Snow loads on roofs 1960-61: fifth progress report

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DIVISION OF BUILDING RESEARCH

SNOW LOADS ON ROOFS 1960-61

FIFTH PROGRESS REPORT

by

J. F. Scott and B. G. W. Peter

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of the

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PREFACE

The heaviest load that roofs in Canada have to support is usually the load imposed by snow. It is obvious, therefore, that the magnitude and distribution of the design snow load have a considerable effect on the safety of a structure, as well as its cost of construction. This is true for any roof but particularly for roofs of smaller dwellings under ordinary, relatively sheltered conditions for which wind loads are generally of less importance.

Snow loads for design purposes are given in the National Building Code of Canada. In the 1953 edition of the Code, the loads which were shown on a map were derived directly from measurements of snow on the ground. It is frequently observed, however, that snow depths on the ground cannot be applied directly to the determination of design snow loads for roofs. Consequently, the Associate Committee on the National Building Code, which is responsible for the preparation and continued revision of the Code, asked the Division of Building Research to carry out a survey of actual snow loads on roofs. This survey was begun in 1956. Because of regional and annual climatic variations, such a study must extend over several years and must take into account the whole of Canada.

This fifth progress report in the continuing survey gives the results of the 1960-61 snow load observations and also discusses the significance of the findings to date.

The Division of Building Research wishes again to express its sincere appreciation to the many observers across Canada who have contributed so greatly to the success of this survey. In particular, thanks are expressed to the many building inspectors, private companies, and individuals who made B-Station observations, and also to the RCAF personnel at the C Stations and their organizers in Ottawa. Grateful appreciation is recorded also to A-Station observers of the Meteorological Branch of the Department of Transport at Goose Bay and Gander, the Department of National Defence at Fort Churchill, Ecole Polytechnique (Montreal), Macdonald College (Ste. Anne de Bellevue), Queen's University (Kingston), University of Toronto, University of Manitoba (Winnipeg), University of Alberta (Edmonton), Aluminum Co. of Canada at Arvida, the Federal Day School at Inuvik, and the Atlantic, Prairie and B. C. Regional Stations of the Division.

This report was prepared by J. F. Scott, graduate in civil engineering from Queen's University, summer worker with the Building Structures Section, and B. G. W. Peter, Research Officer with the Section, under the direction of W. R. Schriever.

Ottawa
November 1961

Robert F. Legget,
Director.

TABLE OF CONTENTS

SNOW LOADS ON ROOFS 1960-61

Fifth Progress Report

by

J.F. Scott and B.G.W. Peter

The country-wide survey of snow loads on roofs being carried out by the Division of Building Research has once again provided a substantial amount of information. This survey covers observations of snow depth and density on a large number of roofs and on the surrounding ground. In this fifth progress report, these observations have been analyzed, their trends and unusual features discussed, and their results correlated with interim conclusions of previous reports.

The survey, which was begun in 1956 at the request of the Associate Committee on the National Building Code, provides information on which to base more rational snow load specifications in future editions of the Code. In the 1953 edition of the Code, the roof loads were computed by adding the maximum depth of snow cover on the ground and the maximum winter rain that might fall into that snow cover; it was found, however, that depths on the roof frequently did not correspond to depths on the ground. To investigate this, a pilot survey was carried out during the winter of 1956-57 to assess the method and apparatus proposed for the full survey; in 1957-58 the survey proper was begun. Density as well as depth was measured, and in order to determine the nature of the snow loads, a gauge numbering system was devised whereby the formation of unbalanced loading patterns could be traced. A full description of the background and results of the survey are presented in seven DBR Internal Reports (Refs 1 to 7).

On the basis of information gathered in the years preceding 1960, several revisions were made in the 1960 edition of the Code. Prominent among the revisions recommended by the Associate Committee on the National Building Code, is that the ground load be reduced by 20 per cent to arrive at a design roof load. Whereas the 1953 Code merely pointed out that non-uniformly distributed loads conceivably in excess of those specified would be anticipated, the 1960 Code specified "shape factors" to be used for accumulated loads on canopies, marquees, porch roofs, sheltered roof portions and particular roof shapes.

Where reference to NBC design loads has been made in this report the corresponding figures are those specified in the

Climate Information Handbook of the NBC 1960 (8) unless otherwise indicated. The 1960 values are based on a longer series of records and a longer design period (30 years) than were the 1953 loads, and thus the new maximum ground load figures are often slightly larger. The design roof loads of the 1960 Code are 80 per cent of the ground load and show both an increase and decrease compared with the 1953 loads.

2. SUMMARY OF 1960-61 OBSERVATIONS

Although the snowfall was below normal in most parts of Canada, the results of the survey, with respect to roof load to ground load ratios and positions of drift accumulations, were useful and confirmed previous results. A few roofs had maximum average* roof loads exceeding the corresponding ground loads. As in previous years, concentrated loads were quite high and on several roofs these concentrations exceeded the basic design load.

On the average, roof loads were considerably less than ground loads, with many roofs covered with negligible amounts of snow. Concentrations occurred where expected but the size of these was extremely variable. Wind, combined with shelter, shape and orientation of the roof again proved to have the greatest effect on snow loads. High temperatures reduced roof loads rapidly while solar radiation during cold weather was a relatively minor factor in snow load reduction.

3. DESCRIPTION OF THE 1960-61 OBSERVATIONS

The procedure used to collect information was similar to that used in previous winters. The survey (2) made use of three types of observation stations where measurements were recorded as follows:

A-Station observers continued to make detailed observations of snow depth and density on one flat and one pitched roof of residential size, and on the surrounding ground. These measurements, made weekly and after every heavy snowstorm, were carried out as described in Ref. (7).

B-Station observers made periodic depth measurements on one roof and on the surrounding ground. Additional measurements were made on other roofs at the time when snow loads were at a maximum

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* "maximum average" means the average roof load at the time of maximum snow during the winter considered.

for the winter.

C-Station observers made the equivalent of A-Station observations on large flat roofs located at RCAF bases across Canada. Each station observed two or more of the four standard C-Station roofs, the four being the Unit Supply Depot roof, the cantilever hangar roof, the mechanical equipment garage roof and the wings of the arch hangar roof.

Observation reports for the 1960-61 winter were received from 44 stations; 7 of these reported that measurements were not taken due to insufficient snowfall. Fifteen A Stations reported observations on 41 roofs, 15 B Stations reported on 19 roofs, and 7 C Stations reported on 20 roofs, for a total of 80 roofs. The locations of all Stations where readings were taken are given in Figs. 1 and 2.

4. WEATHER

The winter of 1960-61 featured many deviations from normal weather conditions. In British Columbia precipitation was above normal, but because of high temperatures most of this occurred as rain. In the Prairie Provinces snowfall was generally below normal although Fort Churchill experienced a snowfall more than 100 per cent above normal. Temperatures were 4 to 12 degrees above normal. In Ontario and Quebec snowfall was as much as 45 per cent below normal, with extremely little snow during the months of January and February. Temperatures were above normal in November, February and March, and below normal in the other winter months. In the Maritimes snowfall was generally above normal and temperatures below normal. At Gander snowfall was 40 per cent above normal while Goose Bay reported 40 per cent below normal. Throughout the country, wind, the factor with the greatest influence on snow loads, did not show any significant departure from normal.

5. PRESENTATION OF RESULTS

As in previous progress reports, A-Station results are given in detail for each roof by graphs in which the average ground load, the maximum, average and minimum roof loads, and in some cases, the maximum load on a canopy or lean-to roof are plotted against time. With these graphs are further graphical records of wind, temperature, and accumulated snowfall as well as drawings giving the gauge positions and basic dimensions of each roof. These detailed results are given in Figs. 3 to 17 inclusive, and are summarized in Table I and its graphical equivalent, Fig. 23.

B-Station results are presented in the same manner as for the previous two winters. Figure 2 gives the B-Station locations as well as the "stick" graphs of maximum average roof and ground loads for these locations, while Table II presents a tabular summary in which roof details and loading influences are noted.

With the exception of the graphical summary, C-Station results are presented in the same form as those of A-Stations. The load-time curves for each roof are given in Figs. 18 to 22 inclusive and the tabular summary in Table III.

One change has been made in the plotted meteorological data that accompany the load-time graphs for A and C Stations. Replacing the sunshine graph used in previous reports is a new plot showing accumulated snowfall in inches against time in days. Because solar radiation was found to be a relatively minor factor in snow load reduction, it was believed that a record of accumulation of total fresh snowfall would be more useful than the sunshine. Whereas in previous progress reports it was not possible to correlate roof loads with snowfall distribution during the winter, the effects of wind and temperature during any specific snowfall can now be clearly seen.

It had been originally planned to plot the accumulated snowfall in pounds per square foot so that a direct comparison could be made with the observed ground load. This necessitated the use of an assumed density for freshly fallen snow; the value 0.10 gm/cc was selected. In some locations, however, the observed ground load exceeded the load from the accumulated snowfalls. Because this would have led to contradictory information on the load-time graphs, it was decided to show the accumulated snowfall in inches of fresh snow. This sheds some light on the validity of an assumed density of 0.10 gm/cc. Potter (8) indicates that the density based on a single snowfall may often vary from 0.02 to 0.23, and although the assumed density of 0.10 gm/cc is valid for long periods and is an average for the whole of Canada, densities in the Maritimes exceed this value and those in the Prairies are less than 0.10 gm/cc.

6. RESULTS

In general, the results of the 1960-61 survey were not unlike those recorded in previous years. An unusual feature was observed at Revelstoke, a new station, where the maximum average roof load was 66 psf while the maximum average ground load was 47 psf. This load, to be discussed later, occurred on an unheated park hut in a sheltered region. In direct contrast to this was the bare roof observed at Gander where the maximum average ground load was 60 psf.

There was wide variation in the ratio of roof load to ground load, but in general the average roof loads were low compared with current design values. On 8 roofs the concentrated loads were greater than the basic NBC design values, but the use of the 1960 Code shape factors satisfied 7 of these cases. The ratio of the average roof load to ground load varied from 1.40 to 0; for all observed roofs the average was 0.47 with only 25 per cent of the roofs having a ratio exceeding 0.75. For A and C Stations where detailed measurements were taken, the ratio was 0.42; for B Stations it was 0.61. The extent to which a roof was sheltered was the predominant factor producing high ratios.

The 1960-61 results also showed that uniformly distributed snow loads occur only on roofs that are well sheltered, or in regions where winds are very light. As in previous years drifts and accumulations occurred at the junction of split-level roofs, on porch roofs and canopies, along parapet walls, on the leeward side of pitched roofs, and around chimneys and ventilators. The magnitude of these loads remains very difficult to predict.

The following comments on individual A-Station observations point out some of the variations in the roof load to ground load ratios and the concentrations mentioned above.

(a) A Stations

Inuvik. - Observations on the roof of the E-3 school were changed to the Home Economics Annex, a building of the same design, after the E-3 school was torn down. The E-3 Residence was relocated on a new site during the winter. With normal annual snowfall, the maximum average ground load rose to 28 psf, whereas during the previous two winters the ground load had exceeded the 1953 NBC design load of 35 psf. The 1960 NBC design load is 37 psf. Light winds and extremely low temperatures allowed the snow to accumulate with fair uniformity, although there were minor drifts along the peaks of the pitched roofs. The maximum average roof load was 11 psf.

Revelstoke. - Observations at Revelstoke, a new station in the mountainous region of B.C., were begun to compensate for the temporary discontinuation of measurements at Glacier.

Three roofs were observed, two in the town of Revelstoke the parapet wall were relocated to 4 ft from the parapet wall. These gauges had previously been closer to the parapets in drifts so that the computed average loads were larger than the averages which had actually occurred. Gauge #7 was left in its original position since, in previous years, the maximum drifts occurred consistently at this location.

On the flat roof of McNeill House the maximum load of 30 psf occurred at the intersection of two parapet walls, while lesser drifts occurred on the lower windward edge of the gable roof. Little snow fell during the months of January and February, and the roof loads decreased very slightly, indicating that solar radiation is a minor factor in snow load reduction. High winds and frequent thaws prevented the accumulation of loads to any appreciable extent.

Ottawa. - With snowfall 22 per cent below normal, the maximum average roof load was only 21 per cent of the NBC design load. Maximum concentration of 21 psf occurred at the intersection of two parapet walls on the roof of the Building Research Centre. The two gable roofs remained completely bare during most of the winter. Solar radiation did not appreciably affect the snow loads during the long period without snowfall.

Ste. Anne de Bellevue. - Although the snowfall was 11 per cent below normal, the average ground load rose to 35 psf, the same as the previous year when the snowfall was 40 per cent above normal. Thaws during the winter of 1959-60 reduced the loads on several occasions. The maximum average roof loads were quite small, however, with 8 psf on the flat roof and 5 psf on the gable roof. Sublimation did not significantly reduce roof loads. Strong winds (50 mph according to meteorological records) following the long snow-free period failed to clear the roofs, indicating that densification and bonding with the roof surface had taken place. As in previous years concentrations occurred on the east end of the hip roof, and on the flat roof immediately beside the sloping portion of the higher roof.

Arvida. - On the large flat roof the maximum average load was 8 psf i. e. 35 per cent of the ground load, while the maximum drift occurring next to the higher portion of the roof was 17 psf. Considering the total snowfall of 106 in., these loads are small indicating the effect of wind on a large exposed roof.

Halifax. - The snowfall was 23 per cent above normal but the mild weather, as in previous years, prevented any sustained accumulation of loads. The roof-to-ground load ratio was 0.90 which might be expected from an area of frequent thaws. A 5-in. snowfall accompanied by winds of 30 mph, resulted in a 44-psf accumulation (basic NBC design load = 36 psf) in the lee of a 14-ft penthouse while the exposed portion of the roof was swept completely bare. Using the shape factor of 1.5, the design load would have been 54 psf. On 4 January, a 19-in. snowfall with high wind speeds produced maximum load of 9 psf on the same roof, indicating the extremely variable effect of wind.

Gander. - With a snowfall 39 per cent above normal, the maximum average ground load reached 80 psf, exceeding the NBC ground load by 28 per cent. This high ground load occurred on 29 March when measurements showed 24 in. of snow with a density of 0.65. Although the density appears extremely high, the weather could have been the cause. In March, Gander had 42 in. of snow (normal is 18 in.) and 6.2 in. of rain. The total snowfall up until 29 March was 142 in. On 22 March there was a measured depth of 32 in., and on 25 March 5 in. of snow fell. The snow was compacted under very slushy conditions. Despite the heavy snowfall, the large flat roof of the M.E. Room retained very little snow, and the roof-to-ground load ratio for the pitched roof was only 0.14. The maximum accumulation of 34 psf occurred near the peak on the leeward side of the gable roof.

Goose Bay. - The roof load was only 11 per cent of the design load, and the roof-to-ground load ratio was 0.17. These low values may be partially explained by the below normal snowfall, but it appears that, in spite of shelter, the high winds decreased the roof loads. After four years of observation the maximum average roof load has never exceeded 10 psf on these A-Station roofs, and yet Goose Bay is in an 82-psf zone according to the 1960 National Building Code. In comparison to these A-Station roof loads, the roof loads at the Goose Bay C Station were quite high. This indicates that a small number of roof observations must be analyzed with caution in order to determine "representative" loads for any specific geographic area.

Other A Stations. - Loads observed at A Stations not mentioned above showed that average roof loads are usually less than the corresponding ground load. No unusual features were observed; the results given in the graphs (Figs. 3 to 17) are therefore self-explanatory.

(b) B Stations

As in previous years, the information received from B Stations substantiated that roof loads are generally less than ground loads and that accumulations are found on the lower levels of split-level roofs, along parapet walls, on the leeward slopes of pitched roofs, and on marquees and canopies. Strong winds and mild weather were again the main factors in snow load reduction.

Two of the largest loads for B Stations were observed at Amherst, N.S. and Sarnia, Ont. At Amherst a 4-ft (50-psf) triangular drift occurred at the split level of two flat roofs. The top roof was free of snow. At Sarnia an average snow depth of 3 ft (30 psf) occurred on a first-story roof which was sheltered on three sides by the second story of the same building. The basic design snow load for Sarnia is 24 psf; by applying the shape factor of 1.5, however, the design load would have been 36 psf.

It has been decided to modify the character of the B Stations. During the 1961-62 winter the B Station survey will be extended, and approximately 450 building inspectors will be asked to record extreme and unusual snow load conditions on roofs. The request for regular weekly observations, however, will be dropped. This information will be used to compile a "case record" book which eventually should offer statistical evidence to the designer indicating the type and magnitude of loading that can be anticipated on a wide variety of roofs.

(c) C Stations

Goose Bay. - Despite a snowfall 39 per cent below normal, some high accumulations were observed. As in previous years the lean-to roofs of the Unit Supply Depot experienced heavy loads; the maximum of 74 psf was $3\frac{1}{2}$ times larger than the maximum drift on the main roof. Heavy drifting occurred next to the elevated section of the M.E. Garage; the maximum load of 90 psf exceeded the basic NBC design load of 82 psf but was less than 123 psf which would be the design load for this section of roof. This accumulation built up from a load of 18 psf during a period of minimum snowfall, illustrated the extreme importance of wind in snow load analysis. With a maximum average ground load of 77 psf, the greatest roof-to-ground load ratio was 0.38.

Other C Stations. - All average roof loads were less than the corresponding ground loads, although in several cases concentrated loads exceeded the ground loads. As in previous years drifts occurred along the parapet walls, on the canopies of the Unit Supply Depot, on the flat wings of the arch hangars, immediately beside the elevated portion (5.5-ft difference in height) of the Mechanical Equipment Garage, and near the door housings on the cantilever hangar roofs. Large flat roofs had low average loads.

7. GENERAL DISCUSSION

After one winter of pilot observations and four winters of full observations the survey has provided considerable information of a wide and varying nature on the subject of snow loads on roofs. Although general trends have been clearly indicated, it is still difficult to predict with certainty the roof loads that could be expected under any given set of circumstances. It is now possible to state that roof loads are generally considerably less than ground loads, and the assumption of a uniformly distributed snow load is unnecessarily crude.

The weight of snow accumulating on any given roof surface depends on many factors. These have been roughly divided into two groups - the meteorological factors over which the designer has no control, and the roof factors which come to a large extent under the designer's "jurisdiction." There is a large degree of interaction between these factors and any analysis for the purpose of revising specifications must necessarily involve a study of many combinations. Because of the variability of the factors concerned, original hopes for quantitative answers from the first few years of the survey have been dimmed; it now appears that future refinements of design load specifications should be based on the statistical strength of many observations.

