# PREDICTION OF SNOW ACCUMULATION ON ELEVATED GUIDEWAYS FOR GUIDED GROUND TRANSPORTATION

## SYSTEMS

W.F. Hayes and H.G. Tucker        F.H. Theakston

Railway Laboratory            F.H. Theakston and Associates
Division of Mechanical Engineering    Guelph, Ontario
National Research Council
Ottawa, Ontario

## ABSTRACT

Advanced passenger transportation systems having vehicles running on weather-exposed elevated guideways are under development in North America, Western Europe and Japan for both urban and intercity applications.

The practicality of such transportation systems operating in regions subject to significant snowfall has been investigated in a water flume using 1/66 scale models of representative dual-track elevated guideways having 'U' channel, inverted 'T' and flat-topped running surfaces, wherein the wind-blown snow is simulated with fine sand. The principal results of this investigation are presented with particular reference to the effectiveness of cross-wind induced clearing of dry snow from the flat-topped guideway configuration and to the estimation of the wind velocity above which such clearing occurs.

The probability of days per winter season when any specified snow depth on the running surface of a flat-topped elevated guideway would be exceeded is determined. This probability is based on the analysis of extensive winter climatic records for the Canadian Toronto-Montreal corridor and accounts for the clearing of dry snow from the flat guideway surface above the cross-wind velocity predicted by the snow simulation study. The results of the probability study indicated that, provided the guideway is flat-topped and well-exposed to the prevailing winds, a minimal disruption of vehicle operation due to guideway snow accumulation would be expected except for vehicles having very small running clearances.

## INTRODUCTION

Advanced passenger transportation systems having vehicles running on weather-exposed elevated guideways are being developed in a number of the industrialized countries for both modest speed urban and high speed intercity applications. Examples of such transportation systems incorporating elevated guideways are:-

- the intermediate capacity urban system ALRT (Advanced Light Rapid Transit) developed by the Urban Transportation Development Corp. (UTDC) of Kingston and currently being installed in Vancouver, B.C., to be completed for the 1986 World Exhibition in that city.

- the high-speed intercity linear synchronous motor propelled electrodynamic Maglev system, incorporating superconducting magnets, which is being developed in Japan by Japanese National Railways. A 7 km full-scale elevated test track has been operational since 1978.

- the high-speed intercity linear synchronous motor propelled electromagnetic Maglev system, incorporating conventional electromagnets, which is being developed in West Germany by the Magnetbahn Transrapid Consortium. A 21 km section of full-scale elevated test track has been constructed.

- the low speed electromagnetic Maglev "people mover" system being installed at Birmingham Airport in England by British Rail.

Examples of operational passenger transportation systems incorporating elevated guide-ways are:-

- the rubber-tire wheel-on-beam conventional electric motor driven monorail system between downtown Tokyo and Haneda Airport in Japan

- the rubber-tire wheel-on-beam conventional electric motor driven monorail systems at Disney Land and Disney World.

The practicality of operating elevated-guideway based transportation systems in regions subject to significant snowfall requires investigation since virtually all of the existing elevated guideway systems are located in temperate regions while some of the potentially lucrative locations for such systems are subject to severe winter weather conditions (e.g. the north eastern region of North America where many major population centres are located). In particular, the frequency of occurrence of guideway snow drift accumulation exceeding the operational clearance of the vehicles on elevated guideways requires evaluation such that the economic impact of snow plowing and/or snow-induced system downtime may be realistically predicted.

This paper reports a study on the potential for wind clearance of snow from three possible guideway configurations for a high-speed Maglev system currently being investigated for economic and operational feasibility in the Toronto-Ottawa-Montreal corridor which typically experiences relatively severe winter snow conditions. The specific guideway configurations investigated are comprised of inverted 'T', 'U' channel, and flat-topped box cross-section beams elevated on vertical columns at least six meters above ground level. Although the probability data calculated to predict weather-induced downtime of the elevated guideway transportation system is particular to the Toronto-Montreal corridor, the method of such prediction is quite general.

DESCRIPTION OF PROPOSED CANADIAN MAGLEV SYSTEM

The economic feasibility of an electrodynamic Maglev system design concept, generally as per Hayes (1977) and Eastham (1977), for the 600 km traffic corridor between the population centres of Montreal (2.3 million), Ottawa (0.7 million) and Toronto (2.5 million) is being investigated. Although the corridor between these centres has a relatively low population density, there are numerous secondary road and railway crossings as well as one major and several minor river crossings. A route alignment (Figure 1) was selected (Section 3.2 to 3.4 of Lake (1980)) without recourse to tunnelling to incorporate sufficiently large vertical and horizontal radii of curvature outside of the downtown urban areas to allow for a sustained cruise velocity of at least 450 km/hr without passenger
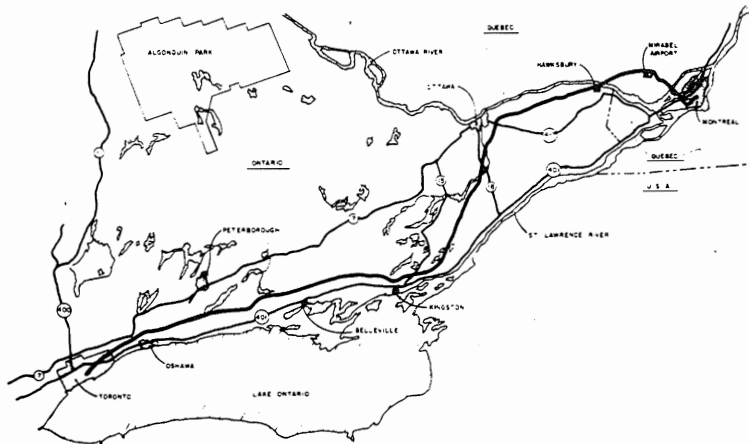


Figure 1.   Proposed Toronto-Montreal Corridor Maglev System Route

discomfort. The corridor climatic conditions are characterized by seasonal temperature extremes of +40°C to -40°C, by ice storms in the early and late winter, by heavy snow storms throughout the six month winters and by significant frost heave of the ground in the spring.

