Annotated bibliography on snow drifting and its control

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Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/40001584
Bibliography (National Research Council of Canada. Division Of Building Research); no. BIBL-38, 1968-12-01

ANNOTATED BIBLIOGRAPHY

ON

SNOW DRIFTING AND ITS CONTROL

compiled by

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Drifting snow and its deposition is a familiar characteristic of the Canadian terrain. Its occurrence must be considered in the design, construction, and operation of many structures and transportation services. Although numerous studies have been made on drifting snow and its control, few of these have been of the nature that give directly to the engineer the information that he requires. There is a growing need for this information, much of which can be obtained through a review of the results of past investigations complemented, when necessary, with appropriate field and laboratory studies. This bibliography has been compiled as a step in this task and with the hope that it will aid and encourage the investigations that are required.

The references available up to June 1964 have been used in compiling this bibliography. Acknowledgement and appreciation must be expressed to the main source of references and abstracts, the Bibliography on Snow and Ice compiled by the Library of Congress for the Cold Regions Research and Engineering Laboratory, U.S. Army Materiel Command.

Ottawa, December 1968

DIVISION OF BUILDING RESEARCH • NATIONAL RESEARCH COUNCIL • OTTAWA, CANADA

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ON

SNOW DRIFTING AND ITS CONTROL

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1. SNOW IN THE AIR

Arai, Hideo, Masao Shiotani, and Taizo Ogasawara. On Blowing Snow. Seppyō, May 1953, Vol. 15, No. 1:1-5.

The results of studies in Japan from Jan.-Feb. 1952 on the vertical distribution of blowing snow are reported and the method and device used for collecting the snow are described. An experimental equation is presented relating the amount of blowing snow caught in the collecting device and the height of the device above ground. Data are tabulated and graphed on the amount of snow blown at heights from 5-500 cm., air temperatures at the time of observation, and the vertical wind distribution.

(In Japanese)

Bontchkovsky, V. Snowstorms and Blowing Snow According to Observations at the Observatory of Moscow University in 1905-1913. Bull. Inst. Physique Cosmique de Moscou, 1923, Fasc. 1:68-91.

The characteristics of snowstorms and blowing snow are described and correlated with individual meteorological elements. The frequency of snowstorms and blowing snow at the observatory ranges from 7-32/yr. and averages 16. The max. number of snowstorms during the season is observed in Jan.-Feb., the min. in April and Oct., while blowing snow occurs most frequently in Feb. and not at all in April and Oct. The optimum conditions for the occurrence of snowstorms and blowing snow include air temperature from -4° to -6°C for snowstorms and -7° to -9°C for blowing snow, SE. winds at 7-8 m./sec., a relative humidity of 90% at temperatures down to -10°C and 80% at lower temperatures, and negative pressure variations. Data are tabulated and graphed on snowstorms and blowing snow in individual years and accompanying meteorological conditions, the monthly and annual frequencies of snowstorms and blowing snow, their relation to temperature, wind direction and speed, and pressure variations, and relative and absolute humidity at various temperatures.

(In French)

Bucher, E. Mass Transport by Wind. Referate und Diskussionen der Hydrologischen Tagung der Eidg. Kommission für Schnee- und Lawinenforschung vom 9. und 10. Oktober 1947, Interner Ber. No. 92, Eidg. Inst. f. Schnee- und Lawinenforsch, Davos, Switz., Nov. 1947, 4-7.

The movement of snow by wind is analyzed briefly. Wind-speed gradients and the amount of suspended snow per unit volume determine the amount of snow accumulation.

Snow accumulation is uniform with constant wind speed but decreases in areas where wind speed is greater and increases where wind speed is less. The more snow the air contains, the greater the effects of variations in wind speed. Results of laboratory and field investigations by K. Croce on the effect of snow fences on snow accumulation are summarized.

(In German)

D'i͡unin, A.K. Mechanics of Snow Erosion. Trudy Transportno-Energeticheskogo Inst., 1954, Vyp. 4:59-69. Eng. Trans., TT-1101, National Research Council, Ottawa, Can., 1963.

The erosion of dry snow is shown to be a special case of the erosion of granular materials in water and air and depends on the same parameters. Erosion was calculated for various combinations of water, air, sand, soil particles and snow particles. A formula is derived on the basis of dimensional analysis for determining the critical wind speed preceding snow erosion. This critical wind speed increases with increasing particle size, roughness of the snow surface, and cohesion of the particles. Therefore, in any program for prevention of snow erosion, provision should be made for increasing these three factors.

D'i͡unin, A.K. The Solid Flux of a Snow-Wind Flow. Trudy Transportno-Energeticheskogo Inst., 1954, Vyp. 4:71-88. Eng. Trans., TT-1102, National Research Council, Ottawa, Can., 1963.

A general formula for the solid flow of a fluid plus granular-material mixture is derived by dimensional analysis and is applied to the specific case of a snow-wind flow. Solid flow is defined as the weight of the snow transported per unit area cross section of wind flow per unit time and is measured in gm./sq.m.sec. The transport of snow in an air stream obeys the general laws of transport of heavy granular material in a fluid medium whose specific gravity is less than that of the transported particles. The general formula is checked against field measurements and is found to be satisfactory. Variants of the general formula can be used to calculate the magnitudes of wind transport or deposition of snow for a series of storms or for the whole winter and for different measuring devices. Generally, the flow of snow in a given sector and snowstorm is a function not only of the translation velocities of the wind flow, but of the state of the snow surface (density, freezing, roughness), stream turbulence, size and density of the particles, and air temperature. Some of these factors can be controlled and thereby the snow drifting of roads can be controlled or modified to a certain extent.

Di͡unin, A.K. Vertical Distribution of Solid Flux in a Snow-Wind Flow. Trudy Transportno-Energeticheskogo Inst., 1954, Vyp. 4: 49-58. Eng. Trans., TT-999, National Research Council, Ottawa, Can., 1961.

Theoretical calculations of the height distribution of the solid flux in a snow-wind flow are presented. The theoretical analysis is compared with field observations of the wind transport of snow. Formulas are offered which give the dependence of the amount of snow transported in a given time on the wind speed and height above the ground. The following conclusions are drawn: (1) the vertical distribution of the solid flux of a snow-wind flow depends on the profile of the averaged translational velocities and the linear characteristics of the wind-flow turbulence, (2) the derived formula for expressing the total solid flux agrees satisfactorily with experimental data obtained under field conditions, and (3) when the derived formulas are used, most of the drifting snow measurements can be made with drifting snow gages and these data can be used to determine the total solid flux of a snow-wind flow more precisely.

Di͡unin, A.K. Fundamentals of the Theory of Snowdrifting. Izvest. Sibirskogo Otdeleni͡ia Akad. Nauk SSSR, 1959, No. 12:11-24. Eng. Trans., TT-952, National Research Council, Ottawa, Can., 1961.

This paper is theoretical treatment of the problem of snowdrifting. Equations are developed which describe the movement of snow by wind. Theoretical expressions for the dependence of the mean velocity of the snow particles and the total rate of snow transport, upon the air flow velocity at the 5 cm. level, are compared to wind tunnel observations with snow.

Gerdel, R.W. The Simulation of a Blowing Snow Environment in a Wind Tunnel. Proc. Western Snow Conf., Spokane, Wash., Apr. 1961, 106-114.

A research program has been undertaken at New York University to derive the essential scale parameters for a model snow and to select a material which would properly simulate snow when used with small scale models of structures and facility layouts. The problems associated with wind tunnel studies are discussed briefly, the criteria for a snow simulator are listed, and the wind tunnel operation and model tests are described. Some of the results are indicated.

Gerdel, R.W. and Gordon H. Strom. Scale Model Simulation of a Blowing Snow Environment. Institute of Environmental Sciences, 1961 Proceedings, Mt. Prospect, Ill., 1961, 53-63.

Scale factors for the simulation of drifting snow were determined in connection with wind tunnel studies of snow drift formation on the Greenland Ice Cap. Model structures on a scale of 1:10 were used and the parameters of the material for simulating snow were devised accordingly. The following factors were considered: diameter and velocity of the snow particle, its free fall velocity, the ambient air velocity at the particle, the acceleration due to gravity, and the coefficient of restitution (ratio of velocity of rebound to the velocity of impact). The diameter of blowing snow particles on polar ice sheets may vary from 0.4 - 0.1 mm., but the particle size distribution of snow grains in a specific area frequently does not vary more than ±15% from the mean. The free fall velocity of 0.1-mm. snow particles was measured and found to be 200 cm./sec. The coefficient of restitution was found to be 0.555. Preliminary calculations showed that the simulating material must have a density of 2 gm./cu.cm. or more to give the required fall velocity of 63 cm. at a diameter size of 0.1 mm. Of the various materials tested, commercial borax was found to be the most promising and has been used successfully in scale model tests. Remarkable correlation was found between drift accumulation around one of the "Dye" site buildings on the S. Greenland Ice Cap and around a model of the same building in the wind tunnel. Wind tunnel tests lasting a few hours can provide information on drift characteristics that could not be acquired in less than 3-5 yrs. under natural field conditions.

Gerdel, R.W. and Gordon H. Strom. Wind Tunnel Studies with Scale Model Simulated Snow. General Assembly of Helsinki, 1960, Publ. No. 54, Intern. Assoc. Sci. Hydrol. Gentbrugge, Belgium, 1961, 80-88.

In Polar regions where little or no summer melting occurs, improperly designed structures may be quickly and permanently buried by drifting snow. In most wind tunnel studies on drifting snow no consideration is given to the relationship between the velocity of air in the tunnel and the physical and aerodynamic properties of the material selected to represent snow nor to the extent of saturation of the wind with the synthetic snow. Recognizing the deficiencies in knowledge on snow drifting and the advantages inherent in wind tunnel studies, the U.S. Army Snow Ice and Permafrost Research Establishment (now U.S. Army Cold Regions Research and Engineering Laboratory) has supported a research program leading to the selection and use of materials which might be used to suitably simulate snow in controlled investigations on scale models of structures within the range of 1/10 to 1/50 prototype size. Some of the results of the wind tunnel studies with a scaled, simulated snow are presented.

Godshall, Frederic A. The Mechanics of Snowdrifting. Thesis (M.S.), College of Engineering, New York University, N.Y., May 1958.

Modeling criteria for simulating drifting snow with ground cork were developed on the basis of aerodynamic analyses and data collected during wind tunnel experiments on the efficiency of snow fences. The formation of snowdrifts around models of various types of fences was measured, and curves of accumulation at various saturations are graphed. From data on the percentage of snow blown past the fence and deposited in the eddy region of the fence at various stages of drift until full saturation is reached, an equation was developed for quantifying collection efficiency. Of the 4 models tested, the efficiency-collection capacity of the 50% dense slatted fence was greatest. The Swedish slat fence, however, was more efficient at certain drift stages than the other models tested, and in actual use, this type of fence is removed after the latter stages of drifting have been reached and is placed at the new snow level where the efficient collection characteristics may again function. Measurements were also made of the vertical distribution of wind-blown particles and a Boltzmann equation was applied to these data. Finally, a brief suggestion is offered for improving snow fence design by adding a forward deflector to strengthen the vortex movement of the wind on the lee side of the fence.

Higuchi, K. Experimental Studies on Drift and Turbulent Diffusion of Paperlets Emitted from Aircraft as a Model of Snowflakes. Jour. Meteorological Soc. Japan, June 1962, Ser. 2, Vol. 40, No. 3: 170-180.

Field experiments were carried out Feb. 1, 28 and March 16, 1961 on drift and turbulent diffusion of paperlets (2 x 2 cm.) emitted from aircraft, as a model of the drift of snow crystals and flakes. Fallen paperlets were collected by Sapporo citizens, and returned to our laboratory. The isopleths of the collected paperlets emitted at 450 m. and 1800 m. respectively are shown. The horizontal diffusion coefficient was estimated as the order of magnitude of $10^5 cm.^2/sec.$, according to Sakagami's formula for an instantaneous point source.

Hirada, Tokutarō. Snow Storm. Seppyō, Mar. 1951, Vol. 12:165-167.

Three sets of data on the vertical distribution of blowing snow 0.1 - 11 m. above the ground are analyzed mathematically with regard to the relative quantity of snow at each level up to 1 m., particle size, and total quantity of blowing snow.

(In Japanese)

Khodakov, V.G. The Transport of Snow by Drifting in the Polar Urals. Akad. Nauk SSSR, Mezhduved. Komit. Proved. MGG, Gli͡at͡siologicheskie Issledovanii͡a, Sbornik Stateĭ, IX Razdel Programmy MGG (Gli͡at͡siologii͡a), 1961, No. 6:136-142.

Drifting snow plays a large role in the nature and economics of the Polar Urals, as has been demonstrated by various investigations, and is an important consideration for road building and construction. The wind transport of solid material (snow) along the surface in the Polar Urals in the middle section of the Bol'shaya Khadata river valley was measured by the IGY expedition of 1957-58. The factors contributing to the wind drift of snow are discussed and four empirical equations are derived for determining the transport of solid material in the 1-m. surface layer of air as a function of specific conditions of the snow surface, the wind force, and the general meteorological situation.

(In Russian)

Lister, H. Glaciology. 1. Solid Precipitation and Drift Snow. Trans-Antarctic Expedition 1955-1958, Sci. Rept. No. 5, 1960, 1-51.

Three aspects of the glaciological studies of the Trans-Antarctic Expedition at Shackleton and Southice are treated: solid precipitation, drift snow, and snow accumulation. The data are tabulated and graphed, and the results of other expeditions are included in the discussion of accumulation. The instruments employed for measuring snow precipitation proved unsatisfactory, so precipitation was measured by observing both drifting snow and drifting snow plus solid precipitation. A logarithmic relationship is given which best expresses the variation of drift density with wind speed. The state of the surface proved to be about 1/5 as important as wind speed. The mean particle approaches a rounded form (dominant size approx. 0.07 mm. diam.) and the size decreases slowly with height in the range 0.2-6.0 m. Plate and columnar snowflake fragments are common, and composite grains produced by surface firnification are frequent in drift. Deflation is <1 gm./sq. cm./yr. over Antarctica and the net annual accumulation of snow is - 13 gm./sq. cm., ranging from >30 gm./sq.cm. near the coast to 7 gm./sq.cm. near the center of the high plateau. At

Southice, accumulation was -10 gm./sq.cm. around 1900, reached a peak of 17 about 1929, and decreased to 10 gm./sq.cm. in the 1950's.

Lord, Roddee Edward. Forecasting Visibility in Blowing Snow. Master's Thesis. Seattle, Washington Univ., 1960.

Results from this study indicate that the problem of forecasting specific values of visibility during blowing snow storms is still unsolved. Although formulas were determined which would give mean values for visibilities at various wind speeds, fluctuations in visibilities are so great as to make the formulas useful only as a guide. Forecasting visibility values during blowing snow is a highly complex problem, and the observed fluctuations are probably dependent upon many parameters, of which wind speed is only one.

Mellor, M., and U. Radok. Some Properties of Drifting Snow. Antarctic Meteorology; Proc. Symposium held in Melbourne, Feb. 1959, New York, Pergamon, 1960, 333-346.

Five sets of snow-drift measurements with new snow-traps were used for estimates of drift-snow density as a function of height. The expected drift densities at 4 and 200 cm. were computed from those observed at 100 and 400 cm. and compared with observations. The theoretical estimates and actual observations at the 200 cm. level were in reasonable agreement. At 4 cm., however, the observed values were substantially larger, indicating a different snow drift mechanism near the ground, similar to the "saltation" described for sand. The saltation drift transport is estimated at 10% of the total.

Odar, Fuat. Scale Factors for Simulation of Drifting Snow. Proc. Am. Soc. Civil Engrs. Jour. Eng. Mechanics Div., April 1962, Vol. 88, No. EM2:1-16.

Theoretical scale factors for simulating drifting snow in a wind tunnel were derived by using the equation of vertical transport and the threshold characteristics. The scale factors derived from the equation of motion of the particles can be substituted for the scale factor obtained from the vertical-transport equation which involves the mass transfer coefficients that cannot be solved readily. These scale factors were derived for small spherical particles which determined relationships between the size and the density of the particles of simulating material. The vertical-transport equation also provided another scale factor that determined the amount of accumulation or change in elevation of the snow surface in the model. The simulation of change in

elevation of a snow surface during a long period of time is examined briefly. Since the simulating material in the model does not compact or settle as does natural snow, this scale factor was modified accordingly.

Rusin, N.P. Horizontal Transport of Snow in Antarctica. Trudy Glavnoi Geofizicheskoi Observatorii, Vyp. 96, 1959, 31-37.

Observations at Mirny in 1956-57 on 400 cases of snow drifting during katabatic winds (SE. and SSE.) are analyzed. Data are tabulated and graphed on the mean wind speed at various heights (0.5-10 m.) and the magnitude of the turbulence coefficient at which horizontal drifting begins; mean surface roughness at various wind speeds; the relation between the intensity of drifting and wind speed; wind speed, turbulence, and surface roughness for various drift intensities; the amount of snow transported horizontally at various heights (0-300 cm.); variations with height of the amount of snow transported during medium-strong drifting; and the amount of snow transported during drifting of various intensities at various heights. Snow drifting out to sea averages 800 kg./hr. running m. at a height of 0-4 m., and 140 kg./hr. running m. at 0-1.5 m., which is equivalent to a loss in water of 3-5 million tons a year for each km. of shoreline.

(In Russian)

Shiotani, Masao. On the Snow Storm. Researches on Snow and Ice, Nov. 1953, No. 1:29-33.

Drifting snow is shown to be an Austausch phenomenon due to eddy diffusion. A modified eddy viscosity coefficient is introduced, taking into consideration the motion of the snowflake itself.

(In Japanese)

Shiotani, Masao. The Vertical Density Distribution of Blowing Snow. Seppyō, May 1953, Vol. 15, No. 1:6-9.

The vertical density distribution of drifting snow is analyzed mathematically taking into account snow diffusion as a function of the spatial distribution of snow, air density, the turbulent diffusion coefficient of wind, and the falling speed of snowflakes. Theoretical results are compared with those obtained experimentally, and data on the diam., mass, and falling speed of snowflakes, and snow-crystal types are tabulated and graphed.

(In Japanese)

Strom, G.H. and others. Scale Model Studies on Snow Drifting. Res. Rept. 73, U.S. Army Cold Regions Research & Engineering Lab., Sept. 1962.

Scale model tests were conducted to study experimental and theoretical aspects of snow drifting phenomena. Modeling criteria for drifting snow were developed and a number of materials were tested for use as geometrically and physically scaled synthetic snow. Crystalline borax 0.01 cm. in diam. was found satisfactory for a 1/10 model scale. The feasibility of using scaled materials to simulate drifting snow was demonstrated by the similarity of drift patterns obtained in the wind tunnel tests and those observed around full-scale structures on the Greenland Ice Cap. Further, several years of Arctic snow drift can be simulated in the wind tunnel in a matter of hours. Qualitative analyses are offered of drift accumulation characteristics around various scale model structures. The following experimental results were obtained. (1) Close spacing of buildings will result in coalescence of drifts. (2) If rectangular buildings must be grouped together, they should be erected with their long axis parallel to the dominant wind direction. (3) Erosion of the snow surface may occur beneath buildings erected on columns. (4) V-shaped snow fences produce a clear area downwind for a distance of approximately 25 times the height of the fence.

Tanifuji, Shozo and Tetsuo Ogawa. Experimental Researches on Snow Drift Control (1). Jour. Res. Public Works Res. Inst. (Japan), July 1954, Vol. 1:129-142.

The similarity of air flow in the field and in a wind tunnel is established theoretically as a basis for future studies of the aerodynamics of snow fences. This similarity depends on the equivalence of two values in the flows: the eddy Reynolds number and the intensity of turbulence. These values are shown to be equal in the two situations by inductive statistics using the Navier-Stokes equation and the equation of continuity for laminar-flow and turbulent-flow fields. The results are summarized graphically.

Walsh, K.J. Occurrence of Blowing Snow on the Greenland Ice Cap During 1953-1954. Snow Ice and Permafrost Res. Est., Special Rept. 13. 1954.

The results of an investigation on the frequency of blowing snow at two sites and its relation to wind speed, air temperature, and snowfall are tabulated and graphed. At Site 1, blowing snow occurred from 12-15 days (83-153 hr.) out of each month from Aug.-

Nov. 1953, increasing to 20 days (172 hr.) in Dec. and 26 days (295 hr.) in Jan. 1954. The phenomenon was noted at Site 2 on 11 days in July, 4 days in Aug., 12 days in Sept., and 24 days in Oct. 1953, or 53-68 hr. in July-Sept. and 210 hr. in Oct. Blowing snow was generally accompanied by winds of 15 m.p.h. or more. In at least 85% of the cases, blowing snow occurred with winds greater than 20 m.p.h., and on 50% of the cases with winds 15-20 m.p.h., and only 15% of the time with winds less than 15 m.p.h. Blowing snow was independent of air temperature and the presence of falling or newly fallen snow. More blowing and drifting occurred after the major accumulation period than during the months of greatest snowfall.

Zelenoĭ, I.K. Qualitative Characteristics of Snowstorms. Meteorologiîa i Gidrologiîa, 1940, Vol. 6, No. 1-2:124-125.

Snowdrifts were studied at the Yuspor station (900 m. elevation in the Khibiny Mts.) during 1936-1938. The intensity of snowstorms was determined in terms of wind velocity and amount of snowdrifts. Snowdrift measurements in relation to snow cover depths and wind velocity are presented in 3 graphs. Max. snowdrifting of 25.8 gm./sq.cm./min. occurred at a wind velocity of 25 m./sec.

(In Russian)

1.(a) SNOW IN THE AIR - MEASUREMENT

Bastamov, S.L. Laboratory Study of Snowdrifting at the Geophysical Observatory at Kuchino. Trudy Nauchno-Issledovatel'skogo Upravlenii͡a Narodnogo Komissariata Puteĭ Soobshchenii͡a, 1930, Vol. 109:75-76.

Research conducted from 1918 is briefly reviewed. Artificial snowstorms were produced in the laboratory to study the aerodynamic properties of various snow fences used by railroads for snowdrift prevention. An instrument suggested by Kuznetsov for measuring snowdrifting intensity can be used to improve the construction design of Sabinin. An instrument was developed by P.A. Gusev to determine snow-cover mobility.

(In Russian)

Cherepanov. Measurement of Amount of Snow Drifted by Snowstorms. Vestnik Edinoĭ Gidrometeorologicheskoĭ Sluzhby, 1933, Vol. 3, No. 7:15-16.

An instrument for measuring the amount of drifting or blowing snow at various heights is described. The streamlined body of the instrument is 30 cm. long and made of sheet iron. Drifting snow enters the instrument through a 25-cm. opening. Baffle plates retain the snow in the instrument as the air passes through. The instrument is painted white and placed on a mast at the desired level.

(In Russian)

Govorukha, L.S. and E.F. Kirpichev. First Results of Drifting Snow Observations with the Drifting Snow Meter "Cyclone". Inform. Bi͡ull. Sov. Antarkticheskoĭ Eksped. 1961, No. 26:22-25.

