Feature

Electric Heating Systems For Combatting Icing Problems On Metal Roofs

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ICICLES AND ICE DAMS MAY DEVELOP ON METAL ROOFS THAT DRAIN TO COLD EAVES. MELTWATER that backs up behind such icings may leak into buildings, causing serious damage. Large icings are also a safety hazard. Electric heating systems may be needed to provide a path for meltwater to drain safely off such roofs.

Fifteen different electric heating systems were evaluated during five winters on several buildings with severe icing problems at Fort Drum, NY. All of these buildings had standing seam metal roofs and inadequate attic ventilation. The heating systems installed in their valleys had various power outputs, layouts, and attachment methods. Most heaters were attached mechanically or adhesively on top of the metal roofing, but some were installed under it. When too much heat was generated in a valley, excess meltwater was produced and icing problems increased if the fascia was not well heated. Several techniques for heating fascias were evaluated. Heater attachment with a special silicone adhesive and low-profile perforated stainless steel clips worked well. Mechanical fasteners also worked well. Plastic clips attached with epoxy did not survive. Heaters placed under the metal roofing also worked well but were difficult to install. It was also determined that snow guards are needed to prevent heater damage by moving snow and formation of icicles on overhanging snow which bypasses the best of heating systems.

Introduction

The most effective way to reduce icings and ice dams on metal roofs is to cool the underside of its surface with outside air resulting in a "cold" ventilated roof. Paine[1] states that "roofs should not have to depend on an energy supply to work properly." We agree with that statement since most new buildings can be designed so that their roofs do not need electrical heating systems to function properly in cold climates. However, there are situations when electric heaters can be used to solve localized icing problems anticipated on new roofs and chronic icing problems on existing buildings.

Although minor icings can be caused by daytime solar melting of snow on a roof and nighttime refreezing of that meltwater, *building heat is the primary cause of ice dams and icicles on warm roofs that drain to cold eaves*[2,3]. Adding insulation to reduce heat loss from occupied spaces and heat-producing equipment in attics will help, but ventilation is still the key to a "cold" roof.

Meltwater produced from melting snow on a "warm" roof above heated portions of a building may freeze at cold eaves producing icicles and ice dams there. Meltwater that backs up behind an ice dam may leak into the building, causing serious damage and possible loss of occupancy. Some warm roofs can produce very large ice dams and icicles which are also a safety hazard (see *Figure 1*). Electric heating systems do not prevent icings from occurring. They prevent ponding behind icings by providing a path through the ice for meltwater to drain safely off such roofs. This greatly reduces the size of the icing and the risk of roof leaks.

Standing seams on metal roofs direct the flow of snow, ice and meltwater directly downslope along the seams. That flow pattern is complicated by valleys and obstructions (e.g., vents, dormers, and snow guards). Standing seams are in the way of most traditional heater layouts. Zigzagged loops of electric heaters must either go up and over each standing seam or be placed on the flat panel between them. Generally, holes should not be drilled in metal roofs for mechanical attachment of electric heaters. Adhesive attachment to metal roofing is difficult. Creeping and sliding snow

Figure 1. Severe, problematic icings and ice dams along eaves of a dining facility at Fort Drum in upstate New York.

and ice removes anything not well attached.

When using electric heaters, meltwater from the warm roof above and that produced by the heater must be kept from freezing on lower portions of the roof. This is difficult to do since these conductive metal surfaces are exposed to cold air and wind. Icings on building walls and on walkways or parking areas below also need to be prevented.

Types of Electric Heaters

Henry[4] provides a summary of the various types of electric heaters, listing some of their advantages and disadvantages. Electric resistance heaters are available for 110 and 220 volt systems in a variety of heat outputs. Most constant wattage heaters cannot be overlapped, since they will burn out at the hot spot created. Mineral-insulated, constant-wattage heaters are available with metal sheathing. They are quite durable, but since they are custom-made to length, they are rather expensive. Plastic-sheathed, constant-wattage heaters are also available. Some must be custom-made, but others can be cut to length in set increments. Plastic-sheathed, self-regulating heaters can be cut to any length and can be overlapped without creating problems. They are generally more expensive than plastic-sheathed, constant-wattage heaters.

