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Design Heat Requirements for Snow Melting Systems

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Please note

During the past ten years there has been a substantial increase in the use of embedded electric heating cables or embedded steam or hot water pipes to keep building entrances, sidewalks, parking areas, loading docks, garage ramps, driveways and bridge approaches free of snow and ice. The rising cost of labour and equipment, the lack of space for storage of snow, and an increasing demand for better and more rapid snow and ice removal has contributed to this growing use of melting systems.

One of the more difficult determinations in the design of snow melting systems is the heat input required to prevent ice formation or snow accumulation that will impede traffic. Designers must provide sufficient heat capacity for effective melting but not over-design the system and unnecessarily increase the cost of an already expensive operation. At present, published information on good design practice for Canadian conditions is limited, particularly for regions with severe winter weather. This Digest contains a brief description of the factors controlling the heat needed for snow melting systems and offers guidelines for estimating heat requirements for several urban locations in Canada.

Heat Requirements for Snow Melting Systems

Snow and ice melting systems must provide sufficient heat to melt snow as well as to offset surface heat loss by evaporation, convection and radiation and heat loss from the slab into the ground.

Heat Required to Melt Snow

The heat to melt snow is a large part of the total heat requirement. If a completely bare pavement is required, the system must be designed to melt the maximum hourly rate of snowfall anticipated at a site. Table I provides some typical estimates of such requirements. Because a large amount of heat is needed to maintain a pavement completely free of snow during periods of heavy snowfall, melting systems are seldom designed to melt snow as it falls. Even larger amounts of heat are needed for areas subject to drifting snow because the rate at which it can drift into a site can be several times the average rate of snowfall during a storm.

Table I. Heat required to Melt Snow

Average Rate of Snowfall During Storm	Estimated Maximum Hourly Rate of Snowfall (in./hr)	Heat Required to Melt Maximum Hourly Rate (Watts/sq ft)
0.25	0.5-0.9	12-20
0.5	1.1-1.8	24-40
1.0	2.2-3.6	48-80

Radiation, Convection and Evaporation Losses from Bare Surfaces

Various formulae are available for calculating heat transfer from a surface to the atmosphere by radiation, convection, and evaporation. The many variables that influence such losses include air temperature, wind, cloud cover, surface roughness, and local site conditions. Figure 1 shows the approximate combined heat loss by radiation, convection, and evaporation from a bare, exposed surface at 34°F (1.1°C).

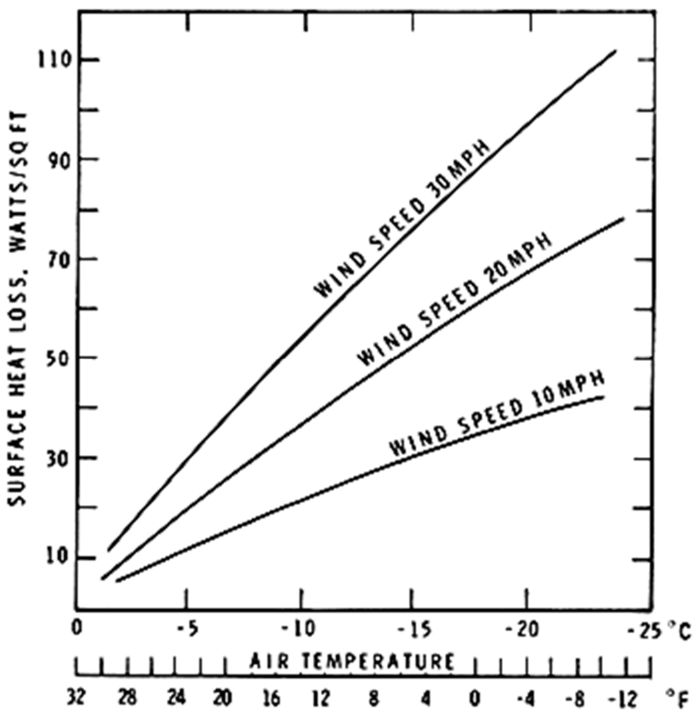

Figure 1. Combined surface heat loss (radiation, evaporation, convection) from bare heated pavement at 34°F (1.1°C).

With high wind speeds, heat loss from convection is the largest component; with low wind speeds and large air-surface temperature differences, heat loss from radiation becomes more significant. The rate of evaporation is limited by the vapour pressure difference between the surface and the air, but it is an important part of the total heat balance at high wind speeds, particularly from wet pavements after snow has melted. It is important, therefore, to provide adequate drainage for snow melting systems that pavement can dry quickly, cutting down on substantial heat loss by evaporation. As surface heat loss is directly proportional to wind speed, the heat loss at sheltered sites will be substantially less than that at exposed sites.

Surface heat losses by evaporation, convection, and radiation are reduced in direct proportion to the percentage of heated pavement covered by snow. If the area is half covered, surface heat losses are reduced to about one half the value of a completely bare area; if the pavement is completely covered by even a thin layer of snow, the only surface heat loss, in addition to that for melting, is the small amount of heat transferred by conduction upward from the pavement surface through the snow cover.