The adaptation is reported of a centrifugal dust-catching mechanism such as is employed in many factories, to the measurement of drifting snow, and a detailed description is included. Field experiments at Mirnyy have shown the instrument to be almost 100% effective inasmuch as the properties of snow such as granular composition, specific gravity, particle form, adhesive and abrasive qualities are so similar to those of dust and ash. Observations have been carried out with equipment installed at levels of 3, 6, 12, 25, 50, 100, and 250 cm., and results show that the density of drifting snow in the air decreases logarithmically with increasing height. The sole drawback to the widespread use of the mechanism for the measurement of drifting snow is the large amount of labor required for operation. This difficulty can be overcome, however, by the installation of a single regulating device which may be operated by remote control.

(In Russian)

Izi͡umov, N.N. Instruments for Measuring the Amount of Drifted Snow. Trudy Nauchno-Issledovatel'skogo Upravlenii͡a Narodnogo Komissariata Puteĭ Soobshchenii͡a, 1930, Vol. 109:86-91.

Snowdrifts produced by winds were measured from 1927-1929 at the Vodenyapino Experimental Station of the Kazan Railroad. The data indicate that 86-90% of the snow was drifted in the 10-cm. air layer next to the snow surface. About 5-6% was drifted in the layer from 10-20 cm. high. The remaining 4-9% was drifted in the layer from 20-200 cm. high. Data obtained by the Kuznetsov meter indicated that the snow transfer in the 2-m. layer above the snow surface reached 2.67 gm./sq.cm.min. in light snowstorms and increased to 18.97 gm./sq.cm.min. in heavy snowstorms. The Kuznetsov meter collected an average of about 45-50% of drifted snow. These experiments aided in the construction of new instruments.

(In Russian)

Kedrolivanskiĭ, V.N. and M.S. Sternzat. Blowing-Snow Meters. Meteorologicheskie pribory, Gidrometeorologicheskoe Izdatel'stvo, Leningrad, 1953, 165-167.

Instruments used in the USSR for measuring drifting snow in the air layers near the ground are described in detail. The Kuznetsov meter constructed near the beginning of the 20th century was modified and is now known as the VO-type meter. This modified instrument consists of a cylinder with an egg-shaped top and an open pipe measuring 2 x 12.5 cm. in front and 3.5 x 10 cm. in back. The meter is equipped with a wind vane and turns about a vertical axis. Three diaphragms are placed inside which trap the blowing snow. The streamlined receiver and larger rear opening result in a smooth air flow by the apparatus.

(In Russian)

Kooznetsov, V. On Measurements of the Amount of Snow Carried Horizontally by the Wind. 1900. Transl. by I.I. Schell, Blue Hill Observatory, 1946.

An instrument is described and illustrated for measuring the horizontal snow transport during a given time interval through a fixed cross-section in a vertical plane. A cylindrical box with an attached wind vane is mounted so that the box can turn about the vertical axis. The air enters an opening in the side of the cylinder and passes out through the top; the snow drops to the bottom of the box. Preliminary measurements during the winter of 1896-97 indicated that the transport increases at a rate approximately proportional to the square of the wind speed; at a wind speed of 10 m./sec., the transport will be 30 times as great as the amount of snow falling on a horizontal surface.

Madigan, C.T. Snowfall and Snowdrift. Australasian Antarctic Expedition, 1911-14, Sci. Repts., June 1929, Ser. B, Vol. 4:49-51.

An improvised snow gage from stove piping is described. The total annual snowfall beginning March 14, 1912 was 51.82 in. water equivalent and 60.98 in. water equivalent beginning Dec. 15, 1912. Drifting snow was systematically measured with a specially designed drift gage. A wooden box, 3 x 2.5 x 3 ft. equipped with a tin cone at one end and a smaller wooden box with baffles at the other, was fixed firmly on the ice with the receiving cone facing south. The snow was removed periodically for weighing 1 lb. of snow representing 5.213 ft. water equivalent. The total drift for 1 yr. beginning March 14, 1912 amounted to 6246 ft. water equivalent.

Mellor, M. Gauging Antarctic Drift Snow. Antarctic Meteorology; Proc. Symposium held in Melbourne, Feb. 1959, New York, Pergamon 1960, 347-358.

Two types of snow-traps designed to measure drifting snow density at various heights above the ground are described. These traps have rocket and airfoil shapes, respectively, and remove the snow from an airstream by expanding the stream's cross-section and thus reducing its velocity approx. 50%. The traps orient themselves into the direction of the wind and contain no impediments to the passage of the air. The traps can be set at heights 4-400 cm. above the snow surface. The rocket-type trap was found to collect with complete efficiency, whereas the airfoil type allowed some drifting snow to pass through.

Molochnikov, A.V. Measurements of Blowing Snow at Yukspor. Meteorologiía i Gidrologiía, June 1939, Vol. 5, No. 6:137-138.

Special measurements of blowing snow were initiated at the Yukspor avalanche station in 1936. Observational data for 1937-38 are tabulated. Special instruments constructed at the Vodenyapino Experimental Station were used for the measurements. Observations indicated that the horizontal transfer of snow begins at wind speeds of 3 m./sec. The maximum amount of blowing snow at wind speeds of 3 m./sec. was 0.1 gr./sq.cm.min.; at 10 m./sec. the transfer reached a maximum of about 7.3 gr./sq.cm.min. and at 18 m./sec., 24.4 gr./sq.cm.min. (In Russian)

Orlov, N.I. New Method of Measuring Blowing Snow. Akademiîa Nauk SSSR, Institut Geografii, Rol'snezhnogo pokrova v prirodnykh protsessakh, Moscow, 1961, 258-264.

The Soviet snow gage currently used for measuring drifting snow, the VO-2, is deemed both cumbersome and inaccurate and a new type of recorder is proposed. The new instrument consists of a photocell, a light source with a system insuring parallel position of the rays, a device for limiting the area cross section of the snow-wind flow, an anemometer, a galvanometer, and a battery with a rheostat. Snow particles carried by the wind inside the limiter of the area cross section of the instrument cast a shadow upon the active surface of the photocell illuminated by the parallel rays of a steady light source. The photo-current value varies as the intensity of the shading. The light source is chosen such that the particles of transported snow will become practically opaque. Two series of experiments were conducted. In the first series, blown snow was sifted through a sieve 5-10 times, a homogeneous, loose, granular mass was obtained and then blown through the electronic instrument at varying rates. The data obtained on the concentration of snow particles vs. the variation of the photocurrent and time are graphed and tabulated. The second series of experiments was conducted in the open in actual blowing snow. Theoretical calculations agree with recorded results and it is concluded that the described method increases the accuracy of recording the amount of blowing snow.

(In Russian)

Shliakhov, V.I. Methods of Making Drifting-Snow Measurements in the Antarctic. Inform. Biull. Sov. Antarkticheskoi Eksped., 1960, No. 20:26-28.

Standard Soviet drifting-snow gages proved inadequate under Antarctic conditions, where snow drifts almost continually across the coastal strip to the ocean, so a new gage was designed by the author and built by the workshop of the 4th Continental Expedition. It consists in the following: a sheet-aluminum cylinder 50 cm. in diam. and 350 cm. long, with a receiving slot 0.5 cm. wide along the entire length of the cylinder, a shaft through the cylinder to a cross piece fastened to a shed roof (roof at snow level). Bearings allow the gage to rotate and a vane keeps it facing the wind. Snow is collected in a silk bag at the base and is weighed 4 times daily. A gradient snow gage is used in conjunction with this low-level gage; it consists of a cylinder 10 cm. in diam. and 15 cm. long, enclosed in a 1-m.-long silk casing, and a rod passes from the cylinder into a block of wood attached to the instrument mast to keep the collecting bag facing the wind.

The height of the blowing-snow layer is determined by the ceiling light technique, and the amount of unrecorded drifting snow is estimated from the gradient measurements. The upper limit of drifting snow turbulence varies greatly with wind speed and wind structure: it is 1-5 m. with a wind speed of 6-10 m./sec., 12-16 m. with winds of 15-18 m./sec., and 25-28 m. with wind speeds of 19-22 m./sec. In gusts and very strong winds it can vary from 1-90 m. and more. In 28 days of June 1959, 380,199 kg. of snow drifted across a 1-m. strip of coast to the ocean at an average wind speed of 11.8 m./sec.

(In Russian)

2. DEPOSITION OF BLOWING SNOW

Bates, G.H. Observations on Snowdrift Formation and Methods of Control. Surveyor, May 7, May 14, 1948, Vol. 107:231-232, 247-248.

Observations on drifting snow during blizzards are presented. A survey of the location of the drifts was made and the reasons for their occurrence are discussed. Drifting sand and snow are compared. The snow forming drifts travels only a few in. from the surface of the ground. Dryness is essential to drifting snow which is in the form of granules. The drift forming on the lee-side of a hedge is due to snow which has filtered through. The formation of drifts on the windward side of impenetrable walls is discussed. The influence of ground surface and wind velocity are analyzed. Drifts formed by right-angle fences and downwind from apertures between obstacles were studied. Discarded tar barrels or 6 ft. lengths of chestnut paling wired together to form cylinders, placed at 6-ft. intervals are recommended as snow fences.

Chernigov, V.A. Nature of Snow Drifting at Mirnyy. Sovetskaîa Antarkticheskaîa Ekspeditsiîa, No. 10, Vtoraîa Kontinental'naîa Ekspeditsiîa 1956-1958 gg., glîatsiologicheskie issledovaniîa, by Arkticheskiĭ i Antarkticheskiĭ Nauchno-Issledovatel'skiĭ Institut, Leningrad, 1960, 180-181.

In 1958, the Mirnyy base consisted of 22 buildings, 12 of which were built on rock and were not subject to snow drifts. The position of the remaining 10 is shown, and the nature and causes of drifts that formed about and over them are examined. The drifts varied considerably in depth and configuration, but were relatively stable after April, the first month of the Antarctic winter.

(In Russian)

Chirvinskiĭ, P.N. The Formation and Metamorphism of a Snow Cover under the Influence of Wind. Universitetskiîa Izvîestiîa (Kiev), Sept. 1909, Vol. 49, No. 9:1-72 (i.e. 117-189).

The influence of wind velocity and the aerodynamic properties of obstructions and depressions on the uneven accumulation of snow is analyzed. Various wavelike formations on the snow surface (sastrugi, snow-barchans, rippling, etc.) are described, chiefly on the basis of Cornish's observations in Canada during 1900-1901. The roles of wind and temperature in snow metamorphism and the abrasive action of wind are discussed. The meteorology of snowstorms and blowing snow in European Russia is described.

(In Russian)

Cornish, Vaughan. On Snow-Waves and Snow-Drifts in Canada, with Notes on the "Snow-Mushrooms" of the Selkirk Mountains. Geophysical Jour. Aug. 1902, Vol. 20:137-175.

Observations of snow-waves and drifts were made on a trip from St. John to Vancouver, (Can.). The snow types ranged from wet and sticky to dry slippery snow. Snow-mushrooms and other bosses were studied and an account of the growth process is given. Normal waves of drifting snow, formed in dry snow only, and normal ripples of granular drifting snow are discussed with respect to their physical characteristics, mode of formation and motion. Scarped wave-surfaces, and longitudinal erosion forms in consolidated snow are analyzed. A study is made of snowdrifts caused by ground irregularities or other fixed obstructions, and the character of stationary snowdrifts and their relation to traveling snowdrifts. Appended is a discussion of snow ripples in Scotland and sun pillars.

Cornish, Vaughan. Wind-Waves in Water, Sand, Snow, and Cloud. Quart. Jour. Roy. Meteorological Soc., July 1909, Vol. 35:149-160.

Fresh, dry snow falls at once into trains of traveling waves when drifted by wind, usually at temperatures near 0°C or lower. The process is best observed on level ground and with great uniformity of exposure. The waves are unrippled due to the friability of the snow. Icy snow with sand-sized granules forms ripples a few inches from crest to crest. The ratio of length/height in traveling snow waves may be as great as 50.

Cornish, Vaughan. Waves in Drifting Snow. Ocean Waves by V. Cornish and H. Jeffreys, Cambridge, 1934, 65-74.

Various snow-wave formations observed at sub-zero temperatures in Canada are described. Included are traveling waves, ripples in granular snow, crescentric dunes, and undulating surfaces. A comparison of each formation is made with those formed in sand.

Dingle, W.R.J. and Uwe Radok. Antarctic Snow Drift and Mass Transport. Extract of Pub. No. 55 of I.A.S.H. Symposium on Antarctic Glaciology, 77-87.

Relations for the density of drifting snow as function of height and wind velocity are established theoretically and tested by means of observations made at the Australian National Antarctic Research Expeditions base at Wilkes during 1959. The measurements comprise 26 sets of drift snow collections with 8 Mellor type traps at levels ranging from 3 cm. to 400 cm. and 3 anemometers in winds from 12 m./sec. to 30 m./sec. at the

10 m. level. The wind observations conform to logarithmic profiles with very small roughness parameters. The drift densities reveal a discontinuity in the particle fall velocity; this occurs between the 25 cm. and 50 cm. levels and may be connected with the saltation mode of progression prevalent at the lowest levels. The drift density at a given height is an exponential function of the reciprocal of the wind velocity at that height. This gives the appearance of a power law when a restricted velocity range is explored and explains why the exponent in such a law increases with height from less than 0.5 for the 3 cm. level to over 5 at 400 cm. The observed drift snow transport in different layers are exponential functions of the wind velocity at the 10 m. level. The total transports between 1 mm. and 300 m. confirm the very large preliminary estimate previously made for Mawson. However, more than half the total transport is contributed by layers below and above that containing the present measurements. This underlines the need for more information regarding the vertical profile of the katabatic wind.

Dons, Carl. Concerning Snowdrifts. Naturen, 1919, Vol. 43:137-142.

Characteristics of snowdrift formations around a cylindrical wooden stack and a house were observed in Tromsö during a steady wind. Airflow on the windward and leeward sides of cylindrical and rectangular obstacles is briefly discussed and presented graphically in vertical and horizontal projection.

(In Norwegian)

First Engineer Arctic Task Force. After Operations Report, Research and Development Program, Greenland, 1955, Annex M, Preliminary Report, Project 23 (Snow Drift and White-Out Studies). 1955, 132-136.

The results of investigations in 1955 on snow drifting and drift control, visibility during drifting and white-out, heat balance, and meteorological conditions on the Greenland Ice Cap are reported. Tests were made on the effectiveness of wood-slat fences of 40% density and of a snow wall 4 ft. high and 50 ft. long as means for protecting installations. Three parallel rows of fences 200 ft. long, (two 6 ft. high and one 3 ft. high) were erected at 200-ft. intervals normal to prevailing winds. Bamboo poles were set up between 2 of the fences to measure snow accumulation, and the amount of snow moving in the air parallel to the surface was recorded by a special instrument designed to catch and retain the snow. The effectiveness of the fence was 20%. Snow moving past a sector of the 3-ft. fence was about 88 lb./min. during moderate drifting and 1500 lb./min. during a storm period, while accumulation during the latter period around the 6-ft. fence was 145 tons. Net radiation balance over snow was close to zero and was reflected in the small change in cold content of the upper 100 cm. of snow, which was 160 cal./sq.cm. on July 8 and 196 cal./sq.cm. on Aug. 6. The largest values of incoming radiation occurred nearest the snow surface, probably due to a reflection phenomenon produced by blowing snow. Restricted visibility was caused by ice-crystal or water-droplet fog and falling or drifting snow. Tests indicated that the angle of internal friction for new snow varies from 30° - 35°.

Georgievskiĭ, N. Snowdrift Control in the Arctic. Sovetskaía Arktika, 1938, No. 6:103-104.

The problem of snowdrift control in the Arctic is discussed and snowdrift conditions observed at Cape Schmidt from 1934-1937 are described. Drifts formed around obstacles to depths of 4-5 m. Max. snow deposits were observed near the N walls of structures, while the ground near walls remained free of drifts. The distribution of snowbanks around the station in Dec. 1934 is diagrammed.

(In Russian)

Holzapfel, Rupert and Gerhard Kirsch. The Surface Waves of the Greenland Inland Ice. Meteorologische Z., July 1934, Vol. 51:262-264.

Three differing inland ice surface forms are distinguished: sastrugi, a large and irregular undulation which decreases towards the center, and parallel waves. The length of the waves varies from 5-7 km., the amplitude decreases towards the center from about 15-20 m. to about 5 km., and the direction is normal to the prevailing wind direction. The waves are attributed to the final deposition of snow at high wind speeds during frequent drifts. The intensity regularly changes with wind direction due to a disturbence with a specific critical wave length. The waves are explained mathematically as a function of Reynold's number, a disturbance parameter, flow velocity, and a kinematic coefficient of viscosity.

(In German)

Karrer, Enoch. The Shape Assumed by a Deformable Body Immersed In a Moving Fluid. Jour. Franklin Inst., Dec. 1921, Vol. 192:737-756.

A general discussion of the problem is presented with specific reference to shapes of snowdrifts among other examples from geology, meteorology, physics and biology. It is suggested that the deformable body will assume a shape that is as nearly as possible "stream-line".

Kimura, Kōichiro, and Takamasa Yoshisaka. Scale Model Experiments on Snow-Drifts Around Buildings, Report No. 1. Seppyō, March 1942, Vol. 4:96-99.

Wind-tunnel experiments with scale models of buildings of varying outlines are described in detail. $MgCo_3$ powder (screened through 0.533-mm. mesh), used to simulate snow, was subjected to winds averaging 1.8 m./sec. for 5 min., and its accumulation around the models was observed. The models tested included: a square structure with a 30° shed roof, a rectangular structure with a hipped roof, a similar model with the roof hipped on one end only, a rectangular model with a shed roof, a rectangular structure with a hipped roof facing the wind longitudinally, and a similar structure with a gable roof. Snow accumulated in ridges on the sides of each model tested, with varying amounts of snow on the windward side, and practically none on the lee side. Results are diagrammed in detail.

(In Japanese)

Kotliakov, V.M. Dynamics of the Snow Cover Surface in the Antarctic Littoral. Akad. Nauk SSSR, Mezhduved. Komit. Proved. MGG, Sbornik Statei, IX Razdel Programmy MGG (Gliatsiologiia), 1960, No. 5:72-87.

Results are analysed of studies made from Feb. 1957-Feb. 1958 at Mirnyy on the formation of snow cover and the factors involved in the constant changing of its surface relief. Eight meteorological conditions are distinguished and the type of snow cover produced under each is described. Snow deposition forms such a stationary drifts and moving barchans are created during periods when cyclonic winds prevail, while ablation forms like sastrugi and depressions are related to periods when katabatic winds are dominant. Features of a given surface once formed are frequently preserved through the entire cold season under the protection of wind-, radiation-, or glaze-produced crusts, though falls of fresh snow may subsequently obliterate them. Snow density is discussed in terms of the velocity of the wind necessary to deposit it and that necessary to blow it away. The problem of determining the age of surface snow is touched on and some estimates are presented of the length of time a given particle of snow will remain on the surface under varying conditions.

(In Russian)

Kuznet͡sov, M.A. Barkhan Movement of Snow in the Wind Belt of Eastern Antarctica. Sovetskai͡a Antarkticheskai͡a Ekspedit͡sii͡a, No. 10, Vtorai͡a Kontinental'nai͡a Ekspedit͡sii͡a 1956-1958 gg., gli͡at͡siologicheskie issledovanii͡a, by Arkticheskiĭ i Antarkticheskii Nauchno-Issledovatel'skiĭ Institut, Leningrad, 1960, 175-179.

Investigations of snow barkhans by a glaciological party in 1957 are reported. The formation, shape, motion, and dissipation of the barkhans as related to the effect of wind velocity, season, snowfall, snow composition, and geographic zone are described. Emphasis is on the shape and motion of barkhans at wind velocities from 5-7 m./sec. up to 20 m./sec. Within this range, width of barkhans is from 5-8 m., length 10-15 m., and height of the crest 30-50 cm. Near the upper figure of wind velocity, the barkhans are dissipated. The nature of snow crystals in this phenomenon is also mentioned.

(In Russian)

Lawrence, E.N. Eddies Unusually Defined by Snow. Meteorological Mag., June 1954, Vol. 83:185-186.

A small snowdrift formation near the Meteorological Office at Harrow (England) is illustrated. The snow took the form of 2 or possibly 3 parallel waves. The number of waves appears to be a function of the length of the eddy-flow path, strength of the general air flow and the height of the obstruction.

Loewe, F. The Importance of Snowdrifting for the Mass Economy of Inland Ice. Meteorologische Z., Nov. 1933, Vol. 50:434-436.

Wegener and Holzapfel estimated the Greenland inland ice sustained an accumulation loss due to snowdrifting of 1 mm./yr. equal to .01 mm. of the annual accumulation. Higher values were measured by other investigators. It is believed that the number of snow-drift hours assumed by Wegener and Holzapfel is too low. The experiments conducted are critically discussed. It is concluded that precise values could be obtained by this method only if the quantity of drifted snow were calculated as a function of the 4th power of the effective wind speed. The magnitude of snow losses due to drifting is believed to be greater by 1-2 times the 10th power.

(In German)

Mather, K.B. Further Observations on Sastrugi, Snow Dunes and the Pattern of Surface Winds in Antarctica. Polar Record, May 1962, Vol. 11, No. 71:158-171.

Observations of sastrugi and snow dunes in the area around Mawson (Antarctica) are reported and discussed. Their magnitude varied from year to year, but they were more severe at greater distances from the coast, reaching a max. height near 70°S. lat., then diminishing farther inland. The elevation of the ice plateau also increases away from the coast, reaching a max. elevation of 8700 ft. near 70° 18' S. lat. and then dipping steeply to the S. In addition, the sastrugi were similarly oriented at the same locations in subsequent years. Direct wind observations are always consistent with prevailing sastrugi orientations, and there is little doubt that katabatic winds are the primary cause of sastrugi. More extensive data on the orientation of snow dunes are available from aerial photographs. Although dunes are less consistent in direction than sastrugi, the two features tend to be oriented similarly. This supports the observation that continental slope effects blizzard winds as well as simple katabatic flow. Both features confirm the extensive drainage of wind onto the Lambert Glacier, indicating that the glacier is an important factor in determining the characteristics of blizzard winds as well as the more moderate katabatic winds. Data included from Wilkes also indicate the correlation between ice slope, wind directions, and orientation of snow surface features.

Moroshkin, A.I. The Role of Eddies in the Formation of Snowdrifts. Sbornik Nauchno-Issledovatel'skogo Instituta Puti NKPS (Babushkin), 1934, Vol. 33:128-130.

An earlier laboratory investigation (c. 1911) on the formation of eddies behind flat and elliptical bodies is discussed briefly and some typical eddy forms illustrated. It is concluded that the formation of snowdrifts may depend on the Reynolds number characterizing the obstacle causing the drift.

(In Russian)

Oettli, Max. Horseshoe Snow Dunes. Naturw. Wochenschrift, Oct. 21, 1917, Vol. 32:593-594.