The authors chose to use 110 volt plastic-sheathed, self-regulating electric heaters with outputs from 10 to 66 watts per meter (3 to 20 W/ft). The ability to safely overlap such heaters and their ability to be cut to any length were important attributes. Ground fault interrupters were used on all circuits.

Icing Problems at Fort Drum

Many new standing seam metal roofs at Fort Drum, near Watertown, NY, suffered from severe icing and leakage problems (*Figure 1*). The authors determined the primary cause to be excessive attic heat[3] and developed natural and mechanical attic ventilation improvements that solved most of these problems.

Several new buildings contained significant heat-producing mechanical equipment in their attics. The authors were concerned that these roofs would be difficult to keep cool by improving attic ventilation only and that they might require electric heaters in their valleys. Many valleys were also difficult to drain, due to a parapet wall ending at their lower ends. *Figure 2* shows an icing at a typical valley-parapet intersection (shown in *Figure 3*) that constricts the flow of snow, ice, and meltwater. Many roof leaks occur here (even in the summer) since it is a difficult place to waterproof. The authors worked with Public Works personnel at Fort Drum to develop and test ways of heating these constricted valleys to provide a meltwater flow path through the icings there.

Figure 2. Large ice dams and icicles form where the gable parapet ends at the bottom of valleys.

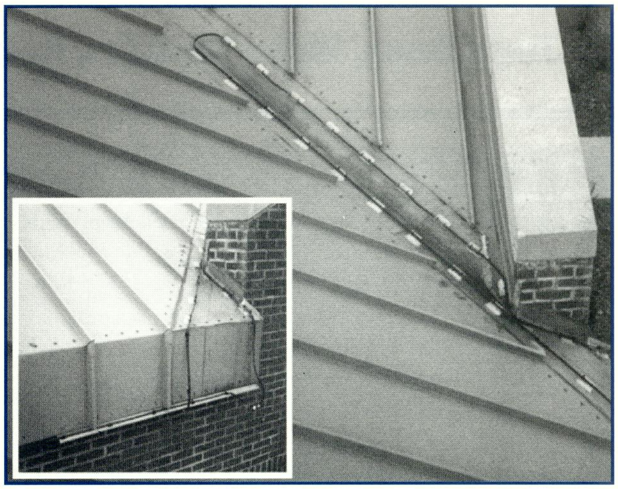

Figure 3. System with single heater loop in valley. Inset shows heater runs on the fascia and drip edge at this location.

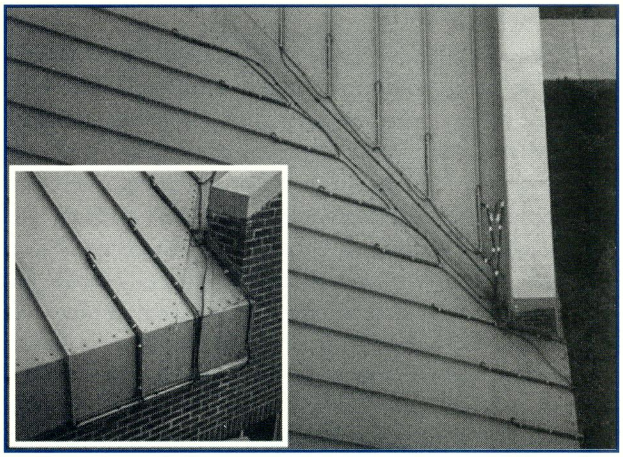

Figure 4. System with multiple heater runs in the valley, behind the parapet and on several standing seams. Inset shows heater runs at its fascia and drip edge.

Electric Heaters Installed for the Winter of 1991-'92

The authors chose six similar buildings with 27° (6:12) roof slopes and the same solar aspect to test the electric heater systems. The gable parapet at the front of these buildings constricted a valley at each end (*Figure 2*). An electric heater was installed in the left valley on each building and the adjacent unheated right valley was used as a control. The structural standing seam metal roof on these buildings had flat-topped standing seams. The 20-mm- (0.8-in.-) wide, 51-mm- (2-in.-) high seams were spaced 0.5 m (20 in.) apart. Power consumption and air and roof surface temperatures were recorded using dataloggers. Periodic photos were obtained by the authors and Public Works personnel.