It is becoming increasingly clear that code specifications will never be able to cover the many variations in roof shapes and in other conditions that will occur in practice so that the code will have to be supplemented by a collection of "case records" for special snow load problems. These "case records", now being gathered, will deal with extreme and unusual snow-load conditions on a large and varied selection of roofs. Eventually they should offer the designer records of some comparable roof and statistical strength to confirm this information.

The following discussion presents some of the more salient features of the snow load problem. The results of an attempt to analyze the observations to date are also shown.

Meteorological Factors

(a) Solar Radiation. - During the winter of 1960-61 several stations across Canada experienced long periods during which no snow fell and roof loads were not reduced to any appreciable extent. Compared to the effects of strong winds and high temperatures, solar radiation appears only a minor factor in snow load reduction.

(b) Density. - Snow density again showed wide variation from location to location and from month to month. The general trend indicated in Ref. (4), however, holds true for the most part.

(c) Wind and Temperature. - These two meteorological factors play a leading role in the analysis of snow loads. As in previous years high temperatures invariably reduced snow loads, while strong winds reduced or increased them. The quantitative effects of wind remain extremely variable and difficult to predict, so that, for design purposes, a wide range of possible effects (decreases and increases) have to be taken into account.

Shape Factors

(a) Snow Loads on Large Flat Roofs. - As before maximum average roof loads were usually considerably less than the corresponding ground loads. The 1960-61 results are shown in Table IV. In order to find out just how much the difference was, a study of the large flat roofs observed at C Stations for the past four years was carried out. It was found that the roof-to-ground load ratio, on the average, was 0.40, and that 9 out of 10 roofs had a ratio less than 0.75. All average roof loads were well below the specified NBC load, indicating that for large flat roofs design loads may be reduced further than as specified in the 1960 Code. Drifts in regions of localized shelter were often in excess of NBC design loads, but these could be dealt with by the use of appropriate "shape factors."

(b) Drifts at Parapet Walls. - For the past four years observations indicate that the increase in the height of the parapet wall is directly proportional to that of the ratio of the maximum concentration along that wall to the maximum average roof load. To establish a basis for comparison of parapet wall drifts the graph shown in Fig. 24 was plotted. Observations on all roofs with parapet walls at A and B Stations for the past four years were used. The points on this graph are scattered to such an extent that no definite quantitative conclusions can be drawn. Only a limited number of roofs with parapet walls have been observed to date; it is therefore not possible as yet to subdivide the group any further by taking into account such factors as location, shelter and roof size. This would indicate the need of local concentrated observations.

(c) Drifts on the Lower Portion of Split-Level Roofs. - A study of drifts on the lower portions of split-level roofs was made from the observations taken over the past four years. The correlation between the maximum drift load and the difference in elevation of roof portions is too varied to give any definite relationship (Fig. 25). It does appear, however, that on the average, the drift loads are

2 to 3 times the average roof load and that the size of the drifts does not increase beyond a difference in elevation of about 6 ft.

(d) Roof Slope. - The 1960 National Building Code recognizes roof slope as a factor which reduces the load on pitched roofs from that which would occur on a flat roof. Whereas the 1953 Code specified that reductions could be made on slopes over 20°, the 1960 Code states that reductions should not be made unless the slope is greater than 30°. Based on results from the survey of the past four winters, a study of this factor has been carried out. The findings are shown in Fig. 26, where the ratio of the maximum average load on the entire surface of the pitched roof to the maximum average load on a flat roof in the same geographic area is plotted against the slope of the pitched roof. It will be noted that in several cases the loads on pitched roofs exceeded those on flat roofs at the same location. Three reasons for this apparent anomaly are offered. First, some of the pitched roofs were sheltered while the comparative flat roofs were not. Second, a few of the results were taken from roofs during winters of relatively light snowfall and so some of the ratios may not be representative. The third reason may be attributed to wind action. Although wind will tend to blow snow off a flat roof conversely it will tend to pile it up on the leeward side of a pitched roof. The peak in itself tends to provide localized shelter which is conducive to snow accumulation. There is some indication that design loads for roofs of medium pitch should be greater than those for flat roofs. Although some roofs with less than 30° slope have reduced loads, others have increased loads, indicating that reductions on pitched roofs should not be made unless the roof slope is greater than 30°, thus substantiating the specifications in the 1960 Code (Fig. 26).

(e) Concentrated Loads on Pitched Roofs. - A study of survey results to date revealed that pitched roofs are seldom uniformly loaded, but that in the majority of cases concentrations occur along the ridge. The average ratio of maximum roof load to average roof load was calculated to be 2.1, but it must be realized that this figure has been arrived at without regard to roof slope, magnitude of the roof load, and the difficult aspect of shelter. Roofs were not segregated on a basis of their degree of shelter, as shelter depends to a large extent on the direction of the wind, which is extremely variable. The degree of shelter, therefore, cannot always be specified with any reasonable accuracy.

(f) Unbalanced Loads on Pitched Roofs. - The 1960 Code states that sloped or hipped roofs shall be designed for an unbalanced load 1.25 times the uniform load on one side and no load on the other side. Unbalanced loading may be caused by snow transfer (due to wind), which, theoretically, could lead to twice the design load on one side and zero on the other. Snow is also apt to slide or melt off one roof surface before it does on the other. Unbalanced loads caused by drifting have been observed during the past winters (Fig. 36) (4); (Figs. 24, 25, and 26) (5), and although the present specification has not been definitely confirmed it does appear quite reasonable.

8. INTERIM CONCLUSIONS

On the whole the 1960-61 observations substantiate the interim conclusions presented in previous reports. The conclusions can now be restated with more certainty:

(a) The average snow loads on roofs are substantially less than the load on the surrounding ground.

(b) The amount by which the snow load on the roof and the load on the ground differ depends primarily on the degree to which the roof is sheltered. (The effects of shelter are, however, extremely difficult to predict quantitatively.)

(c) Concentrations (drifts) sometimes exceeding the load on the ground are to be expected on roofs in any area of localized shelter, the magnitude being dependent on, among other things, snowfall and the size of the roof area which is "contributary."

As the result of an attempt to analyze the survey information to date, several additional points have been indicated:

(i) Because of the complexity and variability of factors in the snow load problem it appears that a theoretical approach is impossible.

(ii) "Shape factors" in all probability will have to be arrived at empirically. Indications are that a concentrated localized survey of the problems of unbalanced loading on pitched roofs, parapet wall drifts, drifts on split-level houses, and snow slide-off should be carried out. This would not only give more breadth to the present study, but also would yield data in a much shorter period of time.

(iii) Building codes will not be able to cope with all the possible roof shapes. This indicates the importance of a "case record" book showing extreme and unusual snow load conditions on a wide variety of roofs.

REFERENCES

1. Allen, D. E. Snow Loads on Roofs. The present requirements and a proposal for a survey of snow loads on roofs. National Research Council, Division of Building Research, Internal Report No. 106, Sept. 1956. 19p.

2. Allen, D. E. Snow Loads on Roofs, 1956-57 - A progress report. National Research Council, Division of Building Research, Internal Report No. 134, Jan. 1958. 7p.

3. Allen, D. E. and C. J. Turkstra. Snow Loads on Roofs, 1957-58 - Second progress report. National Research Council, Division of Building Research, Internal Report No. 163, Nov. 1958. 6p.

4. Thorburn, H. J. and B. G. W. Peter. Snow Loads on Roofs, 1958-59 - Third progress report. National Research Council, Division of Building Research, Internal Report No. 184, Nov. 1959. 16p.

5. Peter, B. G. W. and H. J. Thorburn. Snow Load Observations at B Stations, 1958-59. National Research Council, Division of Building Research, Internal Report No. 189, Dec. 1959. 13p.

6. Watt, W. E. and H. J. Thorburn. Snow Loads on Roofs, 1959-60 - Fourth progress report. National Research Council, Division of Building Research, Internal Report No. 204, Nov. 1960. 10p.

7. Allen, D. E. Field Instructions for Observers at A Stations of Snow Loads on Roofs. National Research Council, Division of Building Research, Technical Note No. 233, Oct. 1957. 11p.

8. Climate Information Handbook. Supplement No. 1 to the National Building Code 1960. National Research Council, Associate Committee on the National Building Code. To be published in January 1962.

9. Potter, J. G. Density of Freshly Fallen Snow. Proceedings of the Eastern Snow Conference, 1959-60. p. 141-147.

TABLE 1

SNOW LOADS FOR A STATIONS

Station	Roof	NBC roof (psf)	Max avg ground (psf)	Max avg roof (psf)	Max observed roof (psf)
Inuvik, N. W. T.	Gable: not heated, insulated, exposed	37(30)*	27	5	9
	Gable: heated, insulated, exposed	37(30)	27	11	16
	Flat: heated, insulated, exposed	37(35)	28	5	8
Revelstoke, B. C.	Gable: heated, insulated, exposed	70(-)	45	31	33
	Gable: not heated, sheltered	—	47	66	71
	Flat: heated, insulated, exposed	70(-)	40	32	39
Edmonton, Alta.	Gable: not heated, sheltered	22(25)	12	4	6
	Flat: heated, insulated, exposed	22(25)	13	3	4
Saskatoon, Sask.	Gable: heated, insulated, exposed	28(33)	16	2	7
	Gable: heated, insulated, exposed	28(35)	26	2	5
	Flat: heated, insulated, exposed	28(35)	18	7	23
	Flat: heated, insulated, exposed	28(35)	16	2	3
	Flat: heated, ventilated, exposed	28(35)	17	7	16
Winnipeg, Man.	Gable: heated, insulated, exposed	36(32)	22	3	11
	Flat: heated, insulated, exposed	36(35)	22	6	7
Fort Churchill, Man.	Gable: heated, insulated	53(55)	36	4	12
	Flat: heated, insulated	53(55)	36	0	0, 40[a]
	Flat: (corridor) heated, insulated	53(55)	36	25	56[b]
	Flat: (corridor) heated, insulated	53(55)	36	24	50[b]
	Flat: (corridor) heated, insulated	53(55)	36	14	47[c]
Toronto, Ont.	Gable: heated, insulated	26(24)	6	5	6
	Flat: heated, insulated, sheltered	32(35)	8	10	18
Kingston, Ont.	Gable: heated, insulated	40(47)	12	5	13
	Flat: heated, exposed, 2.5' parapet	40(55)	13	8	30
Ottawa, Ont.	Gable: heated, insulated, exposed	48(43)	13	4	7
	Gable: heated, insulated, exposed	48(43)	13	4	5
	Flat: heated, exposed, 2' parapet	48(50)	13	10	21
	Flat: heated, insulated, sheltered	48(50)	14	9	13
	Flat: heated, insulated, exposed	48(50)	13	6	10
Ste. Anne de Bellevue, P. Q.	Gable: heated, insulated, exposed	35(34)	35	5	25
	Flat: heated, insulated, exposed	44(50)	35	8	28
Montreal, P. Q.	Gable: heated, insulated, exposed	43(43)	27	3	13
	Flat: heated, not insulated, exposed	43(50)	31	7	9
Arvida, P. Q.	Flat: heated, insulated, exposed	60(55)	25	8	17
Halifax, N. S.	Gable: heated, not insulated, sheltered	36(34)	16	5	12
	Flat: heated, insulated, exposed	36(40)	11	3	26
	Flat: heated, sheltered, parapet	36(40)	11	14	44
Gander, Nfld.	Gable: heated, insulated, sheltered	50(42)	80	11	34
	Flat: not heated, insulated	50(45)	60	0	0
Goose Bay, Lab.	Gable: heated, insulated, exposed	82(78)	50	9	12
	Flat: heated, insulated, no parapet	82(90)	52	8	13

* The first figure indicates the NBC 1960 roof load; the figure in ( ) the NBC 1953 load.

a = on main roof and lean-to
b = corridor running NW-SE
c = corridor running SW-NE

TABLE 11

SNOW LOADS FOR B STATIONS

Location	Type of roof	Heated and insulated	Heated and uninsulated	Not heated	Major Influences			Loads in psf				Remarks
					Strong winds	Heat loss	Mild weather	NBC roof (psf)	Observed loads Ground (psf)	Roof (psf)	Drifts (psf)	
Trail, B.C.	Gable	x					x	50(68)[*]	9	8	-	mild, low snowfall
	Flat	x					x	50(70)	7	6	-	2' parapet tall building
Nelson, B.C.	Gable	x						[52(70)][**]	9	7	15	single snow-fall
Calgary, Alta.	Flat		x			x		15(25)	16	9	31,34[a]	drift at 4.5' parapet
Lethbridge, Alta.								18(25)	4	4	-	
Yorkton, Sask.	Flat	x						40(35)	9	4	18	
The Pas, Man.	Gable	x			x			47(40)	28	8	10	sheltered
Brandon, Man.	Gable	x			x			[37(35)]	10	6	25	drifts on lee-ward slopes
Wawa, Ont.	Gable			x				40(55)	24	13	-	24°sheltered
Sault Ste. Marie, Ont.	Flat		x					40(55)	8	0	-	low snow-fall
Sarnia, Ont.	Flat	x						36[b](30)	19	31	37	sheltered, 2nd story
Belleville, Ont.	Gable	x						40(50)	13	3	19	
	Flat	x						40(50)	13	16	19	
Three Rivers, P.Q.	Gable	x			x			67(60)	37	14	55	
	Flat				x			67(60)	37	14	55	parapet
Fredericton, N.B.	Gable			x				[48(65)]	35	21	23	
Amherst, N.S.	Flat				x			48(55)	20	-	50	drift at split level
St. John's, Nfld.	Gable						x	47(33)	12	7	16	
	Flat		x				x	58(50)	21	9	-	

* ( ) brackets indicate 1953 design load
** [ ] brackets indicate basic design loads
a = drift on marquee
b = design load increased by shape factor of 1.5

TABLE III

SNOW LOADS FOR C STATIONS (in psf)

Roof / Station	Supply Depot			Arch Hangar			M. E. Garage			Cant. Hangar			NBC (Basic)
	Max Ground	Max Avg Roof	Max Drift	Max Ground	Max Avg Roof	Max Drift	Max Ground	Max Avg Roof	Max Drift	Max Ground	Max Avg Roof	Max Drift	
Comox, B. C.	-	-	-	5	0	0	5	0	0	5	0	0	46(45)[a]
Lancaster, Alta.	-	-	-	-	-	-	29	5	22	29	13	29, 24	22(25)
Cold Lake, Alta.	15	8	11	16	12	24	16	7	14	17	7	12	33(30)
Winnipeg, Man.	15	5	13	23	9	25	19	5	13	13	10	38	36(35)
North Bay, Ont.	18	2	6	19	5	11	23	5	5	-	-	-	43(55)
Toronto, Ont.	6	4	9	-	-	-	6	6	13	-	-	-	32(35)
Goose Bay, Lab.	71	17	22, 74*	-	-	-	77	29	90	-	-	-	82(90)

Note: - indicates roof not available

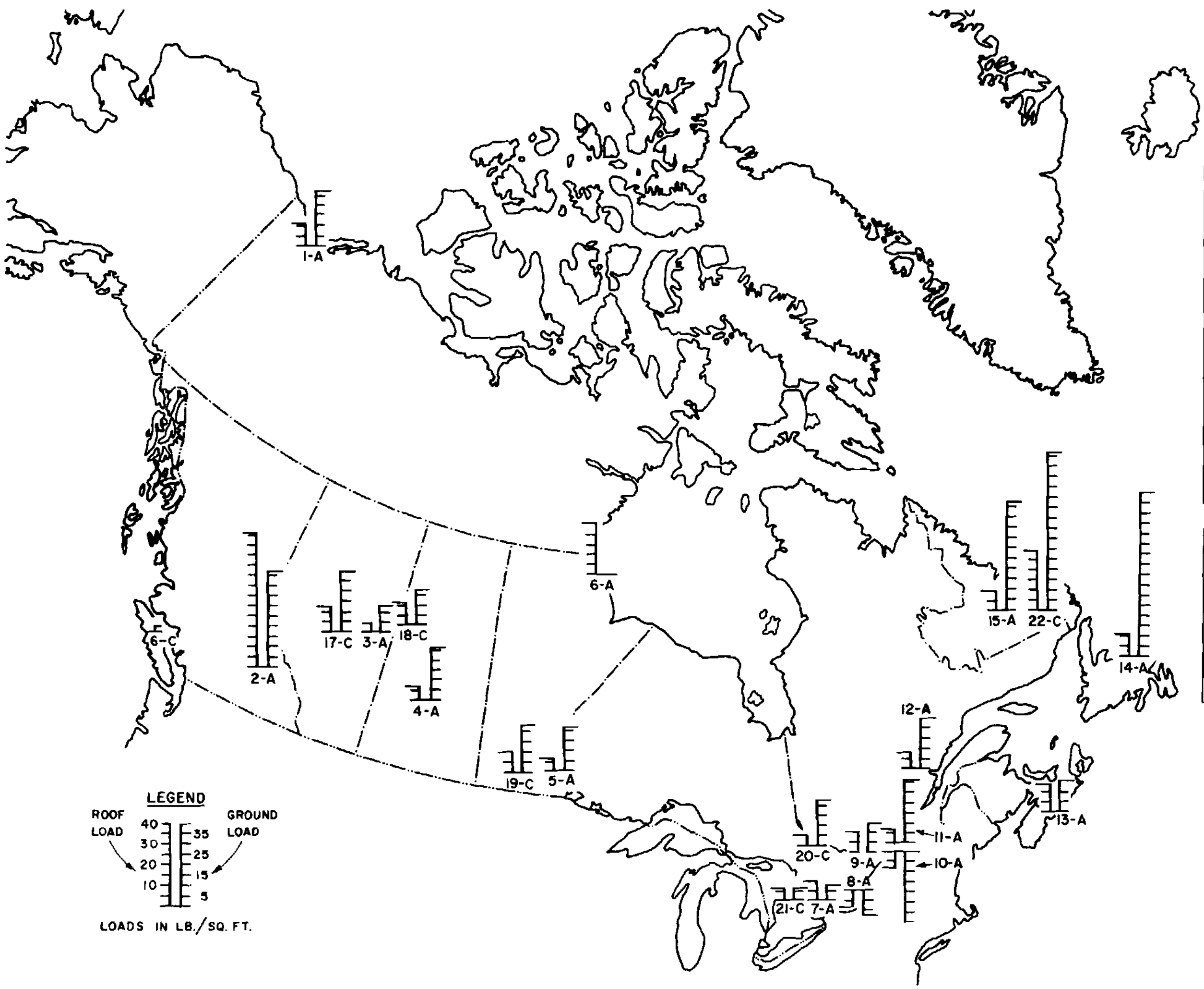
* second figure indicates maximum on canopy or lean-to

