Observations on Pressures Exerted by Creeping Snow, Mount Seymour, British Columbia, Canada

J. R. MACKAY and W. H. MATHEWS

Departments of Geography and Geology, Univeristy of British Columbia
Vancouver, British Columbia, Canada

Abstract

Snow studies have been conducted since 1963 on a site 16 km NE of Vancouver, Canada, at an altitude of 1 200 m. Snow reached maximum depths of 5.9 m (March, 1964) and 4.2 m (February, 1965); water equivalents reached maximum values of 3 m (May, 1964) and 1.6 m (April, 1965). The pack is isothermal at 0°C throughout most of its depth at virtually all times of the season. The study site is on a relatively smooth rock slope averaging 21° amid widely scattered trees.

An array of remote-registering hydraulic transducers in the lowest 0.45 m of the pack displays a complex seasonal pattern in the downslope component of pressure, reaching maxima (0.35 to 0.42 kg/cm^2 in 1965) in mid season at 0.4 m above the base of the pack, but not until very late season (May) at 0.15 m above the base. Distribution of loading between adjacent transducers varied throughout the season, and close correlation of load with total ram energy is lacking.

Deflection of steel poles penetrating the full thickness of the snow pack reached a maximum in mid April of 1965; slight but measurable deflection of a nearby tree was also recorded during the same period.

Mechanical transducers, recording only maximum loads of the season, and tensiometers attached to objects of various sizes and shapes have been devised to record effects of snow creep.

I. Introduction

Snowcreep studies were initiated in 1958 at Mount Seymour, British Columbia at an altitude of about 1 100 m some 15 km northeast of the city of Vancouver. The observations for the period 1958 to 1962 have been described (Mathews and Mackay, 1963). In the summer of 1963, a new site was selected at an altitude of 1 200 m near the upper terminal of the Mount Seymour chair lift, thus making it easily accessible under adverse weather conditions. The new site is about 100 m higher than the old site and is characterized by a much longer snow season, greater snow depths, and no mid-winter period when the ground is free of snow. On the other hand the new site is somewhat more confined by trees (Fig. 1) and has but a single angle of slope. Like its predecessor, this site consists of a relatively smooth bedrock pavement in which holes can be drilled to anchor the snow poles, transducer assembly, and other items of equipment attached to them (wooden balls and thermistors). It is the purpose of this report to discuss observations on pressures exerted by creeping snow at the new site for the period 1963–65. Although observations have been carried out through the winter of 1965–66, they have not been completed at the time of writing, and so are omitted from this discussion.

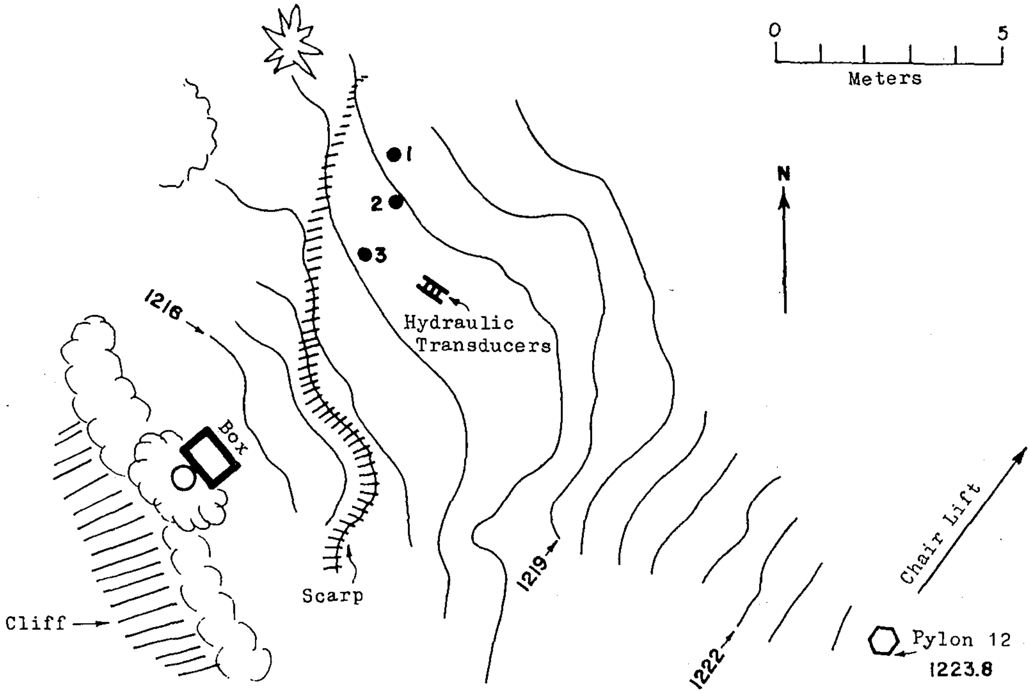

Fig. 1. Location map of site at Mount Seymour, British Columbia. Altitude in meters. Number 1, 2 and 3 refer to the snow poles