Six heating systems were installed by a contractor from Dec. 30, 1991 to Jan. 4, 1992. They had various power outputs, layouts and attachment methods as summarized in *Table 1* (Note: power outputs are defined in Note 1 on *Table 1*). The authors

Building #	10110	10120		10130	10210	10220	10230
Heater located *above* or *below* metal roofing	Above	Below in Valley	Above on Fascia	Above	Above	Above	Above
Power Output (see Note 1)	Medium	High	Medium	Medium	Medium	Low	Medium
Heater Layout (see Note 2): Number of heater loops in valley Number of heater runs behind parapet Number of heater loops up and over seams	 2 2 13	 See Note 3	 0 1 2	 1 0 0	 1 0 0	 1 2 2	 1 2 2
Heater length, m. (Heater length, ft.)	46.9 (154.0)	34.6 (113.7)	13.5 (44.3)	12.9 (42.3)	12.8 (42.1)	22.9 (75.0)	22.4 (73.4)
Avg. heater wattage (if measured) from 3/3-4/8/92	907	1649	273	263		316	468
Average watts per meter (Average watts per foot)	19.3 (5.9)	47.4 (14.5)	20.2 (6.2)	20.4 (6.2)		13.8 (4.2)	20.9 (6.4)
Plastic mounts adhered with epoxy (Number failed - see Note 4)	44 (17)		36 (25)	10 (4)	30 (30)	18 (16)	60 (52)
Angle clips adhered with silicone (Number failed - see Note 4)	3 (1)			24		42 (1)	
Heater adhered with silicone only	10						
Stainless steel loop clamp mechanically attached (Number failed - see Note 4)	87		1	2	2	5	5 (1)

Notes

1. Manufacturer's power output ratings for self-regulating electrical heaters were:
   High: 65.6 W/m (20 W/ft) on an insulated metal pipe at 10 degrees C (50 degrees F)
   Medium: 32.8 W/m (10 W/ft) in ice at 0°C (32°F) or 16.4 W/m (5 W/ft) in air at 0°C (32°F)
   Low: 9.8 W/m (3 W/ft) on an insulated metal pipe at 10°C (50°F).
2. All heater layouts also had a single run of heater either under or on the drip edge at the base of the fascia.
3. There were four runs of heater under the metal roofing in this valley (two runs in the metal decking flutes on the parapet side of the valley and two runs [i.e., one loop] covered with insulation under the metal decking on the eaves side of the valley).
4. The number of attachment failures is given in parentheses below the total number of attachments (e.g., "(17)" means that 17 plastic mounts failed). If there is nothing in parenthesis, nothing failed.

Table 1. Electric heaters installed during winter 1991-92.

chose to demonstrate a range of electric heating systems from little heat to what was expected would be too much heat (this was the amount the industry was recommending at the time). *Figure 3* shows a system with only a single loop of heater in the valley, two heater runs on the fascia, and a heated drip edge. *Figure 4* shows a system with multiple heater runs in the valley, on the standing seams approaching the valley, behind the parapet, on the standing seams at the eaves, on the fascia and on the drip edge. Another high-powered system is shown in *Figure 5* where most of the heater was installed below the metal roofing. Two runs of high output heater were placed in the flutes of the metal decking supporting that valley (left side of *Figure 5*). On the other side of that valley, a loop of high-output heater was run down and back up under the insulation shown strapped to the bottom of the metal decking. These heaters ran about 7.6 meters (25 ft) up the valley. The area behind the parapet, and the fascia and eaves were heated with medium-output heater adhesively attached to the outer surface of the metal roofing. All six systems had a run of heater along the drip edge similar to the one shown in *Figure 6* and vertical runs of heater on the fascia with drip loops provided at their lower end.