Barkhan-like snow accumulations observed in 1917 on the ice cover of Lake Constance (Germany) and their development are described. The barkhans were 10 m. long, 2 m. wide and 30 cm. high on the concave side, while the side exposed to the wind was tapered. Snow was removed by the wind from the dune sector behind the center of the convex forward slope, so that a horseshoe shape was maintained.

(In German)

Rikhter, G.D. Some Conditions Concerning the Formation and Distribution of Snowdrifts and Principles of Preventive Measures. Izvestiia Akademii Nauk SSSR, Seriia Geograficheskaia, 1953, No. 1:15-22.

Transfer of snow is usually observed in the layers near the ground at wind speeds of 4 m./sec. and more. The most frequent snowstorms in USSR occur at wind speeds of 6-9 m./sec. Greater wind speeds do not affect the rise of snowdrifts, which is explained by the small turbulence of air flow and by the heavy compressive action of strong winds. Rough surfaces covered by grass and the surface of wet or crusted snow do not contribute to snow transfer. Retention of snow, but not protection against snowdrifts, is an effective preventive measure. The western part of USSR has a deep snow cover, but few snowdrifts because of frequent thawing weather. Small snowdrifts are also observed in Eastern Siberia and in Central Asia. Strong winds and low temperatures cause intensive snowstorms in the arctic, the steppe of Western Siberia, and the southeastern part of USSR. The 5 regions of varying snowdrift intensity are indicated.

(In Russian)

Sapozhnikova, S.A. Things that Occur Near the Ground. Atmosfera Zemli, Gosudarstvennoe Izdatel'stvo Kul'turnoprosvetitel'noĭ Literatury, Moscow, 1953, 215-240.

The microclimate near the ground as it varies according to latitude, relief and surface cover is described in popular form, and the importance of snow covers for agriculture and transportation is discussed. Snowdrifts and snow accumulation at forests, fences and other obstacles and in depressions are discussed in detail.

(In Russian)

Staff, Hans von. Wind and Snow. Z. Deut. u. Österr. Alpenver, 1906, Vol. 37:45-56.

Various modifications of snow covers under the influence of wind are investigated. Three types of configuration, including snow ripples, snow dunes and obstruction dunes, are considered and their formation discussed. Snow ripples reach a height of 24 cm. and are spaced up to 86 cm. apart; they are due to the differences in the temperature and moisture content of the air in and at the surface of the snow cover. Dunes are the result of the uneven accumulation of wind-driven snow near elevations and depressions in the snow surface and may be classified into 4 types: snow-barchans, wind troughs, snow cornices and mound dunes.

(In German)

Stepanov, K.V. Snowdrift Control. Planirovka i zastroika naselennykh mest Kraĭnego Severa by Leningradskiĭ Filial, Akad. Stroitel'stva i Arkhitektury SSSR, Leningrad, 1959, 46-58.

The difficulties caused by snow in settled areas in the Soviet Far North, where winter is 8-10 months long and snowdrifts of 30 m. or more are recorded, are described, and the planning of cities for max. protection against snow is discussed. Effective control is achieved by proper site selection and planning, the erection of retention devices, and the use of mechanical snow-removal equipment. Houses at the periphery of a settlement should face 30° into the prevailing wind. Small settlements should be built as a row, with streets parallel to the prevailing wind and clear. Cross streets must be short. Buildings must be tall with smooth walls and a min. perimeter. Roads outside the settlements are best built on embankments. Snow-retaining structures both inside and outside the settlements should be designed in the light of the fact that the bulk of the snow (95%) moves in the 50 cm. nearest the ground. The characteristics of various permanent and temporary snow-retaining structures are outlined and diagrammed, and methods of calculating the most effective type of structure under given conditions are described.

(In Russian)

Theakston, F.H. Snow Accumulation About Farm Structures. Agr. Eng., March 1962, Vol. 43, No. 3:139-141.

Efforts to control the effects of snow and wind were studied with the aid of two devices for simulating natural conditions, (1) a wind tunnel, in which wind velocities could be varied from 8-70 mph. and in which light sawdust was used to simulate snow, and (2) an open water channel, in which light sand with aluminum flakes was immersed to simulate drifting snow. Special attention was devoted to snow accumulation around buildings, characteristics of the buildings which aggravate wind and snow conditions, and the design and placement of windbreaks. It is noted that (1) open-front buildings tend to create suction pressures which cause snow to swirl to the interior, except for buildings more than 50 ft. long, where snow accumulates in the corners of the structure, and (2) wind tunnel and water-flume devices provide a useful means of studying certain snow and wind phenomena.

Trofimov, S.V. New Methods of Planning and Constructing Settlements with Improved Microclimate. Tezisy i plany dokladov...k soveshchaniiu 1956 g. po merzlotovedeniiu, Inst. Merzlotovedeniia AN SSSR, Moscow, 1956, Vyp. 3:27-29.

The difficulties of life in settlements in areas of severe climate are outlined, and modern city planning for N. areas is discussed. The defects of existing settlements include: the orientation of streets in the direction of the wind and the wide spacing of small buildings. The construction of tall buildings in the center of settlements and small ones at the periphery without providing for snow-control measures is a poor solution to the problem. An increase or decrease in wind speed of 1 m./sec. at negative air temperatures is equivalent to an increase or decrease in temperature of 2°C, so that microclimate may be improved by constructing the first row of buildings to act as a wind barrier and the following rows in such a manner as to further reduce the wind. Wind-tunnel experiments indicate that the wind may be reduced 50-75% by this means. Uneven snow accumulation is reduced by this means and by means of special installations. Reducing the area of the settlement by erecting taller buildings closer together simplifies construction and expenditures for sanitary installations.

(In Russian)

Wegener, Kurt. A Defense. Meteorologische Z., Nov. 1933, Vol. 50: 436-437.

The accuracy of the snow quantity assumed by K. Wegener and Holzapfel to be removed by wind from the Greenland inland ice surface is defended. The data quoted by Loewe are based on locations of violent fall-winds not representative of general inland ice conditions; the values for stream flow and wind transportation are not comparable due to the difference in density and descending speed of the materials transported; the results presented were obtained by estimating the firn quantities suspended in the air and by measuring the deposits at obstacles. Observations of snow-dune growth indicate that the measurements are representative and accurate. Snow-gage observations indicate the irrelevancy of wind strength for the snowdrift depths which, however, might be related to the migration of snow dunes.

(In German)

Zhukov, V.F. Snowstorm Roses. Izvestiîa Akademii Nauk SSSR, Seriîa Geograficheskaîa i Geofizicheskaîa, 1944, Vol. 8:128-132.

The quantity of snow deposited by snowstorms depends on the aerodynamic characteristics of roads, buildings, forests and wind velocity. Observations made by the Vorkuta Permafrostology Station showed that the configurations of snow deposits around a building remain constant for several sinters. Snowdrifting occurs in the Vorkuta region during the first half of winter with wind speeds of 7 m./sec. and higher. During the second half of winter, drifting occurs with wind speeds as low as 6 m./sec. These values may be applied to other regions of the European tundra zone but not to other parts of USSR due to varying physical properties of the snow.

(In Russian)

Zhukovskiĭ, N.E. Snowdrifts. Trudy Opytno-Meliorativnoĭ Chasti Narodnogo Komissariata Zemledeliíà, 1923, Vol. 30:5-12.

The dynamics of processes associated with the motion and deposit of snow crystals around obstacles are mathematically analyzed. Studies on the motion of solid particles in a stream of water were used in evaluating the problem. Models of the air flow in depressions as well as in front of and behind obstacles are constructed on the basis of air speeds and eddies rising around obstacles. These theoretical models were found to agree with profiles of snowdrifts around thin cylindrical obstacles.

(In Russian)

Zhukovskiĭ, N.E. Snowdrifts and River Silting. Trudy Opytno-Meliorativnoĭ Chasti Narodnogo Komissariata Zemledeliíà, 1923, Vol. 30:13-29.

The problems of snow-crystal transfer along the surface and in the air near the ground as well as silt settling from water are mathematically analyzed on the basis of hydrodynamic theory and experiments in wind tunnels. Differential equations are given for calculating the effects of wind and eddies on the hydraulic speed of snow crystals. Hydraulic speed is defined as the speed of fall of snow crystals in calm air or of silt particles in stagnant water. A special series of equations is derived for analyzing cases of snowdrifts in a steady flow around a railroad bed, with the motion of the snow crystals along 2 elliptic trajectories determined by wind speed and the size of the snow crystals.

(In Russian)

Air Flow Around Buildings. Architectural Forum, July-Dec. 1957, Vol. 107:166-168.

3. MISCELLANEOUS

Bagnold, R.A. Re-entrainment of Settled Dust. Int. Jour. Air Pollution, June 1960, Vol. 2, No. 4:357-363.

Owing to lack of understanding of nature and magnitude of cohesive forces between fine particles quantitative knowledge is confined largely to entrainment of particles larger than 80μ by steady parallel fluid flow; deposits of fine powders can however be readily dispersed by ballistic impacts of dust particles larger than 100μ and locally by previous mechanical disturbances which have caused sharp edges of deposit to protrude into wind stream.

Chepil, W.S. The Use of Evenly-Spaced Hemispheres to Evaluate Aerodynamic Forces on Soil Surface. Am. Geophys. Union Transac., June 1958, Vol. 39, No. 3:397-404.

Direct and indirect measurements showed substantial lift force on surface roughness elements (such as soil grains resting on surface) in windstream; lift was approximately four-fifths of drag on hemispherical roughness elements ranging from 0.16 to 5.08 cm in height; study throws new light on equilibrium conditions existing between soil grains and moving fluid at threshold of movement of grains.

Chepil, W.S. Equilibrium of Soil Grains at the Threshold of Movement by Wind. Proc. Soil Science Soc. 1959, Vol. 23:422-428.

This paper, based on wind tunnel studies, presents an analysis of the nature and magnitude of forces on soil grains at the threshold of their movement by wind. Forces of drag, lift, and gravity were analyzed in relation to each other. The equilibrium between these forces and the soil grains was found to be influenced by the diameter, shape, and immersed density of the grains, the angle of repose ϕ' of the grains with respect to the mean drag level of the fluid, the closeness of packing η of top grains on the sediment bed, and the impulses of fluid turbulence T_D and T_L associated with drag and lift, respectively. All those factors were measured and related with actual and theoretical forces involved. New approaches to measurement of η, ϕ', T_D and T_L are presented. Analyses indicate that the magnitude of pressure impulses of both T_D and T_L is statistically distributed according to the somewhat skewed normal error law. The ratio of mean pressure to standard deviation σ was constant for any size of grains or fluid velocity and could be expressed by equation $\sigma = c\overline{P}$ in which $\overline{P}$ is the mean pressure of lift or drag and c is a constant which was found to have a mean value of 0.49.

Chepil, W.S. and R.A. Milne. Comparative Study of Soil Drifting in the Field and in a Wind Tunnel. Scientific Agric., January 1939, Vol. 19, No. 5:249-257.

One of the main problems undertaken at the Soil Research Laboratory, Swift Current, Saskatchewan, is a study of the factors pertaining to soil drifting. Since many aspects of this problem cannot be investigated solely from field experiments, two wind tunnels were constructed in which the conditions of the wind, such as velocity, temperature, relative humidity and turbulence, can be controlled. Equipped with wind tunnels, the studies on soil drifting can be continued uninterruptedly even during years when soil drifting is not experienced. The present paper is a report of the studies conducted for the purpose of comparing soil drifting as it occurs in the open field and in a wind tunnel.

Dawes, J.G. and A. Slack. Deposition of Airborne Dust in Wind Tunnel. Great Britain Safety in Mines Res. Est., Rept. No. 105, Sept. 1954, 41.

Experimental work on deposition of airborne dust on small scale wind tunnel; data on deposition obtained on roof, sides, and floor of underground roadway, and also on vertical surfaces of free standing roof support.

Ford, Edwin F. The Transport of Sand by Wind. Transac., Am. Geophys. Union, Vol. 38, No. 2:171-174, April 1957.

The problem of the motion of an individual sand grain in wind is subjected to a physical-mathematical analysis. An empirical equation is obtained for observed wind-velocity profiles near the ground. The behaviour of a sand grain in such a wind velocity gradient is assumed to be the result of three principal forces: the viscous drag of the air, the force of gravity, and the aerodynamic lift. Differential equations are set up on this basis. When solved by approximate methods for an average sand grain and for the profile obtained in a small wind tunnel, these equations give sand grain trajectories that agree fairly well with the trajectories observed and photographed in the wind tunnel.

Hilst, Glenn R. and Paul W. Nickola. On the Wind Erosion of Small Particles. Am. Meteor. Soc. Bull., Feb. 1959, Vol. 40, No. 2: 73-77.

The importance of wind erosion with respect to soil conservation and to the spreading of noxious particles

subsequent to deposit on a soil surface is indicated. The processes of wind erosion and transport are reviewed and are then illustrated by some measurements made at Hanford. Particle, surface, and meteorological factors which influence erosion by wind are listed and discussed briefly.

Kalinske, A.A. Turbulence and the Transport of Sand and Silt by Wind. Annals of New York Academy of Sciences, 1943, Vol. 44, Art. 1:41-54.

Keffer, J.F. and W.D. Baines. Measurements of Pressure Fluctuation on a Cube in Constant and Boundary-Layer Velocity Fields. Univ. of Toronto, Dept. of Mech. Eng. Technical Publication Series No. 6204, October 1962.

Pocock, P.J. Non-aeronautical Applications of Low-Speed Wind Tunnel Techniques. N.R.C. of Canada, Mech. Eng. Rept. No. MA-243, Sept. 1960, (NRC 6066).

Shafer, H. Jerome. A Model Study of the Reduction of Wind Transport of Fine Particles by Aerodynamic Barriers. Proc. 5th Israel Annual Conf. on Aviation & Astronautics, Tel Aviv & Haifa, 27-28 Feb. 1963, 57-63.

Material stored behind an artificial "horseshoe" shaped embankment was subjected to winds of varying intensity and direction. These winds cause loss of stored material and material during "filling" and truck loading operations A 1:500 model of the storage area has been studied in a 60 x 90 cm closed return wind tunnel and a two dimensional model at a scale of 1:100 in a special "sand blowing" tunnel. Various "aerodynamic barriers" have been tested to determine their effectiveness in reducing wind losses under the several abovementioned conditions. It is found that the wind loss varies as the 9th power of the wind velocity.

Sutton, O.G. The Application to Micrometeorology of the Theory of Turbulent Flow over Rough Surfaces. Quart. Jour. Roy. Meteor. Soc., Oct. 1949, Vol. 75, No. 326:335-350.

It is now well established that turbulent flow near the surface of the earth is usually of the type known as "aerodynamically rough", and the present paper discusses the implications of this for diffusion. The various theories of rough flow are discussed and the conclusion reached that the formulation due to Rossby and Montgomery, in which the influence of the surface irregularities dies out with height, is the treatment most appropriate for meteorology, because of the relatively great depth of the layers dealt with as compared with wind tunnel boundary-layer investigations. It is shown that the introduction of a characteristic parameter termed by the author the macroviscosity, defined as the product of the friction velocity and the roughness length, enables a single logarithmic profile to be defined for both rough and smooth flow. Finally, the theory of atmospheric diffusion previously advanced by the writer for smooth flow is extended to rough flow in conditions of neutral equilibrium, and shown to be in good agreement with observation.

Vanoni, Vito A. A Summary of Sediment Transportation Mechanics. Proc. Third Midwestern Conf. on Fluid Mechanics, Univ. of Minnesota, March 1953, 129-160.

Yamashita, I. Experiment on Sand-Grains Accumulated Around Obstacles. Jour. Meteor. Res., July 1955, Vol. 7:295-304.

Snow and sand accumulation around a rectangular baffle was analyzed in a wind tunnel with various wind speeds and baffle heights. Results showed that sand accumulated abundantly not only at points where wind speed was low and the flow of airborne sand high, but also at some points of high wind speed and low sand flow. Accumulations under the latter conditions were due to gravity shifts of sand already deposited. Contour diagrams of sand accumulations obtained and the distribution of sand flow in the air are diagrammed.

Zingg, A.W. and W.S. Chepil. Aerodynamics of Wind Erosion. Agric. Eng., June 1950, Vol. 31, No. 6:279-282.

Basic nature of problems common to dynamic action of fluids on land surface; studies of phenomenon of soil erosion by wind initiated at Manhattan, Kans., Headquarters; experiences with soil blowing tunnel; aerodynamic characteristics of tunnel; formulas applied to description of surface wind movement; problems common to application of relationships to phenomenon of wind movement above field surfaces.

1. SNOW DRIFTING ON HIGHWAYS AND RAILWAYS

American Railway Engineering and Maintenance of Way Assoc., Committee on Signs, Fences, Crossings and Cattle-Guards. Report on Snow Fences, Snow Sheds, and Other Means to Prevent Snow Accumulating. Proc. Am. Ry. Eng. Maintenance Way Assoc., 1909, Vol. 10:881-897.

Various designs of snow fences, snowplows and snow sheds employed by U.S. and Canadian railroads are described and illustrated. Results of limited experience with snow hedges are promising. Closed board fences of sufficient height collect snow on the windward side and should be located 30-40 ft. from the tracks. Open fencing accumulates snow on the leeward side and fencing 50% open should be located 100 ft. from the tracks. The distance between fence and drift depends on the fence height, width of openings, wind velocity and character of the snow.

American Railway Engineering Assoc., Committee on Roadway and Ballast. Fences. Critical Review of All Methods of Preventing Snow Drifts. Pts. 1-3. Bull. Am. Railway Eng. Assoc., Feb. 1954, Vol. 55:655-663.

A preliminary report is presented which discusses protection against drifting snow, opening snow blockades, specifications for wood-slat portable fences and methods of protection against drifting sand. Protection from drifting snow in shallow cuts may be obtained by reducing slopes on both sides to a 4:1 slope of flatter. Flangers should be used for snow removal for depths less than 6 in. above the top of the rail, wedge or push plows on the locomotive pilot for light drifts 2-3 ft. above the top of the rail, and the larger wedge or push plows for snow up to 6-8 ft. deep.

Antonov, F.I. Snowdrift Protection for Railroads. Text in Russian. Peredovye metody truda v putevom khoziaĭstve, ed. by M.A. Chernyshev, Gosudarstvennoe Transportnoe Zheleznodorozhnoe Izdatel'stvo Moscow, 1952, 102-107.

Methods of increasing the effectiveness of snow fences are described. Installation of the snow fence 25 cm. from the ground prevents freezing of the fences to the soil surface. The use of high poles allows the fences to be raised without replacement when snowdrifts reach considerable heights. Removal of grass and other material around the roadbed prevents snow accumulation. Operational experience on the Moscow-Kiev railroad indicated that considerable

savings resulted from the use of double lines of snow fences.

Babkov, V.F. Effectiveness of Snowdrift Preventive Devices Made From Local Goods. Text in Russian. Stroitel'stvo Dorog, 1943, Vol. 6, No. 8-9:3-6.

Stems of sunflowers, weeds, and straw were used during the wartime for the prevention of snowdrifts. The effectiveness of these materials in relation to their supports, meteorological conditions and relief was investigated. Diagrams show the preventive effect of different supports. The most effective devices were fences, 1.5-2 m. high, with strips spaced about 5-10 cm. apart. Snow fences of weeds and straw were satisfactory. Optimum distance from the road depends on the fence structure and relief characteristics, and can be calculated from the suggested formulas. Rearrangement of snow fences during winter increases their effectiveness. Vertical insertion of sunflower stalks into snowbanks prevented snowdrift formation under moderate storm conditions.

Basov, M.M. Correction Factor for the Formula Determining Distance Between Snow Fence and Road. Text in Russian. Stroitel'stvo Dorog, 1943, Vol. 6, No. 8-9:20-21.

The distance of snow fences from the road is usually determined as a value equal to 12-18 times the height of the fence. Observations showed this rule to be incorrect since the deposition of snow is not only a function of height, but also of wind speed and type of snow fence. A formula is given in which the distance of snow fences from the road is determined as the product of the wind speed coefficient, a relative value of the spacing, and the fence height. The coefficient of wind speed varied from 18 for strong winds to 10 for light winds, and the coefficient of resiliency in snow fences varied from 0.6 for snowbanks to 1.5 for brushwood fences.

Bates, C.G. and Stoeckeler, J.H. Planting to Control Drifts on Highways. Eng. News Record, July 16, 1942, 92-96.

Becker, A. Natural Snow Fences Along Roads. Bautechnik, 1944, Vol. 22, No. 37-42:161-166.

Benterud, O. Report from the Nordic Road Technical Union's Meeting in Finland for Discussion of Winter Maintenance. Text in Norwegian. Medd. Vegdirektøren, March 1949, No. 3:32-37.

Snow fences, winter road maintenance and snowplows were discussed at the meeting of Feb. 1948. Studies on snowdrifts and various kinds of snow fences and hedges indicate the superiority of snow hedges. A winter road should not be covered by more than 3-4 cm. of ice. Sanding costs are reduced in Sweden by using ice rakes with steel teeth to groove the ice cover. Sand 2-7 mm. in diam. mixed with salt was considered most suitable for sanding roads. A table indicates the percentages of $CaCl_2$ and NaCl to be used -12 to -29°C and at -12 to -20.5°C respectively. Different types of snowplows were tested to determine discharge in relation to speed and snow conditions, angle of trajectory and distribution of the discharged snow in the direction of movement. The resistance of the plow at various speeds was checked and its net effect was determined mathematically. The graph indicates that the discharge effect rises steadily up to 45 km./hr. when it is increasingly influenced by air resistance. Light and heavy snow was thrown about the same distance.

Bialobzheskiĭ, Grigoriĭ Valerianovich, and Rikhard Andreevich Ambros. Developments in Snow Retention and Control Structures. Text in Russian. Moscow, Nauchno-Tekhnicheskoe Izdatel'stvo Avtotransportnoĭ Literatury, 1956.

The development of methods for road protection from snowdrifts in the USSR is outlined, and technical data on Soviet snow fences are given. Results of studies on the aerodynamic properties of snow fences and their efficiency under various physiographical conditions are described in detail on the basis of laboratory and field investigations by the Research Institute of Road Transportation during 1947-1953. Numerous data on snow distribution around snow fences used recently on highways and railroads in the USSR are tabulated and graphed, including characteristics for new types designed during the last decade. The use of the various types under different conditions is discussed together with improvements needed in snow-retention structures.

Birulia, A.K. Peculiarities of Snowdrift Control on Southern Roads. Text in Russian. Stroitel'stvo Dorog, 1942, Vol. 5, No. 2-3: 14-15.

The southern region of European USSR is characterized by frequent heavy snowstorms, massive snowdrifts, scant snow cover, and frequent thaws. Snowstorms lasting 5 days occur as often as 7 times during Dec.-Feb. Frequent and rapid melting of the snow cover greatly reduces the trafficability of dirt roads. Prevention of snowdrifts is more important than removal with plows. Snow fences are not recommended because strong winds flatten them and because wood is a scarce commodity in the southern steppe area. Stalks of corn and sunflowers are effective in drift prevention. Hedges of corn and sunflowers planted 20-30 m. wide along roads provide satisfactory protection.

