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Soil Temperature Measurements at Saskatoon

K. R. Solvason* and G. O. Handegord M.E.I.C.†

A soil temperature measurement installation using copper-constantan thermocouple is described. Junctions were placed at various levels down to 15 feet under and adjacent to a small heated building. The results presented show monthly isotherm plots for a vertical plane through the building and also the annual variation at several depths for a station 20 feet from the building.

IT IS NATURAL that in Canada, with its extreme range of climate, there should be considerable interest in ground temperatures. The solution of many construction problems is dependent on a knowledge of sub-surface temperature variation. It was for this reason that a program of study was initiated by the Division of Building Research soon after its formation in 1947 under the National Research Council of Canada.

One of the first tasks was to make a search of the literature on the subject. This study[1] revealed not only a substantial volume of papers on the subject but also an insight into a considerable amount of early Canadian work. The most notable historical work was done by Prof. H. L. Callendar[2] who measured temperatures on the McGill Campus to a depth of 9 feet beginning in 1894. Later, measurements were made at the University of Saskatchewan[3] and at the University of Manitoba[4]. For 15 years, until 1939, temperature measurements to a depth of 15 feet were made in Toronto by the Canadian Meteorological Office.

The initial field studies by the new Division of Building Research were made at Ottawa beginning in 1948. The first results from these studies, which were planned to assist in water works design, were published in 1952[5]. This was the beginning of a number of cooperative studies across Canada which are outlined in a recent publication[6].

Soon after the Ottawa studies were started a program of soil temperature measurements adjacent to a small heated building was initiated at the Division's Regional Laboratory in Saskatoon. Since 1949, records have been maintained of soil temperatures at various depths down to 15 feet at distances up to 20 feet from the walls of this structure, as well as at locations within the foundation walls and beneath other portions of the building. Complete analysis of these records as they relate to heat loss to the ground has not yet been made, but numerous requests have been received for the basic soil temperature records. This report has been prepared to provide a description of the test installation and to record some of the soil temperature results which have been obtained to date.

DESCRIPTION OF THE INSTALLATION

The building involved in the soil temperature installation functions as a service building for seven experimental test huts located on the campus of the University of Saskatchewan. This test facility is shown in Fig. 1.

The service building is of frame construction, approximately 20 by 26 feet in plan dimension, with the long dimension oriented due east and west. A basement under the northern third of the building (Fig. 2) provides access to a tunnel that extends some 60 feet to the west immediately beneath the test huts. The basement walls are of plain concrete, 8 inches thick, extending 8 feet below grade to conventional footings. The basement floor consists of 3 inches of concrete over a 5-inch gravel fill. The area above the basement is used for office and instrument space.

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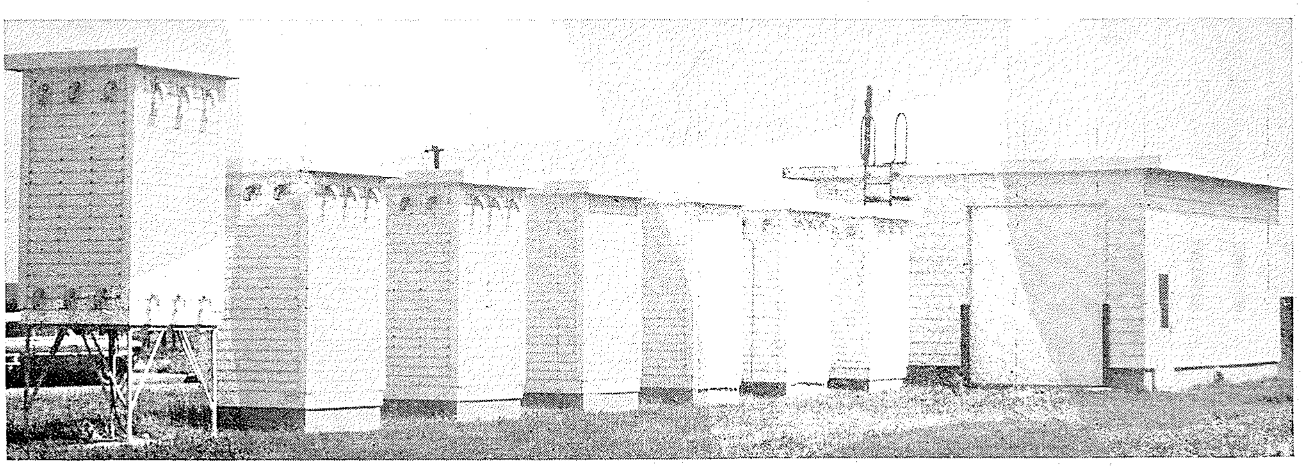
Fig. 1. Service building and seven experimental test huts at University of Saskatchewan.



The remainder of the service building is used as a workshop and laboratory area. This portion of the building has a 5-inch concrete floor placed on a 5-inch gravel mat with an 8-inch thick perimeter foundation wall extending to footings 4 feet 6 inches below grade. Two-inch thick cellular glass insulation, extending 18 inches below floor level, separates the floor slab from the foundation wall. Above floor level, 2-inch mineral wool batt insulation covers the foundation wall, installed between 2- by 2-inch sleepers and covered with ⅜-inch plywood.

