THE SIMULATION OF A BLOWING SNOW ENVIRONMENT IN A WIND TUNNEL

By

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INTRODUCTION

In the Polar regions where little or no summer melting occurs, persistently drifting snow creates major maintenance problems where facilities must be kept operational and may quickly and permanently bury important installations. From their studies in the Antarctic, Roots and Swithinbank (1954) concluded that by proper layout and construction of a base many of the operational problems caused by drifting snow could be eliminated or greatly alleviated.

Rapid expansion in the construction of installations for military use and scientific research in the Arctic and the urgent need for specialized structures of untested, unique design much as those used on the DEW Line prohibits the conduction of full scale tests on a projected installation under natural conditions. The vagaries of natural phenomena associated with blowing and drifting snow and the short lead time between concept and construction make it almost impossible to duplicate a test or to evaluate sequential modifications of a prototype structure under identical conditions.

In a wind tunnel with a properly designed test chamber realistic scale models can be studied, modifications made and the tests repeated until the most satisfactory design is found. Finney (1939) used wind tunnel tests on scale models to evaluate highway design, embankment slopes and snow fence placement for drift control. Warnick (1956) tested models of precipitation gages and shields in a wind tunnel to determine the gage and shield design most effective for use in areas of heavy snow fall. These and other investigators fail to recognize the need for scaling the properties of the materials used to simulate snow to conform with the scale of the structures being tested and the physical dimensions of the test chamber and aerodynamic characteristics of the tunnel.

Problems associated with wind tunnel studies

Scale models may be so small that they project entirely into the stream of moving simulated snow when a low density material such as sawdust is used in a wind tunnel whereas under natural conditions in the field most of the elevation of the prototype would be above the zone of concentrated blowing snow. The elastic properties of snow simulating materials such as sawdust may be much greater than for natural snow, consequently the relationship between the amplitude of rebound of the simulating material and the dimension of the scale model being tested may be unrealistic.

The effect of large differences between the elasticity of a simulating material such as sawdust and natural snow is shown in Figure 1. These photographs taken in the wind tunnel at the University of Idaho (Warnick-1956) effectively illustrate how among other properties to be scaled the coefficient of restitution, which is the ratio of the velocity of rebound to the velocity of impact, must be considered in the selection of materials for the modeling of drifting snow.

The complex nature of snow and of the phenomenon of drifting makes the determination of modeling criteria for a simulated snow very difficult. Fortunately certain geometric properties which would at first appear to be difficult to model become of little importance when dealing with blowing snow on the Polar ice sheets. Under continuous movement by the Arctic wind the dendritic and spicule forms of snow flakes are rapidly abraded into round grains. Although the mean size of the grains may vary from 0.4 mm to 1.0 mm or occasionally even larger, the particle size distribution of the snow grains in a specific geographic or climatological area covers a very narrow range, frequently not exceeding ±15% of the mean. The uniformity of the geometric parameter simplifies the selection of materials which may be adaptable to the simulation of snow. The elasticity and geometry of the particle are cited as examples of the many physical properties which must be scaled in any really satisfactory model snow.

The size and shape of the available wind tunnel test section must be taken into consideration also. The boundary layer in a wind tunnel is wedge-shaped having little or no thickness at the beginning of the test section and increasing in thickness downwind. Such a condition does not exist over a relatively smooth snow surface where there is usually a uniform boundary layer several hundred feet thick. With a sufficiently long wind tunnel test section experiments may be performed at a downstream location where the rate of growth of the boundary layer and change in shear stress are at a minimum. However, realistically