Burton, V.R. Snow Drift Prevention and Control on Highways. Eng. News-Record, Nov. 5, 1925, Vol. 95:752-754.

The theory of drift formation and the effects of snow fences are discussed. Drift formations at a solid board and at a slatted fence are described and illustrated. The distance behind the fence at which snow will pile up depends on the wind velocity, the height and openness of the fence, and the sp. gr. and texture of the snow.

Chicago, Rock Island & Pacific R.R. Co. Snow Fences, Placing Them to Get Maximum Protection. Railway Eng. & Maint. of Way, Dec. 1950.

Cole, C.J. Notes on Drift Sand and Drift Snow. Tech. Paper No. 159, India Railway Board, 1904.

Methods of snow control used on railroads in Hungary, Scotland and NW. India are discussed, including snowplows and snow fences, hedges, walls and screens. Two types of wind-accelerating screens for use at cuts are described in detail and diagrammed: the V-shaped sloping screen of Rudniczki which deflects surface wind upward, and the elevated and tilted screen of W.L. Howie which channels a strong stream of wind down across the track.

Dashkevich, M.D. The Height of Coniferous Hedges and Their Distance from the Road. Text in Russian. Doroga i Avtomobil', 1936, Vol. 7, No. 1:12-14.

The amount of snow retained by a snow fence is a function of the area and height of the fence. If a fence 1 sq.m. in area and 1 m. high retains 7 cu.m. of snow, a fence 7 m. high will retain 49 cu.m./sq.m. Relocation of snow fences during winter increases the effectiveness of the fence. A fence retained 21 cu.m. of snow after 1 relocation; 127 cu.m. after 5 relocations. Two parallel rows of hedges, 7 m. apart, have the same effect as a snow fence moved several times. The first row of the hedge should be about 27 m. from the road. Hedges are recommended for areas susceptible to deep snowdrifts.

Finney, E.A. Snow Control on the Highways. Bull. No. 57, Mich. Eng. Exp. Stn., May 1934.

Different models of fences were set up in a wind tunnel in which wind velocities up to 45 mph. were obtainable. Flake mica of density of 0.2-0.22 and sawdust of density of 0.03-0.15 were used as artificial snow. The following conclusions were obtained as a result of the tests. The eddy area remains constant regardless of wind velocity. Its length varies with the height of the fence in the ratio of about 15:1 for horizontal and vertical slat fences and about 10:1 for the solid fence. The maximum length of eddy occurs when the ratio of slat width to slat openings is between 1:0.5 and 1:1. Fence inclinations from the vertical shorten the length of the eddy. The size and shape of the eddy control the size and shape of the snowdrift. The horizontal slat fence produces a shorter drift than the vertical slat fence. Drifts form on each side of solid fences. The end point of the drift is uneffected by wind velocity in open slat fences but gets closer to the fence with increasing wind velocity in solid fences. The point of maximum depth gets closer to the end point with increasing wind velocity with all fences. Drifts are best controlled with slat fences, 50% open, set 6 in. above the ground. Snowdrifting on highways is described. Drifting can be controlled by clearing drift producing elements from the right of way. Proper highway design is essential for effective snow control.

Finney, E.A. Snowdrift Control by Highway Design. Mich. Eng. Exp. Stn. Bull. No. 75, Mich. State Coll., July 1937, Vol. 13, No. 1.

Foedisch, F. Snow Removal from Roads. Text in German. Verkehrstech 1934, Vol. 15:476-478.

Construction features and applications of blade, V- and rotary snowplows currently used in the U.S. and Europe are briefly discussed; and the effectiveness of snow hedges, snow fences and proper road location in preventing snow accumulation on roads are described and illustrated. Snow fences or snow hedges should be moved a short distance toward the road after each sizeable accumulation.

Forschungsgesellschaft für das Strassenwesen E.V. Provisional Specifications for the Erection of Snow Fences. Text in German. Strasse, March 1942, Vol. 9:55-57.

A comprehensive scheme of winter road maintenance based on the work of Paulcke is presented. The influence of road design on the formation of snowdrifts is shown for roads level with the surrounding flat country, on low embankments having a gentle slope, with snow piled along the sides, on steep embankments or in cuts, on hillsides, and with protective walls, hedges and plantings. Types of protective construction described include snow walls, emergency fences utilizing tree branches and permanent lath fences including Russian and Danish types. Open-type fences are preferable to solid ones. Fences should be about 6.5 ft. high and should clear the ground by 8 in. The area of wood should be approximately equal to that of the air spaces. Coconut matting with a mesh of 2 in. has proved good and has a service life of 15 yrs.

Fraser, C. Experiments with Elevated, Inclined Snow Fence on Ontario Roads. Roads and Construction, April 1950, 88-90, 115-117.

Galimskiĭ, V. Snow Control on Roads of the Far North. Text in Russian. Stroitel'stvo Dorog, 1943, Vol. 6, No. 8-9:9-11.

Experience of military road operations during the winters of 1941-42 and 1942-43 showed some peculiarities of snow removal procedure caused by intensive and long-lasting snowstorms. Snowdrifts were observed 61 times during Jan.-May 1942 and 54 times during winter of 1942-43. The wind velocity accompanying snowstorms reached 10-15 m./sec. and the usual strip snow fences were torn down. Better snow prevention was obtained with strip snow fences, 1.5-2.0 m. high, located at a distance from the road equal to 20-40 times the height of the snow fence. The second line of snow fences was placed 15-20 m. from the first line in regions of heavy snowdrifts. Rearrangement of snow fences increased their effectiveness. Snowbanks and snow trenches were ineffective for snowdrift prevention. Roads were kept open continuously with rotary snowplows like the Niagara or Snogo.

Gavrilov, S.E. Protection of Railroads from Snowdrifts. Text in Russian. Snezhnye zanosy i bor'ba s nimi, Moscow, Transzheldorizdat, 1945, 26-105.

Three degrees of snowdrift susceptibility for railroads are given. The most dangerous regions are in deep valleys, station areas and along slopes.

Railroads elevated up to 0.65 m. in level areas and to 1.0 m. on slopes are least susceptible to drifts. The effectiveness of various protective measures is presented.

Gundorov, D.M. An Increase in the Efficiency of Snow Protection Means on the Roads of Moscow Division. Stroitel'stvo Dorog, 1944, Vol. 7, No. 10-11:17-19.

The efficiency of various snow protection measures were observed under identical topographic and meteorological conditions during 1943-44. The data, in graph and tabular form, indicate the amount, density, and the form of snow retained by snow fences, the number of changes in the location of fences, the amount of labor and material required for construction, the durability of each type of snow fence, and the cost of snow removal from roads protected by various types of fences.

Hallvik, C.C. Cure and Control of Winter Maintenance Problems by Natural Rather than Mechanical Methods. Proc. Northwest Traffic Eng. Conf. 8th, and Road Builders' Clinic 6th, March 16-18, 1955, 132-138.

Methods of reducing or eliminating icing and snowdrifts on roads are discussed, and major causes of these conditions are reviewed. A proper correlation of highway location, design, and construction (or reconstruction) is recommended. New locations should be studied with respect to exposure and snowdrift potential. Worst drift conditions occur when angle of wind to alignment is from 60°-90°. Leeward sides of natural slopes and sharp curvatures should be avoided, and advantage should be taken of sheltered areas with woods on the windward side. Other means of minimizing drift are flattening back slopes, widening cuts, providing flatter foreslopes and ditches, fall removal of roadside weeds, low brush, and debris, cleaning fence lines of brush, limbing trees, and when possible eliminating guard rails in favor of flat slopes and wider shoulders. The correction of poor drainage and the elimination of shade and poor exposure conditions will improve road safety and reduce mechanical maintenance. Shoulders with more of a slope than the traffic lanes are effective in accelerating run-off and minimizing ice conditions. A reasonably gritty to medium pavement texture is desirable in snow and ice areas. Salt mixed into the gravel or rock surface is a very effective stabilizing medium on untreated and under oiled surfaces.

Hay, Alan K. Snow Control and Removal on Winter Maintained Highways. Eng. and Contract Record, Oct. 2, 1935, Vol. 49:851-852.

The erection of portable lath-type fencing on steel posts or pickets is recommended for open country where drifting occurs. It is suggested that the first opening of a road after a snowstorm be performed using a truck-plow of the V and wing-type or by a one-way blade plow with or without wings.

Hutchewon, W.B. Winter Maintenance of Northern Roads. Roads and Bridges, Oct. 1940, Vol. 78, No. 10:34-35.

Snow fences are the most effective means of controlling snow in northern Ontario. The regulation slat type, and brush fences yielded satisfactory results. The plowing of lanes in the fields parallel to the roads creates depressions for catching the drifting snow. Snowplowing methods and equipment are discussed. Power maintainer blades were found to be more efficient than V-plows alone.

Kayser, Josef. The Economy of Snow Fences in Hill Country. Bautechnik, April 23, 1943, Vol. 21:145-146, Text in German.

The cost groups differentiated in snow removal are the operation of snow plows, snow fences, and personnel. The cost of snow shoveling can be saved by the timely erection of snow fences where drifts have been observed over a period of years. A cost comparison is made for a typical road. The annual cost of snow fences proved to be about 2.5 times greater than the cost of shoveling. Therefore, care must be exercised in the location and extent of fences.

Kohler, Hellmut. The Prevention of Snowdrifts. Die Strasse, Sept. 1937, Vol. 4:526-532, Text in German.

Snowdrifts may be prevented by adopting the design of new highways to the terrain. The road surface in flat country should be about 0.5 m. above the terrain or above the maximum snow depth. The lee side of hills and road cuts, 0.5 to 2 m. deep and vertical to the direction of snow-bearing wind, should be avoided. Sides or slopes with an angle of inclination of 1:6 to 1:10 are satisfactory road design. Stationary, semi-stationary and movable installations to prevent snowdrifts are recommended for regions of abundant snowfall. Stationary installations comprise earth walls, fences, hedges, and forest segments. Semi-stationary installations consist of firmly anchored iron or wooden posts with slats, wire netting or woven

material. Movable installations are usually lightweight slatted sections that can be erected as temporary snow fences.

Komarov, A.A. Methods of Improving Snow Control for Transportation. Text in Russian. Voprosy ispol'zovaniia snega..., by Institut Geografii Akademii Nauk SSSR. Moscow, Izdatel'stvo Akademii Nauk SSSR, 1956, 120-133.

The protective effects of various snow-fence and shelterbelt designs for railroads and the aerodynamics of air flow around obstacles are examined in detail on the basis of investigations at the Institute of Transportation and Power Engineering (Novosibirsk) from 1950-1954. The study included theoretical work, observations under natural conditions in the Tomsk Railroad district, construction of various models for snowdrift control, and tests of the models in a wind tunnel. The data were used to derive formulas characterizing (for W. Siberian conditions) the intensity of snowdrifts as a function of wind speed, the effects of decreased wind speed on diminishing snow transfer, and the effects of differences in windward and leeward speeds of wind on the distribution of snow deposits around snow fences. Data on the efficiency of various snow-fence designs as well as on snow-cover distribution near shelterbelts of different densities and widths are graphed and discussed.

Koronski, George W. Timbered Right-Of-Way Reduces Plowing Costs. Better Roads, Nov. 1936, Vol. 6, No. 11:13-16.

The annual average snowfall in Gogebic County (Mich.) was 12 ft. from 1927-1932. Roads totalling 487 mi. were kept open during the season. Roads were plowed in sheltered areas where timber forms natural snow fences, semi-sheltered areas partially protected by snow fence, and protected and unprotected windswept areas. It is estimated that natural timber fences must be at least 200 ft. wide on each side of the road to survive winds. The average annual maintenance costs per mi. in Gogebic County are tabulated for windswept and sheltered roads, indicating a net annual saving of $233.50/mi. when roads are sheltered. The snow removal equipment and plowing and sanding methods are described and costs of operations are itemized.

Kozachenko, G.S. and T.I. Liashenko. Performance of Standard Snow Fences. Text in Russian. Sbornik Nauchno-Issledovatel'skogo Instituta Puti NKPS (Babushkin), 1934, Vol. 33:133-204.

Horizontal and vertical slat fences were tested at selected points on the Kiev-Kursk railroad. Wind, temperature and snow measurements were made under various conditions at different distances from the roadbed. Fence dimensions, density ratios and other construction details and snowdrift profiles are described and illustrated. An increase in the width of the fence slats resulted in an increase in the amount of snow retained at and in front of the fence. An increase in the distance between slats resulted in increased snow deposition behind the fence and longer drifts.

Kudri͡avt͡sev, M.N. Winter Maintenance of Roads. Text in Russian. Avtomobil'nye dorogi, Moscow, Izdatel'stvo Dorozhno-Teknicheskoĭ Literatury Gushosdora MVD SSSR, 1950, Part 2, 43-60.

Winter conditions on Soviet highways are described with emphasis on snowdrifts and their control. The various effects of snow cover on road trafficability are discussed, and theories on snow movement near the ground and on the formation of snowdrifts with various forms of relief are given. Methods of snowdrift control and machinery for snow removal from roads are described. The problems of controlling road slipperiness and road protection from sandstorms are briefly discussed.

Kungurt͡sev, A.A. Planning the Snow Protection of Roads. Text in Russian. Moscow, Avtotransizdat, 1961.

A general plan for removal of snow from highways is proposed and data are presented on the variation of snowdrift in the USSR by region and by year. Laws of the distribution of amounts of drifting snow on highways are stated, and the possibilities of forecasting amounts of snowdrift are discussed. Two fundamental problems are considered, (1) the derivation of an index for calculating snow amounts and planning protective measures, and (2) the application of this index to specific cases. Criteria are given for planning roads in areas of heavy snowdrift, and the relative value of different types of snow fences and barriers are pondered. Instructions are given and specifications stated for dealing with drifted snow under specific circumstances and for reducing the amount of drift. Intensification of the highway snow removal effort has been dictated both by the enormous cost of the current program (1 billion rubles in 1959) and by the projected 3-fold expansion of the highway system under the current 7-yr. plan (1959-1965).

Kuz'min, L.A. Performance of Permanent Snow Fences Along the Omsk Railroad in the Winter of 1932-33. Text in Russian. Sbornik Nauchno-Issledovatel'skogo Instituta Puti NKPS (Babushkin), 1934, Vol. 33:268-288.

Snowdrift protection along 3 sections of the Omsk Railroad was investigated to test the performance and economy of different types of snow fences. Horizontal and louvered slat fences of different heights are described and their performance analyzed. Snow profiles and wind data are graphed. Good results were obtained with fences having openings between slats of 25-35% of the total area. The louvered-type fence was no more effective than the standard type.

Lewis, E.R. Snow Fences and Snow Sheds. Winter Track Work, Chicago, Railway Educational Press, 1917, 89-104.

Types and location of snow fences for railway protection are discussed. Open fences trap snow on the leeside where snow drifts with a slope of about 15 to 1. Solid fences trap snow on the windward side where the snow drifts with a slope of 3-5 to 1, depending on the wind. Track location to avoid the necessity for snow fences is discussed briefly.

Liders, G.V. Snow Control. Text in Russian. Zheleznodorozhnyĭ Put', Moscow, Transzheldorizdat, 1950, 297-310.

Snowdrift liabilities on railroad lines in the USSR are classified into 3 categories depending on the height of the railway cuts. Cuts 0.4-8.5 m. high are most liable to snowdrifting; cuts over 8.5 m. high are not subjected to snowdrifts. Single and double track plows, ram snowplows, Nosorog', rotary, and blower type snowplows, are described. The ram type snowplow raises the snow slightly before pushing it to the sides and is used for snowdrifts over 1.5 m. high. The operation of a rotary snowplow is explained schematically. Snow fence utilization is illustrated. Movable fences, 2 x 1.5 m. or 2 x 2 m., made of wooden boards nailed to wooden poles, are described. When snowdrifts reach two-thirds of the snow fence height, the fences are moved to the tops of the snowdrifts. Evergreen trees are planted in 2 rows 10-15 m. apart at least 30 m. from the roadline. Deciduous trees provide snow protection when planted in single rows 30-80 m. wide and 20-25 m. from the line. Other types of snow fences are described. Railway plows of the Gavrichenko type which transfer the removed snow into freight cars and snow-melting pits in railroad yards are briefly described.

Lyons, M.A. Snow Fence and Permanent Hedges are Manitoba's Most Effective Means of Winter Road Maintenance. Roads and Bridges, Oct. 1943, Vol. 81, No. 10:43, 82.

Snow fences are effective in Manitoba because the topography favors drifting snow. Snow fences are erected on the side of the road toward the prevailing wind, occasionally on both sides, 125 to 150 ft. from the right-of-way. The regular slat fences with steel posts are commonly employed. The snow control program includes 750,000 lineal ft. of hedges, principally of caragana. Snow removal costs approximately 6 to 7% of the annual road maintenance expenditure.

Marks, G.W. Some Autumn and Winter Problems. Better Roads, Sept. 1934, Vol. 4, No. 9:15-16, 21.

Drift control contributes to the economy of winter road maintenance in the Rocky Mt. region. Snow removal, though important, represents a minor part of the winter program. Drift is controlled by highway location, construction design, tree and shrub planting, and snow fences. Proper location is best secured by ignoring right-of-way considerations. High grade line construction design will reduce drift trouble. Trees and shrubs should be planted to the leeward of road sections where drifting prevails. The Wyo. State Highway relies chiefly on 3 kinds of snow fences: the railroad, woven picket, and sectional types. The railroad type is used where roads offer a large area in the direction of the prevailing wind. The woven picket type is used where fences must be removed for spring-to-fall farming operations. The sectional type is mostly an emergency fence. Small trucks and light 6-ft. speed plows are commonly used for snow removal.

Nordling. Means for Preventing Snow Accumulations on Railroads. Text in French. Ann. ponts et chaussées, 4th Ser., 1865, Vol. 2:1-17.

The results of investigations of snow-control measures used on Alpine railroads in Germany are reported. The effects of natural snow cover, snowdrifts, and avalanches on railroads are outlined, and the general design principles and effectiveness of the various protective structures are discussed. The control measures studied included: trenches, embankments, hedges, snow fences, retaining walls, and galleries. The use of snowplows is also considered.

Potapov, M.G. Effective Snow Protection. Text in Russian. Tekhnika Zheleznykh Dorog, 1947, Vol. 6, No. 7:25-27.

Protection from snowdrifts was accomplished aerodynamically by 1 to 5-m. wide wooden snow fences built up to 2 m. above the ground on poles and inclined 30-45°. The wind is forced down, protecting a surface 6-12 m. wide, depending on the wind velocity. The most effective angle and dimensions of the fence for drifting snow in cuts is illustrated. Inclined fences are satisfactory for low drifts.

Potapov, M.G. Experiments to Protect Roads from Snow Drifts. Stroitel'stvo Dorog, 1956, Vol. 9, No. 8-9:14-16.

Snow fences were erected along the roads of the Norilsk industrial enterprise following a study on precipitation, topography, wind velocities, and air temperatures. Experimentation indicated that the 2-row fence, capable of halting 700 cu.m. of drifting snow per meter of fence, was most advantageous. One fence was placed about 80 m. from the area to be protected; the other fence at a calculated distance from it. The distance between fences is determined by the height of the fence multiplied by 20, plus 30 m.

Price, W.I.J. How to Use Fences to Prevent Roads Being Blocked by Snow. Roads and Road Construction, Jan. 1954, Vol. 32:7-10.

The mechanics of snowdrifting were studied to improve the construction and location of collecting-type snow fences. Snow fences may be characterized by height, gap between fence and ground, and the % ratio of material area to the total fence area (density ratio). Snow fences 4-6 ft. high with gap widths 6-9 in. above the vegetation are recommended. Density ratios of 30-100% offer similar protection. Various materials for snow fence construction are discussed and basic fence arrangements illustrated.

Price, W.I.J. Winter Conditions in Great Britain and the Highway Engineer. Jour. Inst. Munic. Engr., April 1953, Vol. 79:485-493.

The control of drifting snow and the removal of snow and ice by mechanical, chemical, and thermal methods are discussed. The height of the road embankment should exceed the depth of the heaviest snowfall and the slopes should not be steeper than 1 in 4. The road should be located beyond the leeward limit of the eddy region through cuts. Collecting fences deposit the windborne snow before it can reach the road and their efficiency is governed by the form of the eddy region to the leeward of the fence. Blower fences placed 15-25 ft. to windward of the road deflect the wind on to the road and prevent deposition of snow on the highway. Blade plows and rotary plows are used to remove shallow and deep snow respectively. The critical throwing distance and velocity of projection at which a rotary plow offers maximum over-all efficiency are discussed. The quantities of salt required to melt porous settling snow, hard impervious snow or ice, thin films of ice and hoarfrost and the damage by chemicals to roads and vehicles are evaluated. The use of thermal methods is considered impractical and too costly.

Rocca. Measures Against Snow. Text in French. Internatl. Railway Congress 2d, 1887, Proc., 1888, Vol. 1, Sect. 2:V1-V57.

Problems associated with snow accumulation on railroads are outlined, and control measures used in various countries are discussed. The effects of natural snow-cover, snowdrifts, and avalanches on railroads are examined individually, and protective measures against each are described and evaluated. The measures considered include galleries, embankments, snow hedges, trenches, retaining walls, slope alteration, windbreaks, snow fences, and avalanche-deflecting structures. Snow removal is discussed, and various snow plow types and their applications are described. The use of chemical agents is also considered.

Sarsatskikh, P.I. For a Rational Snow Control. Stroitel'stvo Dorog, 1947, Vol. 10, No. 2:20-22.

The length, height, and the clearance between individual slots of snow fences are discussed. Various formations of snow drifts in relation to the configuration of the snow fence and its distance from the road are described. Meteorological factors such as precipitation and prevailing winds are considered as important as topographical features. Experiments with adjustable fence slots are briefly reviewed.

Schaible, Lothar. The Development of Snow-Protective Structures. Text in German. Bautechnik, Jan. 22, 1943, Vol. 21:17-21.

Various types of natural and artificial snow protective structures such as forest covers, hedges, stone walls, reenforced concrete fences, and wooden fences are discussed. Applications of these structures for the protection of railways and roads with specification details are presented. The advantages and disadvantages of open and closed fences, and the theory of snow deposition behind the fence are given.

Schneider, T.R. Snowdrift and Winter Ice on Roads. Eidgenössisches Institut für Schnee- und Lawinenforschung, Interner Bericht Nr. 302, 1959, Trans. by D.A. Sinclair, NRC TT-1038.

The first section of this paper contains a discussion on the mechanics of snow drifting, snow drifting and highway design, the design and construction of snow fences, the influence of wind speed and direction and the influence of fence density, height, orientation and arrangement. Available information on field and wind tunnel tests of snow fences are critically discussed. The second section is a discussion of ice formation on roads, its causes, classification and methods for combatting. The use of salt, sand or a combination of the two is discussed under headings such as quantities required, types available, storage, methods of loading, results and damage to road surfaces, clothing, plants, animals. The various types of road heating installations are described and discussed under the headings, quantity of heat required, control, methods of operation, cost. Finally, the author gives his opinion as to the requirements and organization of a salt and sanding service and presents a brief summary of the present situation in Switzerland concerning the use of these techniques.