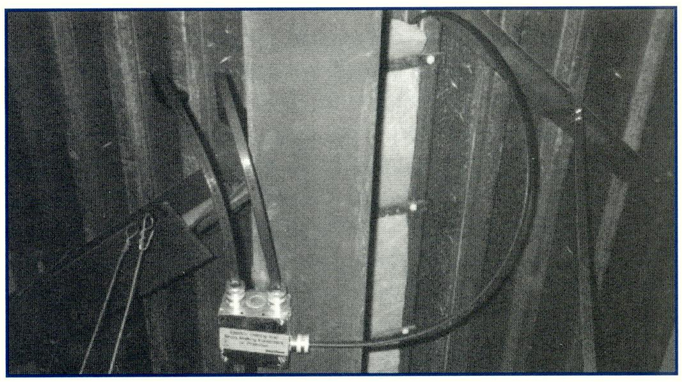

Figure 5. System with high output heater installed below the metal roof in a valley.

Figure 7 shows the four attachment methods used to secure the electric heaters to the metal roof and fascia. Small, commercially-available 25-mm- (1 in.-) square black nylon mounts adhered with epoxy were used to reduce the visual impact of the heaters at all fascias (*Figures 6 and 7a*). Heaters were attached to these mounts with black nylon cable ties. Black nylon cable ties are UV resistant, whereas white cable ties are not. Larger perforated stainless steel angle clips were adhered with a neutral-curing silicone adhesive (*Figure 7b*) that pro-

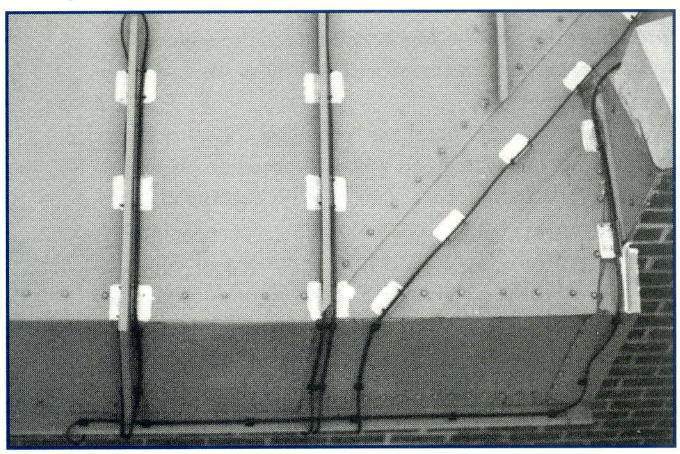

Figure 6. Typical attachment of nylon mounts to fascia with epoxy. Angle clips on the roof itself are attached with neutral-curing silicone. Note horizontal heater all along drip edge.