The concept of electrodynamic Maglev transportation is based on the levitation, guidance and propulsion of vehicles by means of intense magnetic fields generated by on-board super-conducting magnets interacting with guideway-mounted conductor sheets or coils and with the activated guideway stator windings of the linear propulsion motor. The intense magnetic fields generated by the super-conducting magnets allow for efficient operation at vehicle-guideway running clearances of 10 to 15 cm which permit significant relaxation of the guideway construction tolerances and permit accumulation of significant snow on the guideway surface without affecting system operation.

A dual-track elevated guideway supported on single piers having deep pile foundations to minimize frost heave effects is proposed for substantially the full route length ("At grade" track construction in cuts is estimated to be necessary only over about 1% of the route length as per Appendix 3A of Vol. 1, Lake (1980). The elevation of the guideway eliminates the operational safety concerns of level crossings inherent in "at grade" construction.

The optimization of a guideway configuration involves tradeoffs between material and construction costs, system operational safety and, in the context of adverse winter weather operation such as the Toronto-Montreal corridor, susceptibility of the guideway "running surface" to snow accumulation. The original Japanese National Railways (JNR) electrodynamic Maglev test vehicle straddled an inverted T-shaped running surface whereas the current JNR test vehicle is mechanically contained in a 'U' shaped guideway. Although either configuration would appear practical for the relatively temperate Tokyo-Osaka corridor, neither is anticipated to be appropriate under the winter snow conditions typical of the Toronto-Montreal corridor. It has been advocated that any elevated guideway system built in an area of significant snow should incorporate a flat-topped running surface fully exposed to the prevailing winds to maximize the recognized wind-induced snow clearance effects. Accordingly, the snow accumulation characteristics of the flat-topped guideway in the presence of cross winds were extensively investigated while the inverted 'T' and the 'U' channel guideways were briefly investigated for purposes of comparison.

SIMULATION TECHNIQUE FOR INVESTIGATION OF MODEL GUIDEWAY SNOW ACCUMULATION

The snow accumulation on elevated guideways in the presence of cross wind was investigated using 1/66 scale models (Figure 2) in the University of Guelph "snow simulator", Theakston (1975), the scale being chosen to ensure that flume blockage effects were not significant. The "snow simulator", which is shown in Figure 3, is an open channel water flume 7.6 m long, with a 91 cm wide by 46 cm deep working section having transparent side walls for observation purposes. A constant speed pump supplies water to the flume through an entry region fitted with a flow-straightening honeycomb structure and providing a flow area contraction ratio of approximately 9:1. The water velocity through the working section is controlled over a range of approximately 0.1 to 0.4 m/sec by raising or lowering a vertical downstream gate. Dry snow is simulated by silica sand (#60) which can be uniformly distributed into the flowing water at a regulated rate by the overhead hopper as shown positioned above the flume upstream of the model location in Figure 3.

The simulation of blowing snow by sand in flowing water for the investigation of snow accumulation on elevated guideways has the following practical advantages:-

- the simulation technique is readily manageable in that the wet sand remains in place after draining the flume such that the resultant "snow" accumulation may be readily measured, photographed and/or otherwise recorded

- the particle electrostatic adhesion problems which tend to plague wind tunnel snow simulation techniques are avoided

- direct visualization of the guideway-induced flow by means of the injection of aluminum powder mixed with detergent and water into the flowing flume is feasible.
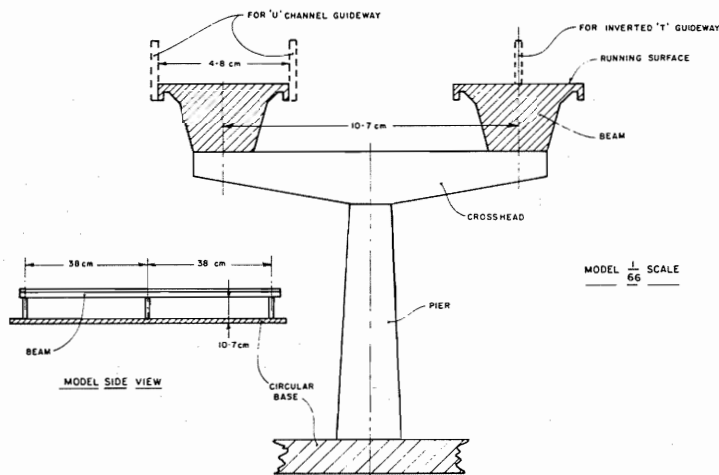
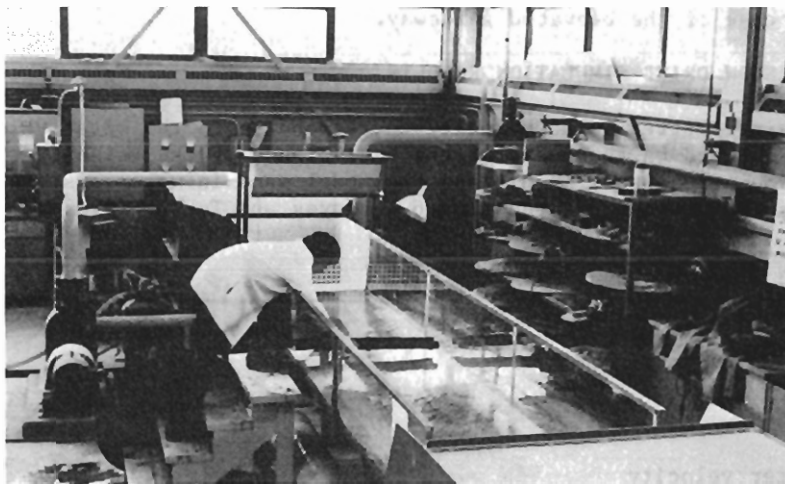Figure 2. Elevated Dual Track Guideway Model