Although surface heat loss from a heated pavement completely covered with snow is small and can usually be ignored, it can under some circumstances be a significant factor. If the density of the snow is increased by drifting or compaction by traffic, the rate of heat transfer will increase markedly owing to increased thermal conductivity; and if the snow melting system is operating at low heat output under low air temperature conditions the heat transferred through the denser snow may exceed the rate at which heat is supplied to the pavement surface by the embedded heating coils. The pavement surface can then cool below the freezing point so that ice will form. The rate of heat transfer through the ice will increase sharply under the same imposed temperature conditions (the thermal conductivity of ice is about ten times that of medium density snow) and further cooling of the pavement will take place. This limiting condition does not apply to systems operating in mild climates where most snowfalls occur with air temperature near 32°F (0°C).

Heat Loss to Ground and Edge Heat Loss

It is customary in calculating design heat requirements of snow melting systems to allow for heat loss downward from the heating coils to the ground or from the under side of a heated bridge or ramp slab to the atmosphere. Recommended values can be as high as 30 to 50 per cent of the surface heat loss.

In deciding how much to allow for ground heat loss, it is necessary to distinguish between continuous operation and intermittent operation. With intermittent operation, when the slab is heated only when snow is falling or expected to fall, allowance must be made for substantial ground heat loss during the warm-up period. This may approach the value of 30 to 50 per cent reported in the literature. It will be a function of the temperature gradient and material under the slab. With a continuously heated slab, however, heat stored in the slab can provide a substantial amount of heat for melting snow during the early hours of a storm.

A substantial amount of heat can be lost from the edges of a heated area to the soil or pavement surrounding it. The rate will depend on thermal conductivity and the temperature gradient through the material surrounding the heated slab. It will be greatest if the system is operated intermittently, because edge ground temperatures will be much lower than the temperature of the heated slab. There are not many values in the literature for edge heat loss, but there is no doubt that for narrow heated areas such as sidewalks or vehicle tracks operated on an intermittent basis the edge loss can be 20 to 30 per cent of the total heat requirement. Both edge heat losses and ground heat losses can be reduced substantially by the use of insulation under and at the edges of the slab.

Standards for Design Heat Requirements

A most important requirement in designing a system is to establish the standard of operation required. A decision must be made regarding the acceptable percentage of heated pavement that can be snow covered during a snowfall. Research and experience indicate that it is neither necessary nor economical to design systems that maintain bare pavement conditions at all times. Designing for 25 to 50 per cent snow cover is a reasonable compromise for most situations. If a heated surface becomes snow covered (as will happen in severe storms) surface heat losses are reduced and more heat becomes available for melting snow, creating in effect a "built-in" safety factor. Designing for complete snow coverage of a heated area may be satisfactory for residential requirements. There is a point, however, at which snow accumulations will become sufficient to impede traffic. With sidewalks or driveways with little traffic, where bridging under undisturbed snow can occur, there is the additional problem of subsequent poor heat transfer from the heated pavement to the snowcover. Conditions following a storm must also be taken into consideration, particularly in regions where snowfall may be followed by a drop in temperature.

The calculation of design heat therefore requires information on design weather conditions. Two approaches can be taken. A frequency analysis of all occurrences of snow over a period of several years can be made at a site and the system designed to handle a certain percentage of any snowfalls that will occur. This approach is recommended by the ASHRAE Guide and Data Book[1], but it is not used in Canada because available meteorological records are not suitable. In the other approach, a "design" storm is chosen that is reasonably representative of weather conditions expected at the site. This method is simpler and probably produces results accurate enough for most situations.

Guidelines for Design Heat Requirements in Canada

The design storm approach has been used to calculate surface heat losses for several urban locations in Canada[2]. Weather records were examined and the five "worst" snow storms occurring over a 10-year period were chosen as a basis for design calculations. The average values of weather data (air temperature, wind speed and snowfall) observed during the five storms were used to obtain design heat losses. Calculations were made for three surface conditions: essentially bare, 50 per cent snow cover, and complete snow cover during the storm (Figure 2). In addition, heat losses from a wet, bare pavement were calculated for the 10 hours immediately following storms (Table II).