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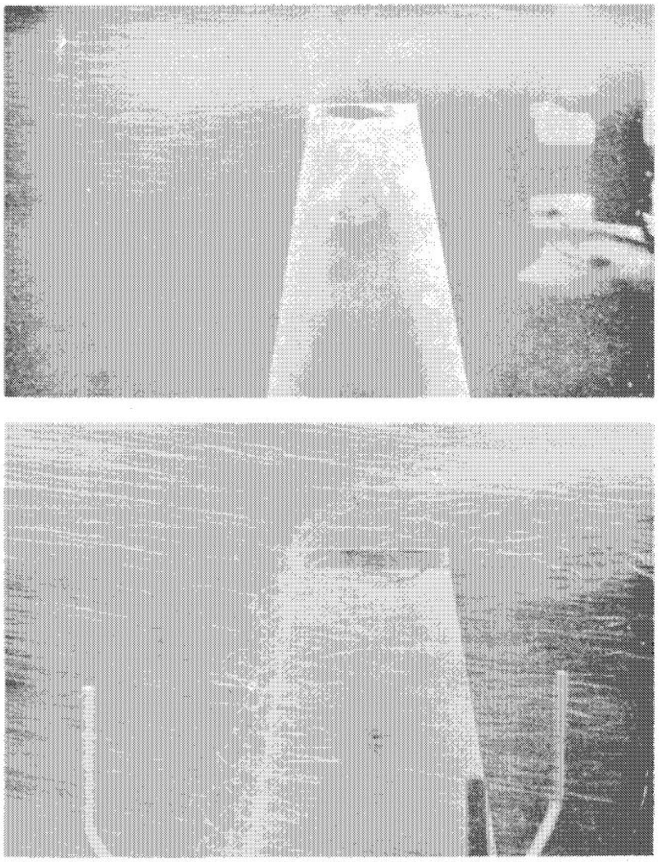


Figure 1. Showing the difference in elasticity between natural snow, (upper photograph) and sawdust, (lower photograph) during tests on precipitation gages in the wind tunnel at the University of Idaho. (From Warnick op. cit.)

proportioned test models may project through the boundary layer in most tunnels presently adaptable to simulated snow studies.

Recognizing the advantages inherent in wind tunnel testing of snow drifting, the U. S. Army Cold Regions Research and Engineering Laboratory has been supporting a program of research at New York University, College of Engineering. The wind tunnel at the University has a test section 3.5 feet high and 7 feet wide with a usable length of 30 feet. Simulated snow can be introduced through a slot in the ceiling at the forward part of the test section.

Criteria for a snow simulator

In the search for a suitable snow simulating material the following factors were considered significant.

a. The linear reference dimension of the structure subject to test.
b. The diameter of the snow particle.
c. The velocity of the snow particle.
d. The free fall velocity of the snow particle.
e. The ambient air velocity at the particle.
f. The acceleration of the particle due to gravity.
g. The coefficient of restitution.

The mathematical treatment of the problem of developing a material suitable for the scale model simulation of snow in the New York University wind tunnel is presented in detail in a report by Strom et al (1961). Many materials were investigated to determine their ability to meet the computed requirements for a modeled snow. Borax ($Na_2B_4O_7 \cdot 10H_2O$) was found to be the most promising. Most of the experiments in the wind tunnel have been conducted with commercial borax of 0.2 mm mean particle diameter.

Wind tunnel operation

The modeled objects were placed approximately 15 feet downstream of the location where the simulated snow was dropped into the air stream. Before an experiment was started, the floor of the test section was covered with a layer of the simulated snow which extended about 13 feet upstream of the modeled objects. Upstream of the simulated snow there was 7 feet of bare test section floor surface which joined the wind tunnel contraction cone. The model of the structure to be tested was positioned near the center of the test section. Figure 2 is a photograph of part of the test chamber of the wind tunnel showing a test in progress on a typical Arctic type modular panel building.

No velocity profile measurements were made during the experiments. However, from observations the boundary layer depth was estimated to be on the order of 1/2 foot at 15 feet where the models were centered. The model experiments may, therefore, be expected to give approximate modeling of velocity profile for a depth corresponding to 5 feet in the atmosphere. Above this level the model air flow is at constant velocity while in the atmosphere the velocity continues to increase with elevations up to several hundred feet. It has not been demonstrated that this difference in the thickness of the boundary layers is important in scale model tests.