Figure 3. University of Guelph Snow Simulator Facility

Further, this technique provides direct equivalence of the resultant snow drift depth distribution, as per Hayes and Tucker (1983), provided that:

- the model is uniformly geometrically scaled (surface roughness scaling not essential)

- the body being investigated is of sufficiently bluff cross-section normal to the incident fluid flow direction and sufficiently short along the fluid flow direction that the body-induced flow turbulence strongly dominates any fluid viscosity-induced effects. (Such body shape effects provide for equivalence between model and prototype independent of fluid flow Reynolds Number equivalence as considered at length in Hayes and Tucker (1983).) The typical bluff shape of the cross-section of guided ground transportation system elevated guideway beams ensures that this criteria for steady-state snow drift depth simulation will be satisfied at least for incident wind directions approximately normal to the guideway length (i.e. for cross wind conditions).

Further, this technique allows for velocity scaling from the model sand-in-water to the full-scale snow-in-air system in accordance with the velocity similarity parameter as per Hayes and Tucker (1983), defined in the following section.

Accordingly, the simulation technique for guideway steady-state snow accumulation was to introduce sand into the flowing flume at an appropriate upstream location such that the model guideway beams were continuously surrounded by water containing suspended sand particles. The process of sand particle settlement onto the model guideway running surface and the simultaneous process of sand particle transport by saltation across the running surface was allowed to proceed until a steady-state condition was realized. The resultant simulated steady-state snow drift depth distribution across the guidway beam was measured and the sand deposit photographed after the flume was drained. Such a simulation technique tends to generate pessimistic results in that it produces the maximum resultant steady-state snow drift accumulation which could be realized with any given cross wind velocity when the supply of snow is unlimited (i.e. independent of the total snowfall). In this respect, the process of snow accumulation on the narrow running surface of an elevated guideway which is subjected to a cross wind differs fundamentally from that for snow drifting across extended open terrain. In the case of the guideway, all of the dry snow particles which are locally exposed to a cross-wind higher than the threshold velocity will be transported by saltation towards and ultimately over the downwind edge of the guideway beam such that the same steady-state snow drift accumulation will always eventually be realized for any given cross wind velocity provided there is a sufficient supply of falling snow. By contrast, in open terrain snow drifting the resultant snow accumulation will be dependent upon the total supply of snowfall since the drifting process continuously redistributes the supply of snow rather than removing the excess supply from the area of interest as in the case of the elevated guideway.

GUIDEWAY RESULTANT SNOW DRIFT SIMULATION RESULTS

The full-scale free stream wind velocity corresponding to the water velocity measured in the flume was predicted on the basis of the equivalence of the velocity similarity parameter between the actual snow-in-air and the model sand-in-water systems as per the following relationship developed as equation 6 in Hayes and Tucker (1983):

$$V_p = 0.55 \ V_M \ \frac{\sqrt{\dfrac{\rho_{SN} \ d_{SN}}{\rho_A}}}{\sqrt{\left(\dfrac{\rho_{SA} - \rho_W}{\rho_W}\right) d_{SA}}}$$

where

$V_M$ = flume water velocity

$\rho_A$ = air specific weight = 0.00122 $g/cm^3$

$\rho_W$ = water specific weight = 1.00 $g/cm^3$

$\rho_{SA}$ = sand specific weight = 2.65 $g/cm^3$

$\rho_{SN}$ = snow specific weight $\div$ 0.27 $g/cm^3$ *1

$d_{SA}$ = mean dia. of sand particles $\div$ 0.25 mm

$d_{SN}$ = mean diameter of snow particles $\div$ 1.00 mm *2

$V_p$ = free stream wind velocity

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*1 averaged snow density from 12 Canadian snow survey stations as per Table II-11 of Isyumov (1971).

*2 most probable dimension for a variety of snow crystal forms for the typical range of 0.25 to 4.00 mm as per Table II-4 of Isyumov (1971).