II. Snow Depths

In the winter of 1963–64, the snowfall was much heavier than in the previous 4 years and reached a maximum depth of 5.5 m at the end of March (Fig. 2). As the site is in a particularly exposed position, subject to drifting and some avalanching on the lower slopes, data for a nearby snow course are included for the sake of comparison (Fig. 3). The winter snowfall was so heavy that some snowbanks persisted through the summer and fall, in a few protected sites, until they were buried by fresh snow in the

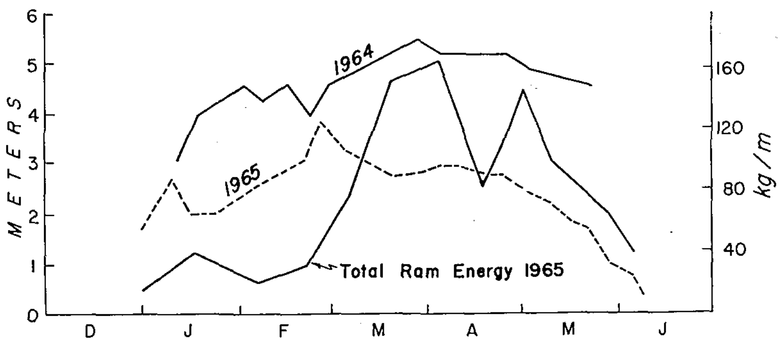

Fig. 2. Snow depths for 1964 and 1965 are graphed in meters (left hand scale). Total ram energy for 1965 is shown in kg/m (right hand scale)

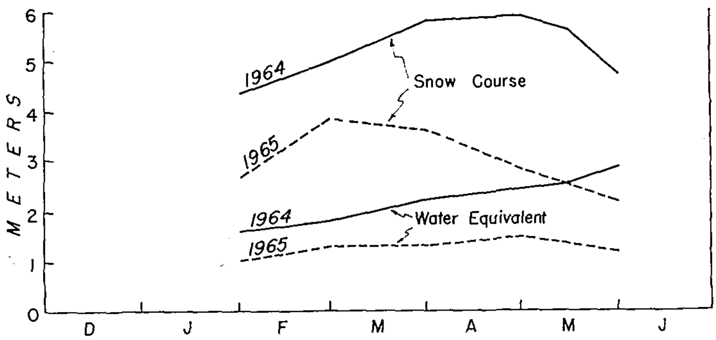

Fig. 3. Snow depths and water equivalent for 1964 and 1965

winter of 1964–65. Judging from the snow survey records, densities increased in 1964 from about 0.35 g/cm³ on February 1 to 0.40 g/cm³ on May 1 and 0.60 g/cm³ on June 1. The very great depth and correspondingly high creep pressures encountered in 1963–64 posed major problems in operations but at the same time provided promise of significant results. Accordingly in 1964–65 instrumention was increased and though the great snow depth of the previous winter was not experienced, more reliable observations were obtained. Though the snow pack persisted uninterruptedly from early December till early June, periods of snow accumulation alternated with mild, thawing, conditions and with cold clear weather during which the water-soaked snow at surface developed hard crusts. These became buried by later snow and were progressively modified until after 2 or 3 months they were indistinguishable, at least by means of a rammsonde, from the remaining snow which had undergone more normal metamorphosis. At the snow course, densities in 1965 varied from 0.35 g/cm³ in February and March to 0.55 g/cm³ in late April and May.