Schubert, E. Snow Fences. Text in German. Centr. Bauverwaltung, Jan. 1, 1887, Vol. 7:5-7.

New railroad fence arrangements which have proved satisfactory in N. Germany are described in detail. One arrangement consists of 2 parallel rows, the outer row an open work fence, the inner a dense fence constructed of rails. The fences are erected on embankments 0.6 m. high with a depression between. Snow accumulates between the fences and drifting is stopped by the inner fence. Another arrangement provides for protection against shifting winds in that the outside fence is erected in a circle leading from a 15.90 m. distance to the track. The height of the fences, their distance from the tracks, and the interval between fence rows can be adapted to varying terrain conditions.

Shestakov, P.N. Maintenance and Repair Work on Roads. Text in Russian. Kurs avtomobil'nykh dorog, 3d ed., Izdatel'stvo Narkomkhoza RSFSR, Moscow, 1939, 589-611.

Seasonal road maintenance is described in detail with emphasis on snowdrift control, snow removal and frost heaving. Snow accumulation on roads and around obstacles is analyzed as well as the controlling effects of shelterbelts and various snow-fence constructions. Several devices used for snow removal are described and performance data given. Various types of frost heaving are classified and countermeasures listed with reference to differences in ground composition, soil moisture and depth of seasonal soil freezing.

Shiotani, M., and H. Arai. Records on Snow-Protection Plantation, Snow Fence and Snow-Storm. Text in Japanese. Bull. Railway Technical Lab. Tokyo, Jan. 1950, Vol. 7, No. 1:23-27.

Data collected by the Niigata and Sendai Divisions of the Japanese National Railway from studies on snow control with shelterbelts and fences as well as from investigations on snow storms are summarized. The results of field experiments on the relation between snowdrifts and the height and width of control structures and that between snow accumulation and eddy currents are also reported.

Slavut͡skiĭ, A.K. The Maintenance of Roads and Associated Structures. Text in Russian. Dorogi i Mosty, ed. by F.V. Krutet͡skiĭ, Izdatel'stvo Ministerstva Kommunal'nogo Khozi͡aĭstva RSFSR, Moscow, 1952, 567-610.

Methods of winter road maintenance and bridge protection are described. Snow fences may have horizontal or vertical slats with a ground clearance of 20-25 cm. Horizontally slatted snow fences are more efficient when the slats are spaced more widely in the lower section of the fence. New snow fences should be added as snowdrifts grow. Trees planted in 2-20 rows at distances from 13-35 m. from the roadbed will give good protection in areas where snow tends to accumulate in drifts up to 2 m. high. Rotary and V-type snowplows will remove snow 1.5-2 m. deep. Ice-control techniques for bridges are described.

Sobolev, I.N. Control of Snowdrift on Roads Used for Lumber Transportation. Text in Russian. Lesnai͡a Promyshlennost', 1949, Vol. 9, No. 11:9.

Snow fences, in 2 x 2-m. sections, ordinarily used for railroads are recommended. The best results are obtained when the snow fences are located 25-30 m. from the road axis. A dense hedge of spruce planted near roads is the most effective, long-term measure.

Sorokin, P.I. Winter Maintenance of Automobile Roads. Text in Russian. Moxcow, Dorizdat, 1942.

The effects of road profile and near-by obstacles on snow drifting are analyzed, and countermeasures are described. Maximum drifting occurs in cuts up to 6 m. deep and along embankments up to 0.6 m. high. Least drifting is observed in cuts below 8.5 m. or along embankments above 1 m. The construction of snow fences and shelterbelts is described in detail, and their effect on drifting is analyzed. Equipment for snow removal, protection of small bridges, and the construction and maintenance of ice crossings are also discussed.

Stepanov, N.N. Planting and Maintenance of Snow Hedges, Forest Belts, and Tree-Nurseries for Railroads. Text in Russian. Moscow, Transpechat', 1928.

A history of snowdrift prevention through the use of snow hedges and forest belts along railroads in presented. Species of bushes and trees according to climate and soil conditions are described and methods of improved maintenance are discussed. Wind flow variations around obstacles are analyzed and results of investigation of snow deposit forms are reviewed. Construction of snow hedges and forest shelter belts, location and width for various forms of relief in steppe regions are described in detail.

Stephenson, Geo. E. Ten Rules for Winter Road Maintenance. Eng. and Contract Record, Oct. 30, 1935, Vol. 49:946-947.

Experience derived from 1 season's work in Bruce County, Ontario indicates that snow fences should be used liberally, kept off the ground as high as possible, and well braced every 100 ft. It is suggested that the wing of a plow be close to the plow to prevent humps of snow from falling in front of the rear wheels of the truck.

Sund, Jakob. Snow Fences Along the Roads in Vestfold. Text in Norwegian. Medd. Vegdirektøren, April 1929, No. 4:58-59.

Horizontal wooden fences, 1.5 m. high and 5 m. long, consisting of 1 x 5-in. boards spaced 5 cm. apart, are described. The fences are placed from 15-30 m. from the road, with the greater distance for more exposed locations. The fences proved very effective in some instances.

Tolstov, V. Wind Control in the Regulation of Snowdrifting. Text in Russian. Zheleznodorozhnoe Delo, Put', Feb.-March 1926, Vol. 3, No. 2-3:8-9.

The influence of wind speed and direction on snow accumulation around obstacles is analyzed. Experiments along the Tomsk Railroad showed that snowdrifts can be better controlled if wind eddies caused by snow fences are taken into account. Vertical planks forming an angle of 30° with the horizontal axis of the fence increase the deposition of snow along the fence. Fences with the free edges of the slats directed upward collect more snow near the fence than those with horizontally oriented slats, while fences with slats directed downward produce an even distribution of snow in the area with no max. near the fence.

USSR. Glavnoe Upravlenie Puti i Soobshchenii͡a. Instruction on Snow Control for the Railroads of the USSR. Text in Russian. Moscow, Gosud. Transportnoe Zheleznodorozhnoe Izdat., 1958.

Instructions are given for snow-clearing operations, snowdrift control, snow-removal procedures, and the operation and maintenance of various types of snowplows and snow fences. The design and performance characteristics of blade plows, V-plows, wing plows, conveyor-type snow loaders, snow brushes, and rotary plows are described; each device is illustrated and diagrammed; and technical data are tabulated. Diagrams of snow fences used in various situations are included, and design data are given. The selection of control measures should be based on the type and amount of drifting in a given area as determined by the profile of the area. Primary consideration must be given to depressions 0.4-8.5 m. or more deep, then to more shallow depressions not exceeding 0.4 m., and finally to small banks up to 0.65 m. high or to 1 m. high on slopes.

Vedenisov, B.N. On the Increased Efficiency of Snow Control on Railroads. Trudy Moskovskogo Ordena Lenina Instituta Inzhenerov Zheleznodorozhnogo Transporta, 1948, Vol. 71:5-46.

Snowdrifts along railroad beds are described and a theory explaining their formation is presented. A study of conditions associated with the operation of various types of snow safeguards and their most effective utilization is suggested. Characteristics of snow-cover surface and the behaviour of snowdrifts are described. The terminology employed in snow control is presented. The drift of snow over snow fences and the relationships between the drift intensity and the ground configuration are discussed.

Wehner, Bruno. First Experiences of Winter Maintenance Service on Russian Roads. Text in German. Strasse, March 1942, Vol. 9: 47-49.

Snowdrifts are most likely to occur in long and narrow cuts, in cuts up to 26 ft. deep, at the ends of deep cuts, and on transitions between cuts and embankments. Other dangerous positions are embankments up to 3 ft. high and hillsides. The Moscow-Minsk highway and a few other important roads were designed to avoid cuts. Snowdrift-prevention measures include protective plantings, emergency snow fences and portable fences. Conifers make the best natural snow fence. In Russia, young fir trees or, in the south, other evergreen trees and shrubs are planted to form a thick hedge 3.5-5 ft. high. Temporary fences include dirt banks placed 50-80 ft. from the road, open-type walls built of snow blocks and low snow banks with evergreen branches inserted. The maximum deposition of snow with fences is attained by increasing the spacing of the horizontal slats towards the top of the fence.

Whiffin, A.C. and Price, W.I.J. Road Problems Arising from Snow and Ice. Chem. and Ind., 1954, Vol. 9:230-237.

Winkler, C.F. Where Snow Removal is Toughest. Am. City, Oct. 1951, Vol. 66, No. 10:88-89.

An annual average of 160 in. of snow, with a record fall of 286 in. in 1951, is reported from Houghton County (Mich.). Snowdrifts attain heights of 10-20 ft. as a result of timber denundation. The county operates 26 five to ten-ton trucks, 8 Sno. Go's, 1 Rotowing, 2 tractor-type rotaries or Snow Kings, and some smaller units. All trucks are equipped with 12-ft. wings. A method of building an 8-ft. snow fence from a 4-ft. picket fence was evolved by using a heavier and longer steel post and superimposing a second 4-ft. fence over the bottom row. A permanent installation consisting of 2 rows of the 4-ft. picket-type snow fence, one above the other, are hung between cedar posts and supported with 0.5-in. galvanized cables.

Wolff, A. The Function of Snow Fences in Winter Road Maintenance. Text in Swedish. Svenska Vägförening. Tid., July 1941, Vol. 28: 154-176.

Correctly placed snow fences catch snow outside the highways through their lee-effect. This effect is analyzed in view of the studies of Finney, Irminger and Nökkentved. Various types of snow fences are described in relation to their effectiveness, construction and design. Detailed studies on snow and local wind velocities indicate the importance of planning, construction and maintenance of winter roads. A table of data (1931-1938) from 700 stations features first and last days, duration and thickness of the snow cover in 24 Swedish regions.

Wolter, Karl. Protection Against Snowdrifts. Text in German. Handbuch der Eisenbahnbautechnik, Berlin, Otto Elsner Verlagsgesellschaft, 1943, Vol. 1:96-100.

Cuts, shelterbelts, hedges, dams, walls and fences used for protecting railroads from snowdrifts are described. Formulas for calculating the height of snow fences placed along cuts are given. Dimensions of fences made from wooden railroad ties and various portable obstacles are included.

Control of Snowdrifting Studied by Wind-Tunnel Tests on Models. Better Roads, Oct. 1934, Vol. 4, No. 10:15-16.

Designing the Road to Keep the Snow Off. Better Roads, Sept. 1939, Vol. 9, No. 9:34-35.

Increasing consideration is given to snow control in location and design of roads in snow states. High, rolling grade lines were effective in avoiding snowdrifts when snow control was first considered in road construction, but as increased amount and speed of traffic required wider roadways and flattened slopes they proved unsatisfactory. The advantages and disadvantages of road location in broken and unbroken country are discussed. Modern engineering tends to locate roads through sheltered areas far enough to leeward of natural obstructions so that snow will trap in drifts before reaching the roadway. Windswept or streamlined grade lines are believed to be essential for roads in snow countries. Road design principles adopted by a number of snow states and countries are reviewed.

Investigations of Snow Fence Effectiveness. Roads and Engineering Construction, March 1951.

This article is an abstract from Road Research Technical Paper No. 19 by the British Road Research Lab.

Note on Snow Protection on Roads. Text in German. Untersuchungen über Schnee und Schneeschutzanlagen an Strassen by Karl Croce and Josef Kayser. Forschungsarbeiten aus dem Strassenwesen No. 6:21-25, 1949.

The most frequent snowdrift formations and road constructions preventing drifts are diagrammatically presented. Different types of satisfactory snow fences are described, such as horizontal and vertical slat fences, fences of jute fabric, and wire fences intertwined with pine branches. The length of the snow deposit is inversely proportionate to the closed area of the fence. Snow deposits to the full height of closely filled fences. Long, shallow snow deposits form at fences with wide spaces. The largest amount of snow is caught by fences which are 60% or 30% closed, and erected from the road at a distance 15 times the height of the fence. Protective fences are most effective if erected at right angles to the wind. Parallel, overlapping fence sections are used for winds with oblique angles of incidence; the length of the fence sections decreases with decreasing angles of incidence. Several snowfence arrangements for the protection of curves, expected snowdrifts from alternate directions and road cuts are explained by diagrams.

The Proper Location of Snow Fences. Ry. Eng. and Maintenance, March 1923, Vol. 19:129-130.

The disposition of snow fences along railways is discussed. The proper distance from the track for snow fences is determined by the slope assumed by drifted snow, which usually varies from 1:12 to 1:15, but local conditions can cuase wide variations. A tight board fence, however, close to the tracks is only effective so long as its height exceeds the depth of the drift. The open board fence, usually of portable Y-shaped sections 12-16 ft. long and 6 ft. high, is designed to deposit the snow between the fence and the tracks and should be set about 20 ft. from the tracks for each foot of its height. Two parallel lines of fence may be placed where space permits and the need warrants.

Snow Drift Control on the Highways. Canadian Engineer, March 9, 1937.

Designing to control drifts - types of snow fence - results of wind-tunnel tests on fencing.

Snow Fence as an Aid to Winter Road Maintenance. Eng. and Contract Record, Oct. 31, 1934, Vol. 48:935.

Wire-bound, creosote-treated slat snow fences, 4-5 ft. high, 0.375 in. thick, in 100 ft. rolls, were found highly satisfactory where exceptionally heavy snow occurred. The fence should be hung on standard steel fence posts placed about a rod apart. The fence should be located about 100 ft. from the center of the road for at least 200 ft. wider than the drift. It is sometimes advisable to erect a second fence, 75 ft. from the first if snowfall is unusually heavy.

Snow Fence Efficiency. Roads and Engineering Construction, April 1951, 136-140.

Three Methods of Snow Drift Prevention. Eng. and Contract Record, Oct. 28, 1936, Vol. 50:966-969.

Proper highway design is a means of snow control. The grade line should be equal to or above the average snow level in low flat country. Shoulders, ditches, and backslopes should provide ample storage space for drifted snow and snow plow accumulations. Cut sections, 6-10 ft. wide, should be allowed for each ft. of depth cut. Artificial snow fences include the horizontal and vertical slat types which are most effective at a ratio of 1:1 for width of slat and openings between slats; solid board fences which are costly and effective only for the deflection of snow-laden wind of constant direction; woven picket fences which are easy to handle and store, inexpensive and which may be erected at any height. Emergency snow fences may be made by tying old grain sacks or NaCl sacks to woven wire or chicken fencing stretched in place, and by piles of hard snow. A ratio of 15 ft. for each foot of height is recommended for fences from roadways. Wind tunnel results showed that each type of snow fence produces a characteristic eddy which remains constant for any wind velocity and height and type of barrier and varies with the height by the ratio of 15:1 for slat fences and of 10:1 for solid fences. Fences erected at 6 in. above the ground with inclination with the wind not more than 30° gave the best results. Trees and shrubs planted in single or multiple rows form permanent natural snow barriers. Evergreen trees and low spreading shrubs should be planted closely allowing adequate space for moisture and root growth. The effective area will average about 16 ft. from the edge of the trees to each ft. of tree height.

2. SNOW FENCES

Arai, Hideo. Performance of Shelterbelt; Experimental Study of Shelterbelt in Simulated Snowstorm. Quarterly Report Railway Technical Research Institute, Japan, 1960, Vol. 1, No. 2; 1961, Vol. 2, No. 2.

Performance of a model forest to prevent snow drifts compared with that of an actual forest.

Bíalobzheskiĭ, G.V. Snowdrifts and Their Control. Text in Russian. Moscow, Izdatel'stvo Dorozhno-Tekhnicheskoĭ Literatury Gushosdora MVD SSSR, 1952.

The physical properties of snow and snow covers and equipment for snow control and snow removal are described. The effects of obstacles on snow accumulation are analyzed and the efficiency of various types of snow fences is discussed. A new snow-fence design developed by P.I. Sarsatskikh and a modification by A.A. Kungurtsev are described as well as a machine designed by Vavilkin for installing fences. Snow-removal equipment used in the USSR is also discussed.

Bíalobzheskiĭ, G.V., A.K. Dfūnin, and A.A. Komarov. Improving the Design of Snow Fences. Text in Russian. Avtomobil'nye Dorogi, Dec. 1959, Vol. 22, No. 12:17-18.

Recommendations based on investigations by research organizations in the USSR, are made for the design and location of 5 types of snow fences. Formulas are proposed for calculating snow accumulation in relation to wind velocity. Results were confirmed by field observations and laboratory experiments with a wind tunnel. Tests indicate that fences with 50% over-all density ratio collected up to 100 cu.m. of snow/linear m. For regions with a wind velocity of less than 65 ft./sec. at a height of 30 ft., fence units 6 ft. 6 in. sq. or 5 ft. high and 6 ft. 6 in. long are recommended with 30 and 50% density ratio for the upper and lower half of the fence. Fences should be placed not less than 65 yd. from the shoulder of the roadway. The fences placed furthest from a road should have the lowest density ratio.

Blum, Bernard and P.C. Newbegin. Inclination for Snow Fences. Ry. Eng. and Maintenance, Dec. 1935, Vol. 31:747-748.

The effectiveness of various types of snow fences is discussed. Effectiveness seems to depend primarily on height and spacing of panels and boards. The effectiveness of a tight board fence varies inversely with the width of the opening between the boards. A fence will remain effective in deepening drifts if an open space is maintained behind the fence by spacing the horizontal boards properly and inclining the panels 30° from the vertical. The resulting groundward deflection of the wind current prevents the deposit of snow until a rolling eddy forms at a distance from the fence. Comparative tests of the efficiency of different designs are difficult because of the variability of wind conditions.

Brudal, Holger. Collapsible Snow Fences. Text in Norwegian. Medd. Veidirektøren, March 1938, No. 3:52-53.

Several wooden snow fences were tested in Østfold for a number of years. The best results were obtained with a fence constructed of wooden slats, 160 cm. high, 5 cm. wide and 1.7 cm. thick, impregnated with creosote and connected by chains at 5 cm. intervals. The fence can be rolled up for storage in lengths of 10-20 m. It can be attached quickly to stationary poles in the field.

Burton, V.R. Snow Drift Prevention and Control on Highways. Eng. News-Record, Nov. 5, 1925, Vol. 95:752-754.

The theory of drift formation and the effects of snow fences are discussed. Drift formations at a solid board and at a slatted fence are described and illustrated. The distance behind the fence at which snow will pile up depends on the wind velocity, the height and openness of the fence, and the sp. gr. and texture of the snow.

Caborn, J.M. Some Observations on the Drifting of Snow Near Barriers. Weather, Aug. 1958, 264-267.

Chukalin, S.G. Experiments with Snow During 1934. Text in Russian. Sotsialisticheskoe Zernovoe Khoziaistvo (Saratov), 1934, Vol. 4, No. 5:64-67.

Snow deposits around fences were investigated in the Saratov region during the winter of 1933-34. Snow fences placed perpendicular to the wind direction accumulated drifts higher than the mean depth of the snow cover. Snow fences placed parallel to the direction of the wind accumulated less snow than perpendicularly placed fences, and often less than the mean depth of the snow cover.

Croce. Performance Tests of Snow Fences in the Winters 1940-41 and 1941-42. Text in German. Arbeitsbericht C1, Schneeforschungsstelle, Generalinspektor für das deutsche Strassenwesen, Sept. 1, 1942.

Studies on snowdrift formation and on the efficiency of snow fences and hedges conducted at Lindenberg (Germany) are described in detail. The protective efficiency of snow fences depends primarily on the height of the fence and its density. Studies with 16 types of snow fences showed that the amount of snow accumulated increases with the square of the fence height, while the length of the area of accumulation decreases with increasing fence density and increases with fence height. The slats of the fence should be distributed evenly at 0.25- to 0.50-cm. intervals, since greater fence density does not improve retaining efficiency. Hedges proved as efficient as fences. No snowdrifts were observed with wind velocities under 7 m./sec.

Croce. Snow Fences Made of Straw Ropes. Text in German. „Arbeitsbericht C2, Schneeforschungsstelle, Generalinspektor für das deutsche Strassenwesen, Aug. 15, 1942.

The efficiency of snow fences made of various types of straw rope for use in the Ukraine is discussed on the basis of investigations conducted in Denmark and Germany. Test results showed that fences of twisted ropes spaced 15/m. and supported by poles 2.2 m. high at intervals of 3 m. are the most satisfactory. Braided ropes are inefficient because of their softness and tendency of stretch. The fences should be set up 35-40 m. from the area to be protected.

Dîunin, A.K. and A.A. Komarov. On the Construction of Snow Fences. Trudy Transportno-Energeticheskogo Instituta, 1954, No. 4:111-118. Trans. by G. Belkov, TT-1103, N.R.C., Ottawa.

A theoretical analysis is given of the conditions that control the accumulation of snow at a snow fence. It was found that for a fence to reduce the blowing snow content of the air stream by a factor of 20, it must reduce the wind speed one meter above the snow surface to less than 0.5 of the wind speed at the 1 meter level away from the influence of the fence. A fence whose density decreases towards the ground was found effective in improving the second condition. The theory is supported by field observations.

Downey, R.R. Paper Snow Fence Installations 1951-1952. Rept. No. 178, Res. Lab. Testing and Res. Div. Mich. State Highway Dept. July 1, 1952.

Tests were made in 7 countries with paper snow fences of 2 parallel 12-in. wide strips, 4-12 in. apart, fastened to steel posts spaced 8 ft. apart. The bottom strips were 6-12 in. above the ground. The fence installations withstood ice, rain and winds during the winter of 1951-52. Special tests were conducted on experimental sections consisting of 1-3 strips, 12 and 16 in. wide, and 8 in. apart. The effectiveness of the various fence sections is graphically presented and compared with that of a regular vertical slat wooden fence in the same area. Installation, maintenance, and dismantling as employed by the participating counties are described.

Ebana, Yasus. Conservation of Shelterbelt; No. 1 - Planting Test (with sugi). Quarterly Report Railway Technical Research Inst. Japan, Vol. 1, No. 2, 1960.

Finney, E.A. Snow Drift Control on the Highways; Designing to Control Drifts, Types of Snow Fence, Results of Wind-Tunnel Tests on Fencing. Can. Engr., March 9, 1937, Vol. 72, No. 10:7-9.

Snow drifts are caused by the deposit of windborne snow on barriers that slow down the normal velocity of the wind. Drift formations on highways may be prevented by designing proper highways and erecting artificial and natural snow fences. Right-of-way widths, grade lines, shoulders, ditches, back slopes and cut sections in highways must be made wide enough to provide storage space for the accumulation of snow. There are 4 types of artificial snow fences: the horizontal slat type, the vertical slat type, the solid type, and the emergency type. Wind tunnel tests indicate that a snow fence, 6 in. above the ground with a barrier of 50% open spaces, is most efficient. Artificial snow fences are erected in locations of previous drifting and by studying the topography along the roadway. Fifteen ft. for each foot of height of fence is the recommended distance from the roadway. A natural snow fence consists of trees or shrubs planted in groups or in single, double or multiple row barriers and is best adapted where permanent snow fences may be left in place the year round. The effective area of a tree barrier is about 16 ft. from the edge of the trees to each ft. of tree height.