The service building is heated by steam convectors located under windows in the office portion and on the interior wall in the workshop area. A pneumatic proportional-type temperature control system is employed in winter to maintain an air temperature of approximately 70°F. in both areas. No special provision is made to heat the basement section, but gains from piping and the heated tunnel maintain the temperature between 70° and 80°F. in winter.

The location of temperature measurement points beneath and adjacent to the building are shown in Fig. 2. All these points are located in a north-south plane through the centreline of the building. Initially a separate temperature installation was made some 50 feet from the building to measure soil temperatures at various levels down to 38 feet below grade. Unfortunately, this installation was accidentally destroyed three months after completion by a workman plowing the site. Since then soil temperatures measured at the location 20 feet to the south of the service building have been used as an indication of natural ground temperatures, although they are slightly affected by the heat loss from the structure.

DETAILS OF MEASURING SYSTEM

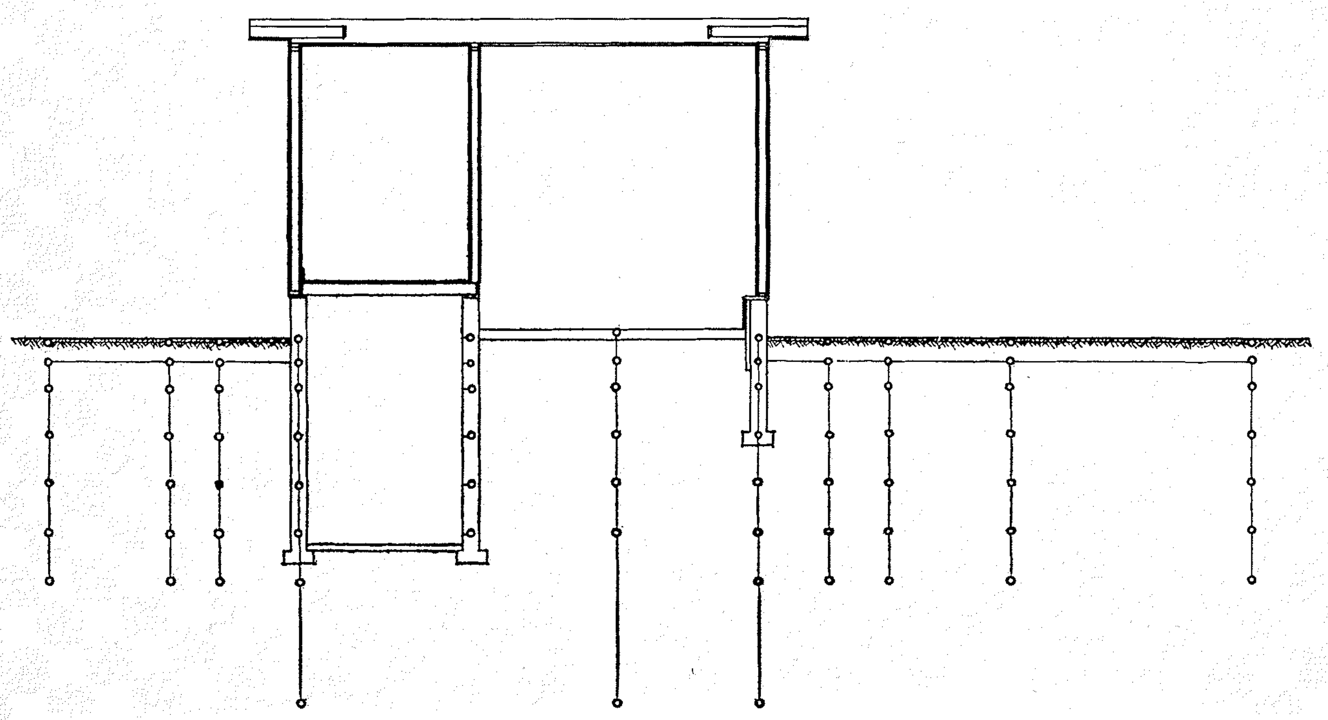
Copper-constantan thermocouples are used as temperature-sensing elements. This choice was made largely because the type of measuring and recording apparatus available was designed for use with this type of element. The thermocouple junctions were fabricated from 30 B and S gauge wire twisted together and soldered. Three separate couples were used for each measuring point for checking purposes and in case of possible breakage during installation.

Half-inch diameter, two-ply rubber garden hose was used as a conduit to protect the thermocouple lead wires against breakage and moisture. The garden hose was cut in sections equal to the spacing between measuring points, and these sections were joined by special nipples that contained the thermocouples. The nipples were fabricated as shown in Fig. 3, using a 2¼-inch length of ½-inch diameter brass tubing to which a brass ring, one inch in diameter, was silver soldered. Three 0.043-inch diameter holes were drilled in the ring, as shown, into which the three thermocouples were soldered. The nipples were given one coat of asphalt paint before assembly and secured into the hose lengths with standard hose clamps. At the end of each string, a 4-inch length of hose was added and sealed with a ½-inch diameter brass plug and clamp. The thermocouple wires were dipped in paraffin before being drawn through the hose as an additional protection for the enamel and cotton insulation originally provided. Mineral wool insulation was placed in the end of each hose length to minimize air convection. Dry air was forced through each completed hose and thermocouple assembly and the ends were sealed with paraffin wax to exclude moisture.