a figure in brackets indicates 1953 NBC load

TABLE IV

SNOW LOADS ON LARGE FLAT ROOFS

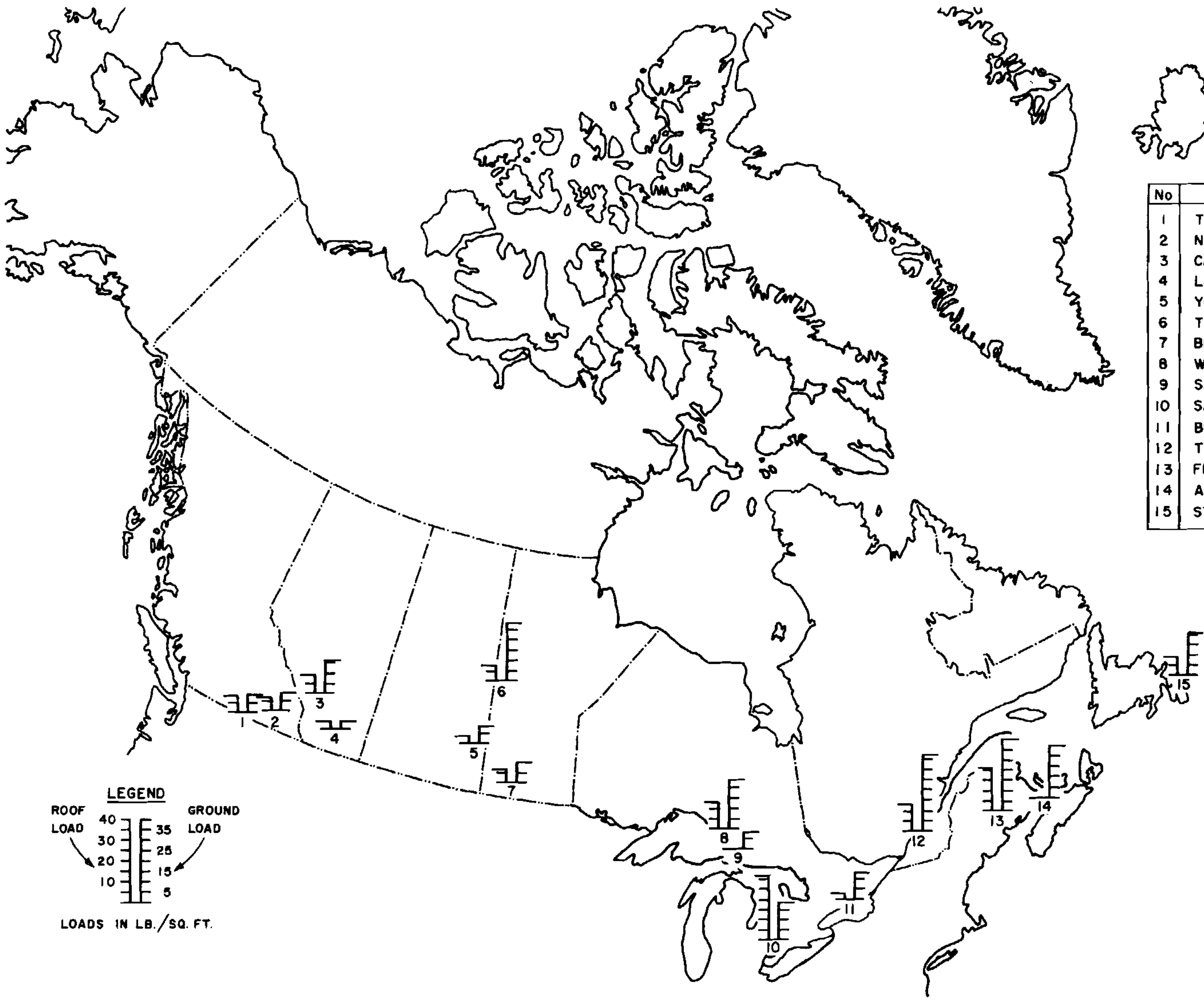
Location	Roof	Average Roof Load (psf)	$\frac{\text{Roof Load}}{\text{Ground Load}} \times 100$ (%)
Inuvik, N.W.T.	Federal Building	5	18
Lancaster, Alta.	M.E. Garage	5	17
	Cant. Hangar	13	45
Cold Lake, Alta.	U.S. Depot	8	53
	M.E. Garage	7	44
	Cant. Hangar	7	41
Saskatoon, Sask.	Gymnasium	7	39
Winnipeg, Man.	U.S. Depot	5	33
	M.E. Garage	5	26
	Cant. Hangar	10	77
Fort Churchill, Man.	Barracks	0	0
Sault Ste. Marie, Ont.	Manufacturing Plant	0	0
North Bay, Ont.	U.S. Depot	2	11
	M.E. Garage	5	22
Toronto, Ont.	U.S. Depot	4	67
	M.E. Garage	6	100
Arvida, P.Q.	Rolling Mill	8	32
Gander, Nfld.	M.E. Room	0	0
Goose Bay, Lab.	D-26	8	15
	U.S. Depot	17	24
	M.E. Garage	29	38



No	A STATIONS
1	INUVIK
2	REVELSTOKE
3	EDMONTON
4	SASKATOON
5	WINNIPEG
6	FORT CHURCHILL
7	TORONTO
8	KINGSTON
9	OTTAWA
10	STE. ANNE DE BELLEVUE
11	MONTREAL
12	ARVIDA
13	HALIFAX
14	GANDER
15	GOOSE BAY

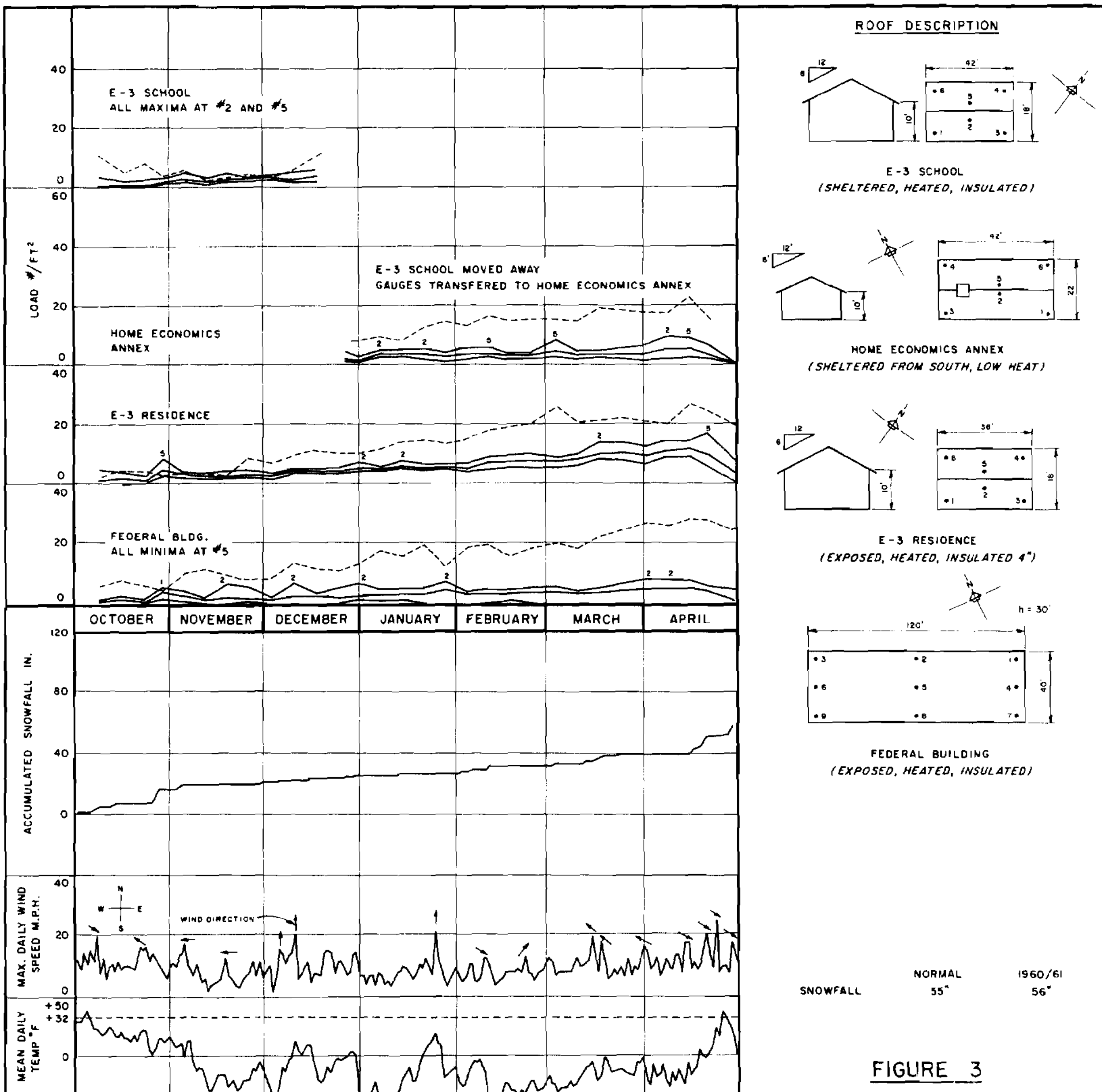
No	C STATIONS
16	COMOX
17	LANCASTER
18	COLD LAKE
19	WINNIPEG
20	NORTH BAY
21	TORONTO
22	GOOSE BAY

FIGURE I A & C STATION LOCATIONS AND THEIR MAXIMUM AVERAGE ROOF & GROUND LOADS (1960-61)



No	B STATIONS
1	TRAIL
2	NELSON
3	CALGARY
4	LETHBRIDGE
5	YORKTON
6	THE PAS
7	BRANDON
8	WAWA
9	SAULT STE. MARIE
10	SARNIA
11	BELLEVILLE
12	TROIS RIVIERES
13	FREDERICTON
14	AMHERST
15	ST. JOHN'S

FIGURE 2 B STATION LOCATIONS AND THEIR MAXIMUM AVERAGE ROOF & GROUND LOADS (1960-61)



SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

LOCATION: INUVIK, N.W.T.

Legend for Figs. 3 to 22
on last page of report

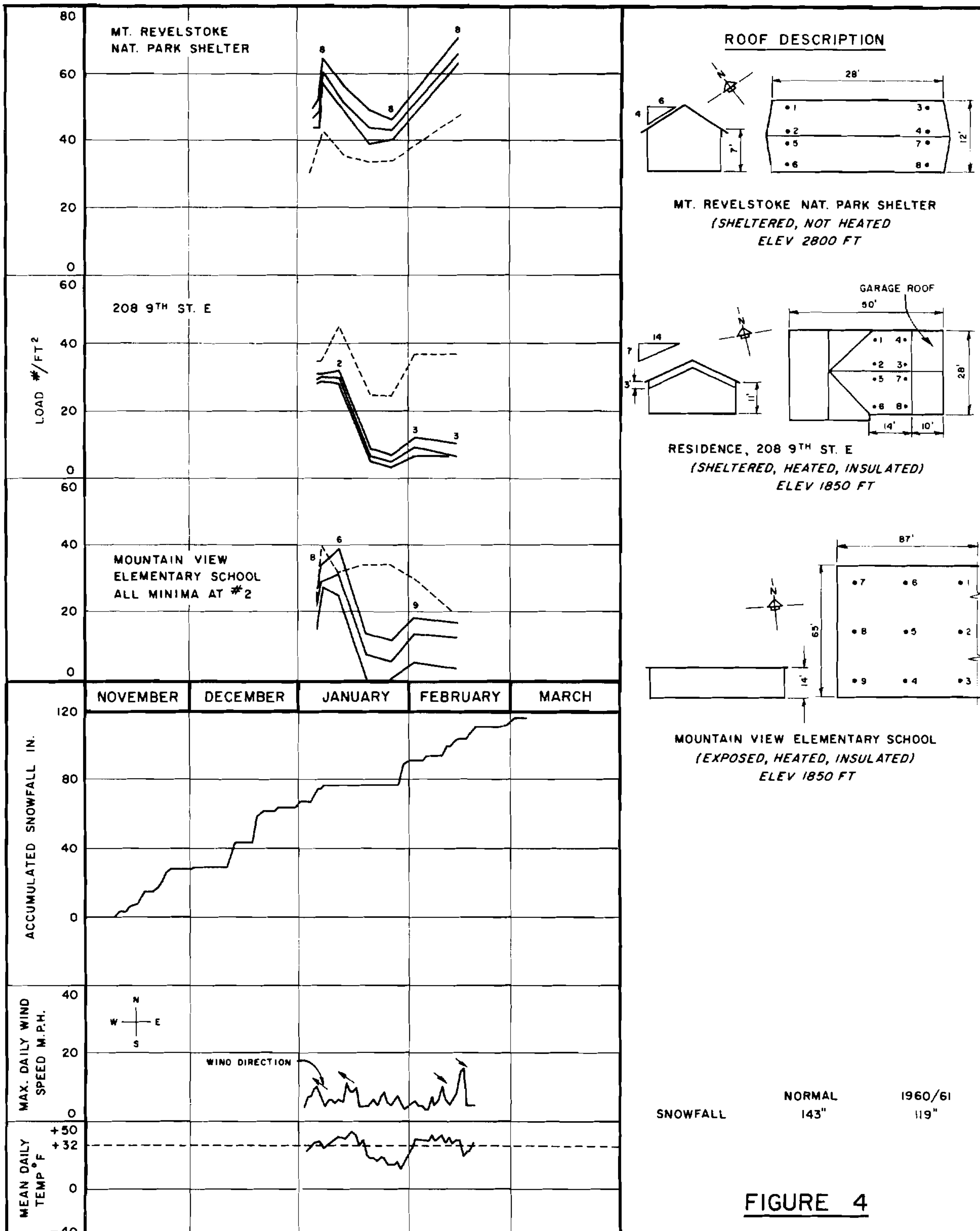


FIGURE 4

SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

LOCATION: REVELSTOKE, B.C.

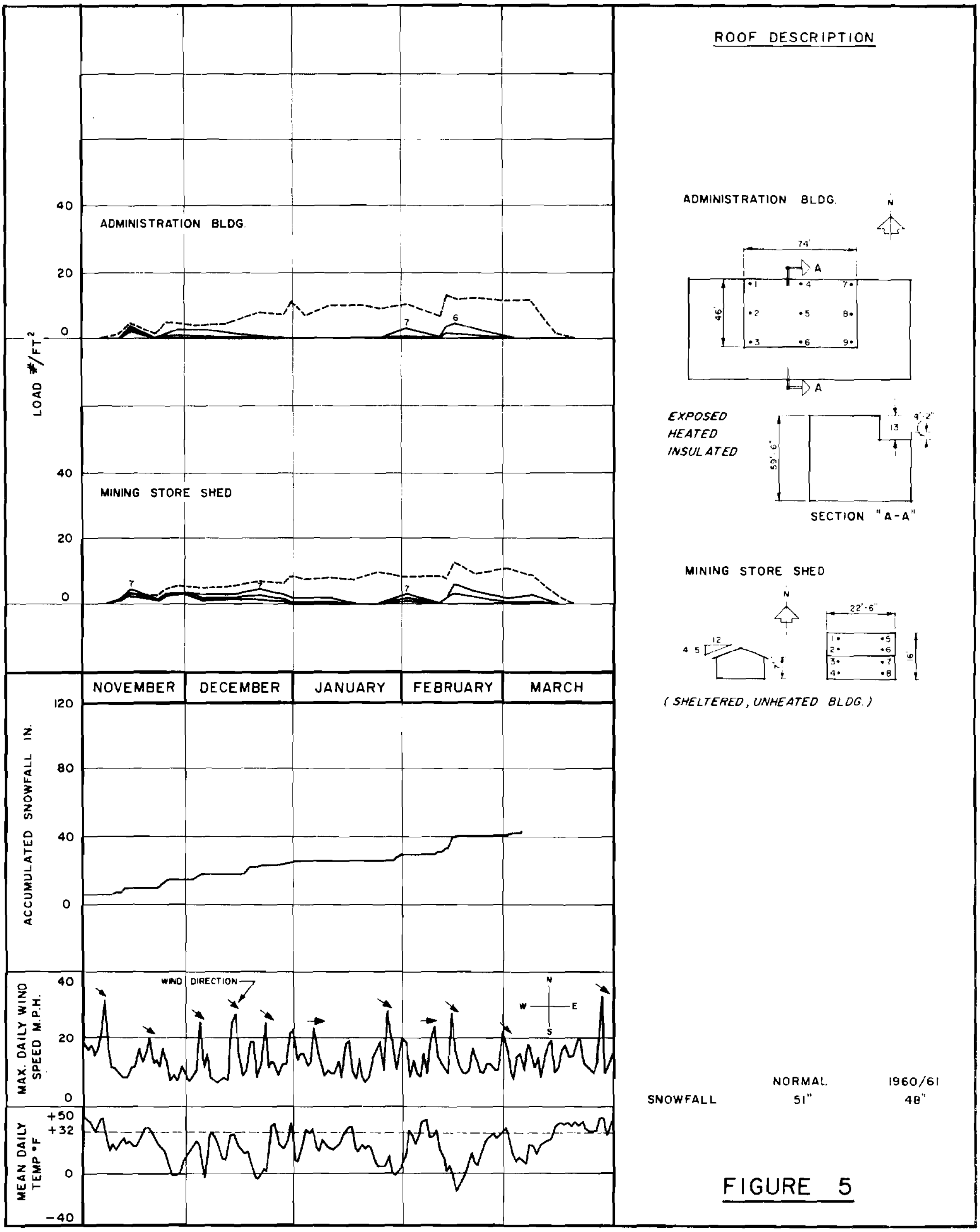


FIGURE 5

SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

LOCATION: EDMONTON, ALTA.