Model Tests

During the development of design and the selection of sites for the Eastern extension of the DEW Line across South Greenland, CRREL was called upon to provide essential climatic and environmental information. The private contractors and the Eastern Ocean District, Corps of Engineers required information on the direction of the prevailing storm winds and the possible effect of blowing and drifting snow on the life of the structures and operation of the communication system. The prevailing wind direction over most of the high ice sheet is determined by the dominant katabatic flow which simplifies duplication of the natural wind pattern in the wind tunnel. Some preliminary tests in the wind tunnel had shown that structures to be erected on the Ice Cap should be elevated on columns to permit drifting snow to pass beneath them. Photographs of one of the sequences in the first series of tests on elevation of structures above the snow surface is shown in Figure 3. The accumulation pattern shown in these photographs is the equivalent of three or four years of natural accumulation on the high Greenland Ice Cap. Subsequent tests showed that much improvement could be attained by eliminating most of the

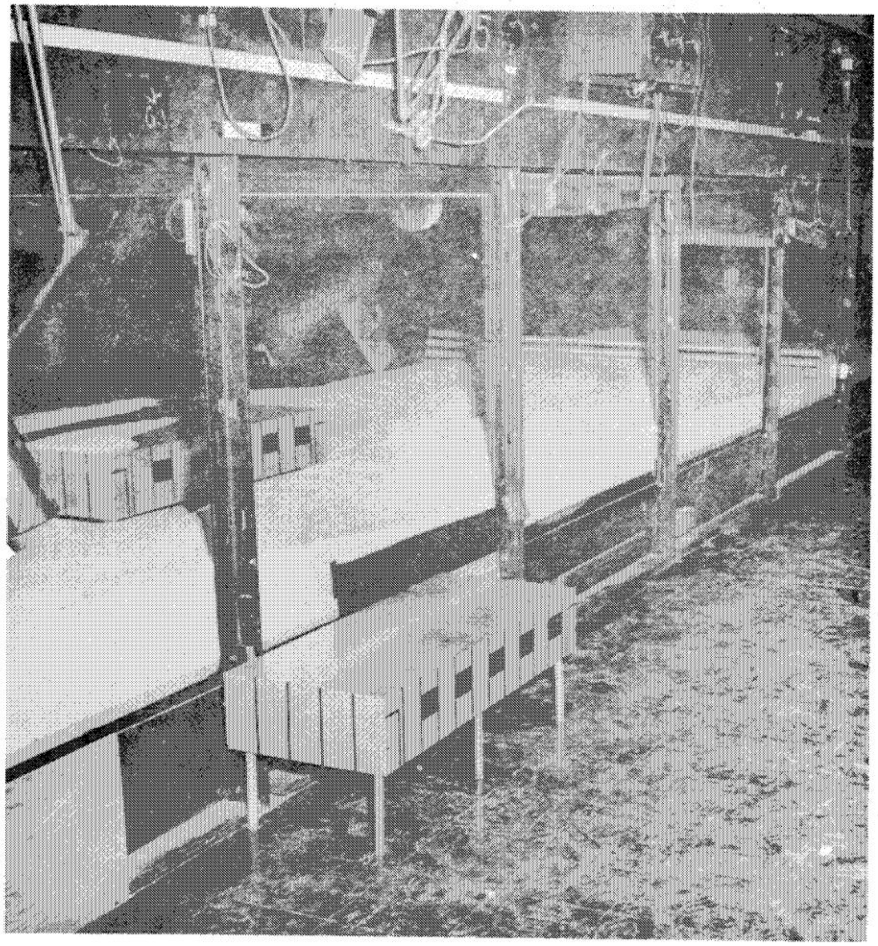


Figure 2. A portion of the test chamber in the New York University wind tunnel. The test section is 7 feet wide, 3.5 feet high and 30 feet long.