Fabrication of this thermocouple-hose arrangement involved a considerable amount of time, but provided a very rugged assembly that could be installed easily with little danger of wire breakage during installation or from subsequent ground movement. To date, no thermocouple in the installation has proved faulty.

The thermocouples measuring soil temperature at depths of 2, 4, 6, 8, and 10 feet outside the building were installed by drilling 4-inch diameter holes to the required

Fig. 2. Location of temperature measurement points beneath and adjacent to service building.



depth at each location. The soil was replaced at the same depth from which it was removed and tamped in place as thoroughly as possible. A one-foot deep trench was dug in which to run the hose and lead wires from each hole into the service building. A horizontal string was also placed in this trench at a depth of 1 foot, with nipples located for measurement of temperatures at the appropriate distances from the building. A similar assembly was installed initially on the ground surface, but was subsequently buried with its centreline one inch below grade.

Thermocouple-hose assemblies were installed vertically at the centreline of the exterior basement wall and workshop foundation wall with nipples located at the 0, 1, 2, 4, 6, 8, 10, and 15-foot depths. These were installed prior to concrete placement with the sections below footing level being placed in a similar manner to that previously described, and the remaining portion held in place during the concreting operation. The thermocouple string below the workshop floor slab was installed prior to concreting with thermocouples at depths of 1, 2, 4, 6, 8, 10, and 15 feet. A thermocouple was later installed just below the slab surface.

No thermocouples were placed in the inner basement foundation wall initially, but in 1952 a series of couples were installed at the 0, 1, 2, 4, 6, and 8-foot levels. These thermocouples were placed at the centreline of the wall in holes drilled laterally into the concrete.

The rubber hoses from each thermocouple string were brought into the service building where the thermocouple lead wires were connected to a terminal board. The terminal board consisted of a series of lucite strips approximately $\frac{3}{8}$ by $\frac{3}{8}$ by 10 inches. The thermocouple lead wires were attached to these strips through a pair of holes; several turns of the bare lead wire were threaded through the appropriate hole to form a copper and a constantan surface on the top and bottom edge of the strip, respectively. Connection to the measuring apparatus was made using a plastic clothespin with its jaws wound with the appropriate wire, as indicated in Fig. 4. This system has proved simple, inexpensive, and free from stray e.m.f.'s which may occur with standard switching arrangements. The thermocouples in each group of three were first checked individually to ensure that equal readings were obtained and then connected in parallel to reduce the resistance of the circuit.

A portable potentiometer with an ice-bath reference junction was employed almost exclusively for measurement of soil temperatures. Occasionally an electronic temperature indicator was used for convenience. Comparison between the two instruments showed agreement to within 0.1°F.

Some special precautions were necessary to ensure that the reference junction employed with the potentiometer was at 32°F. The reference junction (Fig. 4) consisted of a 30 B and S gauge thermocouple soldered into the tip of a $\frac{1}{8}$-inch diameter copper tube, the upper end of which was set into the cork stopper of a standard thermos flask. The copper tube was bent, as shown, and its upper end set below the surface of the cork to minimize conduction effects. Finely chopped ice and distilled water were used, the mixture being shaken periodically in the interval before measurement. Without these precautions differences as high as 1.0°F. were noticed between readings of the deeper thermocouples on successive days. When the above procedure was followed, successive readings on these thermocouples agreed to well within ±0.1°F.

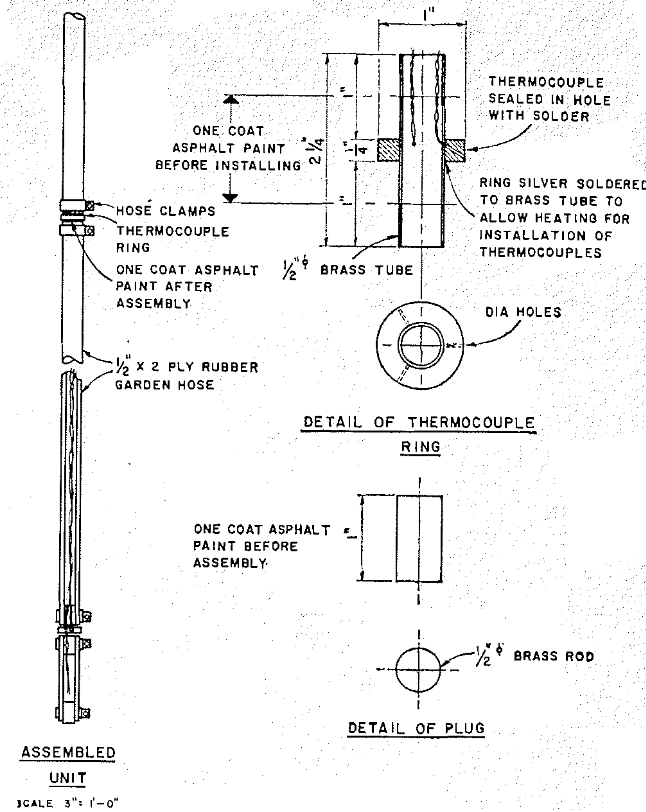
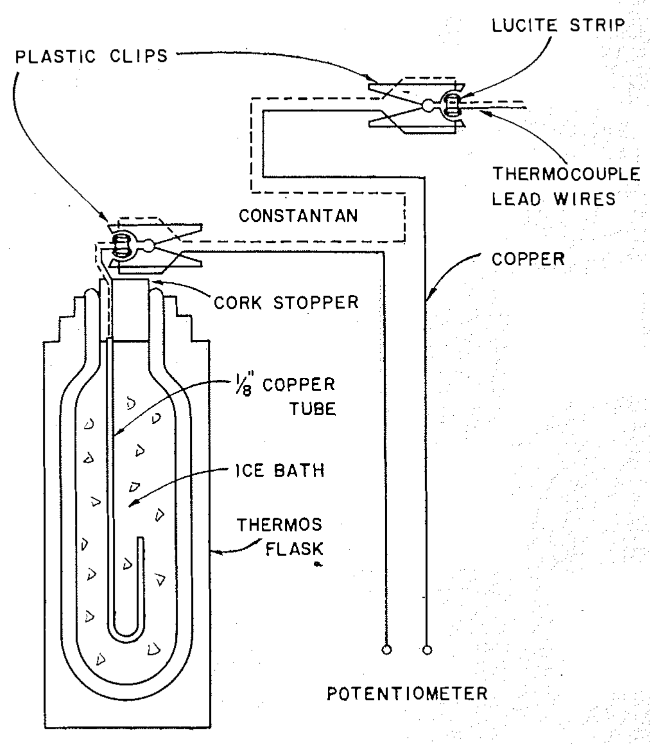