Simulation results for the resultant snow drift accumulation on an inverted 'T' and on a 'U' channel elevated guideway model at a water velocity of 0.13 meters/sec (an equivalent wind velocity of about 6 km/hr) and with the model guideway length oriented at 90° to the water flow direction (i.e. for a simulated cross wind) are shown in Figures 4 and 5 respectively. The resultant snow drift accumulation was observed to progressively reduce as the water velocity was increased over the range available in the flume but with a significant fillet of simulated snow remaining in the corners of the guideway running surfaces even at the high velocity.
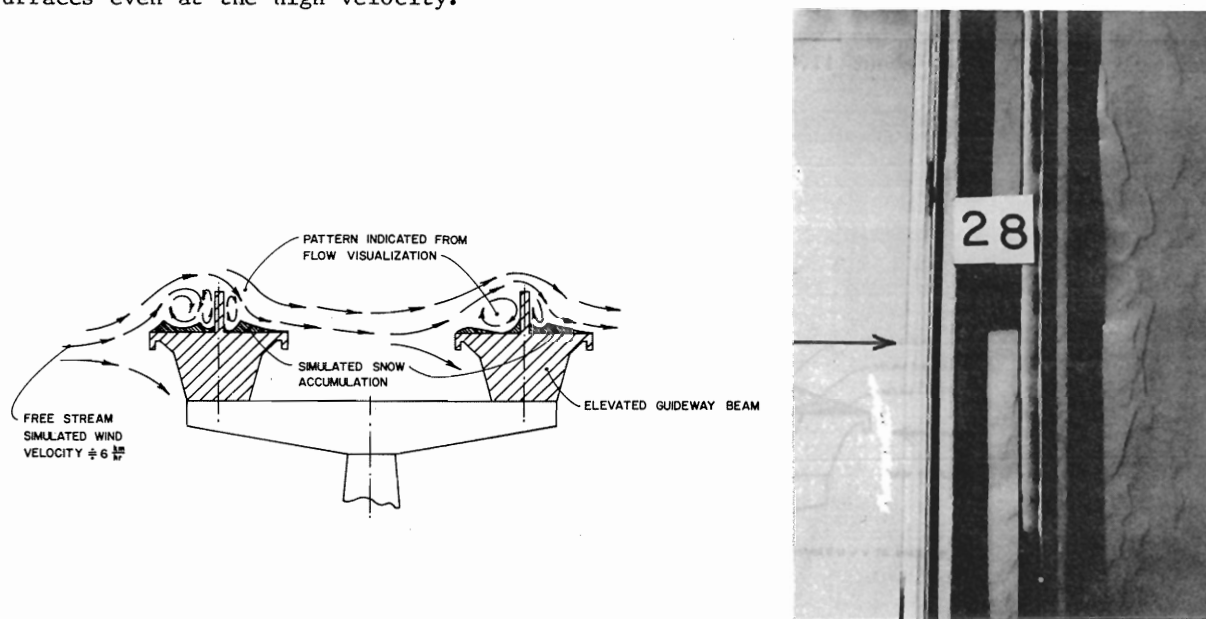


Figure 4. Typical Inverted "T" Guideway-Induced Fluid Flow and Resultant Snow Accumulation
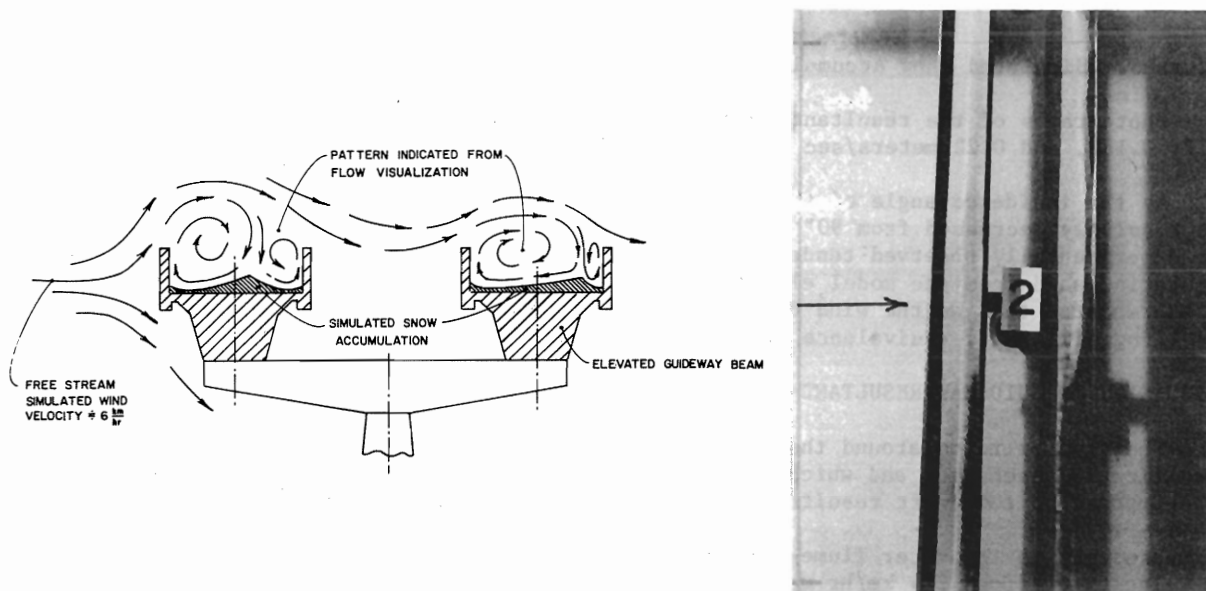


Figure 5. Typical "U" Channel Guideway-Induced Fluid Flow and Resultant Snow Accumulation

The resultant simulated snow drift on a flat-topped guideway, oriented at 90° to the flow direction, at the minimum flume velocity of 0.10 m/sec was of symmetrical triangular cross-section with the slope of the sides limited only by the angle of repose of the sand particles. As the water velocity was slowly increased, the onset of saltation of the surface sand particles (i.e. onset of particle movement induced by the cross flow) was

visually determined to occur in the range of 0.13 to 0.14 meters/sec water velocity (i.e. corresponds to a free stream wind velocity of about 6.2 km/hr).*1

The distinctive steady-state drift distribution produced by the scouring process at the threshold velocity is shown in Figure 6. Also illustrated in Figure 6 is the progressive scouring of the accumulated sand from the running surface as the flume velocity was gradually increased. The downwind guideway track beam was observed to completely clear at about 0.20 meters/sec water velocity (i.e. at about 9.2 km/hr equivalent wind speed) and the upwind guideway track beam was observed to completely clear at about 0.24 meters/sec water velocity (i.e. at about 11.0 km/hr equivalent wind speed).
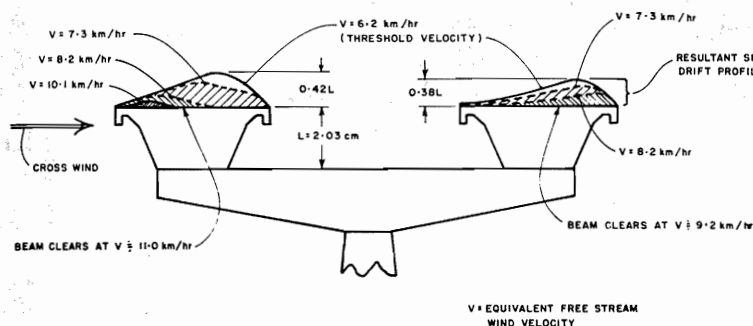