Fraser, C. Controlling Drifting Snow with Inclined Snow Fence. Better Roads, Oct. 1950, Vol. 20, No. 10:25-26.

Slat fences raised above the ground and inclined at an angle toward the wind were used by the Owen Sound division of the Ontario Dept. of Highways. Slat fences increase wind velocity; conventional snow fences decrease wind velocity. It was found that 2.5 to 3 ft. was the most satisfactory distance from the lower edge of a 4-ft. fence to the ground, and an inclination of 45° to 80° with the horizontal was satisfactory. Most successful fences were those erected at the sides of roads which were lower in level than surrounding ground.

Fuchs, Alfred. Report on Wind-Tunnel Experiments with Wind-Baffle Models. Text in German. Forschungsstelle Lizum, Lawinendienst Innsbruck (Austria), Aug. 27, 1954.

Airflow patterns around wind-baffle models were studied as basic to a knowledge of snow accumulation. The effects of variations in wind velocity, in the wind-to-baffle angle, and in the clearance between baffle and ground for square baffles on level surfaces and in depressions are treated as well as flow patterns around triangular and X-shaped baffles. The observations show that airflow patterns are independent of wind velocity; that, with constant baffle cross section the patterns are almost independent of the shape of the board, provided the differences in shape are not too great; that wind-to-baffle angles within 20° of a right angle have little effect on the flow pattern, while outside this range conditions change rapidly; and that ground-to-baffle clearance is not significant when equal to at least 1/3 of the baffle height. Flow diagrams are given in the appendices.

Glanville, W.H. Snow and Ice. Report of the Road Research Board, 1951, 54-56.

Preliminary test results of 2 sets of fences indicate that good drift-forming characteristics are produced by fences with an aperture area equal to that of the slats between, with widths ranging from 1-3 in. The use of salt for snow and ice removal is briefly discussed. Only enough salt to raise the liquid water content to 50% for the snow is necessary. This requirement is 1/80 lb. salt/sq. yd. of road for each in. of snow and for each °F of ambient temperature below 32°F. The amounts necessary for various snow depths and air temperatures are graphed.

Hallberg, Sten. Different Types of Snow Fences and Their Function. Text in Swedish. Svenska Väginst. Medd., 1943, Vol. 67:5-8.

Snow fences are classified according to their function into 2 main types, the accumulating and the deflecting. Each group is further classified as stationary or movable, open or closed fences. The accumulating type is discussed. Open fences are characterized by their aperture ratio, which is the relation of space between the slats expressed in percentage of the total surface. An aperture ratio of 50% was the most satisfactory. Wire fences of the horizontally open type include emergency fences made of straw bands, twigs and branches that were used with good results during World War II.

Hallberg, Sten. Foreigh Investigations in the Capacity of Snow Fences to Accumulate Snow. Text in Swedish. Svenska Väginst. Medd., 1943, Vol. 67:46-51.

Finlay's (USA) scale model experiments are reviewed and summarized. Nökkentved's (Denmark) measurements of the wind speed taken 25 cm. off the ground at different distances behind snow fences are described. The results are tabulated as a function of distance on the percentage of reduction of wind speed. Danish and German experimental results with vertical and inclined fences indicate the significance of aperture ratio. Fences with an aperture ratio of 50% gave best results. It is concluded that aerodynamic scale model experiments may give indications as to the construction of snow fences but only full-scale field tests give reliable results.

Hallberg, Sten. Measurements of Wind Movement at Snow Fences. Text in Swedish. Svenska Väginst. Medd., 1943, Vol. 67:52-65.

Full-scale tests were conducted during 1941-42 on the ice of Mälaren Lake to determine wind velocity at snow fences of different construction and angle of inclination. Four-m. sections were erected in 32-m. lengths and exposed to the full impact of wind at 4 and 8 sec./m. The wind direction was measured at 72 points with a vertical net of silk streamers fastened to horizontal lines. Streamer movement was recorded photographically and by drawings. Wind speed was obtained at 32 points with anemometers. The experimental results with 23 fences of various types and designs are tabulated. The effects of aperture ratio, angle of inclination, and snow shields on snowdrift formation are discussed. No definite conclusions are drawn.

Hallberg, Sten. Some Viewpoints Concerning the Construction of Snow Fences; A Comparison Between the Wire Fence and the Chain Fence. Text in Swedish. Svenska Vägpinst. Medd., 1943, Vol. 67:39-45.

The stability of a snow fence against wind pressure depends on the anchor posts. This resistance capacity was calculated as a function of the horizontal wind pressure at 1-m. height expressed in kg/m. fence. The results are presented for 11 different styles of anchor posts. Material, dimensions, shape, height over free ground and depth into sand anc clay ground are given and the difference in resistance capacity in these soil types are stated in kg. It was found that trussed poles had better resistance than those equipped with snubber plates. A good fence must be of minimum weight and volume and easy to handle. The wire fence meets all these requirements but lacks durability. A simple method for storing board fences is described.

Hallberg, Sten. Types of Snow Fences Used in Sweden. Text in Swedish. Svenska Väginst. Medd., 1943, Vol. 67:8-38.

Detailed field studies were designed to investigate suitable construction and time utilization in erecting and dismantling snow fences. The study included vertical and inclined designs of vertical and horizontal slat fences, both commercial and home-made. Wood materials, shape, anchorage, trussings, extension mechanisms and locks are described and clearly illustrated. Each type of fence was tested in 40-m. lengths exposed to easterly winds. Extended time studies of erection are suggested in order to save time and money. Snow shields of German design were not satisfactory.

Hjort, Ivar. Contribution to Snow Protection; Some Experiences from the Last Winters. Text in Swedish. Svenska Vägförening. Tid., 1928, Vol. 15:215-220.

Various types of snow fences used in Sweden are discussed. The aperture ratio and the height of a board snow fence are more important than horizontal or vertical construction. Horizontal fences accumulate snow over a wider area. An aperture ratio of 2:3 in 1.3-m. high snow fences placed 10-20 m. from the roadside proved satisfactory in central Sweden, and a height between 1.7-2 m. was adequate in Norrland. An open space of 15-20 cm. between the ground and lower fence board is economical and effective.

Huber, Alfred. Paper Mesh as Protection Against Snow Drifts. Text in German. Schweiz. Z. Forstwesen, Dec. 1949, Vol. 100: 592.

Extensive experiments with several types of snow fences were carried out in Germany during World War II. The experimental meshes consisted of turned paper twines, 2-5 mm. in diameter, impregnated with creosote, and with a mesh width of 2-5 cm. The 2 edge hems were each reinforced with a steel wire on which the mesh could be hung and stretched. The meshes are light-weight, low in cost, easy to erect and dismantle, strong and durable.

Inazumi, Toyoji and Masao Shiotani. A Study of Snow Fences. Text in Japanese. Tōkyō, Tetsudō Gijutsu Kenkyū-sho, 1950.

The results of laboratory experiments and field surveys on snow fences, conducted from 1939-1942 are presented. The effects of type and height of snow fences on resulting snowdrifts are reported. A critical height exists, which is a function of climatic conditions. The critical height is approximately 4 m in most parts of Japan. It is concluded that a solid fence over 4 m in height, placed parallel to the railroad at distances of 20-40 m is the most effective measure.

Inazumi, Toyoji. Snow Fences and Snowdrifts. Text in Japanese with English summary. J. Meteorological Soc. Japan, 2d Ser., Dec. 1940, Vol. 18:387-392.

Results of wind-tunnel and smoke tests to study the snow fence-snowdrift relationship are described. The position and amount of drifts are closely related to changes in streamlines of the wind caused by the placement of snow fences.

Jones, E.W. Snow Hedges in Simcoe County. Photostat of Roads and Bridges, May 1945: 132-133.

Snow fences are used until the protection of the newly planted trees can become effective.

Kabanov, P.G. Snow Transfer Influenced by Weather. Text in Russian with English summary. Sot͡sialisticheskoe Zernovoe Khozi͡aĭstvo (Saratov), 1936, Vol. 6, No. 1:80-89.

Conditions of snow transfer were studied during 1932-1935 near Saratov. Wind velocity, snow-cover density, surface condition and moisture content are the principal factors determining snow transfer. Wind initiating snow transfer also causes snow compaction, which prevents further drifting. Even light wind (1-2 m./sec.) forms a thin ice crust over the snow surface. Winds at 7-12 m./sec. produced a dense crust 4 cm. thick within 2-3 days. Massive snow transfer occurred at air temperatures below -5°C. Snow fences with 50% open spaces can retain most snow drifted by winds at 5-10 m./sec. More compact snow fences are needed at wind velocities over 10 m./sec.

Kayser, J. Snow Research in the Ardennes. Text in German. Untersuchungen über Schnee und Schneeschutzanlagen an Strassen, by Karl Croce and Josef Kayser, Forschungsarbeiten aus dem Strassenwesen, 1949, No. 6:5-20.

Tests were conducted on a road section running in a north-south direction to determine the influence of fence type, height, slat spacing, distance from the ground, and the shape and position of the slats on the location, form, height and length of the snow deposit. Slat and board fence sections tested ranged from 23-74 m. in length, 1.1-1.7 m. in height, and 0-0.35 m. above the ground. Distances between fences and the edge of the road ranged from 15-35.3 m. The observations are presented in the form of 7 profiles including date of recordings, wind directions and speed, temperatures, snow density and snow thickness. The results show that the fence height influences the snow deposit length and height only after a prolonged drifting period. The distance of the snow deposit from the fence and the snow deposit length grow with increasing height above the ground and decrease with decreasing heights; the snow deposits nearer to fences with closely-spaced slats; terrain sloping downwards behind the fence diminishes the deposit; snow accumulates near the fence when the angle of incidence is large. Wind velocity is the most influential element in the deposition of snow. Recommendations for locating fences on the basis of the observations are made.

Komarov, A.A. Ways of Increasing the Efficiency of Snow Fences. Trudy Transportno-Energeticheskogo Instituta, 1954, No. 4: 119-126. Translated by G. Belkov, Tech. Translation 1095, Division of Building Research, N.R.C., Ottawa, 1963.

Komarov, A.A. Some Rules on the Migration and Deposition of Snow in Western Siberia and Their Application to Control Measures. Trudy Transportno-Energeticheskogo Instituta, No. 4:89-97, 1954. Translated by G. Belkov, Tech. Translation 1094, Division of Building Research, N.R.C., Ottawa, 1963.

Komarov, A.A. Use of Snow Fences for Snow Retention. Text in Russian. Dostizheniia Nauki i Peredovoi Opyt v Sel'skom Khoziaistve, 1955, No. 1:51-52, Jan. 1955.

The effects of snow fences on wind velocity and snow accumulation around fences are discussed, and results of experiments during 1952-53 are reported. Results showed that snow fences about 75% open and 1 m. high are best for agricultural purposes because the snowbanks that form behind them are smooth and wide. Wind speed behind this type of snow fence is decreased by 15-20% and the width of the snowbank is 25-30 times the height of the fence.

Konno, A., A. Imai and K. Maruyama. An Investigation on the Wooden Fence for Preventing the Growth of Cornice. Text in Japanese with English summary. Seppyō, March 1956, Vol. 17, No. 3: 18-20.

The results of investigations on the growth of snow cornices and the effectiveness of closed and open fences for preventing cornice formation are reported, and data are tabulated. Cornices grow on mountain tops at a rate of 4 cm. in 10 min. with a wind of 11 m./sec. As the cornice reaches a length of 20 cm. it bends under its own weight and keeps growing as the wind continues. Experiments with closed fences showed that the wind velocity at the top is 1.4 times higher than at any other point. Fences with a 70 cm. gap at the bottom cause the wind stream to divide at a point 0.5-1.0 m. below the top, and snowflakes passing through the gap are deposited 10-15 m. beyond.

Koroleff, A. Snow Fences of Paper Mesh. Pulp & Paper Mag. Can., Jan. 1950, Vol. 51, No. 1:110.

Snow fences made of spin paper and impregnated with creosote proved satisfactory in Germany but their use was discontinued after 1945. A paper mesh fence with wire reinforcement in both selvage edges to prevent sagging and treated to be weatherproof, waterproof, and rotproof, was manufactured in Canada by the National Research Council of Canada.

Kreutz, W. Investigations of Snow Accumulation at Snow Fences. Text in German. Strasse u. Autobahn, Feb. 1954, Vol. 5:36-37.

Results of investigations on the efficiency of wooden-slat and fiber-net snow fences carried out at the Giessen Agrometeorological Research Station (Germany) in the winter of 1952-53 are discussed. Snowdrift profiles at both types of fences are diagrammed and aerodynamic effects are analyzed. Fiber fences were found more efficient in catching snow.

Kuroda, Masawo and Koreo Kinoshita. Wind-Tunnel Experiments on Snow Fences. Text in Japanese. Rikwagaku-Kenkyū-jo ihō, Aug. 1940, Vol. 19, No. 8:1175-1191.

Wind-tunnel studies on model snow fences are described and illustrated. Greater efficiency in drift control can be obtained by placing a secondary fence behind the main fence at a distance equal to 10 times the height of the latter. Additional experiments gave information on the formation of snow cornices.

Kuz'min, P.I. Active Snow Control Measures. Text in Russian. Gornyi Zhurnal, Jan. 1958, No. 1:69-71.

Active snowdrift-control measures used at the Noril'sk Industrial Combine (located in a mountain area) are described; various snow fences are illustrated; and air-flow diagrams are presented. The principle of the active method, which is most effective at wind speeds not exceeding 8 m./sec., is to accelerate air flow at the bottom of the fence so that it will carry the snow across the area to be protected. The most effective fences are those built without angle brackets and provided with deflectors at the top (on the windward side). Such fences may be installed at angles as low as 20° to the wind. Portable snow shields are installed 50-70 m. in front of the fences and at a slight angle thereto to increase effectiveness of the fences during weak winds. Higher fences are used with a ground clearance of up to 3 m. on slopes of more than 45°. The angle of inclination of the fences can be varied from 0°-45° to the vertical. The fences are installed 3 m. from the center of railways and on the outer fringe of roads or at the foot of embankments. Snow is transported 6-8 m. from the fences and deposited beyond roads during storms.

Kuz'min, P.I. Increasing the Efficiency of Snow Fences of the Wind Directing Type. Text in Russian. Avtomobil'nye Dorogi, Oct. 1960, Vol. 23, No. 10:20-21.

An illustrated account is given of research in the USSR on the aerodynamic properties of snow fences. Diagrams show the effect of fence design on wind velocities at various heights; angled wind reflectors increased the wind velocity by 83%, ensuring a snow free strip up to 26 ft. in width.

Lambert, Gerald David. Snow Fences and Drifting Snow. Univ. Saskatchewan, April 1949 (Thesis).

The use of snow fences and highway design for drift control is reviewed, and results are given of a brief study on a snowdrift deposited at a fence during one severe blizzard. A mean sp. gr. of 0.275 was determined for this particular deposit, and an estimate of the retained snow indicates that a snow fence, even when clear and at maximum efficiency, is capable of trapping less than half of the wind-borne snow. Construction details are included for a snow trap to measure drifting snow similar to that designed by Bagnold for sand, but lack of snowfall prevented testing of the device. Snowfall and drift data for the Prairie Provinces are tabulated and graphed.

Lawrance, N.G. Drift Control by Snow Fences. Surveyor, December 12, 1947, Vol. 106:643-645.

The more common and some unusual types of snow fences used in various countries are described. The three main methods of snow control along roads consist of adequate design, permanent natural snow screens of trees and shrubs and snow fences. Snow fences currently used may be classified as closed, open and emergency fences. Open-type fences are cheaper and more effective than the closed type. Open fences usually consist of vertical or horizontal slats. An aperture ratio of about 50% is the most effective.

Lyons, M.A. Snowfence and Permanent Hedges are Manitoba's Most Effective Means of Winter Road Maintenance. Roads and Bridges, Oct. 1943:81-82.

Marritt, I.C. Planting of Snow Hedges. Roads and Bridges, May 1945:66-67.

Moore, Henry J. Hedges Reduce Snow-Plowing Costs. Roads and Bridges, May 1945:64-66.

Beauty of roads permanently enhanced, while cost of planting is saved within few years by reduction on expense of winter maintenance.

Nøkkentved, C. Drift Formation at Snow Fences. Stads-og Havneingeniøren, 1939, Vol. 30, No. 8:111-114.

Pugh, H. Ll. D. and W.I.J. Price. Snow Drifting and The Use of Snow Fences. Polar Record, Jan. 1954, Vol. 7, No. 47:4-23.

Mechanics of snowdrifting and formation of drifts are briefly discussed. The lowest wind speed associated with drifting is approximately 10 m.p.h. The 3 main fence types are classified according to function as leading, blower and collecting fences. Several fence designs are illustrated and described. Typical arrangements of collecting snow fences are illustrated.

Pugh, H. Ll. D. Snow Fences. Dept. Sci. Ind. Research, Road Research Tech. Paper No. 19, London, H.M.S.O., 1950.

The paper is a report of present practices and of research on snow fences done in America, Scandinavia, and Germany. Leading fences are designed to lead snow to hollows in the ground. Leading fences are used in Norway where snow-bearing winds vary little in direction. Collecting fences deposit snow on the ground by slowing the wind before the wind reaches the road. Collecting fences are located on the windward side of the road, parallel to the road, with sections staggered at an angle to the road, or wing staggered on both sides of the road. The direction of the wind and of the road govern the arrangement of the fences. The research of Finney and Nøkkentved on wind tunnel model fences is reported. Each type of fence produces a characteristic eddy area in which snow is deposited. Eddy area depends on wind speed, height and construction of the fence. An open fence, 50% covered with slats gives optimum eddy area. Clogging is prevented by elevating the fence 6 in. from the ground.

Robbins, C.A. Theory and Practice in Snow-Fence Erection. Can. Engr., Oct. 18, 1938, Vol. 75, No. 16:16.

The amount of snow transported and the snow particle size increase with wind velocity. Snow is deposited from the wind stream when the wind slackens and in the presence of downward eddies. Moist snow will settle more easily than dry snow. Obstructions such as a snow fence, house, tree, or knoll will produce turbulence and decrease the wind velocity causing a temporary loss of carrying power. The proper location for a snow fence is dependent upon ground contour, wind velocity, road depth below bank, and others. Snow fences are normally 4 ft. high and consist of weatherproffed wooden slats 0.375 in. thick by 1.5 in. wide, spaced 2 in. apart. The slats are woven between 5 double strands of No. 13 or 12 gauge galvanized steel wire. Special steel posts with standard lengths of 7, 7.5, 8, or 8.5 ft. are embedded 3 ft. in the ground. The fence is erected on the posts 6 in. above the ground line.

Robbins, C.A. Theory and Practice in Snow-Fence Erection. Highway Mag., Jan. 1939, Vol. 30:5-7.

Rode, A. Snow Fences. Text in Norwegian. Medd. Vegdirektøren, May 1926, No. 5:69-70.

Snow fences utilizing twigs, juniper, scrub and heather are described. The material was interwoven on rows of wires suspended between wooden posts 3-5 m. high and spaced 3 m. apart. The fences are inexpensive, easy to maintain, and efficient for use in northern Norway.

Saito, Yogo. Prevention of Cornice Formation by Wooden Fences. Text in Japanese. Researches on Snow and Ice, Nov. 1953, No. 1:119-122.

The formation of snow cornices is described, and experiments on cornice control are discussed. Studies were made with fences erected on embankments at varying angles to the vertical and to the wind. Flow diagrams and cross sections of snow accumulations are presented.

Sato, Shoichi. On the Criterion of the Railway Guard Patrol During a Snow Storm in Hokkaido. Text in Japanese. Seppyō, March 1962, Vol. 24, No. 2:21-26.

Accumulation of drifting snow was observed on an experimental field 1 m. deep, 4.5 m. wide, and 8 m. long on the N. coast of Hokkaido. The field represented a section of railway. The critical values of temperature and wind velocity at which the rate of accumulation reached more than 10 cm./hr. were obtained, and the data graphed and tabulated. A diagram of the criteria for railway patrol operations in Hokkaido during snowstorms was constructed on the basis of these findings.

Schneider, T.R. Problems Studied at the Experimental Snow-Drift Field in Sils-Maria, Engadin. Text in German. Strasse und Verkehr, Jan. 1961, Vol. 47, No. 1:35-38.

The establishment of an experimental field to study the effects of design and the use of various material on the effectiveness of snow fences, in Sils-Maria, Engaden (Switzerland) is described. At this field several types of 24-30 m. long fences were constructed and tested. The following conditions are found at Sils-Maria: (1) The wind factors are favorable. (2) The field has an adequate snow cover. (3) The field is horizontal; any inclination would lead to distortions. (4) The field is sufficiently large. (5) The field is easily accessible during the entire winter season. (6) Meteorological stations and observation stations for avalanches exist nearby. The results of the first year of snow-drift observations are briefly discussed.

Schubert, E. Form and Magnitude of Snow Accumulations around Snow Fences. Text in German. Organ Fortschr. Eisenbahnwesens, 1902, New Ser. 39:1-4.

Experiments made in Germany in 1901 with various snow fences are described, and their effectiveness for snowdrift control on railroad right-of-ways is evaluated. Fences studied consisted of 15-cm. boards spaced at intervals of 5-15 cm., 3-9 mm. wire mesh, reed fences, coconut web, and closed board fences. The fences were erected at angles of 30°-75° in a continuous row facing the wind. The height of the fences, measured normal to the ground, ranged from 1.5-3 m. The wind velocity during the tests varied from 8-15 m./sec. Best results were obtained with a 9-mm. wire mesh fence. Snow profiles around fences are illustrated, diagrammed, and explained in detail.

Shiotani, Masao and Hideo Arai. Bibliography on Snow Shelterbelts, Snow Fences and Blowing Snow. Text in Japanese. Seppyō, Nov. 1949, Vol. 11, No. 4:140-149.

Abstracts of 12 papers on shelterbelts, 16 papers on snow fences, and 8 papers on blowing snow from the Japanese and Russian literature are presented.

Smirnov, I.V. Snow Deposits by Artificial and Natural Snowstorms and Measurements of the Drifted Snow. Text in Russian. Trudy Nauchno-Issledovatel'skogo Upravlenii͡a Narodnogo Komissariata Puteĭ Soobshchenii͡a, 1930, Vol. 109:79-85.

The results of laboratory experiments with model snow fences and roadbeds are discussed. The snow deposit around snow-fence models in a pipe 120 cm. in diam. with air speeds of 8 m./sec. was similar to the formations observed under field conditions. Experiments confirmed that the ratio of the area of the snow deposit to the product of the snowstorm duration and the hiehgt of the snow fence is constant. Three types of instruments for measuring amounts of drifted snow (Kuznetsov, Tolstov and Sabinin meters) were tested. Best results were obtained with the Sabinin meter. The Kuznetsov meter collected about 45-50% of the drifted snow.

Smirnov, G.S. Snow Retention. Text in Russian. Sovetskai͡a Agronomii͡a, 1953, Vol. 11, No. 1:80-81.