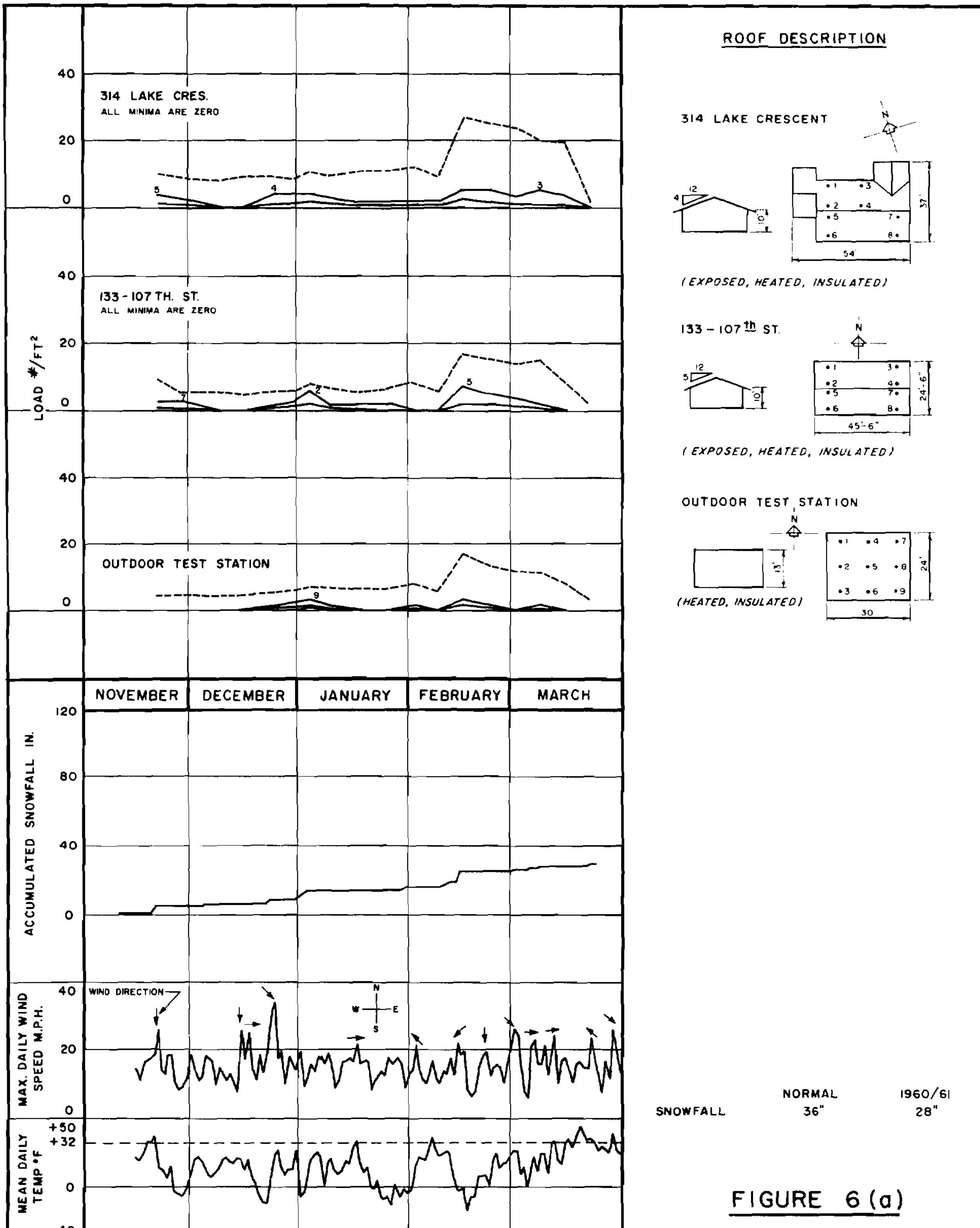


FIGURE 6 (a)

SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61
LOCATION: SASKATOON, SASK.

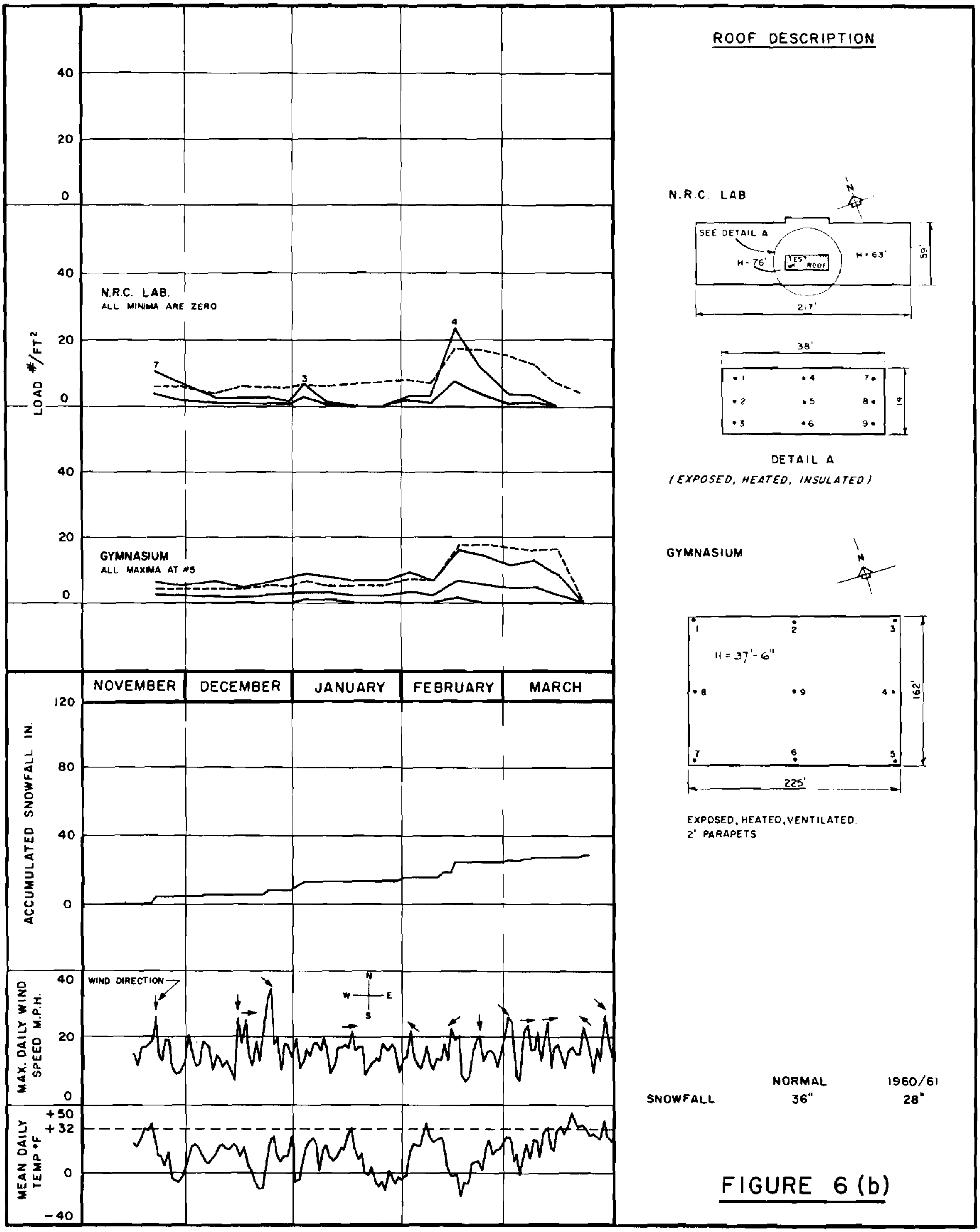
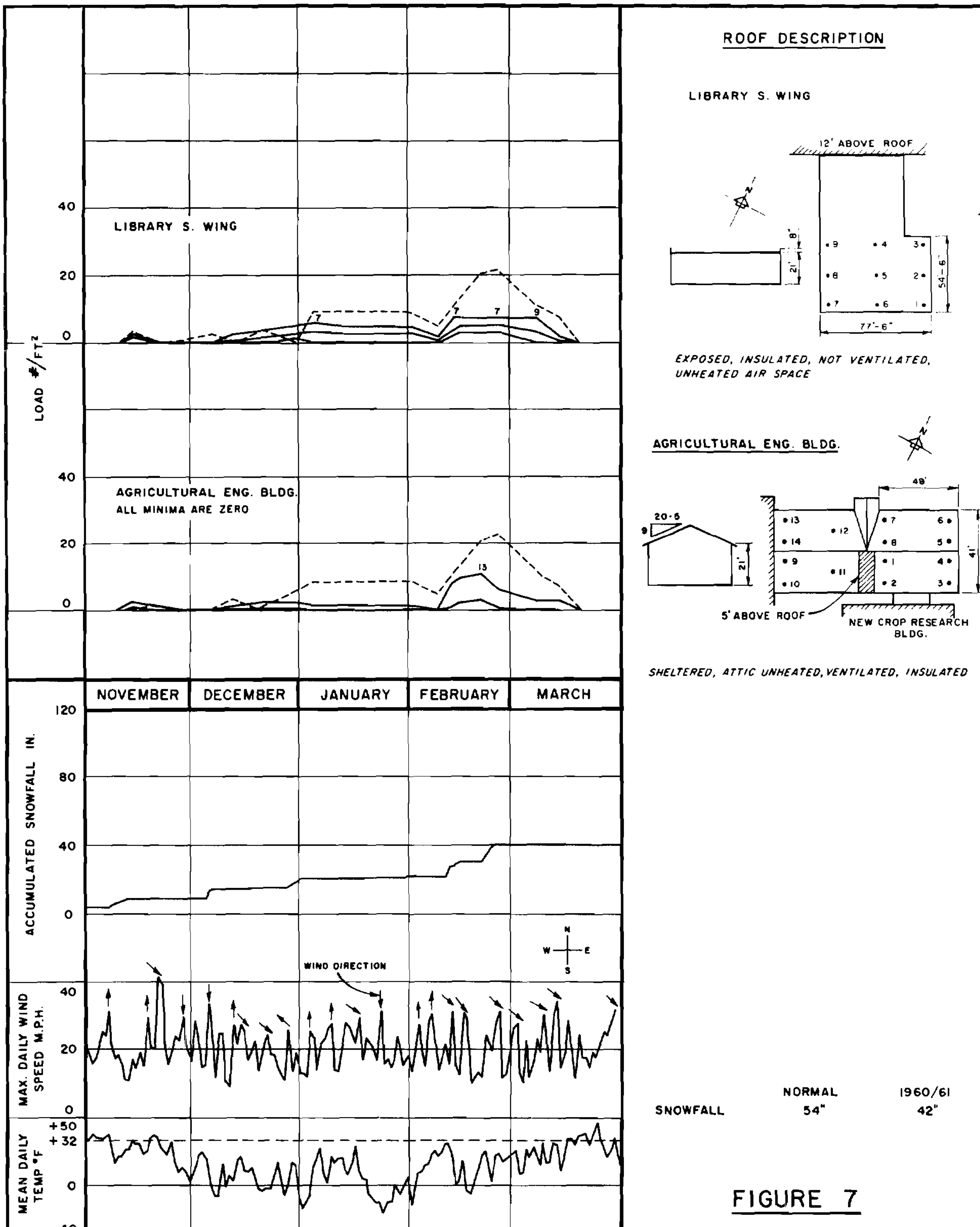


FIGURE 6 (b)

SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

LOCATION: SASKATOON, SASK.



SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

LOCATION: WINNIPEG, MAN.

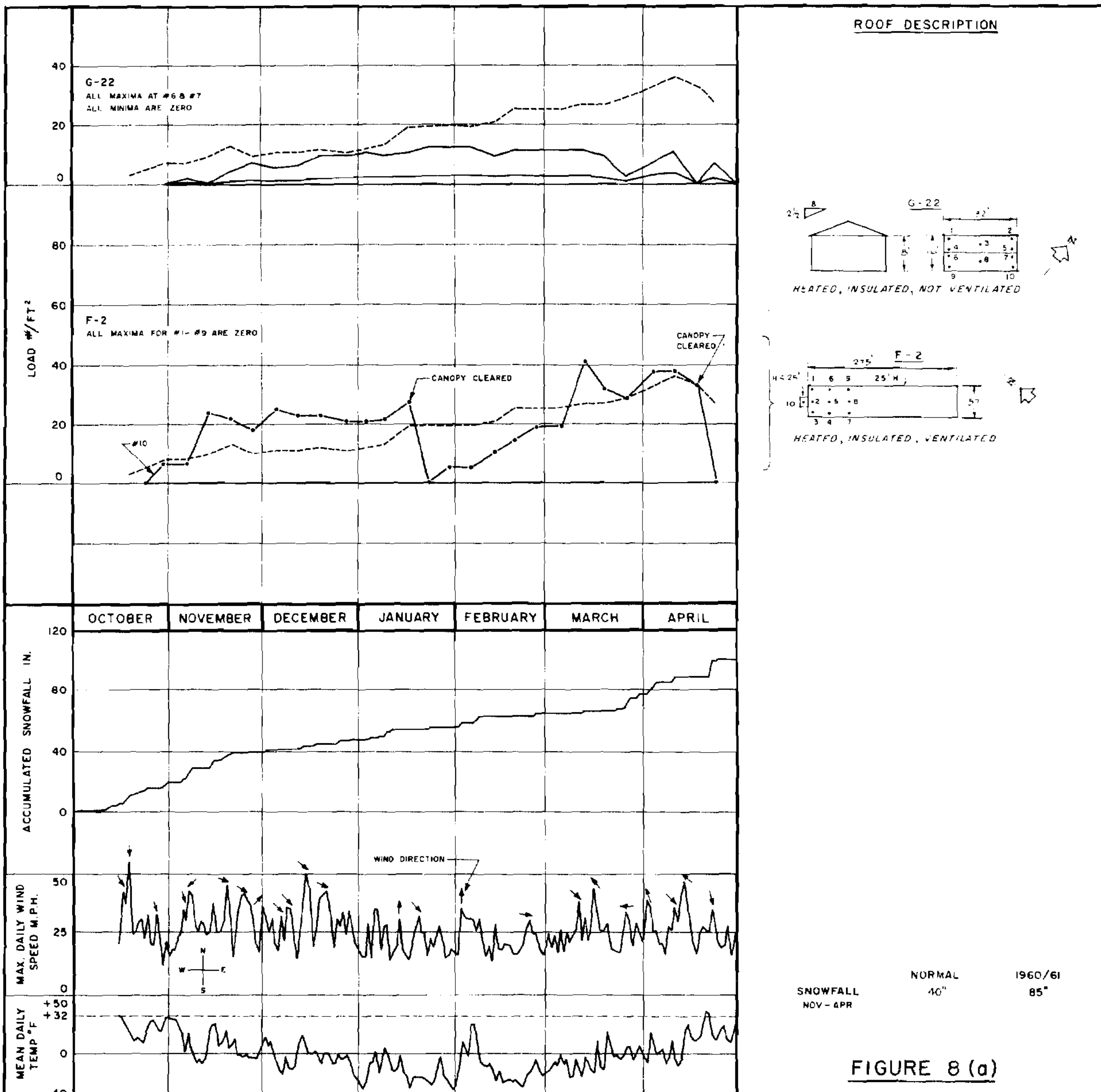
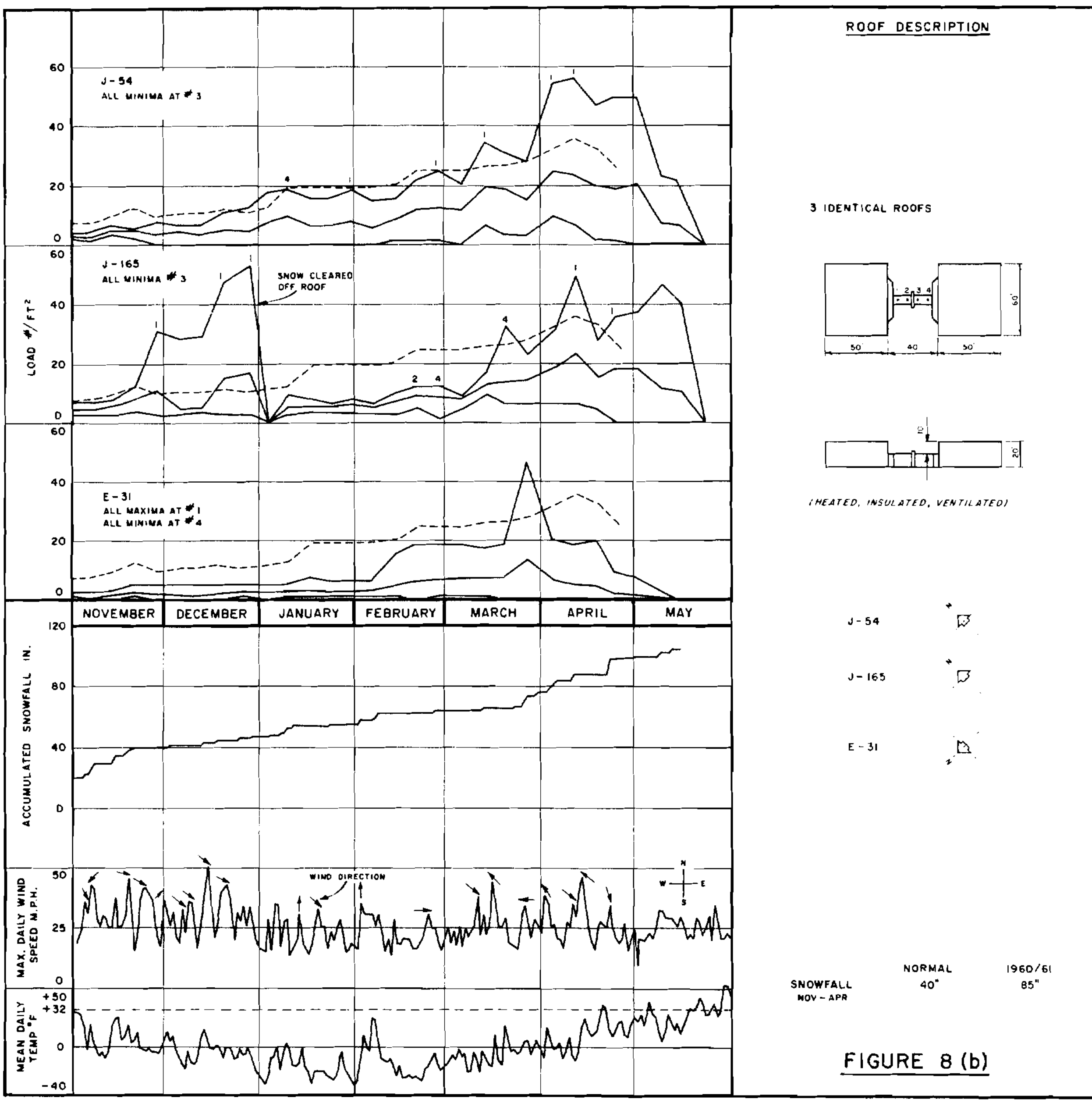


FIGURE 8 (a)

SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

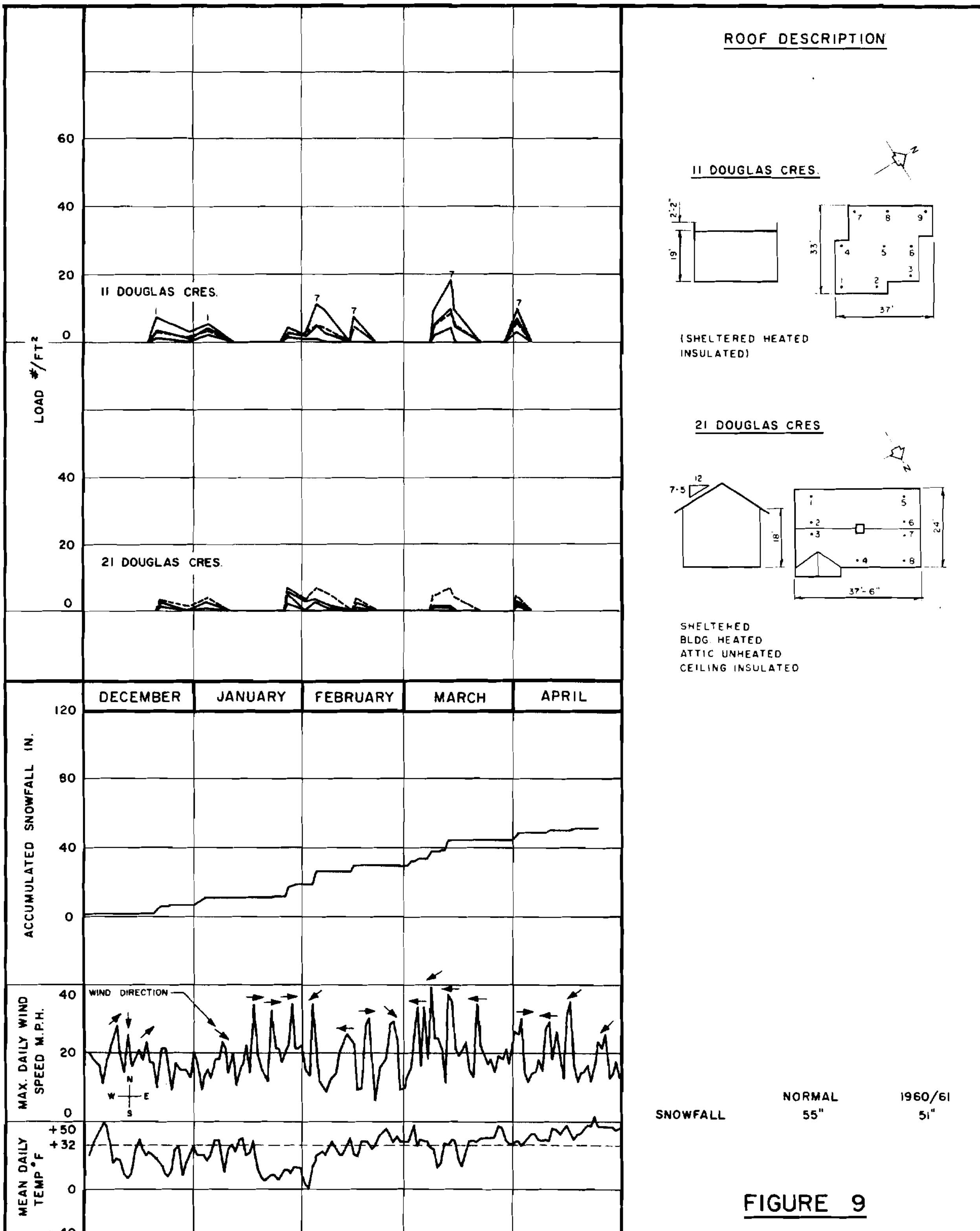
LOCATION: FORT CHURCHILL MAN.



SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

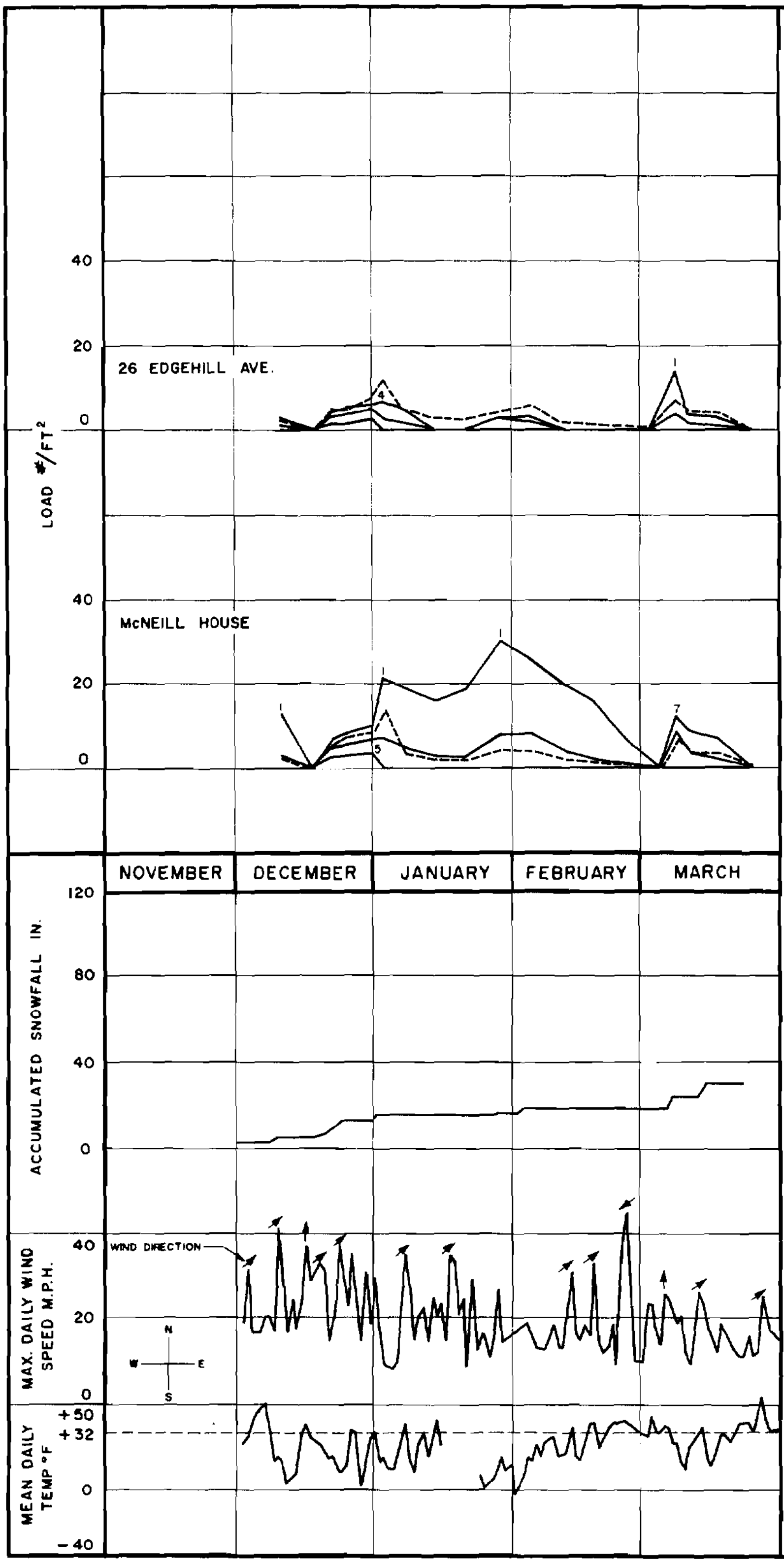
LOCATION: FORT CHURCHILL MAN.



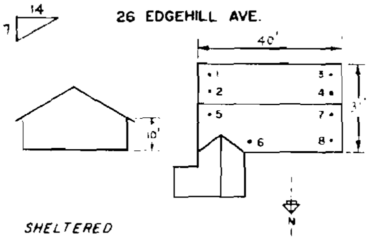
SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

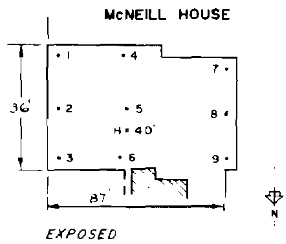
LOCATION: TORONTO, ONT.



ROOF DESCRIPTION



SHELTERED
ATTIC NOT HEATED
BLDG HEATED
INSULATED



EXPOSED
INSULATED
ATTIC NOT VENTILATED
ATTIC NOT HEATED
BLDG HEATED
PARAPET 2' 6"

	NORMAL	1960/61
SNOWFALL	57"	30"

FIGURE 10

SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61
LOCATION: KINGSTON, ONT.

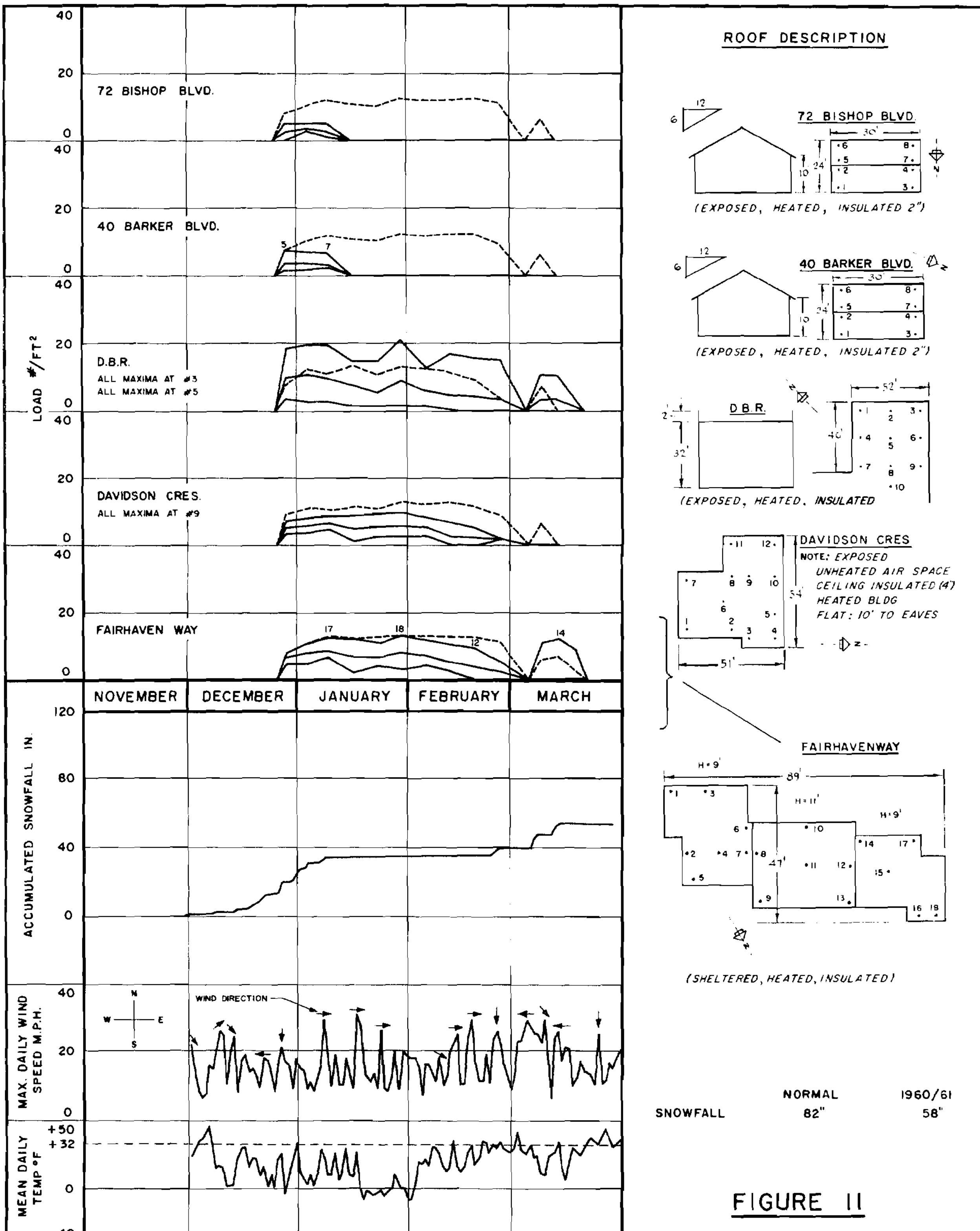


FIGURE 11

SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

LOCATION: OTTAWA, ONT.

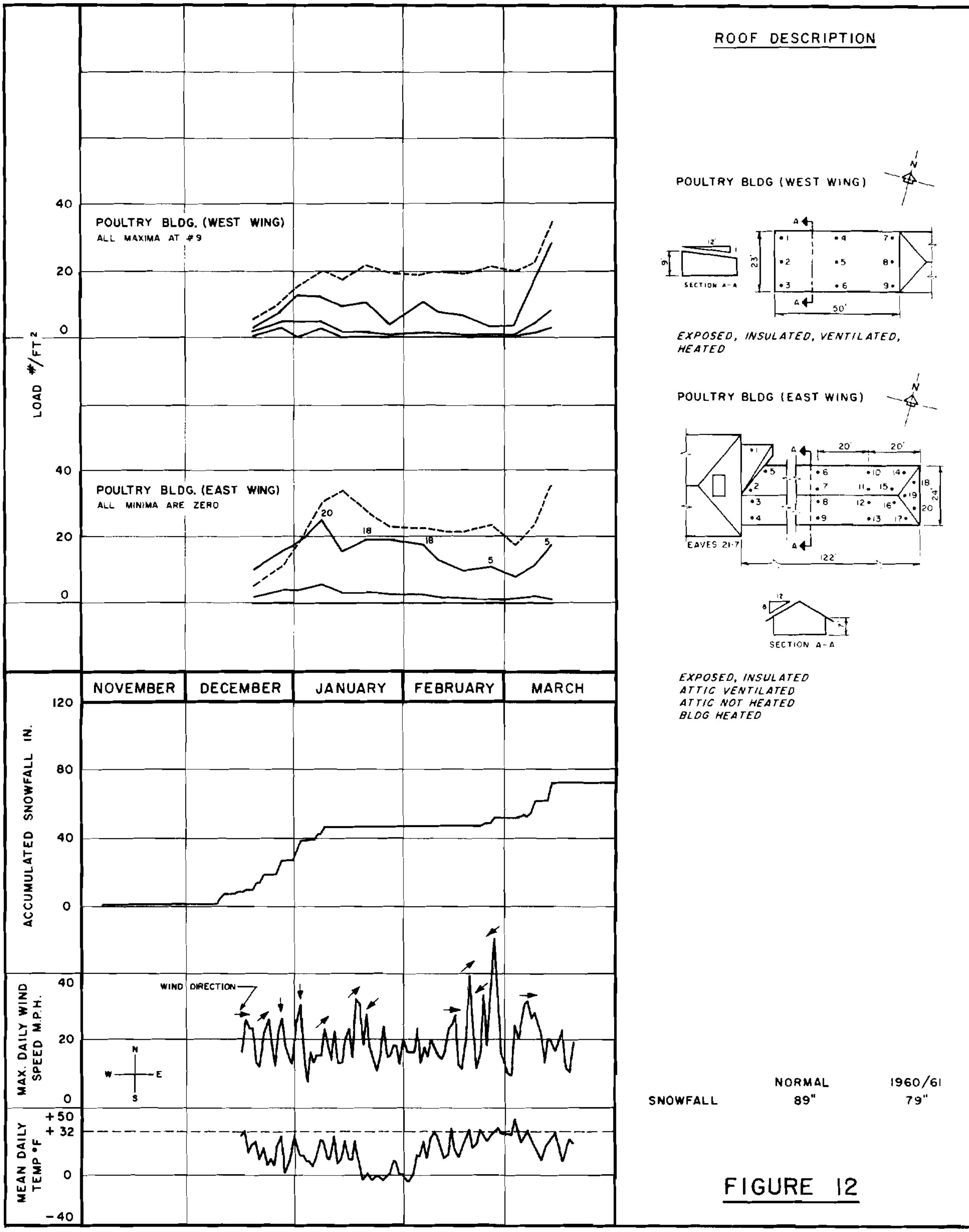


FIGURE 12

SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

LOCATION: STE. ANNE DE BELLEVUE P.Q.

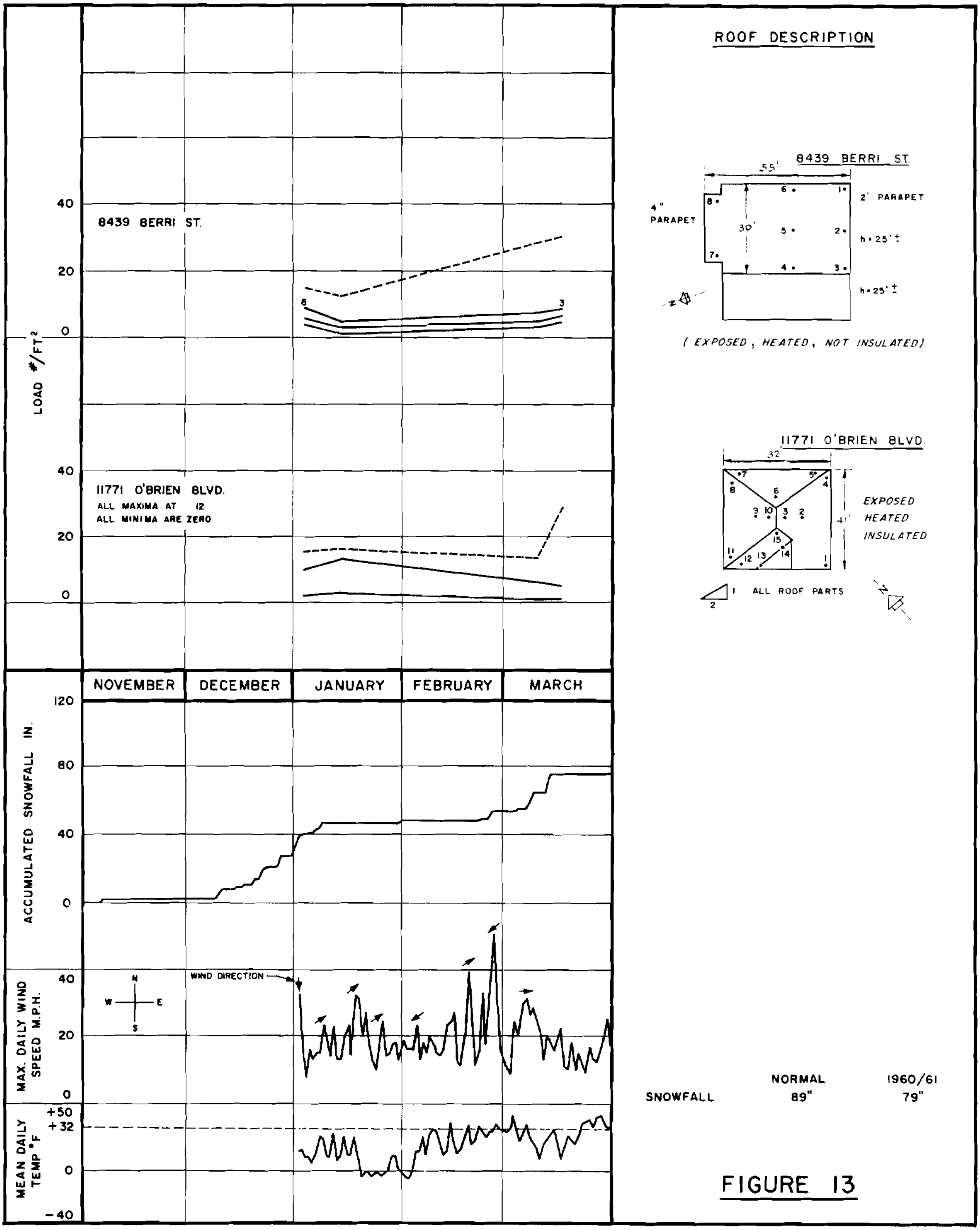


FIGURE 13

SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

LOCATION: MONTREAL, P.Q.