III. Ram Energy

Rammsonde measurements were taken in the early winter of 1963–64, but had to be abandoned when the depth of the snow and the steepness of slope made further readings impossible. Rammsonde data for 1965 are shown in Fig. 2. Ram hardness (Heafeli, 1939) increased in general downwards, apart from more or less obvious crusts, surface or buried, to values of roughly 50 kg in March, 1965 and to more than 100 kg in May. It may therefore be inferred that the density of the deeply buried snow was significantly higher than shallower snow unless the latter had been subjected to surface thaw and freeze. However, the lowest part of the snow pack often proved to be very loose and the penetrometer dropped as much as 20 cm on the final blow; on other occasions, or perhaps at other places, the bottom of the snow pack was distinctly harder than elsewhere. On excavation of the transducer array and wooden ball in May and June, it was found that some materials, notably wood, were coated by an exceedingly hard ice layer. The mechanism whereby such an ice coat develops remains inadequately understood.

Total Ram energy (Haefeli, 1939) increased with the accumulating depth of snow through December, 1964 into early January, 1965; it then decreased in late January, then increased both because of added snow and internal reconstitution of the pack to a maximum in early April and finally decreased irregularly with melting of the pack in the latter part of the season (Fig. 2).

IV. Snow Temperatures

In the winter of 1963–64, five thermistors were used to record snow temperatures. Four thermistors were placed inside a plastic tube attached to a steel snowpole at the following heights: ground level; 1, 1.75 and 2.25 m. A fifth thermistor was placed in the transducer assembly at a height of 20 cm above ground. During January, snow temperatures at the snowpole lay between −3.0 and 0°C. From February to the end of May, temperatures were close to 0°C, the lowest being −0.5°C, and the lower portion of the snowpack was nearly isothermal throughout the period. The thermistor probe installed in the middle of the transducer assembly gave positive or zero temperatures all winter, except for a negative reading of −0.1°C on April 19. The mean of 14 weekly or bi-weekly readings was +0.4°C. In order to check on the possibility of an instrumental error, two probes were placed in the same position and read during the winter of 1964–65. The temperatures of the two probes agreed to within 0.1°C all winter. From the end of December, 1964 to mid-January, 1965, the temperatures were slightly negative, being −0.2 to −0.3°C. From mid-January to early May, temperatures were slightly positive, ranging from 0.3 to 0.7°C. The agreement of the positive temperatures for three different thermistor probes, over two winters, suggests that heat conduction from the rock along the two steel poles, which anchor the transducer assembly, is sufficient to maintain an air space in which the thermistors, which projected a few centimeters from the steel poles, could register slight positive temperatures. Rock temperatures were not taken in 1963–64, but ground temperatures in a nearby site were taken at depths of 0.5 and 1.0 m in 1960–61. Using this data, the heat flux per square centimeter ranged from slightly over 12 g·cal/day in mid-January, 1961, to about 5 in mid-April. If the same general range occurred in 1963–64 and 1964–65, the total winter heat flux was of the order of 1 000 g·cal or more. This ground heat flux, together with rain and meltwaters, leads to isothermal conditions of near zero temperature through most of the snowpack in the spring months.

V. Snow Movement

The early experiments of the period 1958–62 were concerned largely with snowcreep at the bottom of the snowpack. Total 1958–59 winter movements of wooden balls, resting on slopes of 35° to 50°, were from 20 to 60 cm under snow depths of 2 to 3 m (Mathews and Mackay, 1963, p. 67). Maximum movements of a meter were measured. Therefore, in 1963–65, less attention was given to basal snow movement, as the amount had already been measured. In 1963–64, a single wooden ball, 15 cm in diameter, was placed on the ground and attached to a snow pole with a 20 kg test wire. Although the method of attachment was designed to permit the ball to move downslope, with the basal snow, the wire broke after a 5 cm displacement. In 1964–65, the movement of another 15 cm diameter wooden ball, at the base of the snowpack, totalled 25 cm from December 6, 1964 to May 23, 1965. However, three styrofoam balls, 7.5 cm in diameter, which were placed at the same time a centimeter above the ground were completely flattened, and moved only 0.5 to 2 cm downslope. Fragments of the tape wrapping of one of the snow poles torn from points 40 and 100 cm above ground level were carried 9 and 15 cm respectively downslope from the poles. Allowing for the displacement of the poles themselves (see below) the snow containing the fragments moved at least 30 and 60 cm respectively downslope. Cavities in the snow, filled in part with hoar, extended 6 cm to possibly 15 cm directly downslope from the base of the poles. Assuming they were created by creep of the snow, these indicate movement of at least these amounts at the base of the pack. Finally a vertical hole in the snow filled with sawdust in January was, at the end of May, tilted 12° off plumb though not notably curved; movement at higher levels was clearly greater than at depth, but the absolute displacement in this case could not be established.