Fig. 3. Thermocouple unit details.



THERMOCOUPLE CONNECTOR SYSTEM

Fig. 4. Thermocouple connector system.

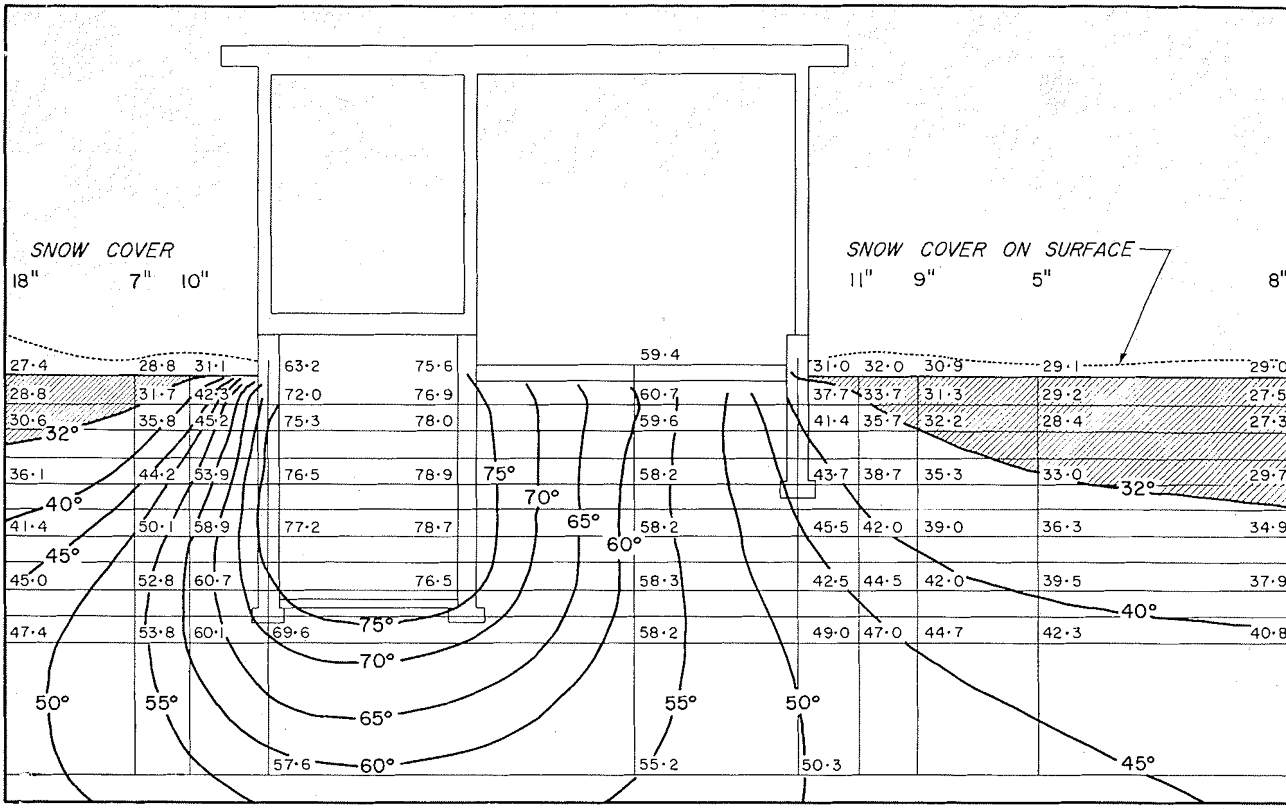
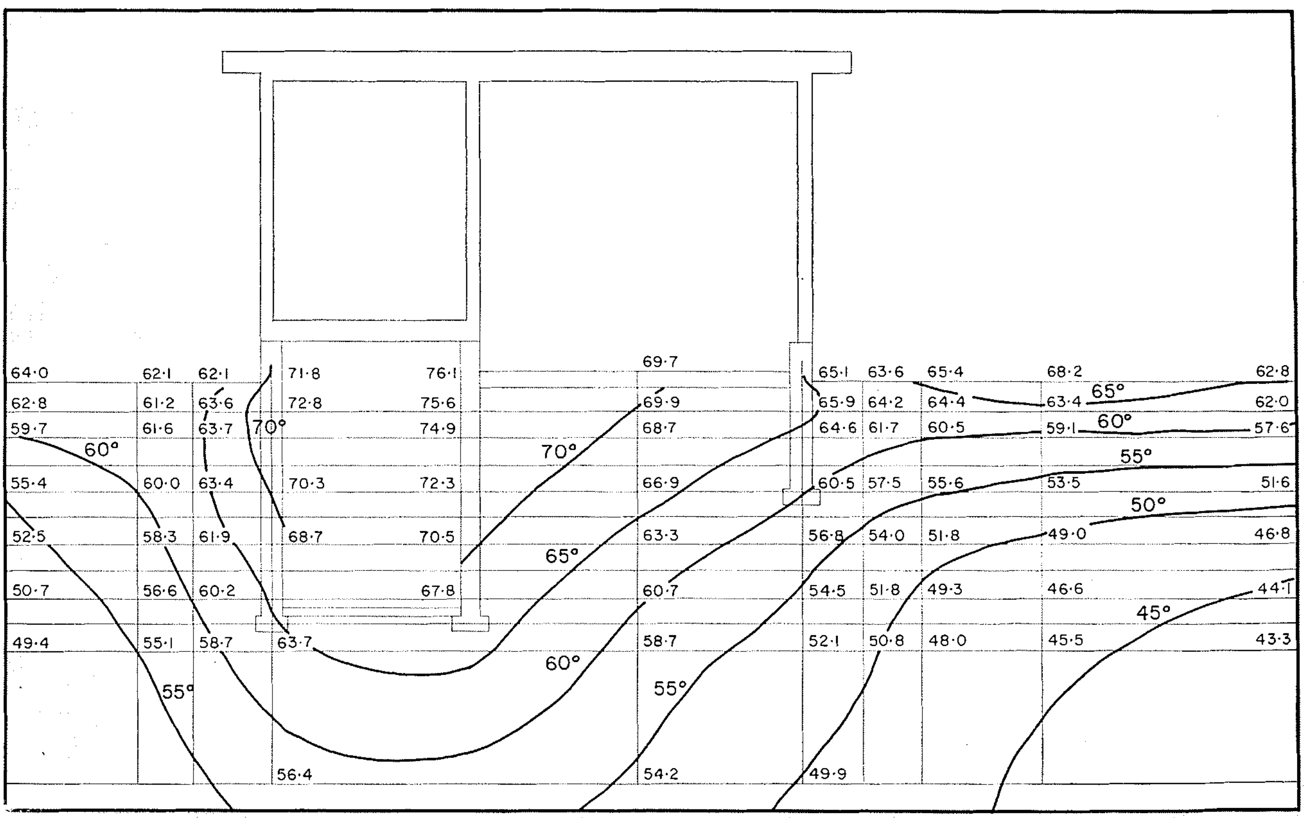