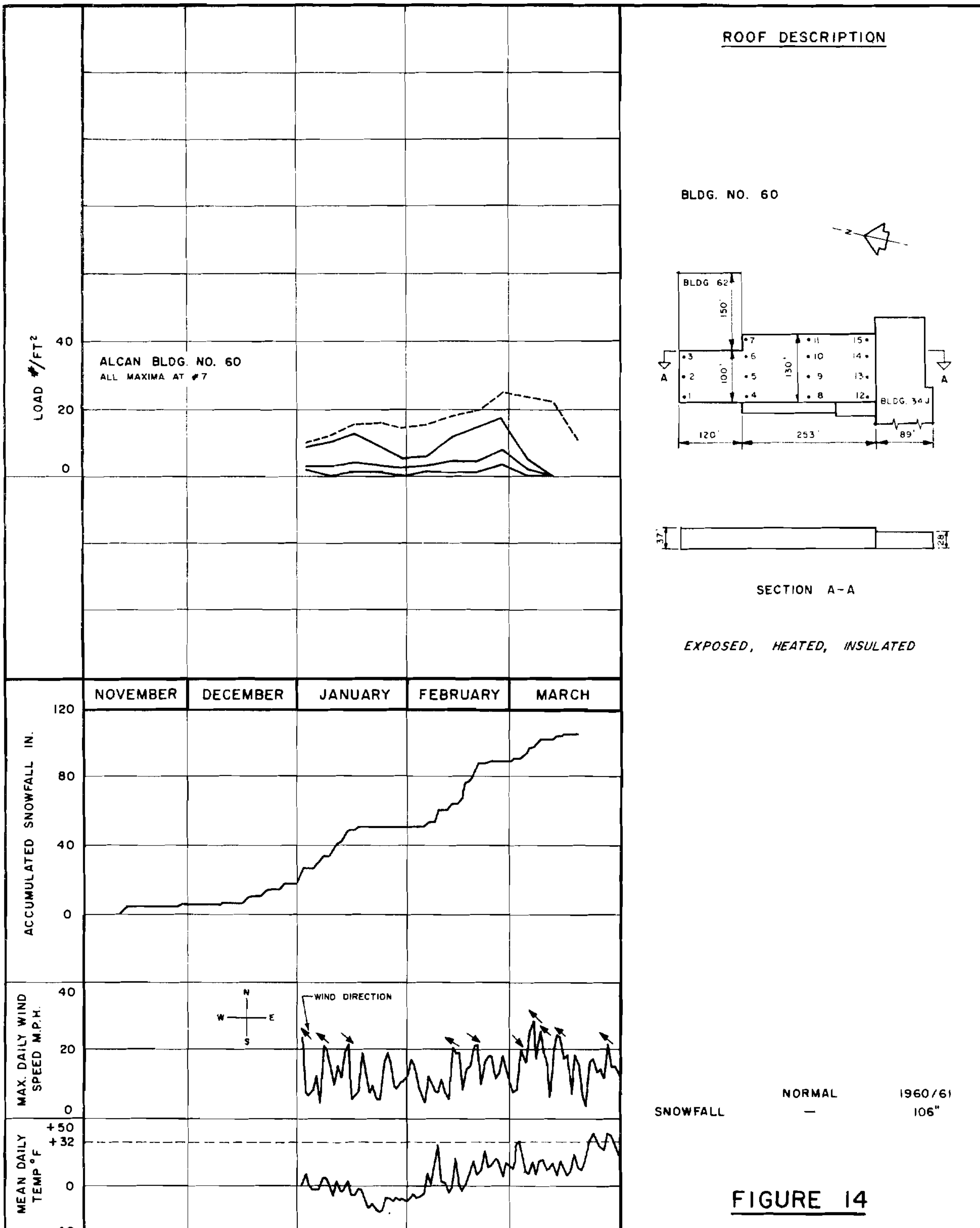


FIGURE 14

SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

LOCATION: ARVIDA, P.Q.

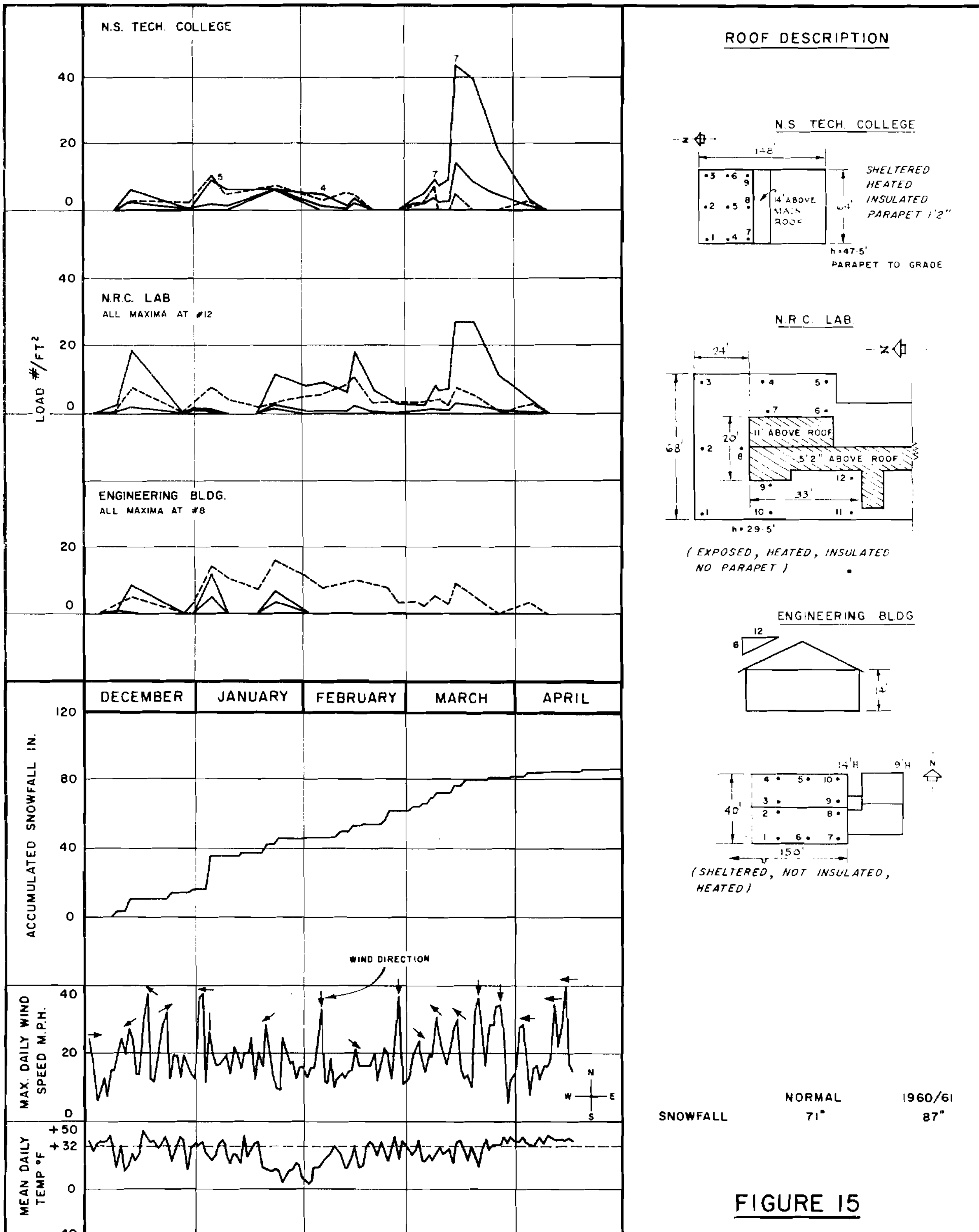


FIGURE 15

SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

LOCATION: HALIFAX, N.S.

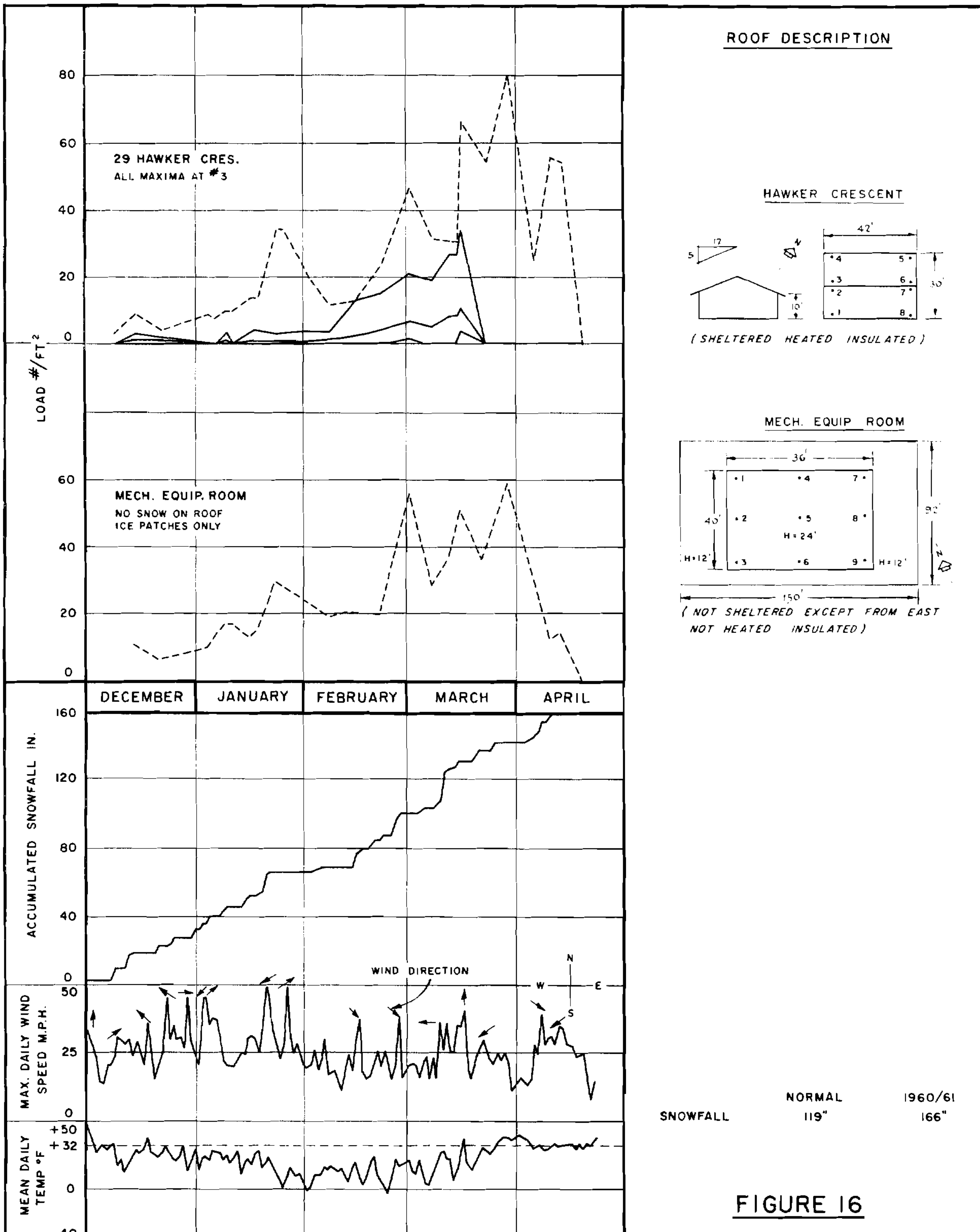


FIGURE 16

SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

LOCATION: GANDER, NFLD.

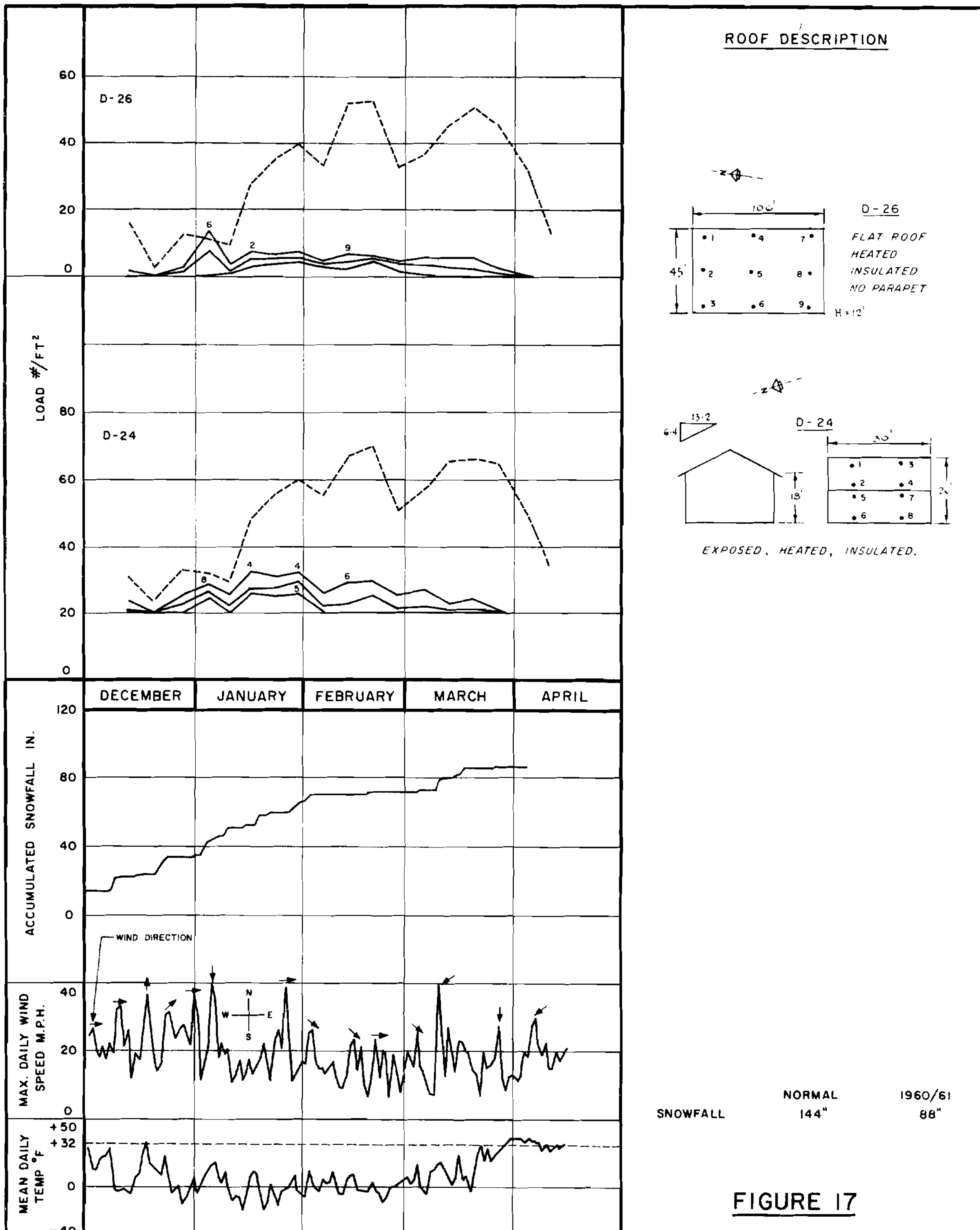


FIGURE 17

SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

LOCATION: GOOSE BAY, LAB.