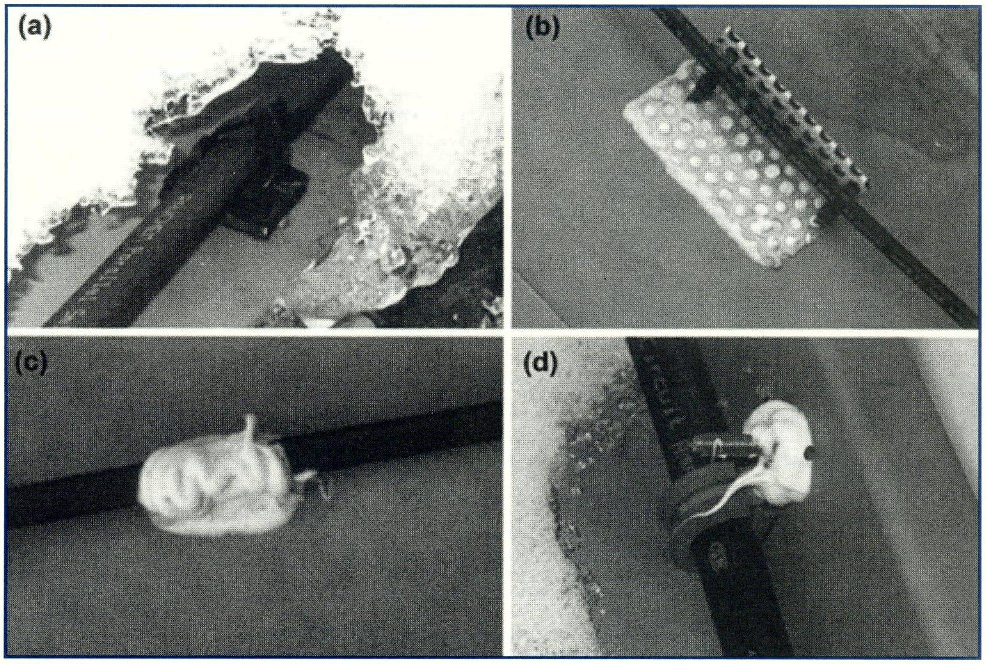

Figure 7. Heater attachments: (a) epoxy adhered plastic mount, (b) angle clip adhered with neutral-curing silicone, (c) heater adhered with silicone only and (d) mechanically attached stainless steel loop clamp high on the standing seam.

duces methyl alcohol as a by-product of curing rather than acetic acid, which is corrosive. Even though our metal roofs had a polyvinylidene fluoride ("Kynar") coating, there are cut edges and scratches that would rust when exposed to acid-curing silicones. Neutral-curing silicones are used extensively by the electronics industry, but the silicones used by the construction industry are of the acid-curing variety. Neutral-curing silicones are much more expensive than acid-curing silicones. Silicone adhesives are flexible, which is an advantage since the metal panels flex with diurnal and seasonal temperature changes and roof traffic. During application, this neutral-curing silicone flowed slowly and evenly when pressed between the clip or mount and the metal roof and had sufficient uncured stiffness to hold the fastener in place until it cured. Silicones like the "hardware store" acid-curing variety flow out too fast and leave air bubbles or gaps. Metal roof surfaces were cleaned with isopropyl alcohol and allowed to dry before adhesive attachments were made. Tooling was not done for any adhesively-applied fastener.

The angle clips were made from perforated 0.95-mm thick (20 gauge) stainless steel with 6 mm (1/4-in.) diameter holes on 10-mm (3/8-in.) staggered centers. The surface that was adhered to the metal roof was about 50 by 100 mm (2 by 4 in.). The heating cable was held in place by two cable ties through the upstanding perforated leg of each angle clip (*Figure 7b*). The simplest adhesive method used to fasten the heater was to place it in puddles of the special silicone (*Figure 7c*). The authors didn't have high hopes for this method but felt it should be tested. The mechanical fasteners consisted of commercially-available stainless steel loop clamps with extruded rubber cushions. These loop clamps were attached high on the standing seams with stainless steel bolts (*Figure 7d*). The holes drilled through the seams for these bolts were sealed with silicone. On the fascia and under the eaves, the loop clamps were fastened with stainless steel self-drilling screws.

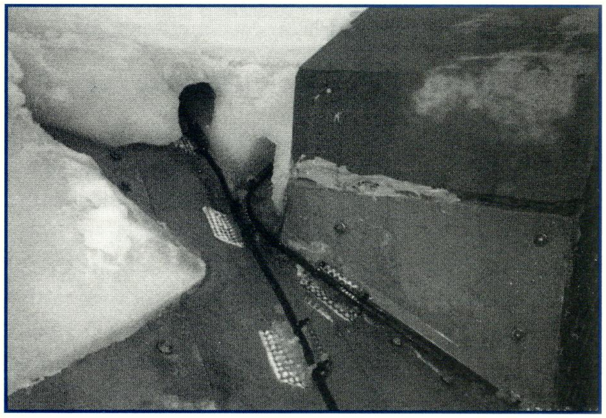

Figure 8. Heaters provide melt paths through snow and ice for meltwater to drain off the roof. Some ice was removed to expose these paths for this photo.

Thermostatic control was provided for all systems so their heaters energized when the outside air temperature was below 4.4°C (40°F). The authors chose this setting to ensure that the system was on when icing conditions were occurring. A setting of 0°C (32°F) was not used since the controllers were not very accurate and they were not located where the problematic icings would occur. The controllers were located under the eaves on the north side of each building. They were checked after installation to ensure proper operation.