Snow fences (100 x 200 cm.) were arranged in a checkered pattern before the winter of 1951-52 for snow retention in a 40-ha. farm in the Ilek region (Chkalov province). The mean maximum depth of the snow cover in snow retention areas was 62 cm. as compared to 49 cm. in regions without a snow retention plan. Snow melting continued 3-4 days longer in retention areas permitting complete absorption of all the meltwater by the soil. Snow fences in some regions of the southeast cannot be obtained because of wood shortage. Snow retention by snowplowing is feasible in these areas.

Tikhobrazov, P. Snow Retention. Text in Russian. Meteorologicheskiĭ Vestnik, July 1895, Vol. 5:243-254.

The effectiveness of various snow fences in snow retention were studied in 1892-93 at the Sezenov Monastery in the Skvirnya River valley. Data on snow depths behind obstacles and their variations during the winter are tabulated. Compacted snow, wood and brush were used to build the snow fences. The height of the fences was varied greatly, with a maximum of 6 m. Deep deposits of snow accumulated behind snowbanks and fences with small open spaces, but fences with large open spaces affected distribution over a wider area with lesser depth.

Vitkevich, V.I. Snow Deposits Near Fences of Various Forms. Text in Russian. Meteorologicheskiĭ Vestnik, 1921, Vol. 31:215-220.

Form and density of snow deposits with different type snow fences were investigated at Kuchino (near Moscow) during the winter of 1919-20. Solid snow fences and fences with horizontal and vertical slats were installed over an ice-covered lake. The fences with vertical slats retained the most snow. The snow deposit near the fence indicated strong eddies, which prevented further drifting. Poorest results were obtained from snow fences with horizontal slats.

Wolff, A. The Function of Snow Fences in Winter Road Maintenance. Text in Swedish. Svenska Vägföreningen. Tid, July 1941, Vol. 28: 154-176.

Correctly placed snow fences catch snow outside the highways through their lee-effect. This effect is analyzed in view of the studies of Finney, Irminger and Nökkentved. Various types of snow fences are described in relation to their effectiveness, construction and design. Detailed studies on snow and local wind velocities indicate the importance of planning, construction and maintenance of winter roads. A table of data (1931-1938) from 700 stations features first and last days, duration and thickness of the snow cover in 24 Swedish regions.

Woodruff, N.P. and A.W. Zingg. A Comparative Analysis of Wind-Tunnel and Atmospheric Air-Flow Patterns about Single and Successive Barriers. Trans. Am. Geophysl. Union, April 1955, Vol. 36:203-208.

Atmospheric wind velocities were measured aft of a single and a series of 3 successive snow fences and compared to velocities measured aft of models of the fences placed in a wind tunnel. Results indicate the wind-tunnel approach gives a reasonable estimate of the effectiveness of full-scale surface barriers under atmospheric conditions. It is also shown that a series of 3 successive barriers is not enough to obtain a beneficial accumulative ground effect. A general lessening of velocity with distance travelled over the successive barriers indicates, however, that an accumulative effect might be obtained in a system containing a larger number of successive barriers extending for a great length. The barriers are shown to increase the velocity fluctuations of the wind from 2-9 times at different locations aft of a single barrier. Maximum fluctuations in a series of successive barriers were found to occur at the 0.5-ft. elevation aft of the 2d barrier.

Woodruff, N.P. Shelterbelt and Surface Barrier Effects on Wind Velocities, Evaporation, House Heating, Snowdrifting. Tech. Bull. 77, Kansas Agr. Exp. Sta., Dec. 1954.

Models of shelterbelts, snow fences and solid walls were tested in a wind tunnel and comparative measurements taken with full-scale snow fences under natural conditions. Results indicate that wind tunnels can be used to make reasonable estimates of the effects of full-scale surface barriers. Measurements with models and simulated snow indicated that 4 fences spaced 12H apart catch 4 times as much snow as a solid wall, 1.2 - 1.8 times as much as 2 similarly spaced fences, and about 2.5 times as much as a single fence.

Control of Snowdrifting Studied by Wind-Tunnel Tests on Models. Better Roads, Oct. 1934, Vol. 4, No. 10:15-16.

Control of Snowdrifts by Snow Fence and Tree Planting. Eng. and Contract Record, Nov. 1, 1939, Vol. 52, No. 44:23-24.

Picket snow fences, erected 100-125 ft. from the road center and posts close enough to prevent wind shipping, are recommended. Picket bottoms, placed 6-8 in. above the ground, increase the effective height of fences and permit a current of air to pile early snow at a distance. Fences of the slat type are not as effective as natural barriers of forest trees or shrubs. Snow barriers, either artificial or permanent, are placed on the windward side of the road, or on both sides if winds are variable.

Cotton Netting New Development in Snow Fences. Roads and Bridges, Nov. 1959, Vol. 87:38.

A fireproof, waterproof, rot-resistant cotton fabric, made from fibres of high tensile strength is used in Canada for snow-fencing. The netting is draped on posts used in wooden-lath snow-fencing, and can be readily dismantled, transported and stored during the summer.

Effectiveness of Snow Fence for Drift Prevention. Eng. and Contract Record, Nov. 2, 1938, Vol. 51, No. 44:23-24.

The 4 types of artificial snow fences (horizontal slat, vertical slat, solid, emergency) are described and advice is given on their erection and location with special reference to recently available metal fences. An all-metal horizontal slat snow fence, with slats 6 in. wide and placed 6 in. apart, must be inclined against the wind at an angle of 23-30° to deflect air downward, keep the fence clear of snow and pile it twice as high as the fence. An all-metal vertical slat snow fence with slats 3 in. wide and spaced 3 in. apart must be erected at an angle of 20-30° with the wind. Solid board snow fences are usually too costly and impractical. Snow fences should be erected at a distance from the roadway equal to 15 times their height and should be durable, light, compact and easy to install.

Michigan Expands Test of Paper for Snow Fence. Eng. News-Record, April 16, 1953, Vol. 150, No. 16.

The 19-mi. snow fence consists of 2-3 strips of kraft paper, 12 in. wide, extended between steel posts. Each paper strip is made of 2 layers of paper cemented together with asphalt and reinforced with hemp or glass fiber and is pressed into the fence pole by strips of soft wood wired to the post. Increasing the 8-ft. spacing between the posts to 10 ft. is under consideration. The effectiveness of the fence depends largely on correct erection and taut spanning of the paper. Advantages of the fence are low cost and easy handling and storing; disadvantages are vulnerability to damage from livestock and children. Sagging during late winter reduced the effectiveness of mesh fences made of twisted paper strands impregnated with paraffin or creosote.

Review of Snow Fence Practice in Various Countries of World. Eng. and Contract Record, Feb. 1949, Vol. 62:155-156.

The 3 main methods of controlling the drift of snow onto roads are adequate road design, planting of snow screens of trees and shrubs, and snow fences. Snow fences may be solid or open. The aperture ratio in open fences should be about 50% whether the slats are vertical or horizontal, and a clearance of 6 in. between the bottom of the fence and the ground should be maintained. The height rarely exceeds 12 ft. Fences have been constructed of wood, metal, reinforced concrete, straw rope, blocks of snow, low earth walls, and leafy branches.

Snow Fence Cuts Winter Plowing Costs. Better Roads, Oct. 1939, Vol. 9, No. 10:18.

The cost of snow removal is reduced when snow fences are used in conjunction with plowing. Natural plantings are permanent, cost little after growth and improve the landscape, besides preventing snowdrifts. Fence posts should be set early enough to permit their freezing firmly into the ground. Fences should be fastened on the windward side. The usual distance of the fence or planting from the edge of the road is 50-100 ft. Results of wind-tunnel tests on eddy characteristics, ratio between slats and openings, position of the fence above the road, inclination of the fence and position of maximum depth of snowdrift, are summarized. Rules for effective planting of natural fences are given. Plowing costs were cut by 50% in all states using fences for road protection. Snow removal costs for Mont., Wash. and Neb. are given.

Snow Fence - Its Importance as a Means of Snow Control. Eng. and Contract Record, Oct. 30, 1935, Vol. 49:953.

A wire-bound slat fence which is easily erected and stored, is recommended as a snow fence. It is made of creosoted or painted slats of lumber in rolls of 100 ft. long and 4 to 5 ft. high. The slats should be at least 0.375 by 1.5 in. in section. Standard steel fence posts should be driven into the ground before frost sets in, about 1 rod apart.

Snow Fence, The Only Preventive Measure in Snow Control. Good Roads, Jan. 1930, Vol. 73:24.

An effective snow fence must be erected properly, in the right locations, and extended an adequate distance along the road. It is suggested that the opinions and advice of the natives in the community be utilized in erecting snow fence, since successful installation depends on meeting local conditions.

Snow Fences - Placing Them to Get Maximum Protection. Ry. Eng. and Maintenance, Dec. 1950, Vol. 46:1132-1135.

Various small-scale snow fence models were tested in a Masonite tunnel with the floor adjustable to different depths and slopes of the cut sides. Screened vermiculite was used as a substitute for snow. Compressed air at a speed of 15 m.p.h. was used for all the tests after preliminary tests indicated little effect of wind speeds on eddy areas and consequently, on drift lengths. The air currents were noted by free-swinging targets on vertical rods in the model cut center and measured at various heights in the cuts by a Pitot tube attached to a manometer. Horizontal and vertical slat, inclined slat, solid board, rail, wire and perforated sheet metal fences were tested for depths of 5, 11, and 18 ft. and for slopes of 1:1.5, 1:4, and 1:6. Test results relative to type and location of snow fences, distance of the snow fence bottom from the ground, influence of the depth of the cut, eddy currents and wind velocities on drift formation are discussed. It is concluded that snowdrift control could be improved and relative recommendations are presented.

3. HEDGES

Andrianova, K.I. Catch Crops as an Effective Measure for Increasing Yield. Text in Russian. Zemledelie, June 1956, Vol. 4, No. 6: 32-36.

Snow cover distribution and drifting in Transvolga Region and Kazakhstan are described, and the effectiveness of various methods of snowdrift control are discussed. Snow cover lasts in the area from 120-170 days, and the water equivalent of snow precipitation varies from 450-600 ton/ha. in arid steppes and up to 1200 ton/ha. in forest steppes; but strong winds blow the snow from fields, reducing the max. depths below 35 cm. Experiments at the Ural Agricultural Station showed an increase of snow depth in fields from 23-35 cm. after plowing of the snow. Sowing of sunflower, mustard, and other high-growing plants proved best for snow retention, increasing the water equivalent of winter-accumulated snow cover up to 1500 ton/ha.

Arai, Hideo and others. Field Tests of Snow Shelter Belts. Text in Japanese. J. Railway Eng. Res. (Japan), Dec. 1960, Vol. 17, No. 12:527.

Three different types of cedar shelter belts 2.5 m. tall and 30 m. wide were tested at Higashinoshiro, Akita Prefecture, from Dec. 1959-Feb. 1960. The models have single, double, and triple rows of shelter belts respectively. The vertical and horizontal effects of the reduction of wind velocity on air currents and snow drift around the 3 models are briefly discussed.

Armand, D.L. Physical Principles of Shelter-Belt Influence on Wind. Text in Russian. Priroda, 1954, Vol. 43, No. 1:64-70.

The influence of shelter belts on turbulent wind flow is analysed. The width and texture of shelter belts determine the form and depth of snow or sand deposits around them. Deep and narrow snowbanks are deposited before and behind compact belts. Wide, thin snowdrifts form behind highly permeable shelter belts. Compact forest shelter belts are recommended as protective measures against snowdrifting along railroads and highways. Open shelter belts are adequate for agricultural purposes, where an even distribution of snow is important.

Baĭko, V.P. and A.S. Gorbulenko. Influence of Forest Shelterbelts on Soil. Text in Russian. Pochvovedenie, June 1949, Vol. 44:313-324.

The influence of shelterbelts on the composition, structure and moisture of soil as studied from 1943-1945 at Kamennaya Step' (Voronezh Province) is discussed. Snow depths, which equalled 17-23 cm. in open fields, increased to 40-44 cm. in sheltered fields and to 50-69 cm. under shelterbelts. Narrow belts 6-10 m. wide accumulated more snow than wide belts. The minimum frost-penetration depth observed under wide shelterbelts promoted maximum infiltration of meltwater and better soil-moisture conditions throughout the growing season.

Bates, C.G. and J.H. Stoeckeler. Planting to Control Drifts on Highways. Eng. News-Record, July 1942, Vol. 129:92-96.

More extensive planting of trees and shrubs is proposed for prairies and plains of northern states as a substitute for slat snow fences. Profiles of snowdrifts show that a single row of low, dense shrubs is more effective in trapping snow in a limited belt than a 17-row belt of tall-growing trees devoid of limbs near the ground. Hardy shrubs and trees are listed with suggestions for several types of planting. Soil preparation and planting are described. Earlier cost estimates are cut in light of experience gained in planting shelterbelts to protect farmsteads.

Birner, W. Paula. Effective Evergreen Snow Barriers. Better Roads, Feb. 1941, Vol. 11, No. 2:38, 40, 42.

Jack pine, Norway spruce, balsam fir, and American arborvitae, of various heights and formations were planted on a test site north of Madison, Wis., during Jan. and Feb. Anemometers were used to determine the wind velocity and the extent to which the velocity was reduced by the hedges. The arborvitae were the most efficient, particularly the 4 to 5 ft. size. It is shown that multiple-row hedges act as snow traps, as well as barriers. The effectiveness of snow hedges is determined by the wind velocity, hedge density, and hedge height. Taller trees give a long, tapering drift formation, and the shorter trees pile up the snow nearer the hedge.

Biruli͡a, A.K. Peculiarities of Snowdrift Control on Southern Roads. Text in Russian. Stroitel'stvo Dorog, 1942, Vol. 5, No. 2-3: 14-15.

The southern region of European USSR is characterized by frequent heavy snowstorms, massive snowdrifts, scant snow cover, and frequent thaws. Snowstorms lasting 5 days occur as often as 7 times during Dec.-Feb. Frequent and rapid melting of the snow cover greatly reduces the trafficability of dirt roads. Prevention of snowdrifts is more important than removal with plows. Snow fences are not recommended because strong winds flatten them and because wood is a scarce commodity in the southern steppe area. Stalks of corn and sunflowers are effective in drift prevention. Hedges of corn and sunflowers planted 20-30 m. wide along roads provide satisfactory protection.

Boĭchenko, E.P. Protective Forest Belts for Cities in Steppe Regions. Text in Russian. Moscow, 1952, Izadetel'stvo Ministerstva Kommunal'nogo Khozi͡aĭstva RSFSR, 54p.

Forest belts to protect city road approaches from snowdrifts are described. Trees are planted in several rows 2-3 m. apart in open level areas, in 2 or more rows at bends or cuts, and in groups in winding or hilly areas. Forest belts vary in width from 20-50 m. according to the threat of snowdrifts. The distance from the forest belt to the centre of the roadbed varies from 15-20 m. according to the width of the belt. The density of planting is highest on the windward or field side of the belts. Trees are planted at an average distance of 0.5-0.7 m. apart. Trees used for forest belts vary greatly in size and species. A tabulation of the snow-protective properties of individual tree species is appended.

Budi͡uk, V.P. Catch Crops as an Effective Measure for Snow Retention. Text in Russian. Dostizhenii͡a Nauki i Perdovogo Opyta v Sel'skom Khozi͡aĭstve, 1953, No. 6:68-69.

The effectiveness of sowing mustard in fields for snow retention was tested during 1940-1949 in Pavlodar Province. The mustard was sowed near the end of July before winter crops were sowed. A dense growth of mustard up to 150 cm. high retained about 5 times as much snow during the winters as snow fences and about twice as much as sunflower strips. Snow-cover depth in the fields with mustard reached 85-90 cm. and destruction of winter crops was never observed there.

Dashkevich, M. The Width of Snow Hedges on Roads. Text in Russian. Doroga i Avtomobil', 1935, Vol. 6, No. 8:20-21.

The amount of snow deposited behind a snow hedge is determined by the width of the hedge. An empirical relationship is given relating the hedge width to the product of a coefficient and the square root of the maximum cross-sectional area of the snowbank. The coefficient is equal to 4-5 for forest zones, and 5-6 for steppe zones.

Evdokimov, K.T. Snow Retention by Rows of Planted Trees. Text in Russian. Les i Step', 1953, Vol. 5, No. 1:81-82.

A regular distribution of the snow cover on fields protected by trees depends on an even distribution of the tree rows. The snow depth around 9-yr. old plantings at distances up to 150 cm. and for various wind directions is tabulated. Measurements repeated 1 yr. later indicated about half as much snow cover was retained in places where the trees were removed.

Ferguson, H.C. Live Snowbreaks in Pennsylvania. Better Roads, 1943, Vol. 13, No. 9:21-22.

The planting of permanent rows of deciduous and evergreen trees and shrubs adjacent to highways is an effective and economical method of controlling snowdrifting. Methods of aligning trees and shrubs for maximum results are described. The staggered 2-row barrier of evergreen trees from 5 to 10-ft. centers is widely used. The maintenance cost of natural snow barriers is lower than that of mechanical snow fences.

Fil'bert, P.A. Snow Protective Plantings of the Stalingrad Railroad. Test in Russian. Les i Step', 1953, Vol. 5, No. 2:88.

Coniferous trees were planted 0.7 m. apart in rows spaced 1.5 m. apart. In chernozem soil 24 rows were planted and a wider spacing (20-30 m.) was provided between the 15th and 16th row. A total of 21 rows were set in light soils and 27 rows in dark brown soils, each wood lot being interspersed with 2 wider spacings of 10-15 m. each.

Finney, E.A. Snow Control by Tree Planting. Bull. No. 75, Mich. Eng, Exp. Sta., July 1937, 81p. incl. illus, tables, graphs, maps, diagrs.

A comparative study of conifers is presented and those suitable for snow control are described in detail. Deciduous trees and shrubs are used where climate conditions preclude the use of conifers. A deciduous tree suitable for planting in a snow barrier should have dense growth of strong branches from base to top and grow rapidly under adverse conditions. Advice on transplanting, maintenance, and protection of trees and shrubs and the methods of and factors to consider in tree and shrub planting for snow control are given. Wind tunnel tests using model trees indicate that the effective area produced by a barrier is about 15 times its height. Wind velocity has no effect on the size of the eddy area produced by a tight or dense barrier but influences the position of the drift with respect to the barrier.

Fursa, N.T. and P.S. Denisov. The Planting of Hedges in Steppe and Forest-Steppe Areas of the Transural Region and Siberia. Text in Russian. Zemledelie, May 1954, Vol. 2, No. 5:21-28.

The influence of hedges on thermal and moisture conditions of the soil as well as on the yield of winter crops was studied from 1947-1953 at many places in Western Siberia. Sunflower, sorghum, corn and mustard were planted as hedges. Max. snow-cover depth during the time of the study varied in open steppes between 10-20 cm. Max. depth in hedge-protected areas during the same period ranged from 47-100 cm. The water content of snow before melting was 30-80 mm. in the open steppe and 188-380 mm. between hedges. A deeper snow cover increases soil moisture and diminishes soil freezing.

Garîugin, G.A. Effects of Forest Shelterbelts on the Snow Conditions in Surrounding Fields. Text in Russian. Agrobiologiîa, 1955, No. 3:132-134.

Snow distribution around shelterbelts (3-4 yr. old) was studied in Rostov Province during the winters of 1952-1954. Dense shelterbelts caused intense drifting. One such case is diagrammed showing snow depths immediately behind belts from 119-140 cm. while in the open between plantings, depths ranged from 0.5-23 cm. Drift areas extended behind the belts for about 80 m., depending on slope. Shelterbelts do not necessarily improve snow conditions on fields since, as in this case, less snow and deeper soil freezing may occur in the major portion of the area between plantings than in corresponding open areas without shelterbelts.

Gorshenin, N.M. Shelterbelts and the Conservation of Spring Meltwater. Text in Russian. Les i Step', Dec. 1950, Vol. 2, No. 12:14-22.

The effects of shelterbelts on snow retention, soil freezing and meltwater run-off were studied in Kuybyshev Province during 1940-1944. The snow collected by shelterbelts 12-14 m. wide reduced the depth of soil freezing over an area extending 30-50 m. from the belts. Spring meltwater in the protected area penetrated 30-60 m. to the ground-water level, while penetration in neighboring unprotected fields was only 100-180 cm. deep. The snowbanks which formed around the shelterbelts prevented the immediate run-off of surface water and allowed it to percolate into the snow. Evaporation from the snow surface and the soil during the melting period reached 20 mm. or 7 per cent of the meltwater run-off near forest belts, and 75 mm. or 22 per cent of the run-off in open fields.

Jones, T.L. Living Snow Fence Piles up Savings as Well as Snow. Railway Age, 6 October 1952, Vol. 133, No. 14:104-105.

First-year seedling trees were planted along the C & IM railroad in 1938 in 5 rows, 6 ft. apart, with the distances between the trees in each row varying according to the specie. The rows consisted of black locust, Chinese elm, green ash, and a mixture of Russian olive and wild plum. The old slatted-type snow fence was retained until the trees had reached a height of 4-5 ft. Cost comparisons show a saving of over 50 per cent with the use of the natural snow fence.

Kaiser, H. Do Snowdrifts Around Windbreaks Constitute a Danger to Fields and Roads? Text in German. Umschau, 1960, Vol. 60, No. 2:33-36.

The effects of various types of hedges, shelterbelts, and fences, and that of wind direction and topography on snow accumulation are examined on the basis of the literature and personal observations, and snowdrift control measures are discussed. Snow accumulation is primarily dependent on the density of the hedges and fences. Narrow, dense hedges promote snow accumulation in confined areas behind and in front of the hedge, while at narrow hedges with a density of 50 per cent snow accumulates on the leeward side in a large, flat area extending 12-15 times the height of the hedge. Wide shelterbelts promote accumulation on their windward side. Accumulation around fences depends primarily on the ground clearance of the fence, the distance at which snow accumulates on the lee side being greater as the clearance is higher. Windbreaks should be erected at least 15 times the height of the windbreak away from the road for best effort. Where this is impossible, a system of windbreaks should be established in order to break the terrain and reduce drifting. Loose, narrow windbreaks must be erected on the leeward side of roads, and narrow shelterbelts free of underbrush must be planted on the windward side. Forest stands more than 20 m. wide, if placed on both sides of the road, afford max. protection against snow.

Kalugin, M.I. Sunflower Strips for Snow Retention in Fields. Text in Russian. Dostizhenii͡a Nauki i Peredovogo Opyta v Sel'skom Khozi͡aĭstve, 1953, No. 6:65-67.

The effectiveness of sunflower strips for snow retention was experimentally tested during 1941-1952 at many points in Altai Province. The snow cover between strips was up to 30 cm. deep, as against 10-15 cm. in open fields of grass. Compacting the snow 2-3 times during the winter gave additional protection against snowdrifts and resulted in a gradual snow melt that caused better infiltration of melt-water into the thawed soil.

Kawase, Gen'ichi. Forest Trees for the Prevention of Snowdrifts on the Railway. Text in Japanese. Seppyō, 1942, Vol. 4:254-260.