Figure 6. Simulated Snow Accumulations on Flat Guideway

Photographs of the resultant sand accumulations corresponding to water velocities of 0.17, 0.185, and 0.22 meters/sec are shown in Figures 7, 8 and 9 respectively.

As the incidence angle of the flow direction relative to the model guideway length was progressively decreased from 90° towards 0° (i.e. from cross flow towards parallel flow) the experimentally observed tendency for the flow velocity to induce clearing of the snow simulating sand from the model elevated guideway increasingly diminished. Herein, it will be appreciated that as the wind direction approaches 0°, the bluff body requirement for modelling similarity equivalence becomes increasingly invalidated.

DISCUSSION OF GUIDEWAY RESULTANT SNOW DRIFT SIMULATION RESULTS

The flow patterns around the guideway as indicated by the water flume flow visualization technique and which induce the observed drift accumulations, are shown superimposed on the drift results for the inverted 'T' guideway and for the 'U' channel

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*1 Subsequent to the water flume investigation reported herein, a free stream air threshold velocity of about 2.4 km/hr was visually estimated for the same guideway model but using an NRC wind tunnel with #60 silica sand to simulate the snow. This converts to a full scale free stream wind threshold velocity of about 8.6 km/hr on the basis of the threshold velocity similarity parameter equivalence, as per Hayes (1983) between model sand-in-air and the actual snow-in-air systems. The full scale threshold velocities independently predicted using the water flume and the wind tunnel facilities (about 6 and 9 km/hr respectively) fall within the range of 4.7 to 10.5 km/hr determined for the threshold velocity of light loose snow under both actual field and wind tunnel test conditions as per Table II-2 of Isyumov (1971).
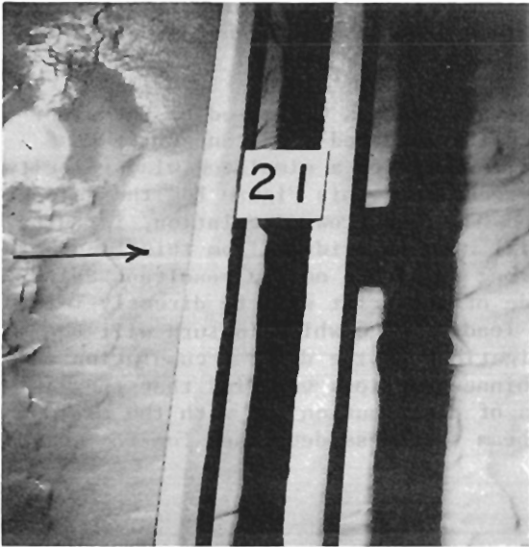
Figure 7.  Simulated Snow Accumulation on Flat Guideway (Equivalent Wind Velocity = 8.0 km/hr)
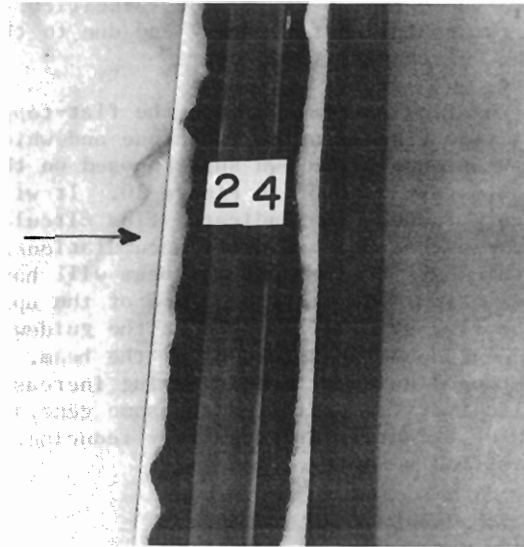
Figure 8.  Simulated Snow Accumulation on Flat Guideway (Equivalent Wind Velocity = 8.7 km/hr)
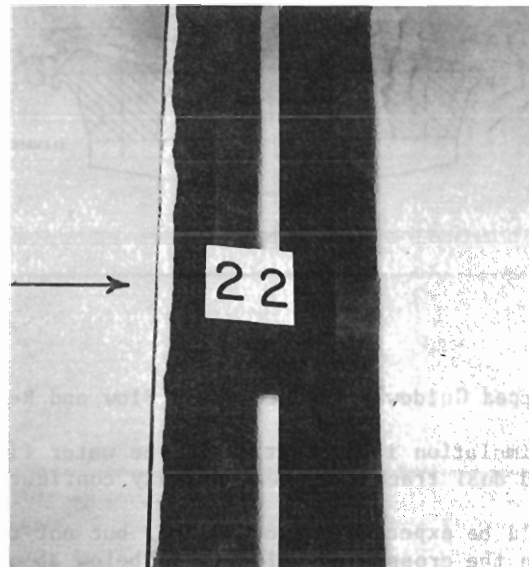
Figure 9.  Simulated Snow Accumulation on Flat Guideway (Equivalent Wind Velocity = 10.3 km/hr)