VI. Bending of Steel Poles and Shelter

Two steel pipes, 3 m long, 2.5 cm outer diameter, and 1.25 cm inner diameter were set in 30 cm deep holes drilled vertically into bedrock in the autumn of 1963. The poles became completely buried in January, 1964, and were not exposed until June, by which time their tops had been displaced nearly a meter downslope. The uppermost 1.2 m of the poles were straight though tilted; the lower 1.5 m of the exposed pipes were bent into a smooth curve and it was obvious that here the bending movement exerted by the creeping snow pack on what were essentially cantilevered beams exceeded the elastic limit of the pipe. Measurements indicate a moment of 17 250 kg·cm is required to produce a permanent bend in the pipe, such as could be provided by a uniform loading of 0.46 kg per linear centimeter throughout its exposed length. Since plastic deformation of the pipe, beyond its elastic limit, is a time-dependent process and the length of the period during which bending occurred was unknown, no attempt was made to reconstruct bending stress from the curvature of the pipe. It was also recognized that because of inhomogeneity of the snow the assumption of uniform loading need not be valid.

Three steel poles of the same dimensions were mounted in the autumn of 1964 and in the following winter these were completely buried only for short periods. It was

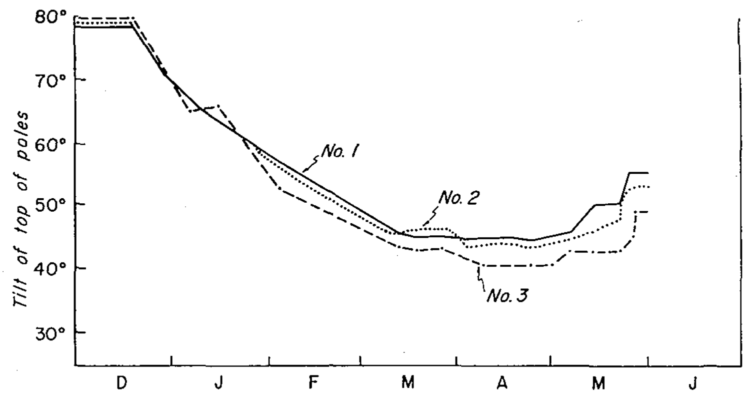

Fig. 4. Tilt of top of poles 1, 2 and 3 shown for December, 1964, and January to May, 1965

therefore possible to observe progressive tilting of the top of the poles at frequent intervals (Fig. 4). When the poles were finally freed of snow (the last meter by digging) on May 23 and 29 there was a notable and consistent elastic rebound. Bending during this season was confined to the lower 5 to 10 cm around the bedrock surface and nearly all the 2.7 m exposed length of the pipes remained straight.

The construction of a shelter to provide access to instruments close to the ground level throughout the winter offered another opportunity for study of effects of snow creep. The shelter, built of lumber and plywood, 1 m wide (across the slope), 75 cm deep (parallel to the slope) and 3.6 m high was mounted against the upslope side of a stout tree (*Tsuga mertensiana*) 40 cm diameter at breast height. A plumb line was mounted on the shelter on the back wall (adjacent to the tree) when it was built in November, 1964. By March, 1965 the shelter was canted down-slope some $1\,^3/_4^\circ$ (3.0%), and slightly more (3.1%) in early April, but by late May, when the snow had almost completely melted away from the structure, it was again almost plumb (0.4% off line). Some of the deflection of the plumb line may be related to "permanent" adjustments within the woodwork, but the rebound between early April and late May should almost certainly be ascribed in large part to an elastic response, on release of snow load, of the tree against which the shelter had been built.

VII. Hydraulic Transducers

Hydraulic transducers, similar to those used in 1961–62 (Mathews and Mackay, 1963) were again employed in 1963–65. The transducers have bearing plates 12.5 cm square. The bearing plates were mounted in a pattern of 3 abreast in 3 successive rows one above the other, to give a square array of 9 plates mounted vertically. The lowermost row just cleared the bedrock surface and the highest extended from about 28.5 to 41 cm above this surface. Attachment was to a heavy pipe frame cantilevered into two drill holes immediately behind (downslope) from the array.