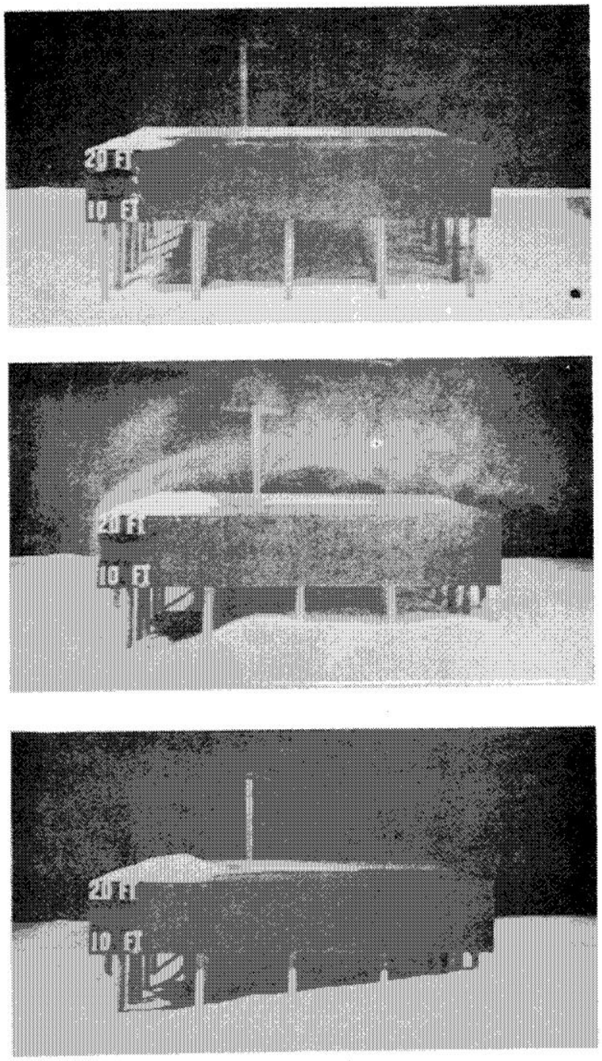


Figure 3. A series of photographs showing the drift pattern developed around a building erected on columns. The center photograph shows the pattern developed during a period of precipitation accompanied by high winds. The lower photograph shows the effect of erosion by high winds during a period of no precipitation.

columns in a plane normal to the flow of the prevailing wind leaving support only on the sides and in a plane parallel to the wind.

The new DEW Line buildings which were given the coined name "DYE Site" were sufficiently completed by the end of the summer of 1959 to permit a survey in the spring of 1960 and the plotting of the drift accumulation patterns which had developed during the winter storm period. Since the contractor and the Eastern Ocean District, Corps of Engineers were interested in the long term effect of drifting snow on the DYE Site operations CRREL was requested to undertake some wind tunnel tests on scale models of the buildings. The two photographs in Figure 4 show the construction of one of the DYE Site facilities at an elevation of 7,000 feet on the central part of the Ice Cap in South Greenland. Figure 5 shows the wind tunnel tests on scale models of the composite DYE Site building during corresponding stages of construction.

The snow accumulation patterns which developed over a 10-month period at one of the DYE Sites on the Greenland Ice Cap and in the wind tunnel test on a scale model are shown in Figure 6. The test in the wind tunnel was conducted over a sufficient period of time to accumulate drifts which would definitely interfere with the operation of the communications antenna on the sides of the building under natural conditions, and to determine if possible the service life of the building before it would have to be jacked up on the columns which are shown extending through the roof along both sides of the structure. There is an obvious similarity between patterns developed at the field installation and in the scale model test. The much greater scaled height of the accumulation in the model test represents 3 or 4 years of normal accumulation on the South Greenland Ice Cap. The pattern developed in the synthesized environment indicates that the accumulation in the field will continue in approximately the same general form as established naturally during the first 10 months.

The similarity of the accumulation patterns is particularly gratifying since in order to test a model of this large building in the wind tunnel it was necessary to use a 1:100 scale and to achieve some of the essential modeling parameters through variations in flow velocity and the volume of the modeled snow being introduced to the chamber during the test.

On the basis of this evidence of highly localized accumulation the decision was made to level the major drifts with a bull dozer at least once each year. This maintenance operation would prolong the life of the communication system before the building would have to be raised.

Tests have been made also on the design and layout of new facilities for the Marie Byrd Facility in the Antarctic and models are being constructed for the testing of nuclear power plant installations and NIKE site control structures which are particularly susceptible to large amounts of drifting snow.