The planting of trees along the railway is effective in preventing snowdrifts. The optimum width of the strip, the method of planting and notes on its subsequent care are described. The influence of the forest was studied by measuring the snow cover and the wind velocity in the forest. Some notes on the use of forest trees to prevent avalanches are given. (Abstract by Ukitiro Nakaya)

Kéri, Menyhért. Shelterbelts for the Protection of Railroads against Snowdrifts. Text in Hungarian. Időjárás, March-April 1955, Vol. 59:127.

The results of experiments in Hungary on the most effective arrangement of shelterbelts are reported. The use of bushes and trees trimmed or planted so as to present an undulating upper surface to the wind is recommended. This type of shelterbelt was found to give complete protection.

Kissis, T. Ya. Results of Observations on the Influence of Continuous and Strip Plantations on the Distribution of the Snow Cover and on the Infiltration of Moisture into the Soil in Spring. Trudy Instituta Lesa Akademii Nauk SSSR, 1958, Vol. 43:138-151. Translated from Russian: Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D.C., IPST Cat. No. 1141.

Komarov, A. A. and V. B. Lîakhovich. Forest Shelterbelts as a Positive Means of Snowdrift Control on Railways. Text in Russian. Zheleznodorozhnyĭ Transport, 1956, 37, No. 6:65-70.

Shelterbelt protection of railways against snowdrifts is discussed on the basis of theory, experimental investigations, and observational data collected in the USSR during the last few decades. Investigations in W. Siberia showed that narrow belts of moderate density cut wind speeds in half. These belts provided protection from wind for a distance equal to 17-20 times tree height. Several narrow 5-yr. old shelterbelts provided complete protection from drifting.

Kopanev, I.D. Snow Accumulation Around Various Types of Shelterbelts. Text in Russian. Lesnoe Khozîaĭstvo, 1954, 7, No. 12:64-66.

The influence of shelterbelt type on snow accumulation was studied in Balashov Province during 1951-52. The length of snowbanks formed in the lee of shelterbelts varied from 70-170 m. and was least behind dense shelterbelts with brushwood. Eddies between and behind belts diminished the depth of snow accumulated. The distance of the eddy zone from the shelterbelts was 6-8 times the height of the trees for the more open types of shelterbelts or 12-16 times for dense shelterbelts.

Kuhn, Wolfgang. Damages in Country Criss-Crossed by Hedgerows as the Result of Winter. Text in German. Umschau, 1953, 53:210-211.

The use of shelterbelts is justified only after careful determinations of the climatic and morphological conditions of a terrain are established. Damages caused to agriculture by unplanned hedgerows are described. Long snow cornices form on the lee side of freely exposed, thin hedgerows with deep snow accumulations. The cornices thaw much slower than the snow cover of the open fields. The winter grain rots under the cornices due to the lack of light and oxygen and accompanying excess moisture. Cornices also form on sloped tilled terraces.

Kungurtsev, A.A. Compacting and Plowing of the Snow Cover on Fields and Meadows. Text in Russian. Zemledelie, 1955, 3, No. 11: 88-93.

The effects of depth and density of snow cover on soil temperature are discussed, and depth-density data for the protection of wintering crops are graphed. Compacting of snow is considered as a protective measure against loss of snow from drifting and lowering of soil temperature in upper ground layers. Optimum temperature for wintering crops ranges from -5° to -15°C. In deep snow, increase of snow density protects the upper ground strata from thawing. A snow density of 0.20 is sufficient to protect against drifting over large portions of the USSR. In areas with winds of 14 m./sec. and more the snow should be compacted to a density of 0.25-0.30.

Liashenko, G., and N. Vigovskiĭ. Improvement in the Planting and Maintenance of Shelterbelts. Text in Russian. Avtomobil'nye Dorogi, 1959, 22 (11):30.

The proper planting and maintenance of shelterbelts for snowdrift control on roads are discussed on the basis of studies conducted by the Rostov-Ordzhonikidze Road Administration and experience in various areas. The spacing of 1.5 m. between rows of trees and 0.6-0.7 m. between individual trees in a row as practiced earlier is inadequate. Trees should be planted 0.5-0.6 m. apart in rows spaced 2.3-2.5 m. to allow the roots to spread and permit mechanical cultivation. It is recommended that trees with low crowns, such as black locust, green ash, Tartar maple, Canadian poplar, etc. be planted with a compact border of shrubs.

Lull, H. W. and H. K. Orr. Induced Snow Drifting for Water Storage. J. Forestry, 1950, 48:179-181.

Results of preliminary investigations on natural and artificial snowdrifts are presented. Earlier studies for extending snow melt for the dry season by induced drifting are reviewed. Discharge from the Cphraim Creek watershed in the Wasatch Plateau region averages 10-15 acre ft./day in fall and winter, increases during the melting period to 400 acre ft./day early in June, and decreases to 10-15 acre ft./day by Sept. 1. The prerequisites for induced drifting (deep winter snow and strong, single-directed winds) are present, and alpine-fir clumps form natural wind barriers on 10 per cent of the 3900 acres of the subalpine zone. Drifts which formed to the lee of the fir clumps were measured after snow disappeared from undrifted areas. Drifts containing 2 ft. H_2O remained until 400 day-degrees above 32°F had been accumulated. Snow fences, 7 and 11-ft. high, were erected in the subalpine zone. The 7-ft. fences did not induce drifting, but drifts which formed behind the 11-ft. fences were 93 in. high on April 1 and 30 in. high on June 1, with a water content of 38 and 15 in. respectively. The 11-ft. fence drift had a water content and duration of 70 per cent of drifts behind tree barriers twice as high. Further study is required to ascertain the extent to which the fences repacked previously fallen snow or trapped snow which would otherwise have blown into another basin, and to evaluate cost, efficiency and spacing of different kinds of fences.

L'vovich, M.I. Afforestation as a Means of Decreasing the Amount of Water Needed for Field Irrigation. Text in Russian. Izvestiia Akademii Nauk SSSR, Seriia Geograficheskaia, 1954, No. 2:29-44.

The results of extensive studies in soil-water economy at Kamennaya Step are discussed. Experiments with forest shelterbelts showed that afforestation is an important factor in soil amelioration, the prevention of snowdrifts and the retention of snow moisture in fields. Investigations by Gurevich in 1952 showed that for optimum snow retention a field should not exceed 20 ha. in area. A 20-ha. field will accumulate 32 per cent more snow than an open field, while a 150-ha. field will accumulate only 12 per cent more.

Marritt, I.C. Tree Planting to Stop Snow Drifting on Roads. Farmer's Advocate and Home Mag., 1940, 75:324-325.

The advantages derived from substituting tree plantings for snow fences in controlling snowdrifts are discussed. Trees should be planted about 40 ft. from the roadway. Evergreens should be spaced 3-6 ft. in the row and deciduous trees 3 ft. or closer.

Marritt, I.C. Planting of Snow Hedges. Roads and Bridges, 1945, 83, No. 5:66-67.

Snow hedges, 4 to 10 ft. in height, should be planted 50 to 400 ft. from the edge of a roadway protected from the west and north. Trees, 15 ft. high, provide drift protection to the road when planted 25 ft. from the road. Evergreens, such as spruce, pine and cedar, are preferable to deciduous trees for a snow hedge but fine-foliage deciduous trees, such as maples, oaks and basswood, may be used. Shrubs or a row of raspberries may be planted where tall trees are not desired. Trees may be planted in single, double or multiple rows. A spacing of 6 to 12 ft. in a single row and 3 to 5 ft. in a belt of evergreen trees is recommended. Two rows may be planted 2 to 6 ft. apart, multiple rows should be 12 to 15 ft. apart.

Nakano, Kokichi. Forest Shelterbelts for Snow Protection. Text in Japanese. Seppyō, July 1951, 13:12-18.

The results of observations on the effect of shelterbelts planted in critical areas along a railroad in Hokkaido are described, and data are tabulated and graphed. Pine and cedar stands 80-120 m. wide were planted 20 m. from the track in equilateral triangles with one side normal to prevailing winds. Snow on the lee side, as recorded by snow gages, was 3 per cent of that on the windward side during 10 min. of observation at a wind speed of 12 m./sec. and an air temperature of -5°C.

Panfilov, I͡A. D. Forest Shelterbelts in the Steppe Zone of the Volga Watershed. Text in Russian. Trudy Vsesoi͡uznogo Nauchno-Issledovatel'skogo Instituta Agrolesomelioraţsii, 1937, 8:3-64.

The effect of various types of shelterbelts on wind and snow-cover distribution were studied near Arkadsk (Saratov Province) during 1928-1934. Max. snow accumulation was observed near dense belts. Thin belts open near the ground effect an evener distribution over large areas. As much as 50 per cent of the total snow in open fields and 88 per cent of the snow above ice-crusted layers were found to have been deposited by drifting.

Potter, L.D., John Longwell and Charles Mode. Shelterbelt Snow Drifts. N. Dakota Agr. Exp. Sta. Bimonthly Bull., May-June 1952, 14:176-179.

Three field shelterbelts N of Casselton (N.D.) were examined during Jan.-Feb. 1952 to determine their effect on snow accumulation. Snow-depth measurements were taken along 3 transects across each belt at 5-ft. intervals from 100 ft. windward to 100 ft. leeward and then at 10-ft. intervals to 200 ft. leeward. The average snow accumulation, which represents the seasonal maximum, is graphed for each belt, and the tree and shrub species used in each are listed. Snow retention in terms of water equivalent is tabulated for one of the belts. The average maximum snow depths occurred from 70-100 ft. to leeward of the first windward shrub row. More value for a given acreage devoted to shelterbelts may be derived from dense belts of half the number of rows (3-5) spaced at half the distance between belts.

Povet'ev, A.A. Snow-Protective Properties of Forest Belts. Text in Russian. Sbornik Nauchno-Issledovatel'skogo Instituta Puti NKPS (Babushkin), 1934, 33:5-53.

Snow-protective properties of different trees and shrubs were studied to determine the species best adapted for any climatic region of the USSR. Factors important for effective snowdrift protection such as branch density and rate of growth were investigated. Values obtained over a period of 1-5 yr. for deciduous and evergreen trees are tabulated. The time required for different plantings to become effective in snow-control varied from 4-12 yr. Birch, American maple, English elm and oleaster are recommended because of rapid and dense growth.

Povet'ev, A.A. and V.V. Popov. Wind Penetration Through Snow-Protective Belts. Text in Russian. Sbornik Nauchno-Issledovatel'skogo Instituta Puti NKPS (Babushkin), 1934, 33:54-95.

Preliminary investigations on the effect of young deciduous trees and shrubs on wind speeds were made in 1932 at 2 points in European USSR. Wind-speed measurements were made at intervals inside and outside the planting zone at heights of 0.5, 1 and 2 m. Relationships between height, width, and type of plantings and wind speeds are tabulated and graphed. Wind speeds were normally reduced from 10-25 per cent at distances up to 20 m. on the windward side of the belt. Maximum reduction of the wind speed occurred in the first few m. of the belt and near the ground. Reduction is determined by width, density and height of the belt. The effects of snow banks on the wind distribution are discussed.

Povet'ev, A.A. and V.V. Popov. New Types of Leafy Snow-Protective Belts. Text in Russian. Sbornik Nauchno-Issledovatel'skogo Instituta Puti NKPS (Babushkin), 1934, 33:96-108.

The use of live snow fences by Russian railroads is discussed briefly. Preliminary results of studies on double-row plantings are given. Wind speeds at heights of 0.5, 1 and 2 m. are tabulated and graphed. The double row plantings suggested are as effective as the normal, wider belts and effect savings in costs and material.

Rakitskiĭ, N.P. Kostychev's Ideas on Meltwater Retention in Fields. Text in Russian. Pochvovedenie, 50, No. 11:55-58.

The Kostychev report on snowdrifts and snow retention was prepared in 1892. Its contribution to snowdrift control for agricultural purposes is considered important enough to merit publication in 1955. Snow distribution around obstacles and hedges was investigated in the steppe regions of European Russia. Hedges and the plowing of snow lanes were found to be effective for snowdrift control and for increasing the absorption of meltwater by the soil. Width of snow hedges and the distance between rows are given as functions of hedge height.

Rauner", S. Snow-Collecting Forest Belts in the Steppes of South European Russia. Text in Russian. Sel'skoe Khozi͡aĭstvo i Li͡esovodstvo, June 1905, 207:645-657.

The planting of forest belts along lines of high relief to collect snow as a source of water supply in the steppes of southern Russia is discussed. Belts 200-240 m. wide are recommended for main water-divide lines, and 20 to 160-m. belts for secondary ridges. The average max. snow-cover depth was found to vary from 20-46 cm. (Feb.) in the steppe zone of southern Russia with a density of about 0.3 at that time. Experiments in the Veliko-Anadol Forestry showed that this amount of snow precipitation with snow retention by forest belts is sufficient for irrigation. Snowbanks around forest belts at Veliko-Anadol reached a depth of 12 m.

Sarsatskikh, P.I. "Live" Pickets and Fences for Protection against Snow. Stroitel'stvo Dorog, 1939, 2, No. 9:31-32.

High initial and maintenance costs of wooden snow fences suggested their substitution by willow snow hedges. Willow pickets, 2.2 to 2.3 m. long and about 6 cm. in diameter, were planted along roads subject to snow accumulation. The willows were carefully planted in spring in ditches 60 to 70 cm. deep. The crowns of the willows were sufficiently developed in fall to provide protection against drifting snow.

Sarsatskikh, P.I. Fall Upkeep of Live Tree-Fences as a Protection against Snow. Stroitel'stvo Dorog, 1944, 7, No. 9:13.

A program for tree maintenance, replacement of dead wood with live trees, collection and selection of seeds, and growth of saplings for spring planting is outlined. Perennial maintenance is important because it takes 2 to 3 years to grow a hedge along the highways sufficiently dense to afford protection against snowdrifts.

Shiotani, Masao and Hideo Arai. Snow Control of the Shelterbelt. Union géodésique géophys. intern. Assoc. hydrologie sci. Compt. rend. Assemb. gén. Rome 1954, 4:82-91.

Wind tunnel and field tests of the effectiveness of forest shelterbelts are discussed in detail, and data are tabulated and graphed. The effects on snow interception of shelterbelt height, width, crown density, and mean height of the lowest branches were studied under controlled laboratory conditions. Snow accumulation, air flow, and wind velocity distribution were measured in the field. The causes for the generation of snowdrifts are discussed, and the effective area in the lee of the shelterbelts was determined from the interrelation between drifting snow and wind velocity near the snow cover. Effectiveness of shelterbelts are given for various shapes and densities. Problems for further study are outlined.

Shul'gin, A.M. Snow Retention by Hedges. Text in Russian. Moscow, Gosudarstvennoe Izdatel'stvo Sel'skokhozîaĭstvennoĭ Literatury, 1953, 40p. incl. illus. tables, graphs, diagrs., 27 refs.

A study of snow hedges and the effect of snow retention on the yield of winter crops is presented. The work of other investigators is summarized. Corn, sunflowers, sorghum, white mustard and other fast-growing species are planted in strips 2 or 3 rows wide perpendicular to the prevailing wind and 3.6-15 m. apart. Data on snow cover and air and soil temperatures with and without hedges at several stations in the USSR from 1940-1948 are presented in tables and graphs. The 1941-1948 average snow-cover depth at the end of Dec. at Barnaul measured 10-12 cm. in open fields and 30-50 cm. in hedge-protected fields, and min. soil temperatures at a depth of 3 cm. averaged 7.7°C higher under 30-50 cm. of snow cover than under no snow cover and 26.3°C higher than the average air temperature.

Shul'gin, A.M. Snow-Cover Distribution on Fields. Text in Russian. Voprosy izucheniia snega i ispol'zovaniia ego v naradnom khoziaistve, by Institut Geografii Adademii Nauk SSSR, Moscow, 1955, p.112-136.

The importance of a snow cover as a source of soil moisture in the forest-steppe and steppe zones of the USSR, where the water equivalent of the snow cover reaches 25-30 per cent of the annual precipitation, is noted; and peculiarities of snow-cover distribution are analyzed on the basis of special investigations in Altai Province since 1942-43. Snow depth averages from 10 cm. in the steppes of the S to 30-50 cm. in the forest-steppe zone; but these values vary from 0-100 cm. or more in open fields due to drifting, with deep snow accumulating around obstacles with adjoining bare surfaces. Data are given on snow-cover distribution and soil temperature variations in fields of Altai Province where the effects of snow retention were studied with grass, crops and other kinds of vegetation.

Sladkov, L. Snow-Collecting Forest Belts, their Agricultural Importance and Methods of Planting. Text in Russian. V Pomoshch' Zemledel'tsu (Omsk), 1924, 2, No. 3:10-11.

The importance of snow cover in agriculture is discussed and methods of snow retention are described. Forest belts are highly effective for snow retention. These belts, 20-30 m. wide, modify the distribution of the snow cover. An area of increased snow deposits extends 60-100 m. beyond the belt. Snow, 1-2 m. deep, is collected as compared to a few cm. in the open field.

Sokolova, N.S. The Influence of Forest Shelterbelts on Crop Yield. Text in Russian. Trudy Vsesoiuznogo Nauchno-Issledovatel'skogo Instituta Agrolesomelioratsii, 1937, 8:120-158.

The results of investigations of the hydrological effects of forest shelterbelts in 1932-1934 near Saratov are discussed and data are tabulated. About 243 per cent more snow accumulated in the shelterbelt areas than in the unprotected fields. The removal of underbrush in shelterbelts effects an evener distribution of snow cover around the belts. Shallower soil freezing and the longer snow-melting period in protected areas diminish surface run-off and improve the infiltration of meltwater.

Stepanov, N.N. Planting and Maintenance of Snow Hedges, Forest Belts, and Tree-Nurseries for Railroads. Text in Russian. Moscow, Transpechat', 1928, 216p.

A history of snowdrift prevention through the use of snow hedges and forest belts along railroads is presented. Species of bushes and trees according to climate and soil conditions are described and methods of improved maintenance are discussed. Wind flow variations around obstacles are analyzed and results of investigation of snow deposit forms are reviewed. Construction of snow hedges and forest shelter belts, location and width for various forms of relief in steppe regions are described in detail.

Stoeckeler, J.H. and E.J. Dortignac. Snowdrifts as a Factor in Growth and Longevity of Shelterbelts in the Great Plains. Ecology, April 1941, 22:117-124.

A study was made to determine the extent to which snow replenishes soil moisture in and near shelterbelts. The results indicate that shelterbelts with dense growing shrubs, at least 8 ft. high, effectively trap snow in drifts, 5-8 ft. deep. The drifts increase the soil moisture from fall to spring by 10 in. of water in the belt, and by 5 in. within 80 ft. of the belt. Increment of soil moisture from melting snow contributes to the longevity of 50 years of northern shelterbelts. Tree belts in southern locations with equal rainfall survive only 20-30 years. A 3-ft. snow cover kept the frost depth to 4 in.; under a 1-ft. cover frost penetrated from 12-18 in.

Torkelson, M.W. Planted Snow Fences. Eng. News-Record, 24 Sept. 1942, 129:408-409 (Comment and Discussion).

The effectiveness of plantings in controlling snow drifting along a Wisconsin road is indicated. More snow accumulated on the windward side of the plantings than along an adjacent lath and wire snow fence.

von Kruedener, Arthur. The Snowdrift Problem on Roads. Text in German. Forschungsarb aus d. Strassenwesen, 1941, 31:58-61.

The conservation of snow for agricultural purposes by means of forest shelterbelts is discussed. Snow is deposited in front of, within and behind belts consisting of a combination of trees and hedges. The belts decrease the effect of dry winds in summer, favor dew deposition, effect even snow distribution and favorably influence soil climate and climate near the ground. A program for planting forest shelterbelts is suggested.

Vozianov, V. The Effects of Variations in Width and Number of Strip Plantings on Snow Accumulation. Text in Russian. Klimat i Pogoda, 1935, 11, No. 5:38-40.

Results of an experimental study by the Donetsk Agricultural Station carried out in Artemovsk during 1934-35 are reported and data are tabulated. Measurements were made in a field planted with catch crops as well as between single and double rows of corn. Maximum snow accumulation was on the catch crops. More snow accumulated between the double-rows than between the single-rows of corn.

Williams, Ross. Trees that Beat the Blizzard. Am. Forests, Aug. 1949, 55, No. 8:26-27.

The effects of shelterbelts on snowdrift control and retardation of meltwater run-off are discussed on the basis of studies made near O'Neill (Nebr.) following the 1948-49 winter. Tree plantings, at least 7 rows wide and with a good shrub or conifer row on the windward side, trapped all the drifting snow in or close to the plantings. The effectiveness of other plantings varied as they deviated from this minimum standard. The absence of a shrub row to fill the gap between the ground and tree branches may actually cause harmful drifting.

Live Snow Hedges. Text in Danish. Medd. Vegdirektøren, Feb. 1949, No. 2:26-27.

The Danish delegation to the Nordic Road-Technical Union's meeting reports that fir and spruce trees provide good protection when planted in 2-3 rows spaced equidistantly on the diagonal. The Danish State Railways used spruce hedges but found that 2 parallel low-cut hedges with the outer row on a dike 25 m. from the tracks provided better protection against drifting snow. Hedges planted in Sweden to protect fruit trees against sand have supplanted artifical snow fences in winter. It is believed that planting birch and fir in northern Sweden will effectively replace artifical snow fences. Norwegian experiments showed that live hedges were more effective, less expensive and an improvement of the landscape. German experiments with low beech hedges, and low and high spruce hedges showed good snow accumulative capacities regardless of large percentages of open spaces. No definite conclusions are drawn.

Planting the Standard Windbreak. Minn. U. Agri. Extension Div. Ext. Bull., March 1939, 196:3-15.

Snow fences in Minn. should extend 400 ft. on the north and west sides, at 100-ft. distance from the buildings to be protected. Two rows of low trees or shrubs should be planted 60 ft. outside the main wind break to form a snow trap area. The main wind break should be 80 ft. wide and consist of 8 rows of trees. Trees to be used for the different rows are named and their proper alignment is designated.

Tree Planting to Serve as Railway Snow Fences. Eng. and Contr., March 17, 1920, 53:308-309.

The experience of American and Canadian railroads is discussed. Conifers are planted 75 ft. from the track in 2 rows 3 ft. apart, and the trees are staggered at 3-ft. intervals along the rows. Equally satisfactory results with hardwoods would require 8 rows. Cultivation is necessary for 3 yr. after planting. This method costs one-third to one-half as much as wooden snow fences and is more effective than snow fences in 7 yr.

Wind Erosion Control. Minn. U. Agri. Extension Div. Ext. Bull, June 1942, 235:3-15.

The importance of wind erosion control for agriculture is emphasized and practices including moisture conservation are recommended. Soil moisture may be conserved through catching and holding snow by means of shelterbelts, hedges and buffer strips. Stubble covering helps moisture conservation by preventing deep frost penetration, while rough surfaces check run-off and increase the percolation rate. Winter moisture may be preserved by plowing a series of snow ridges. Implements used for moisture conservation include basin tillers, shovel basin listers, and field cultivators.