Calibration of the instruments was undertaken before installation in a cold room at a temperature of 0°C inasmuch as earlier work had indicated they were influenced by temperature. Except for a brief period in December when they were not deeply buried and hence subject to chilling during extremely cold weather, and again in late spring when the snow level fell below the level of the gauges, the instruments functioned at essentially 0°C and temperature effects could be neglected. In June, 1965 the instruments were recalibrated in the field while still embedded in snow. Consistent, nearly linear plots of load vs. gauge readings were obtained although at higher loading some stickiness or binding in the pistons could be observed and better than 5% accuracy can not be claimed.

In 1963 the array was mounted on a vertical frame and the bearing plates arranged perpendicular to the ground surface, a 21° slope. As a result the bearing plates were lapped slightly over one another somewhat like shingles on a roof. The vertical loading by the very heavy snow pack at some time later that winter moved several of the transducers out of alignment to the point where these may have interfered with their neighbors below. Records from these transducers and those directly below are, therefore, suspect.

In 1964 the frame to which the transducers were attached was bent to a position normal to the slope and the bearing plates thus fell very close to a single plane. Alignment, moreover, persisted through the winter. Unfortunately the middle unit, attached to a chart recorder, developed a leak and lost pressure after the first month of operation; this unit provided readings only for a small fraction of the season.

The results obtained for 1963–64 are set down in Table 1. The bottom row of gauges, numbered from left to right looking downslope at the gauges, are 1, 2 and 3; the middle row are 4, 5 and 6; the upper row are 7, 8 and 9. The snow depths are for the location of the shelter; depths upslope, at the transducer site, are estimated to have been 20% greater. The zero reading of gauge 1 resulted from a damaged transducer; the value of 0.084+ in gauge 7 represented the upper limit for that particular gauge. Some of the constant readings are believed due to stickiness of the pistons or freezing of ice around the bearing plates.

The 1964–65 record is plotted in Figs. 5, 6 and 7. The bottom row, left, center, and right corresponds to gauges 1, 2 and 3 for 1963–64; similarly for the middle and top row.

Table 1. Pressure in kg/cm^2 1963–64

	Jan. 12	Jan. 19	Feb. 2	Feb. 9	Feb. 16	Feb. 23	Mar. 1
Gauge 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.042	0.052	0.052	0.065	0.065	0.065	0.065
3	0.034	0.039	0.039	0.039	0.039	0.039	0.039
4	0.065	0.076	0.070	0.070	0.070	0.070	0.070
5	0.014	0.014	0.031	0.031	0.031	0.031	0.014
6	0.087	0.104	0.107	0.096	0.084	0.112	0.169
7	0.084+	0.084+	0.084+	0.084+	0.084+	0.084+	0.084+
8	0.155	0.171	0.171	0.171	0.171	0.171	0.171
9	0.022	0.025	0.025	0.025	0.025	0.025	0.025
Snow depth	3.0m	4.0m	4.6m	4.3m	4.6m	4.0m	4.6m

	Mar. 29	Apr. 5	Apr. 12	Apr. 19	Apr. 26	May 3	May 24
Gauge 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.065	0.062	0.062	0.062	0.062	0.062	0.062
3	0.039	0.039	0.039	0.039	0.039	0.039	0.039
4	0.065	0.065	0.062	0.062	0.062	0.062	0.084
5	0.014	0.014	0.014	0.014	0.000	0.000	0.000
6	0.132	0.112	0.098	0.076	0.051	0.039	0.039
7	0.084+	0.084+	0.084+	0.084+	0.084+	0.084+	0.084+
8	0.155	0.146	0.146	0.146	0.143	0.143	0.143
9	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Snow depth	5.5m	5.2m	5.2m	5.2m	5.2m	4.9m	4.6m