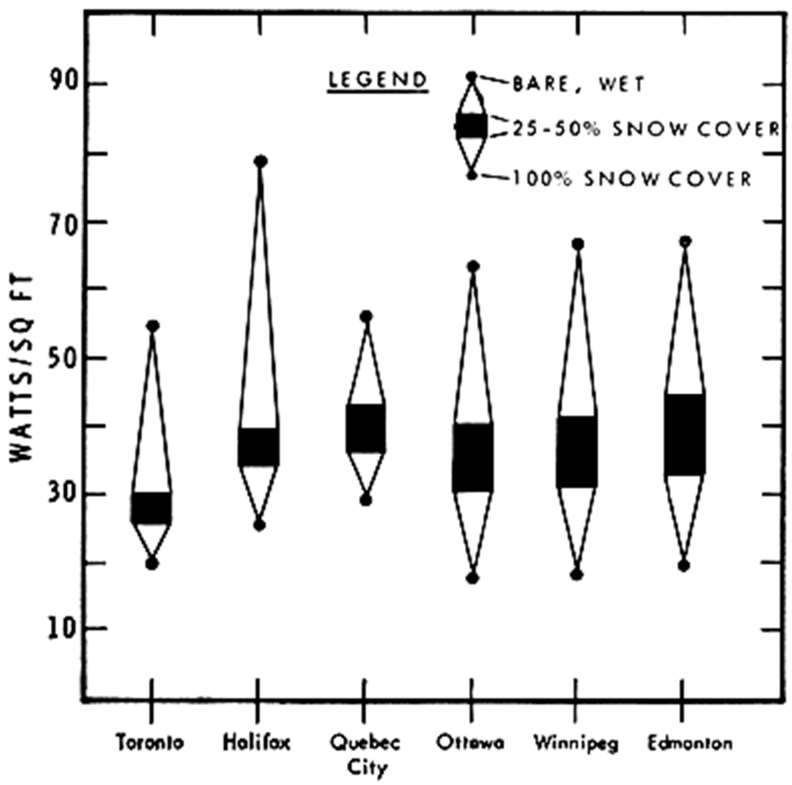

Figure 2. Surface heat losses during design storm for different surface conditions on heated pavement.

Table II. Surface Heat Losses (Watts/Sq Ft) for Maintaining a Bare, Wet Pavement after Design Storm Conditions

Toronto	Halifax	Quebec city	Ottawa	Winnipeg	Edmonton
18	29	33	50	66	65

These results illustrate that design heat requirements depend largely on the required surface standard, i.e. on whether an essentially bare pavement is to be maintained or a completely snow covered surface tolerated. In locations like Winnipeg and Edmonton, subject to low temperatures and high winds, weather conditions after the storm determine design heat requirements. In contrast, high rates of snowfall at locations like Halifax determine heat requirements.

These calculations were made for average exposure to wind. The heat required for sheltered sites where wind effects are smaller can probably be safely reduced by about 15 per cent. Similarly, an increase in the design load of about 15 to 20 per cent should probably be made for extremely exposed sites. In making adjustments for exposure, the possibility that drifting snow will accumulate at a site should be considered.

Some suggested guidelines for design heat are shown on Table III for the six Canadian cities for which calculations have been made. They agree reasonably well with published information on present practice. Adjustments for ground and edge heat losses should be made for these values if the system is to be operated intermittently, and adjustment is specially important for narrow heated areas such as sidewalks. If the system does not provide enough heat at the edge of a sidewalk, ice will form (particularly if drainage is poor), creating a hazardous condition for pedestrians.

Table III Design Heat requirements

	Toronto	Halifax	Quebec city	Ottawa	Winnipeg	Edmonton
Average Exposure	25-30	35-40	37-42	40-45	55-60	55-60
Sheltered	25	30	35	35	40	40
Extremely Exposed	35-40	45-50	5-55	50-55	60-65	60-65

Concluding Remarks

A Digest on the heat requirements of snow melting systems would not be complete without some discussion of cost, which influences the choice not only of standard of performance but also of the system and method of operation. Cost will vary with design criteria (whether bare or snow-covered pavement is required); with power rates (and use during peak demand); location and availability of power transformers and power sources; method of operation (continuous, on and off, or automatic); climatic conditions and amount of snow to be melted; area of pavement to be heated and complexity of installation; and the anticipated life of the system and the repairs that will be needed during its operational life. It is extremely difficult to give reliable cost figures for snow melting systems because they vary a great deal with local conditions and are usually not defined adequately in the literature on the subject.

The annual cost (including amortized installation cost) of melting snow by electrical systems is estimated to be 30 to 40 times that of removing it by mechanical or chemical methods. Embedded pipe systems, with steam, hot water or anti-freeze as the heat-carrying medium, are usually cheaper than electrical systems, particularly if the embedded pipes are installed during the construction of a building and connected to its heating plant. Pit-melting systems, where snow is transported to a pit or tank, are cheaper still, because the system need operate only when snow is to be melted and heat losses to the surroundings can be reduced to a minimum.

Snow melting systems are recommended only for sites where the benefits will justify the high cost of installation and operation: where mechanical methods would be difficult, where use of chemicals would damage structures, and where traffic delays at critical locations such as steep ramps and entrances to parking lots cannot be tolerated and safety is a factor. In some cases, owners of commercial property are willing to pay the high cost of snow melting systems to eliminate the inconvenience of manual snow removal. All such uses must now, however, be given careful consideration in anticipation of shortages and increasing costs of energy.

References

1. ASHRAE Guide and Data Book, 1970. Systems. Chapter 36: Snow Melting. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., N.Y.
2. Williams. G. P. Heat Requirements of Snow Melting Systems in Canada. To be published in the Proceedings of the First National Snow Conference, 16-18 April 1973, sponsored by Roads and Transportation Association of Canada, Ottawa, Canada.