Fig. 5. Ground temperature isotherms for March 23, 1956.

Fig. 6. Ground temperature isotherms for June 29, 1956.



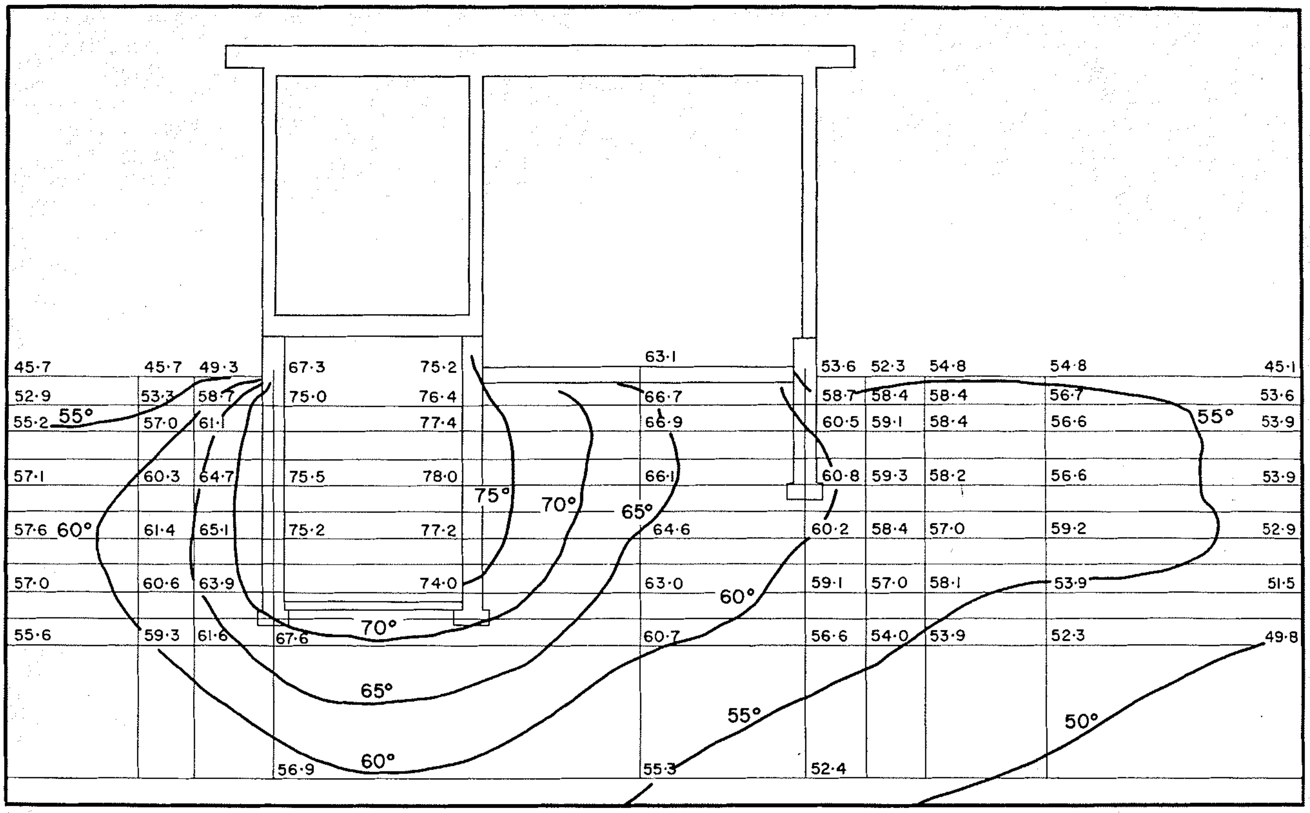
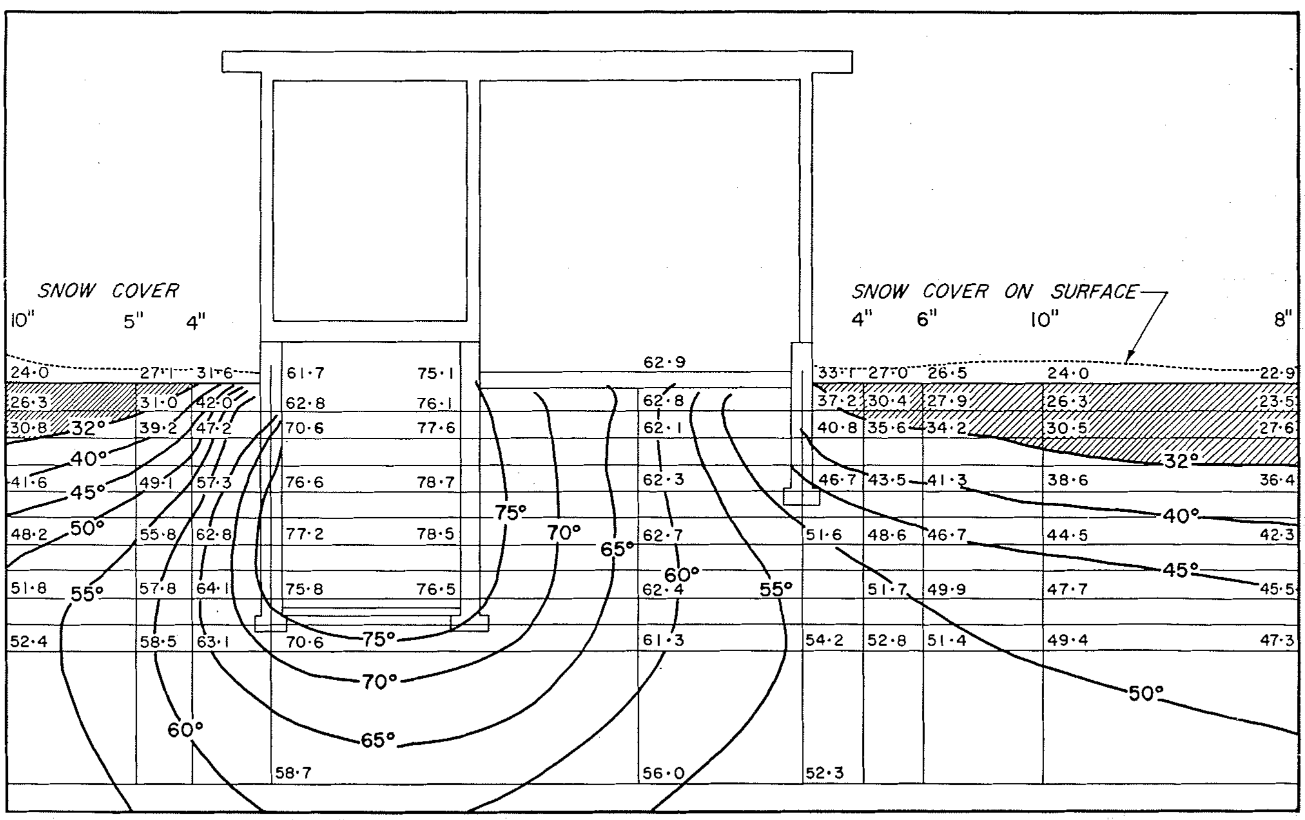


Fig. 7. Ground temperature isotherms for September 28, 1956.