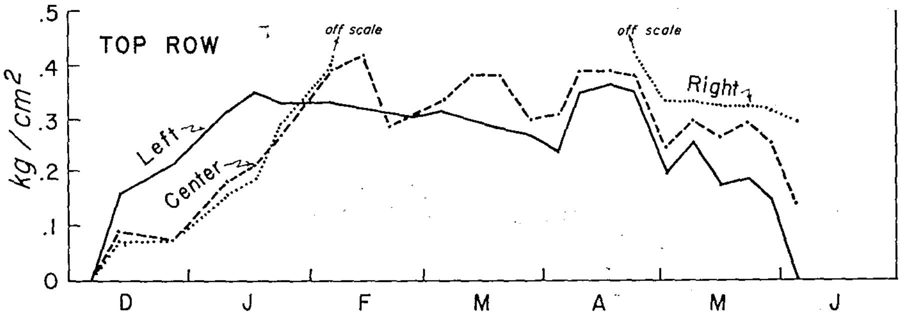

Fig. 5. Hydraulic transducer readings, 1964-65 for the top row

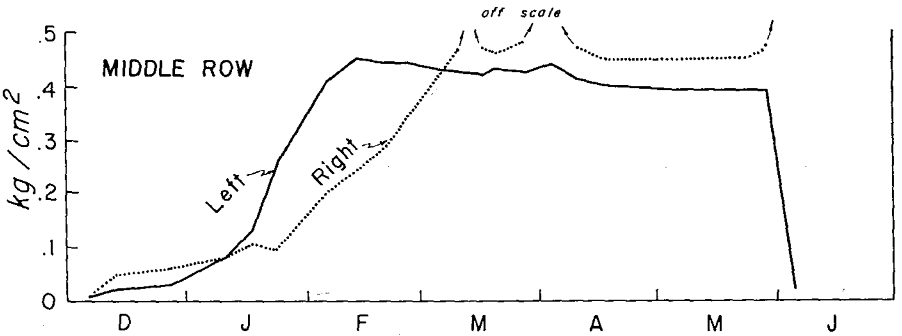

Fig. 6. Hydraulic transducer readings, 1964-65, for the middle row

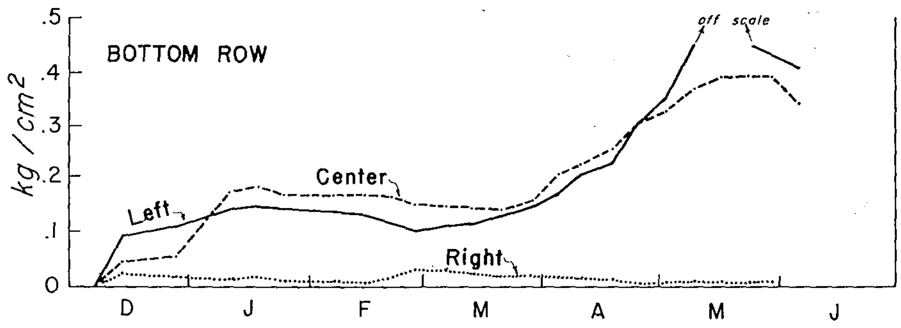

Fig. 7. Hydraulic transducer readings, 1964-65, for the bottom row

From the 1964-65 record of pressures several points can be observed:

(1) Loading by snow creep is subject to continual change both in magnitude and distribution. Only locally and for a fraction of the season does a load remain essentially constant, even though the change from active loading during the time of vigorous snow creep to passive restraint on the transducer at the end of the season might be expected to produce constant pressure for several weeks. Melting of the snow by heat conduction from the ground to the bearing plates may account for the gradual fall in recorded pressure during this transition from active to passive loading. Fluctuations with time are most notable in the upper row of transducers.

(2) Though parallel changes in loading, corresponding among other things to increase and decrease in the total snow pack, are general in the different units of the array, discordant behaviour of even adjacent units is at times conspicuous. Thus the load on the left hand transducer of the top row in 1965 fell gradually for 4 weeks in late January and February while load on the adjacent unit of the same row more than doubled. Similarly loads on the left and right sides of the middle row reached peaks at the end of March which coincided with lows in at least two of the three units of the top row.

(3) In a general way the upper row of transducers recorded maximum pressures relatively early in the season, the middle row generally later and the bottom row only very late in the season. During January pressures increased upward; in March pressures were highest in the middle row, and in May pressures increased downward.

(4) Surprisingly, corner transducers did not record significantly higher loads than those mounted in the middle of a side. Whether there is a reduction in pressure from the edge to the middle of the array is not yet known.

(5) The high degree of correlation between load and total ram energy reported by Haefeli (1939) is not borne out by this study, indeed load on the upper row of transducers varied inversely as the total ram energy from early February to the end of April. Conceivably the isothermal conditions prevailing in the snow may invalidate a correlation that might exist in cold snow such as studied by Haefeli on Weissflujoch, Switzerland; alternatively the load integrated through much of the depth of the pack, as in Haefeli's study, might show a correlation whereas loading on relatively small areas deep within the pack does not.