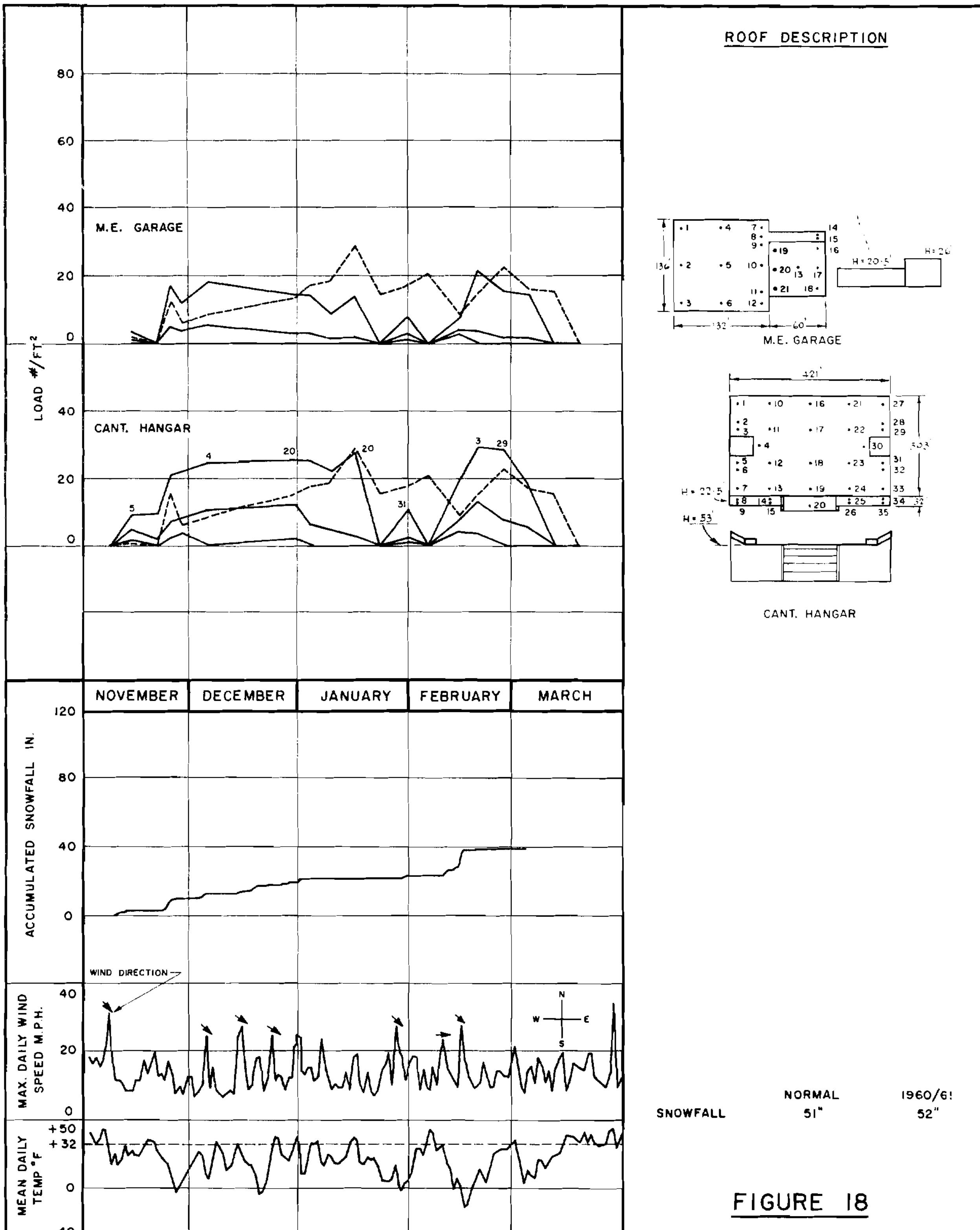


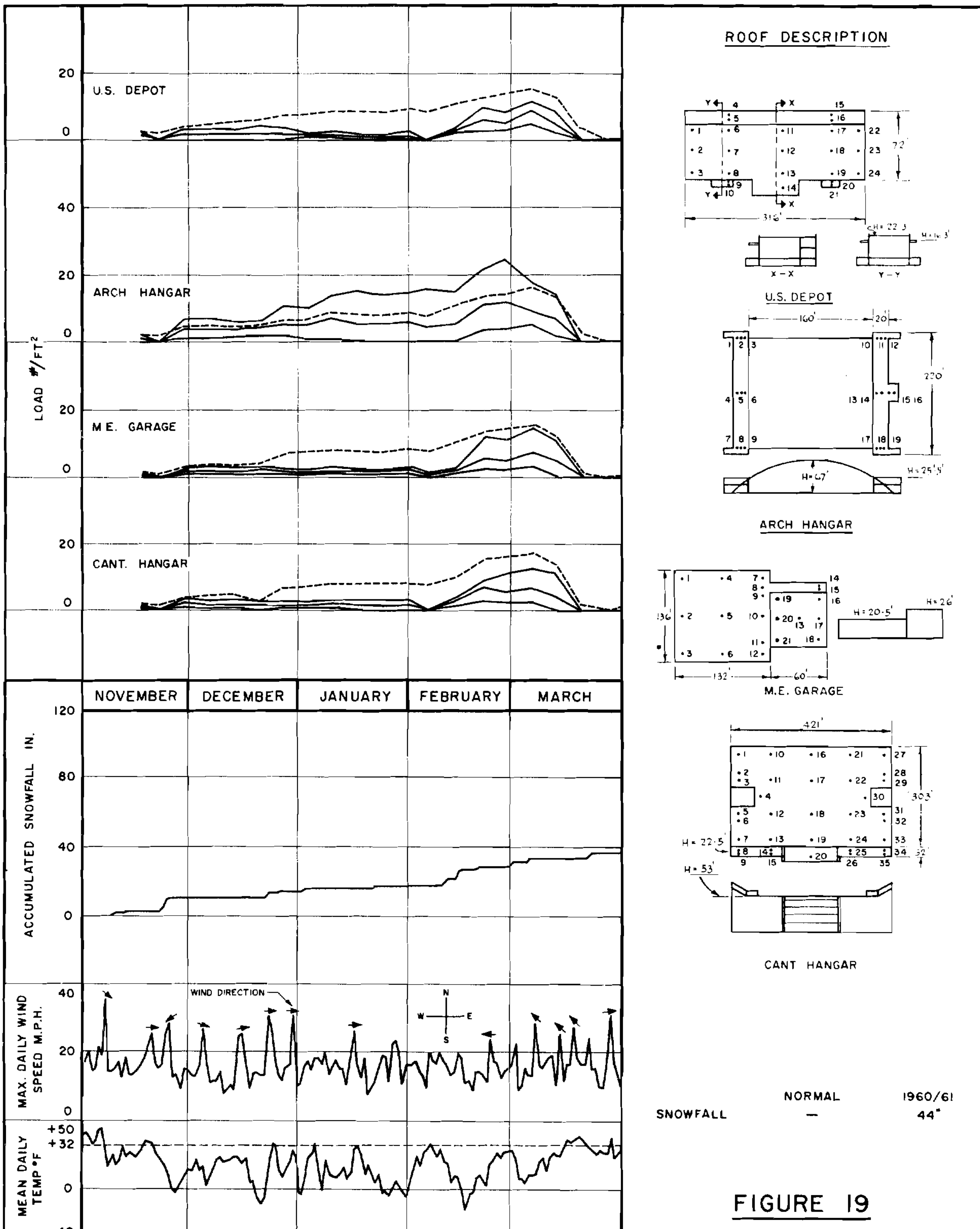
FIGURE 18

SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

LOCATION: R.C.A.F.

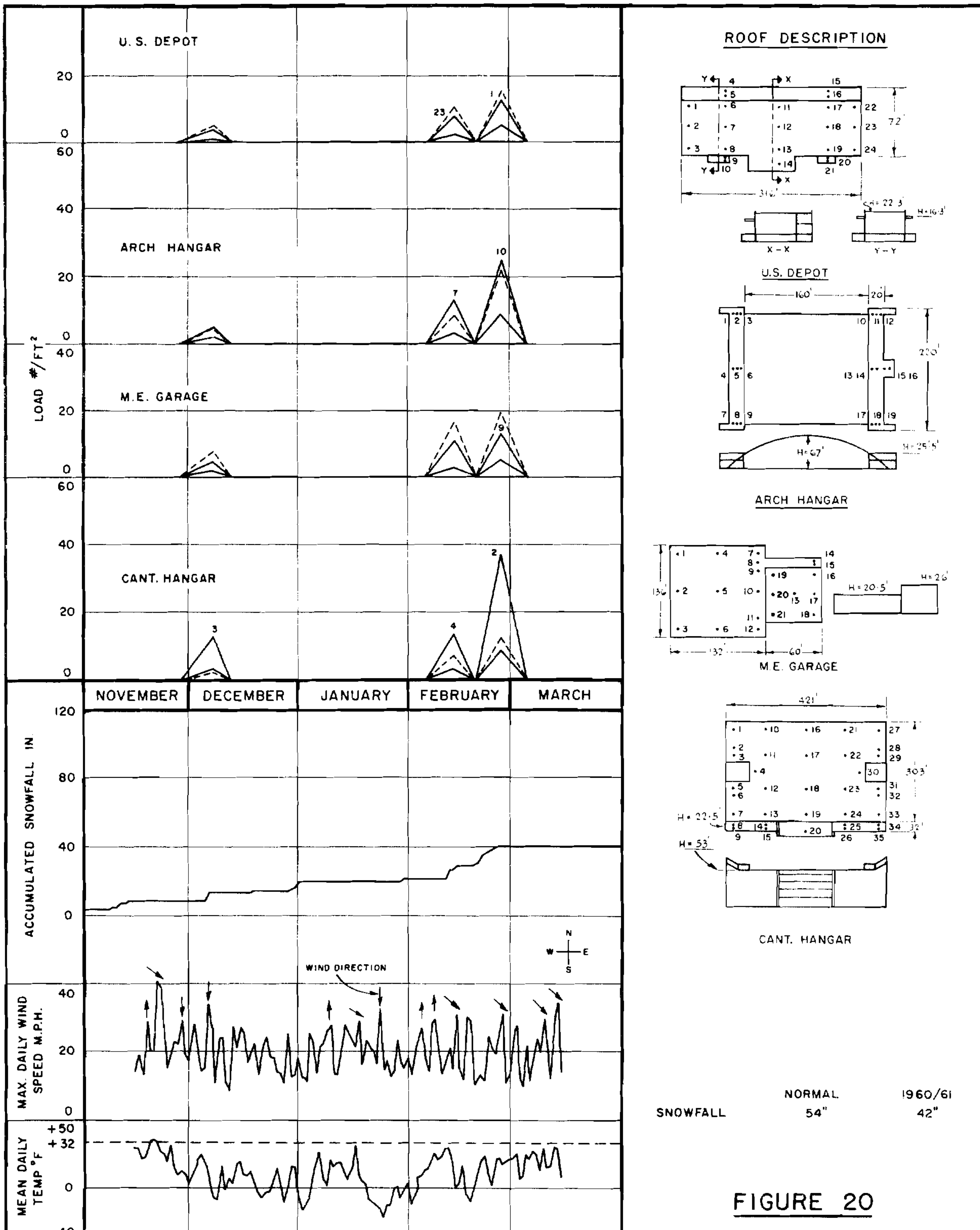
LANCASTER, ALTA.



SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

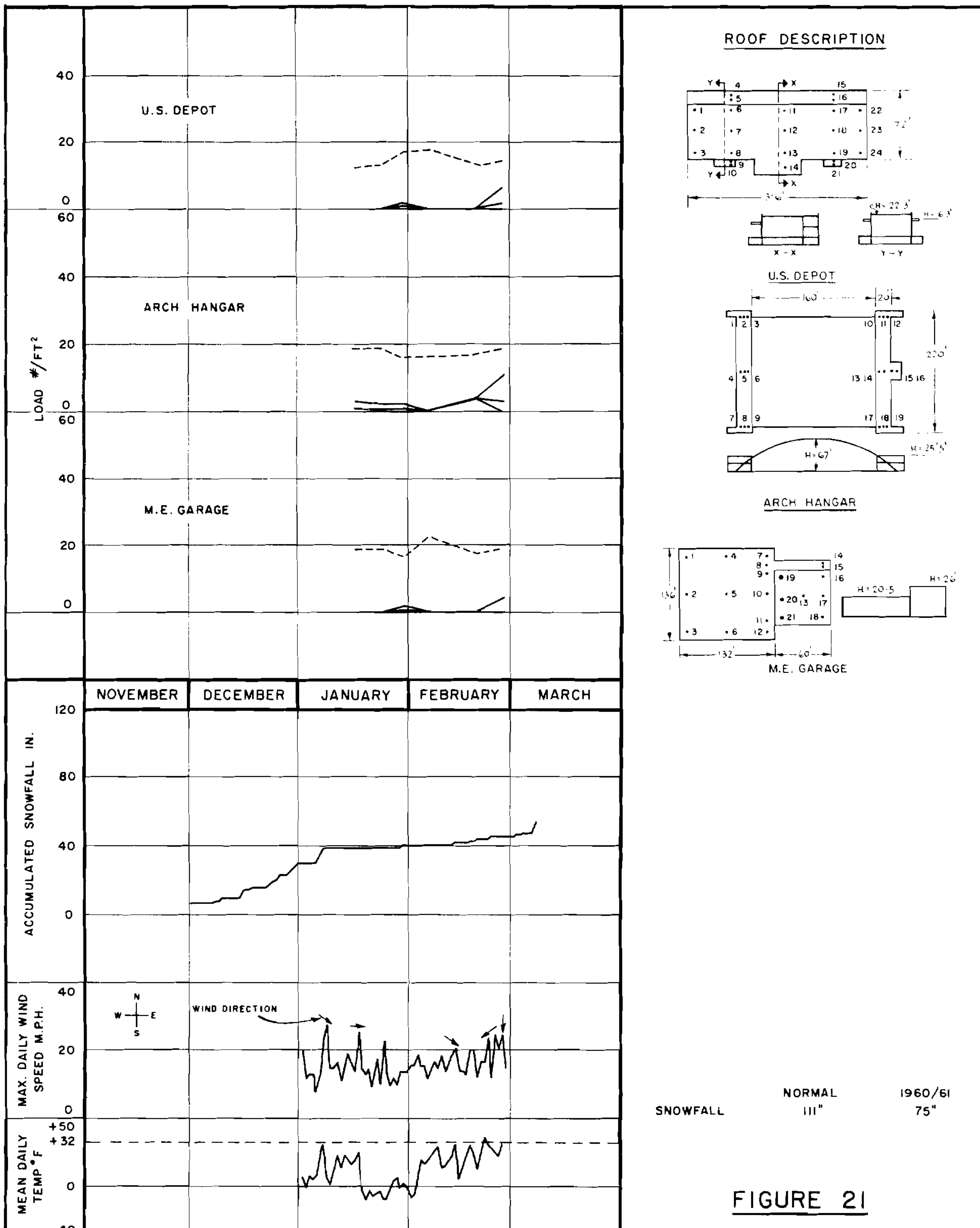
LOCATION: R.C.A.F.
COLD LAKE, ALTA.



SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

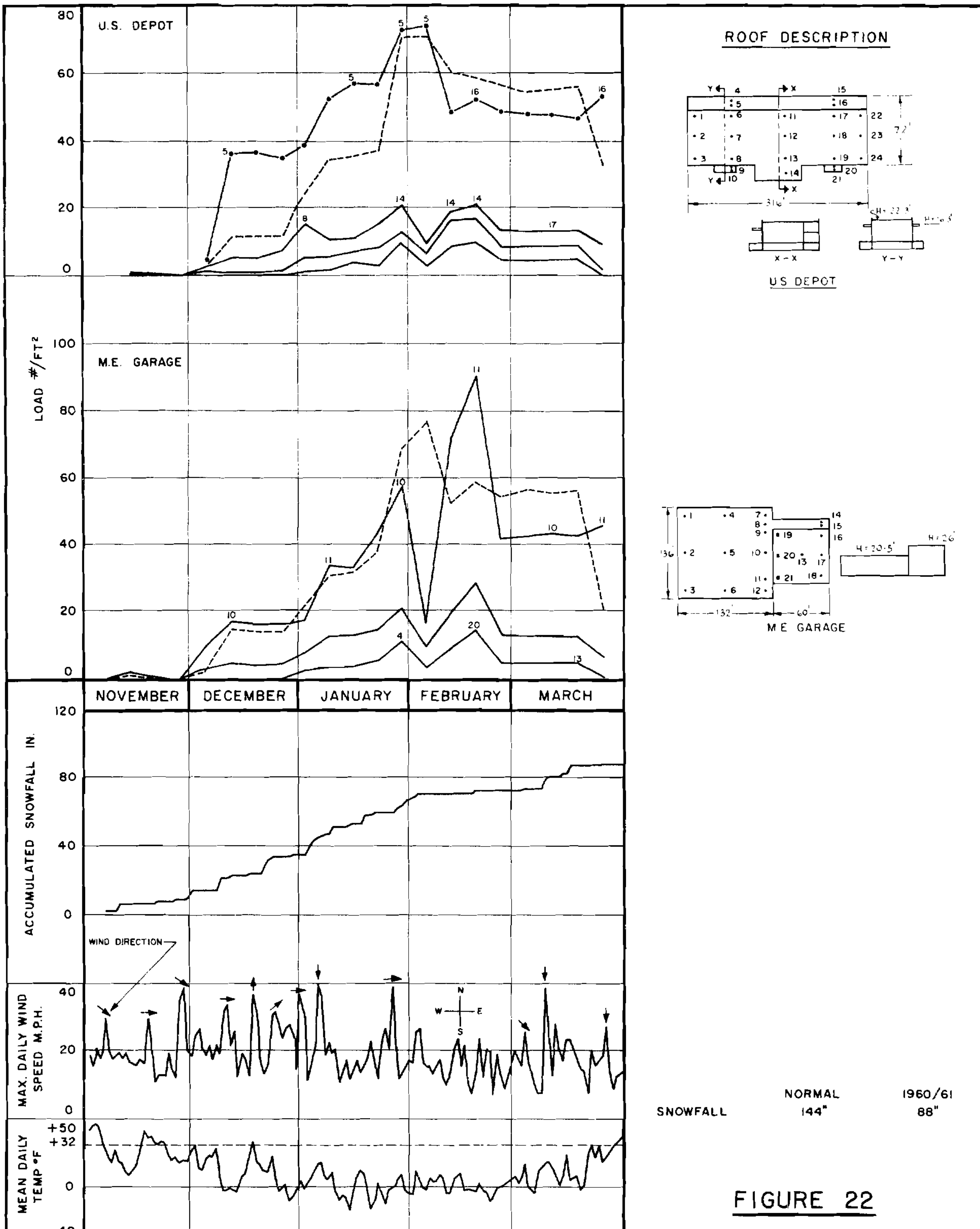
LOCATION: R.C.A.F. WINNIPEG, MAN.



SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

LOCATION: R.C.A.F. NORTH BAY ONT.



SNOW LOAD OBSERVATIONS ON ROOFS

YEAR: 1960/61

LOCATION: R.C.A.F.

GOOSE BAY, LAB.