Fig. 8. Ground temperature isotherms for December 21, 1956.



The only precaution necessary in using the electronic indicator was to ground the case of the instrument adequately. An error of several degrees resulted in some cases when this was not done. It was assumed that this error resulted either from a potential on the neutral of the power supply or from some earth potential.

Measurement of soil temperatures was made daily until satisfactory performance of the system was assured and the trend in temperatures established. The frequency of measurement was then reduced to twice weekly until 1953, and measurements have been made once a week since that time.

SOIL TEMPERATURE RECORDS

The soil temperature records obtained at Saskatoon are plotted in graphical form so that they may be reproduced for anyone interested. Monthly diagrams showing isotherms in relation to the cross section of the building are made. Figures 5, 6, 7, and 8 are examples of these diagrams for the months of March, June, September and December of 1956. Regions at or below 32°F. are shown as shaded areas on these diagrams to indicate the possible frozen regions. The measured temperatures at each depth at the station 20 feet south of the building are plotted as in Fig. 9 to show the annual variation in soil temperatures at different levels. The corresponding outdoor air temperature is also shown in this figure.

The ground cover at the site consists of natural grass which is mowed occasionally by the University grounds' staff but never watered. Foot traffic over the ground temperature installation is kept to a minimum so that the natural snow cover is maintained in winter. Snow depth profiles along the axis of the thermocouple installation are taken periodically and plotted on the isothermal charts, as in Figs. 5 and 8. Average snow depths at the Outdoor Test Station site are determined regularly for the Meteorological Service, and these values have been plotted in Fig. 9. Snow depth readings over the thermocouple station 20 feet south of the building are also shown in this figure.

Soil samples taken at various depths 3 feet and 20 feet south of the building, during installation of the thermocouples, were classified by the University of Saskatchewan Soil Mechanics Laboratory. Moisture content determinations were also made at that time and on several later occasions (Tables I and II).

The moisture content records in these tables indicate a marked drying out of the soil with time down to the 8- or 10-foot depth. This may be partially explained by the fact that the site was flooded twice during the construction stage by the overflow from a buried water storage tank. No further flooding has occurred.