guideway in Figures 4 and 5 respectively.  It will be evident from these figures how the indicated flow circulation is induced by the guideway geometry and how this flow circulation generates the observed drift accumulations.  The drift accumulation on the downwind track of the guideway is less pronounced than on the upwind track due to the reduced intensity of the associated flow circulation which results from the decreased angle of attack of the incident flow at the guideway "leading edge".  Increasing the flow velocity reduces the drift accumulations for both the 'U' channel and the inverted 'T' guideways due to the associated increased velocity of the circulating flow and the corresponding adjustment of the drift distribution until equilibrium is established (i.e. until the flow velocity at the drift surface is everywhere equal to the threshold velocity for saltation).  However, the 'U' channel and the inverted 'T' guideway running surfaces will never be completely cleared of drift accumulation by the scouring action of the wind

due to the very low local flow velocities in the corners (i.e. local velocities of less than the saltation threshold) and due to the containment of snow between the vertical walls of the 'U' channel guideway.

The flow patterns around the flat-topped guideway model as indicated by the water flume flow visualization technique and which induce the observed resultant drift accumulations, are shown superimposed on the drift results for a simulated wind velocity of approximately 6 km/hr in Figure 10. It will be evident from this Figure how the guideway geometry induces the indicated flow circulation and how this flow circulation, in turn, generates the observed drift accumulations. It will also be evident from this Figure that the thickness of the guideway beam will have a strong influence on the resultant drift accumulation. Herein, the slope of the upwind side of the drift will be directly related to the flow streamline angle at the guideway beam leading edge which in turn will be dependent upon the thickness of the beam. Investigations of the drift accumulation on flat-topped guideway models having increasingly thinner sections verified that the resultant drifts exhibited the same general shapes of distribution but with the maximum depth of the drift progressively reducing as the beam thickness decreased for the same free stream flow velocity.
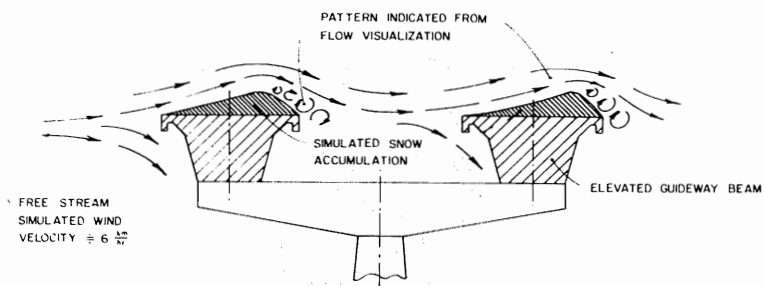


Figure 10. Typical Flat-Topped Guideway-Induced Fluid Flow and Resultant Snow Accumulation

In summary, the snow simulation investigation in the water flume has indicated that for a full scale flat-topped dual track elevated guideway configuration:

- falling dry snow would be expected to accumulate, but not to drift, on the guideway running surfaces when the cross wind velocity is below about 6 km/hr

- drifting of dry snow would be expected to occur on the guideway running surfaces during snow storms when the cross wind velocity is between about 6 and 11 km/hr with the most severe snow drift depths occurring when the cross wind velocity is in the order of 6-8 km/hr

- the guideway running surface would be expected to be effectively scoured clear of dry snow when the cross wind velocity exceeds about 11 km/hr.

PROBABILITY OF SNOW ACCUMULATION EXCEEDING THE MAGLEV VEHICLE RUNNING CLEARANCE

In order to predict the probability of snow accumulation interference with the operation of a transportation system having any given running clearance, it is necessary to determine the probability of the combinations of snowfall and cross-wind conditions which together produce snow accumulation equal to or exceeding the vehicle running clearance. The probability of such snowfall and cross wind conditions occurring along any particular

transportation system elevated guideway route may be determined from the climatic data records for the regions through which the route passes.

In the particular case of the Toronto-Ottawa-Montreal route, the daily snowfall depth data for the three referenced cities was analyzed for the 30 year period of 1940-69 inclusive to determine the percentage probability of the snowfall exceeding a given depth on any 24 hour day of the six month snow season (November to April inclusive). A range of snowfall depths from near zero to about 36 cm was selected and the number of days for which any given snowfall depth was exceeded 'n(>s)' determined from the climatic records. The probability of exceeding any selected snowfall depth was then determined by dividing the days 'n(>s)' by the total number of winter days over the 30 year sample period.

The snowfall probability data for each of the three referenced cities exhibited a good fit to the Weibull equation (Section 2.2.2, Isyumov (1971)), which is typically used to characterize snowfall depth, thereby substantiating that the data sample upon which the probability results are based is sufficiently large to be fully representative. Typical snowfall probability results are shown in Figure 11 for the Ottawa region.
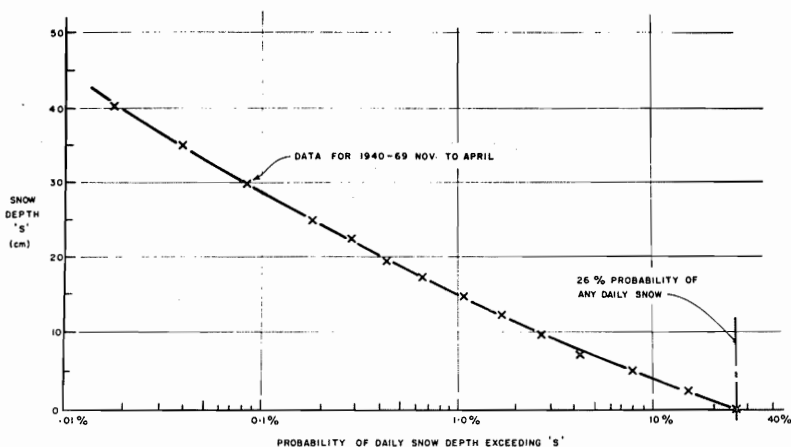


Figure 11. Ottawa Snowfall Depth Probability

The determination of the probability of exceeding any given snow accumulation depth on an elevated guideway also requires the analysis of wind velocity and direction from the available climatic data. The daily wind velocity data for the referenced three cities was analyzed similarly to that for the snowfall depth for the 30 year period of 1940-69 inclusive to determine the percentage probability of the wind exceeding a given velocity on any 24 hour day of the six month winter season. Typical wind velocity probability results are shown in Figure 12 for the Ottawa region. Such wind velocity probability data for each city region exhibited a good fit to the Wiebull distribution for all but very low wind velocities which is consistent with other investigation findings as per Section 2.4 of Isyumov (1971) for example.