An interesting pressure increase was found in the continuous pen record for the center unit of the array on December 11–12, 1964, before this unit ceased to function satisfactorily. In the course of a snowstorm, heaviest between midnight, December 11, and 1:00 p.m., December 12 some 20 cm of snow was added to the pack and the downslope component of load on the 12.5 cm square plate increased by 2.25 kg. Given 21° as the local angle of slope assuming a density of 0.1 g/cm^3 for the freshly fallen snow, and assuming also that the entire downslope component of the added weight of snow is applied against the transducer, a minimum area of influence, A, (Furukawa, 1953) can be obtained from

$$2.25\,\text{kg} = 0.0001 \times 20A \sin 21^\circ$$
$$\text{or } A = 56 \times 56\ \text{cm}.$$

Again assuming this area of influence extends as a strip 12.5 cm wide upslope from this central transducer plate, it would reach 2.4 m from the array. Friction of the base of the snow pack against the ground during the time interval under consideration, or resistance to internal deformation in the pack, could increase the calculated distance upslope within which addition of snow influenced the recorded loads.

VIII. Maximum-Recording Snow Pressure Transducers

In order to record the maximum downslope component of pressure exerted by the creeping snowpack during the winter, a modification of the hydraulic system was devised with the help of Mr. P. Demco (Department of Civil Engineering, University of British Columbia). This consisted of two telescoping brass tubes. The inner brass tube had one end firmly attached to a wooden base and a coil spring, longer than the tube, inside it. The outer brass tube, 5 cm in diameter, had a 12.5 cm square plate centered on one end. When the outer tube was placed over the inner tube, the spring could be compressed by pressing on the square plate. A slip ring on the outside of the inner brass tube was so placed that it was pushed by the outer tube, but remained in place if the pressure was released. The transducers were mounted in a vertical array against a fixed support, with the axes of the transducer tubes parallel to the inferred snow slope. Thus, the maximum pressure was recorded by the position of the slip ring.

Six of these transducers were mounted in January, 1965 in a vertical array, at 30 cm intervals, on the upslope side of pylon 13 on the Mount Seymour chair lift, a pylon which had undergone notable deflection by snow loads in the winter of 1963–64. The seventh was mounted on the upslope face of the shelter within which the hydraulic transducer gages, thermographs etc. were installed. Installation and adjustments were completed on February 6. On March 14 the top four of the 6 transducers on the pylon were exposed by melting of the snow, were measured and reset. The full array was subsequently buried by later snowfalls and re-exposed on April 18 to May 16. The single transducer on the plywood shelter was exposed on March 20, and again on April 24. All instruments were recovered in early June and loaded in the laboratory to the point indicated by the slip rings for calibration. The following results pertain:

Table 2

Transducer	Period	Approximate max. snow depth (m)	Max load on plate (kg)
1	Feb. 6–Mar. 14	1.1	32
1	Mar. 14–Apr. 18	0.4	15
2	Feb. 6–Mar. 14	1.4	35
2	Mar. 14–Apr. 18	0.7	14
3	Feb. 6–Mar. 14	1.7	34
3	Mar. 14–Apr. 18	1.0	17
4	Feb. 6–Mar. 14	2.0	54
4	Mar. 14–May 16	1.3	45
5	Feb. 6–May 16	2.3	50+
6	Feb. 6–May 16	2.6	50+
7	Jan. 24–Mar. 20	1.8	27
7	Mar. 20–Apr. 24	1.1	21

Slopes of 25° prevailed on the snow surface above transducers 1 to 6 and approximately 30° (increasing from 25° through the season) over transducer 7.

In areas where snow depths can be great, and highly variable, the maximum-recording snow pressure transducers would appear to provide records otherwise very difficult to obtain. They are simple to construct, rugged, and require no field maintenance. The only difficulty encountered was icing on the tubes when the snow cover was thin. This resulted in some sticking of the slip ring, but it was found that if the tubes were lightly greased and covered with a thin plastic bag, icing was prevented.