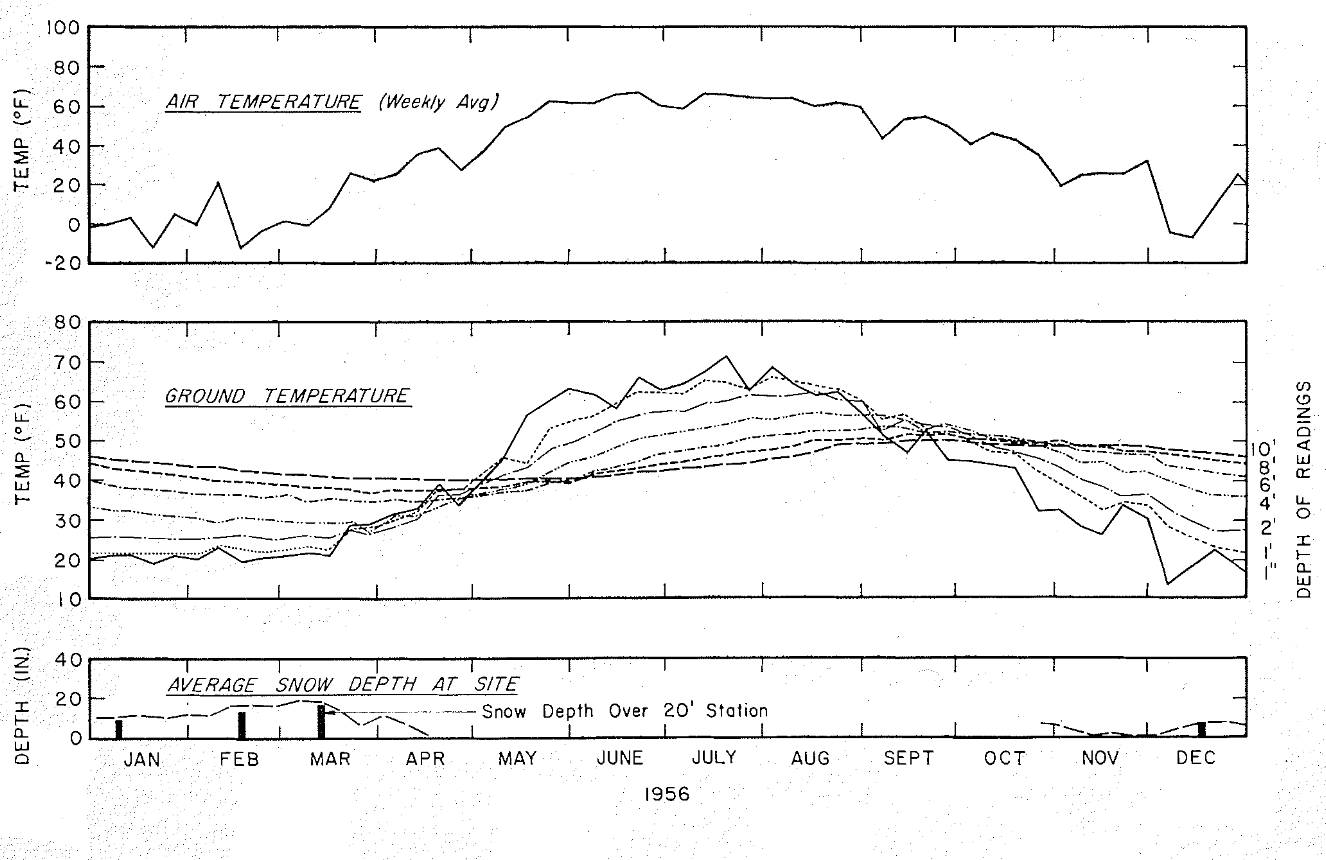
CONCLUSION

The soil temperature installation at Saskatoon is an example of one method of obtaining soil temperature records using thermocouples. The technique employed has proved satisfactory from the standpoint of both installation and operation, with no apparent failure of any thermocouple over an 8-year period.

The results that have been recorded for locations adjacent to the building eventually may be used in conjunction with heat flow measurements to provide further information on the heat loss from basements. Application of the results to slab-on-ground constructions will not be truly representative, however, since the soil temperatures beneath the slab floor in this installation are influenced by heat flow from the interior basement wall. This rather unusual situation should be recognized in any interpretation of the results.

Measurements made at the location 20 feet south of the building have been used in an analysis of the relation

Fig. 9. Weekly ground temperature 1956.



between outside air temperature and soil temperature[7]. This study revealed that the measuring location was not entirely unaffected by the heat loss from the building. For most practical purposes, however, the records may be regarded as representing the natural soil temperature conditions for this particular site.

The soil temperature results recorded at Saskatoon since 1950 are available on request in the forms illustrated in Figs. 5 and 9. Inquiries relating to this information should be addressed to: National Research Council, Division of Building Research, Prairie Regional Station, Saskatoon, Saskatchewan.

ACKNOWLEDGMENTS

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REFERENCES

(1) Crawford, Carl B. "Soil Temperatures, A Review of Published Records", Highway Research Board, Special Rept. No. 2 on Frost Action in Soils, 1952.

(2) Callendar, H. L. "Observations of Soil Temperatures with Electrical Resistance Thermometers". *Trans. Roy. Soc.* Canada, Vol. 3, 1897-8.