SUMMARY

Field tests on the effect of blowing and drifting snow on structure design and installation layout are limited by the vagaries of weather and the many years of time required obtaining usable information.

Wind tunnel tests provide a means for artificial control of the blowing snow encironment and the acquirement of information in a short period of time which may be used for the development of design criteria for construction of Arctic facilities. Under suitable conditions a few hours test in a wind tunnel may provide acceptable information that could not be acquired in less than 3 to 5 years under natural field conditions.

The production of a satisfactory modeled blowing snow environment in a wind tunnel requires that the physical properties of any material selected to simulate natural snow must be scaled in relation to the linear scale of the structure models in a manner that will insure a representative scale model environment.

A research program at New York University sponsored by the U. S. Army Cold Regions Research and Engineering Laboratory has been directed toward the derivation of essential scale parameters for a model snow and the search for and selection of a material which will properly simulate snow when used with small scale models of structures and facility layouts.

The first series of tests were made with borax ($Na_2B_4O_7 \cdot 10H_2O$) which of the several materials studied appears to most closely approach the theoretical requirements for a modeled snow.

No analysis of specific studies are presented in this paper. In each series of test accumulation measurements, still photographs and time lapse movies are made. The recorded information is evaluated

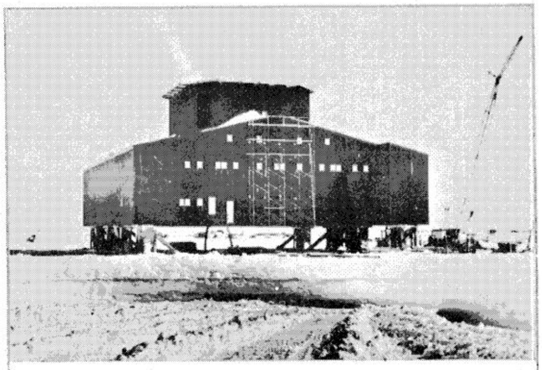
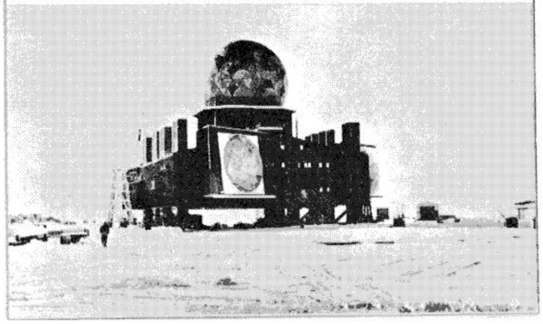


Figure 4. Photographs of two stages in the construction of a Dye Site building at 7000 feet elevation on the South Greenland Ice Cap.



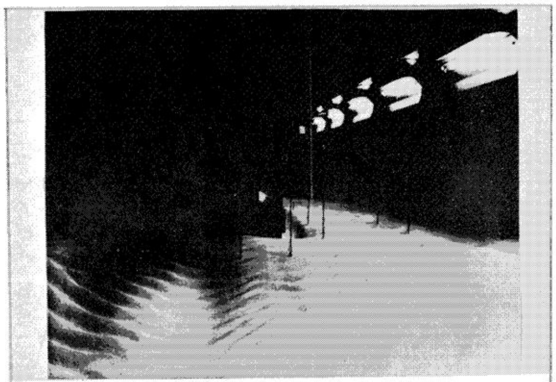
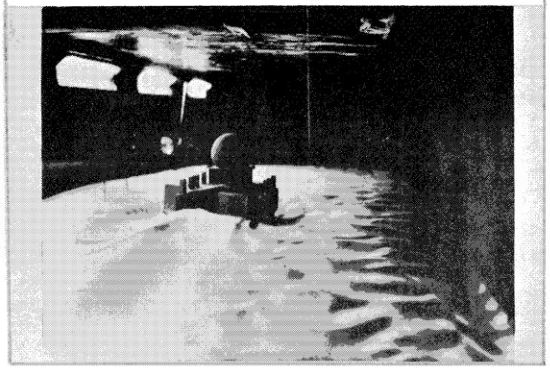


Figure 5. Wind tunnel tests on scale models of the Dye Site buildings during stages of construction corresponding to those shown in Figure 4.