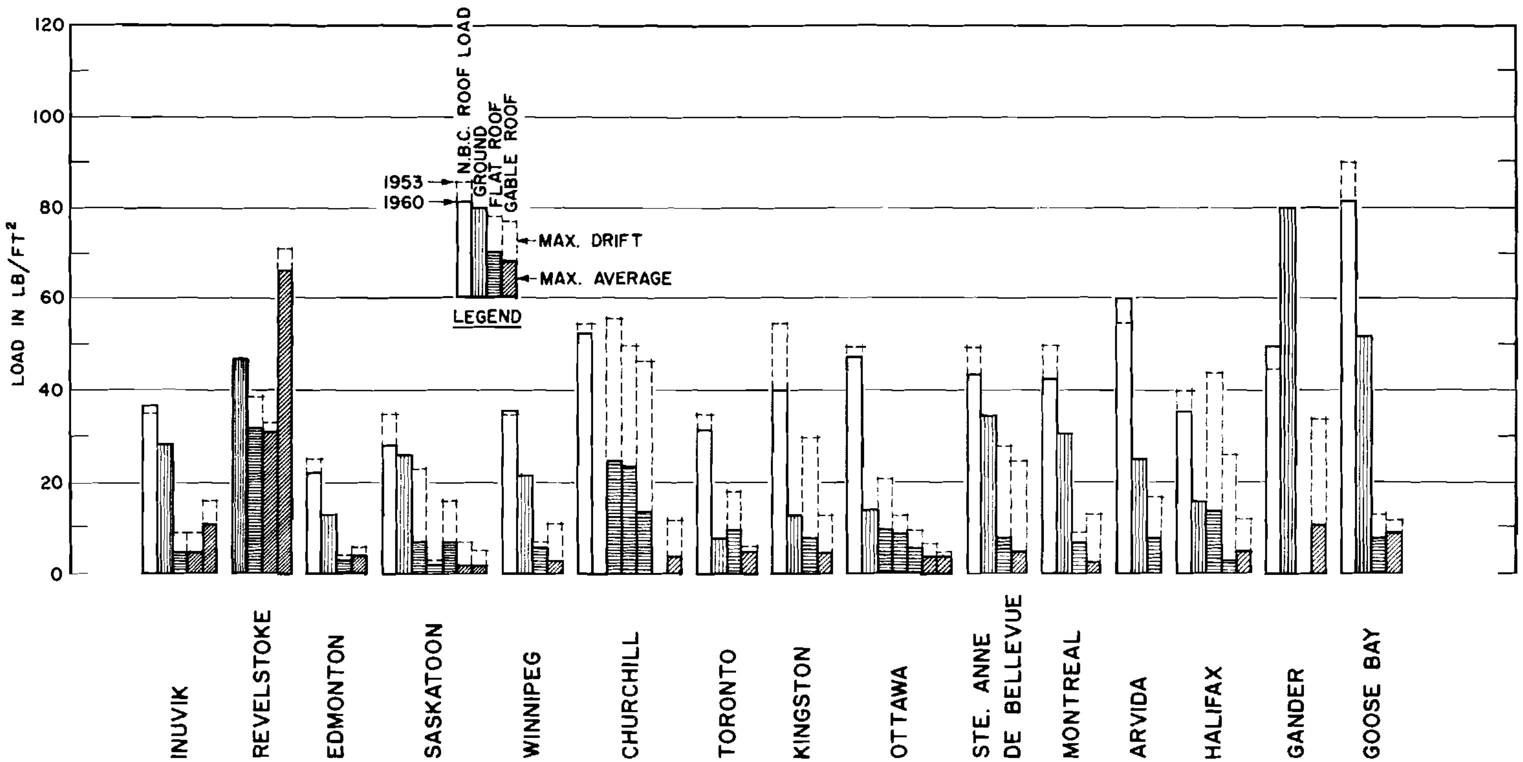


FIGURE 23 MAXIMUM LOADS AT "A" STATIONS 1960-61

$$\text{"SHAPE FACTOR"} = \frac{\text{MAX. CONCENTRATED LOAD BESIDE PARAPET WALL}}{\text{MAX. AVG. ROOF LOAD}}$$

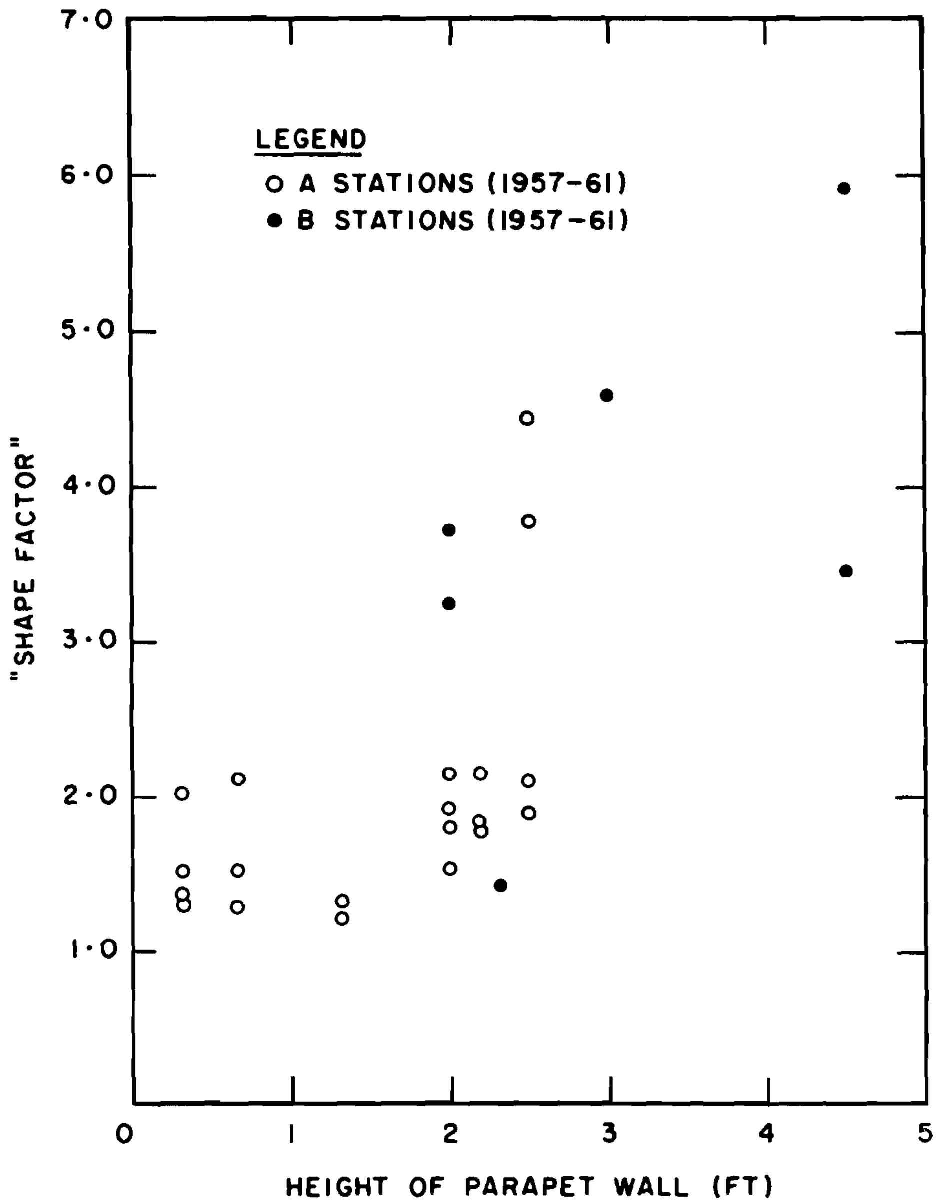


FIGURE 24

"SHAPE FACTOR" VS HEIGHT OF PARAPET WALL

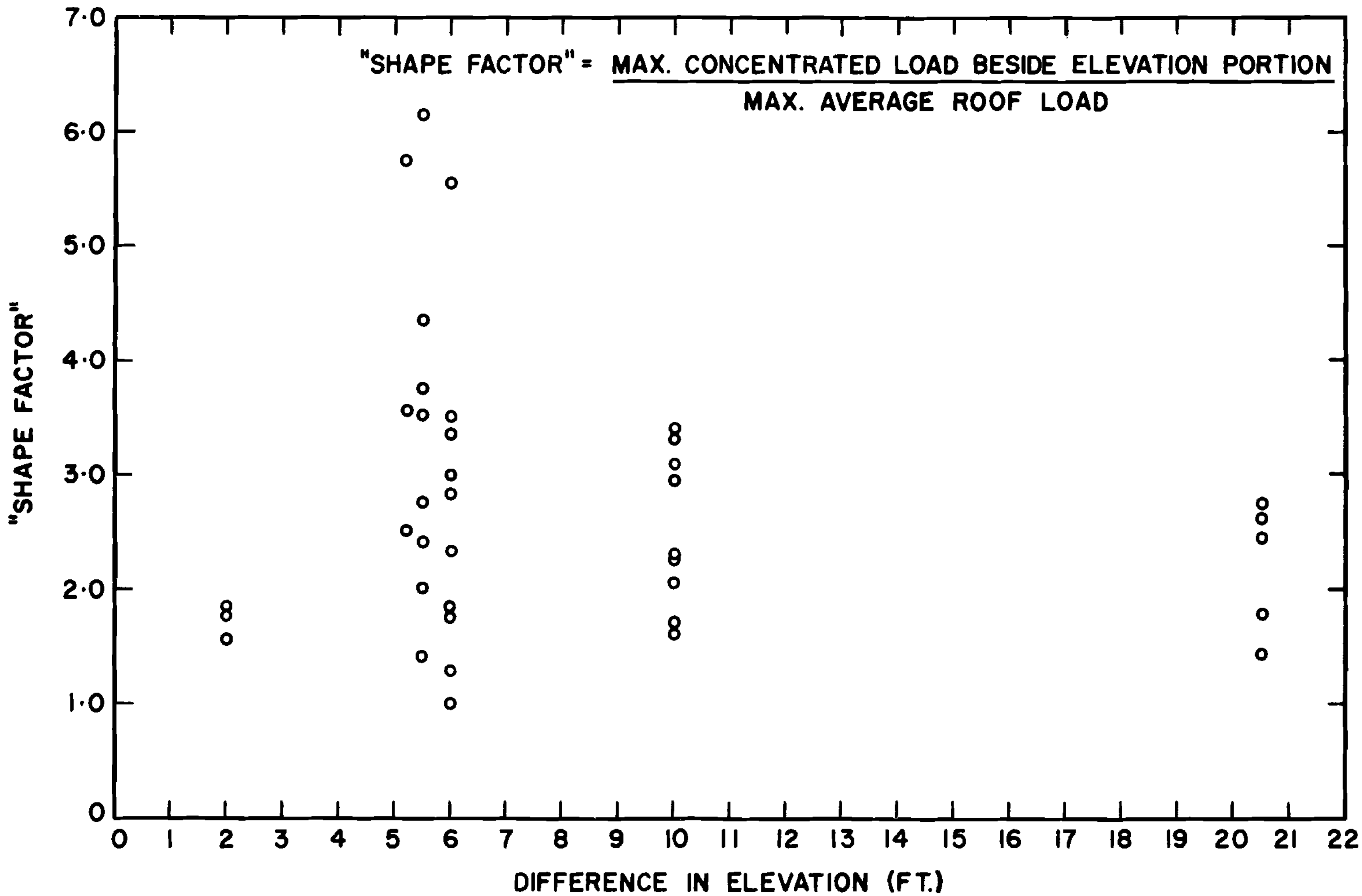


FIGURE 25

"SHAPE FACTOR" VS DIFFERENCE IN ELEVATION FOR SPLIT-LEVEL ROOFS (1957-61)

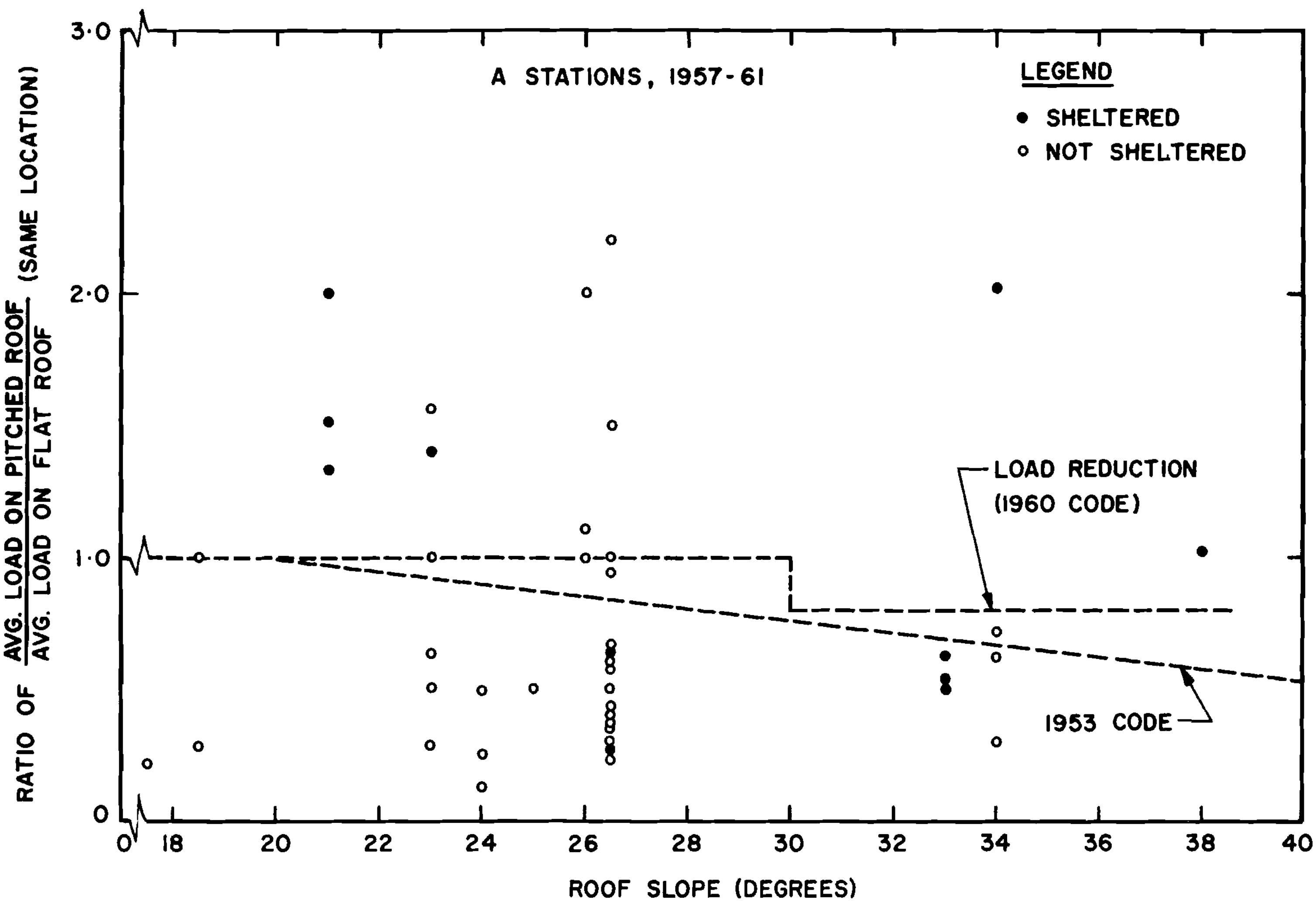
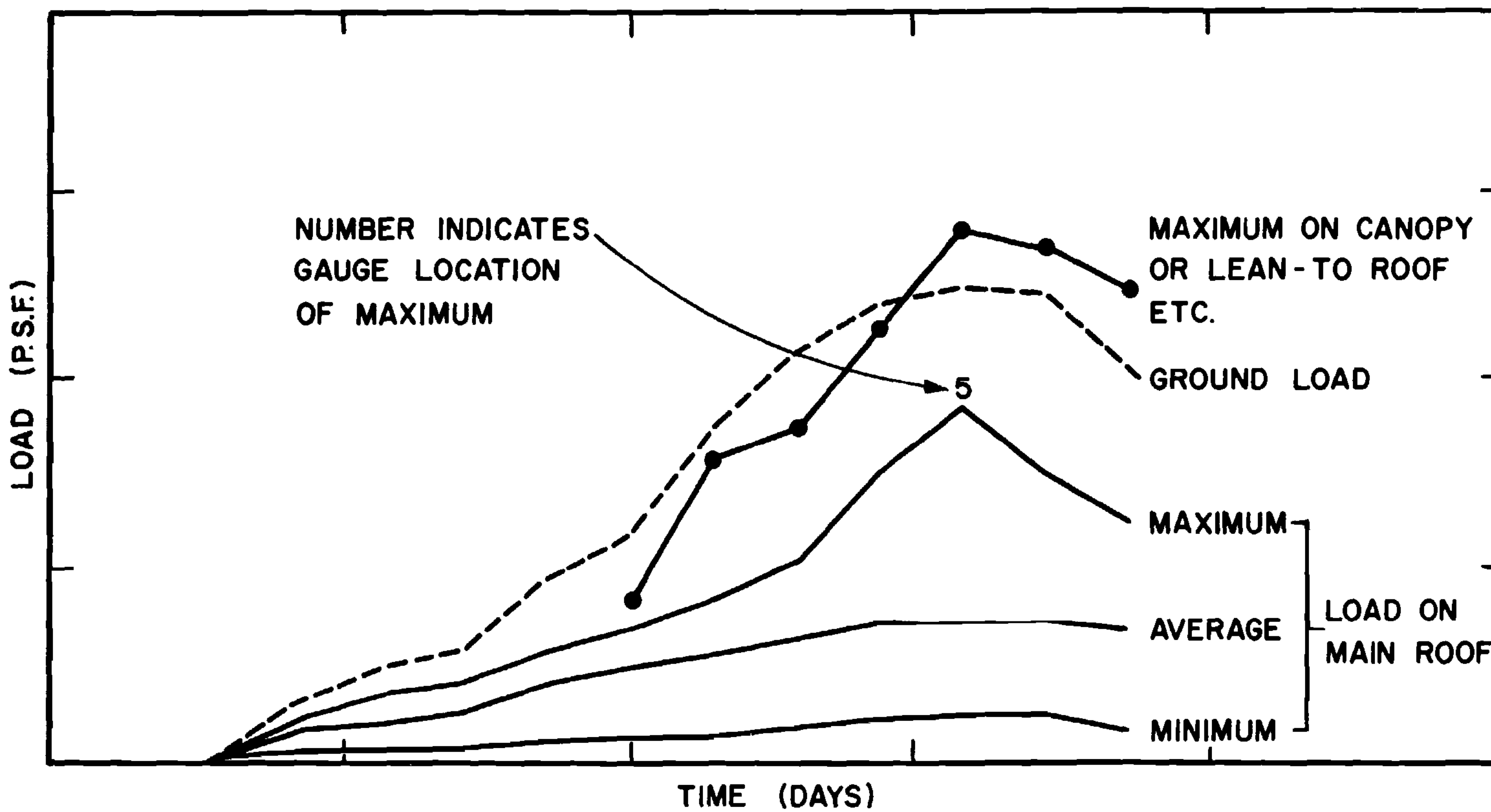


FIGURE 26
ROOF LOAD VS ROOF SLOPE



LEGEND FOR FIGURES 3 TO 22 INCLUSIVE