The daily wind direction data for the three referenced cities was analyzed for the 6 month winter (November to April inclusive) of the 5 year sample period 1977-81 inclusive to determine the direction probability characteristics. Herein, the number of days that the averaged wind direction was within any given 22.5° angular sector over the 5 year sample period, divided by the total number of sample days gives the probability of the wind direction being within the given sector on any given winter day. Typical wind direction probability results are shown in Figure 13 for the Ottawa region. Sample data over separate single month periods for the daily averaged wind velocity and wind direction, were selected and cross plotted to determine the degree of correlation between the velocity and direction of the wind. The results indicated that the winter wind velocity and direction
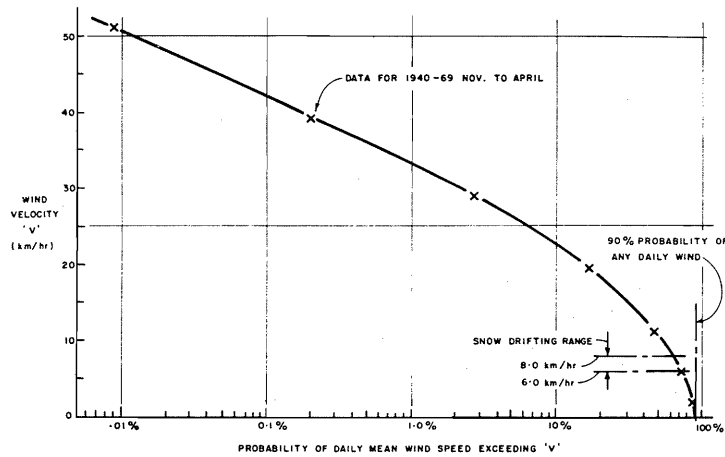
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Figure 12. Ottawa Wind Speed Probability

are substantially independent (i.e. the correlation coefficients between velocity and direction are typically very low). The daily snowfall depth and wind velocity data were similarly determined to be substantially independent.
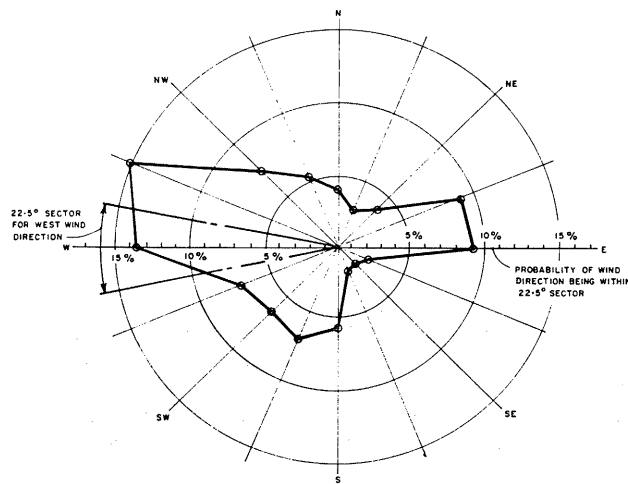


Figure 13. Ottawa Wind Direction Probability

The following four combinations of snowfall, temperature, wind velocity, and wind direction conditions occurring simultaneously in any given 24 hour winter day were considered, on the basis of the water flume snow simulation results, to produce a snow accumulation on the guideway running surface exceeding the nominal vehicle running clearance 'h':

- wet snowfall (temperature >-2°C) of greater than depth 'h', independent of wind velocity and direction (corresponds to the direct accumulation of snowfall on the guideway without any wind-induced guideway snow drifting or clearing)

80

- dry snowfall (temperature <-2°C) of greater than depth 'h' with the wind velocity less than 6 km/hr, independent of the wind direction (corresponds to the direct accumulation of snowfall on the guideway without any wind-induced guideway snow drifting or clearing)

- drifting dry snowfall (temperature <-2°C) of greater than depth 'h'/2 with the wind velocity between 6 and 8 km/hr and with the wind direction within ±45° of normal to the local guideway route directional orientation (corresponds to maximum guideway snow drifting induced by a cross wind)

- dry snowfall (temperature <-2°C) of greater than depth 'h' with the wind velocity greater than 6 km/hr and with the wind direction within ±45° of parallel to the local guideway route directional orientation (corresponds to the direct accumulation of snowfall on the guideway without significant wind-induced guideway snow drifting or clearing).

These selected combinations of conditions for predicting guideway snow accumulation exceeding the vehicle running clearance are postulated as being realistic on the basis of the following assumptions which together tend to result in a rather somewhat pessimistic snow accumulation estimate:

- the guideway would probably be snow plowed, during the daily system shut-down period whenever the snow depth became significant so that it is reasonable to consider only the total snow accumulation over any 24 hour winter day

- wet snowfall exhibits sufficient cohesion between particles to eliminate any wind-induced surface particle movement over the full range anticipated wind velocity. Wet snowfall is somewhat arbitrarily defined as that occurring when the ambient air temperature is higher than -2°C.