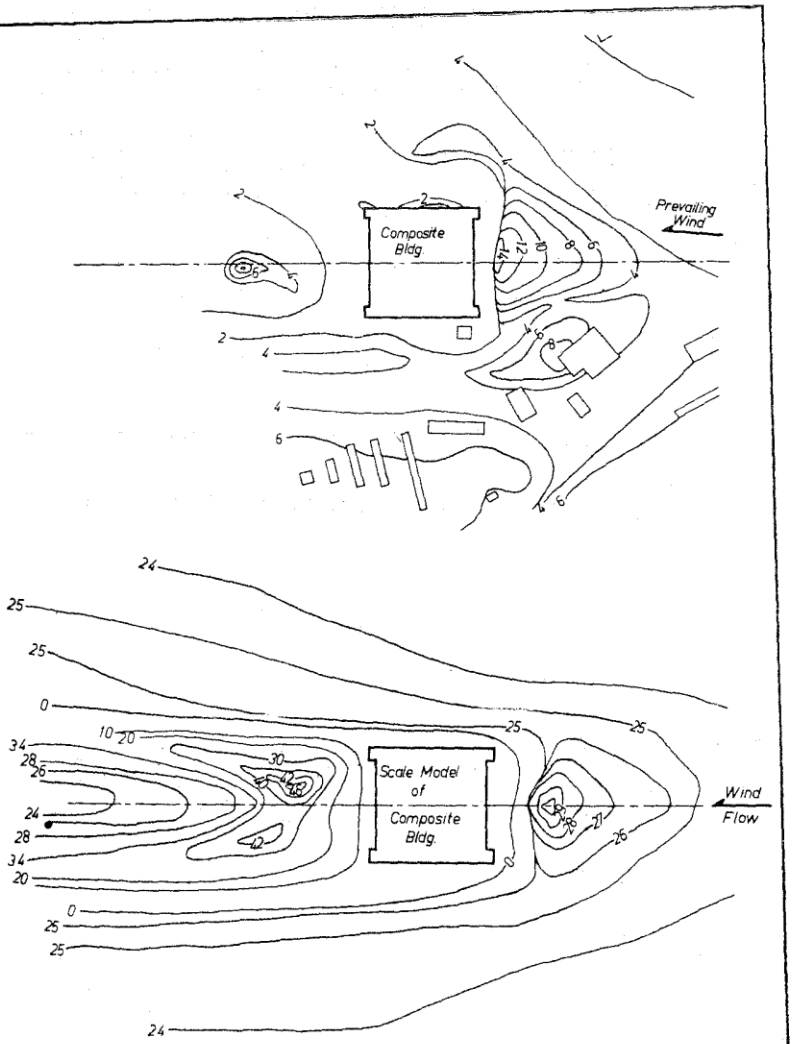


Figure 6. Contours of drift accumulation around the composite Dye Site building on the Ice Cap during a 10-month period (upper drawing) and the contours showing the accumulation pattern developed in the tunnel on a scale model of the composite Dye Site building (lower drawing). Elevations shown are in feet above the natural surface.

in terms of the apparent interaction between the structure and the blowing snow encironment. At the present time informational and progress reports are prepared for the using and cognizant agencies. A comprehensive report is being prepared for publication in the CRREL Research Report series.

A search is being made for materials which will meet the requirements for a modeled snow applicable to testing at 1:200 scale to permit the study of spacing of structures for a large installation.

The problem of scaling blizzards with wind speeds up to 100 knots is under study. This may require the use of material of considerable lower density than ice since such a virtual speed would be difficult to work with and a scaled down speed will require a lower density material. We hope to be able to establish certain parameters and a list of materials which will permit reproducing many types of blowing snow environments at scales from 1:10 to 1:1000 and velocities up to 100 knots.

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