(3) Harrington, E. L. "Soil Temperatures in Saskatchewan", *Soil Science*, Vol. 25, No. 3, 1928.

(4) Thomson, W. A. "Soil Temperatures at Winnipeg, Manitoba". *Scientific Agriculture*, Canada, Vol. 15, No. 4, 1934.

(5) Legget, R. F. and Crawford, C. B. "Soil Temperatures in Water Works Practice". *Jour. AWWA*, Vol. 44, No. 10, 1952.

(6) Crawford, C. B. and Legget, R. F. "Ground Temperature Investigations in Canada". *Jour. Eng. Inst. of Canada*, Vol. 40, No. 3, 1957.

(7) Pearce, D. C. "Ground Temperature Studies at Saskatoon and Ottawa, Canada." Association Internationale d'Hydrologie Scientifique, Union Géodésique et Géophysique Internationale, Assemblée Générale de Toronto, 1957, Gentbrugge 1958, Tome IV, p. 279-290.

TABLE I. — Soil Classification and Moisture Content Twenty Feet South of Service Building

Depth (ft.)	Soil Classification	Moisture Content				
		Nov. 1, 1949	May 14, 1952	Nov. 12, 1952	Oct. 21, 1953	Oct. 16, 1957
1	Highly plastic clay	23.0	24.9	16.0	17.3	16.3
2	" " "	—	24.6	16.8	13.7	15.5
3	" " "	29.0	—	18.6	—	19.7
4	" " "	—	26.5	21.9	15.7	21.5
5	" " "	23.7	—	24.4	—	25.0
6	" " "	—	27.6	27.4	23.6	28.1
7	" " "	34.9	—	28.7	—	29.1
8	" " "	—	32.0	29.9	24.7	30.3
9	" " "	27.0	—	33.0	—	34.1
10	" " "	—	32.4	33.2	25.2	—
11	Silty clay, oxides	—	—	36.8	—	—
12	" " "	—	—	35.5	27.9	—
13	Silty, slightly sandy clay	—	35.4	37.0	—	—
14	Highly plastic clay, oxides	—	37.0	36.5	—	—
15	Highly plastic clay with oxides, pebbles and selenite	—	38.1	36.2	—	—

TABLE II. — Soil Classification and Moisture Content Three Feet South of Service Building

Depth (ft.)	Soil Classification	Moisture Content		
		Nov. 1, 1949	Nov. 12, 1952	Oct. 16, 1957
1	Medium plastic clay	29.1	20.9	15.3
2	Highly plastic clay	—	27.5	14.1
3	" " "	32.2	26.6	15.8
4	" " "	—	28.2	17.4
5	" " "	30.9	31.2	20.9
6	" " "	—	31.2	24.4
7	" " "	34.3	32.2	30.5
8	" " "	—	33.1	34.7
9	Silty clay	34.7	32.9	33.8
10	Highly plastic clay	—	34.8	—
11	Silty alluvial clay	—	35.3	—
12	" " "	—	34.2	—
13	" " "	—	37.7	—
14	Alluvial clay	—	35.9	—
15	Glacial clay	—	33.9	—

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