- dry snowfall (ambient air temperature <-2°C) does not exhibit any significant interparticle cohesion so that the water flume results using sand to simulate snow will be applicable

- the influence of wind velocity upon the drifting or clearing of dry snow on the guideway surface is substantially the same for any wind direction within ±45° of normal to the guideway orientation

- there is negligible wind-induced drifing or clearing of dry snow on the guideway surface for any wind direction within ±45° of parallel to the local guideway route directional orientation. Herein, it was not considered feasible to realistically investigate guideway snow accumulation using the water flume due to the difficulties in realizing flow similarity between the simulated and the actual systems as the flow direction becomes increasingly parallel to the guideway. This assumption is probably quite pessimistic but is considered appropriate in the absence of full confidence in the snow simulation technique when the wind tends to be parallel to the guideway

- guideway snow is drifted to a maximum depth of about twice the mean depth of the snowfall available for drifting by cross wind velocities within the range of 6 to 8 km/hr. This assumption is based on the snow simulation results indicating an approximately triangular cross-sectional snow distribution for the maximum drift condition generally as per Figure 10. The cross wind range for maximum drift depth was selected on the basis of the water flume snow simulation results as per Figure 6 wherein a small cross wind velocity range just above the threshold velocity for the onset of drifting generated the maximum depth of drift.

The probability of any particular one of the identified combination of conditions for snow accumulation occurring on any given day of the 6 month winter is given by the product of the corresponding individual probabilities for the occurrence of snowfall (within a given temperature range, wind velocity and wind direction as applicable in that all of individual probabilities are substantially independent). The probability of any one of the

four identified combinations of conditions for snow accumulation occurring on any given day of the 6 month winter is given by the sum of the probabilities of each condition occurring since these combinations are mutually exclusive.

Typical probability results for the identified combinations of snowfall and wind conditions and the local guideway orientation as per the corridor route of Figure 1 are shown in Figure 14 for the Ottawa region. The results are expressed in terms of the probable days of occurrence per winter that the guideway snow accumulation would be anticipated to exceed a given depth due to each of the identified combinations of conditions for snow accumulation. The resultant probable days of given guideway snow depth per winter are shown in Figure 15 for the Toronto, Ottawa, and Montreal regions. These results indicate that for the Toronto-Ottawa-Montreal corridor region there is a low probability of daily snow accumulation on the running surface of a flat-topped guideway exceeding the 10 cm nominal running clearance of electrodynamic Maglev vehicles (probability of occurrence of slightly more than two days per winter).
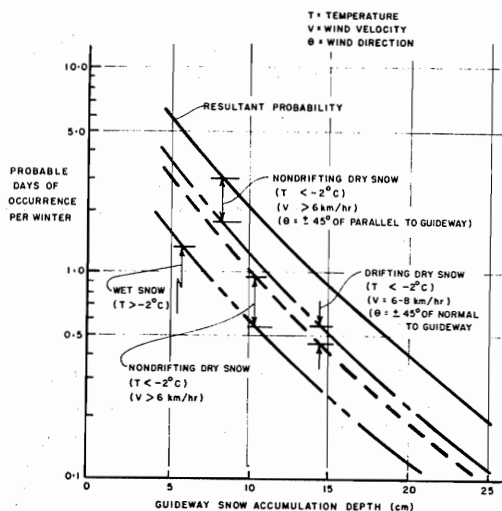


Figure 14. Ottawa Region Probability of Guideway Snow Accumulation
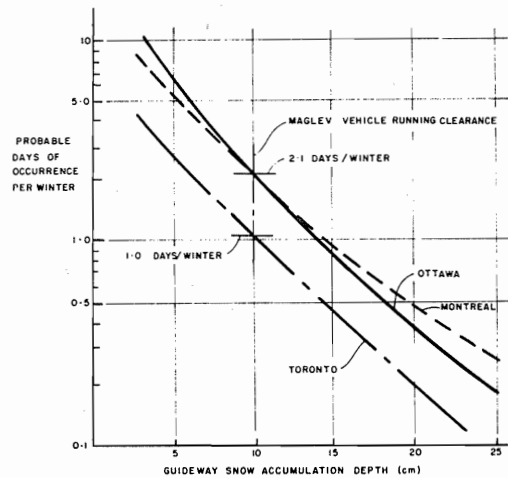
Figure 15.  Probability of Guideway Snow Accumulation

CONCLUSIONS

Extensive simulated snow accumulation investigations using a model flat-topped dual-track elevated guideway suitable for an advanced passenger transportation system have indicated that:

- dry snowfall accumulates but does not drift on running surfaces of such guideways where the wind velocity is low (below about 6 km/hr for the guideway configuration tested)

- heavy drifting of dry snow will occur on the running surfaces of such guideways over a limited range of cross wind velocity (about 6 to 8 km/hr wind range for the guideway configuration tested)

- the running surfaces of such guideways will be completely swept clear of dry snow when the cross wind velocity exceed a limit slightly higher than the velocity range for drifting (exceeds about 11 km/hr for the guideway configuration tested).

The sand-in-water simulation technique of investigating snow accumulations on the running surfaces of typical elevated guideways for advanced passenger transportation systems in the presence of cross winds can be used in combination with regional winter weather records of snowfall and wind conditions to predict the probable number of days per winter when the snow accumulation would be expected to exceed the running clearance of the system vehicles.  For the particular example of the electrodynamic Maglev system having substantial vehicle running clearance (nominally 10 cm) and operating on a wind-exposed elevated dual track guideway in the Toronto-Montreal corridor of Canada, the predicted number of days per winter when the snow accumulation would exceed the vehicle running clearance was only slightly greater than two.

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