IX. Drag on Objects in Snow

The drag exerted by creeping snow on some simple geometric objects embedded in the snow, and the effect of their size, shape, and orientation, was the subject of a pilot study. The objects were cylindrical wooden rods of various diameters, and square or rectangular sheets of plywood laid in the snow and individually connected by means of a bridle to a single strand of stainless steel wire, 55 kg test, and the wire to spring scales (23 kg limit) attached to a tree higher on the slope. The objects were then allowed to become buried by later snowfalls. In six tests the wires were passed through nylon loops near the base of the tree to permit the spring scales to be hung well above the snow level without having the wires exposed for long spans above the snow surface. The nylon loops, it was hoped, would minimize frictional drag at a sharp bend in the wire. A sliding clip was mounted in each scale to record the maximum load attained between readings, but in most cases stresses increased steadily until spring, or wire, or both, broke and the clips thus proved to be of little advantage. The record obtained is outlined in Table 3. The scales were read each week; omissions of dates in Table 3 indicated periods when the scales were deeply buried in snow. Missing numbers indicate damage to the scales or broken wires.

The results of the study indicate that the stresses which could be generated were severely underestimated and that cylindrical rods 25 cm long would have been preferable to the 50 cm rods used. Breakage of wire took place typically at connections with the bridles or in the sharp bends of the wire bridle itself. Since the rods, when excavated, were not reoriented by creep from the original transverse attitudes, it appears

Table 3. Drag on test object, in kg [Max. load prior to date in brackets]

Cylindrical rod 0.5 m long	Jan. 31	Feb. 6	Feb. 14	Feb. 21	Mar. 14
1.3 cm diameter	13 [17]	0	—	—	—
1.3 cm diameter	10	12	13	16	21
2.0 cm diameter	13	16	10	16	14
2.0 cm diameter	15 [21]	0	—	—	—
3.3 cm diameter	14	17	20	—	—
3.3 cm diameter	15 [23]	0	—	—	—

Plywood sheets	Mar. 6	Mar. 13	Apr. 4	Apr. 10	Apr. 18	Apr. 24	May. 2
25×25 cm square	1.4	1.8	6.3	7.3	3.9	3.9	7.7
25×25 cm square	0.9	0.0	3.6	4.5	3.2	3.2	0.0
25×10 cm transverse	2.3	1.8	3.6	5.5	7.3	7.3	7.3
25×10 cm transverse	2.7	1.8	5.5	6.8	7.7	7.7	0.9
10×25 cm longitudinal	0.7	0.0	3.6	3.9	3.9	3.2	0.9
10×25 cm longitudinal	3.6	2.7	5.5	7.3	8.6	8.6	4.1

that the bridles were unnecessary and a simpler method of linking wire to rod can be adopted in future.

Consistency of duplicate tests were not satisfactory and further study of this aspect is required. In other respects the method itself proved to be simple and inexpensive and may open the way to a study of edge pressures and skin friction on a wide variety of shapes and meterials.

X. Conclusions

In an area such as Mount Seymour, British Columbia, where the snow depths may exceed 5 m, the snowpack is nearly isothermal in spring at 0°C, and the density is high, snow pressures may become extremely large. The problems of instrumentation are difficult and for this reason, attempts have been made to design simple, rugged, self-recording equipment. Ram energy studies have proved of limited value because of the difficulty of obtaining valid results when snow depths have been great, drifting has occurred, and icy layers are present. Ram energy studies have proved helpful, however, in interpreting results obtained from other equipment. For example, an icy crust (detected from ram energy studies) at the level of the pressure transducers, may have had a significant influence on pressures recorded in the early part of the 1964–65 season; by March the crust was no longer recognizable in the penetrometer records. Such information could not otherwise have been obtained, except by probing or coring.

The method of using wooden balls, attached to snowpoles, has proven excellent for recording basal snow movement, but it is believed the total basal displacement is usually greater than that of the wooden spheres, because the spheres are moved under a heavy load and are heavily scored and indented by rubbing against the ground. The bending of the heavy steel pipes illustrates the difficulty of anchoring instruments above the ground on a slope. Very sturdy pipes would be required to support an array of instruments. On the other hand, the bending of the pipes gives an indication of pressures to which structures, such as power line towers, might be subjected to in an area of heavy snowfall. In future studies, it is hoped to use strain gauges, attached to poles, to measure their bending and the pressures to which they are subjected. The hydraulic transducers, despite initial difficulties of construction and installation, have proven of considerable importance in giving a week by week record of pressures. Interpretation of results is not entirely simple because of heat conduction from the ground, via the anchoring framework, and the presence of icy layers bearing against the plates. The use of the maximum-recording snow pressure transducers and simple geometric objects inserted in the snowpack are believed to offer new avenues for research on snow pressures at Mount Seymour, B. C.

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