by the Winter Service Commission. These standards would presumably be published by the winter of 1958-59. Avalanche galleries have to be designed according to the circumstances.

216. Most of the machines and equipment used for snow-clearing were multi-purpose (§ 142). Ploughs and clearing assemblies were dismantled in summer and the power-vehicle (lorry, Jeep, or Unimog) could be used for other purposes. However, snow-clearing machines on tracks, used for clearing high mountain roads, and also certain types of manual clearing machines, made an exception to this rule.

217. In Switzerland only the police could close a road (see § 144) and then only when it was dangerous or impassable. In the towns obstruction to snow clearing operations was caused mainly by parked cars, but so far it had not proved possible to remedy the evil.

218. In reply to Mr Borg (§ 155), operational readiness could not be systematized. It depended on the tasks and on available facilities.

219. Flares (§ 157) were not used in Switzerland to melt the snow.

220. The Author regretted that he could not make full and complete comment on all the points raised in the discussion and had addressed himself only to the more direct questions which had been asked.