Figure 9. (a) Large icicle created by a high-powered valley heater and (b) three days later, its remnant hanging from the displaced (but still operating) heater.

Building Number	10110	10120	10130	10210	10220		10230	10150 (See Note 1)			
Valley (NE, NW, SE, SW)	SW	SW	SW	SW	SW	SW	SW	NW	NE		SE
Heater located *above* or *below* metal roofing	Below. See Note 2	Below. See Note 2	Above	Above. See Note 3	Above	In box below gutter	Above. See Note 3	Above. See Note 3	Above	On Drip Edge	Below. See Note 4
Power output (See Note 5)	Medium	Medium	Medium	Medium	Low	High	Medium	Medium	Medium	High	Medium
Heater Layout (See Note 6): Number of heater runs in valley Number of heater runs behind parapet. Number of heater runs on fascia.	2 1 7	2 1 9	2 0 8	2 0 20	2 2 2	See Note 7	2 2 6	2 2 12	2 2 2	See Note 8	1 0 10
Heater length, m. (Heather length, ft.)	16.6 (54.5)	16.5 (54.0)	13.0 (42.8)	19.5 (64.0)	11.3 (37.0)	2.4 (8.0)	11.9 (39.0)	14.7 (48.2)	10.0 (32.8)	3.0 (9.7)	8.0 26.2
Average heater wattage from Nov. 21, 1992 to April 26, 1993	270	296	308	386	287		291	295	411		148
Average watts per meter (Average watts per foot)	16.2 (4.9)	18.0 (5.5)	23.6 (7.2)	19.8 (6.0)	20.9 (6.4)		24.5 (7.5)	20.1 (6.1)	31.8 (9.7)		18.5 (5.7)
Percent of time that heaters were on from 11/21/92 to 4/26/93	82	86	87	74	86		87	93	93		93
Angle clips adhered with neutral-curing silicone (See Note 9)			18 white		20 white				3 gray		
Plastic mounts adhered with gray neutral-curing silicone			21								
Stainless steel loop clamp mechanically attached				5	5		1	3	2	1	
Dome clips adhered with gray neutral-curing silicone (Number failed - See Note 10)							17	21 (5 ties)	16 (2 ties)		
Cable ties through drip edge (Number failed - See Note 10)			5							13 (2)	
Butterfly clips mechanically fastened				17			6	9			15
Channel clips adhered with gray neutral-curing silicone				12							
Tunnel clips adhered with gray neutral-curing silicone				9							
Cable ties through water diverters			5	9				2	3		

Notes:
1. Dining Facility with severe icing problems. All other buildings are Headquarters Buildings with icing problems concentrated at their constricted valleys.
2. Valley heater runs were placed below the metal roofing in the downslope oriented flutes of the valley metal decking. The plywood sheathing behind the fascia metal was routed out, the heater laid in these channels and carefully stapled in place. Upper loops from the heater fascia runs were held tight to the sloped metal roofing near the end of the parapet by aluminum tape and strapping to the metal decking.
3. Heaters on the fascias of these buildings were looped over butterfly clips mechanically attached to the metal fascia and then covered with a false fascia, either closed at the top (Buildings 10150 NW and 10210) or open at the top like a chimney (Building 10230).
4. The single run of valley heater was placed below the metal roofing. The plywood behind the fascia metal was rotten and had to be replaced. The heater runs were looped over butterfly clips mechanically attached to the new piece of plywood installed at the fascia.
5. Manufacturers' power output ratings for self-regulating electric heaters are as in Table 1.,Note 1.
6. All heater layouts had a single run of heater under the drip edge at the base of the fascia except for the gutter layout on Building 10220. Water diverters were used to keep meltwater flowing over heated areas only.
7. A gutter was installed near the top of the fascia and a *high* power heater was placed within a box under the gutter to keep it warm.
8. There was only room for two runs of heater on the fascia between the first standing seam and the parapet. Meltwater coming down this valley had a very narrow drainage path. A single run of *high* power heater was placed under the drip edge at this valley.
9. The angle clips on Buildings 10130 and 10220 were adhered during the winter of 1991-92 with a *white*-colored neutral-curing silicone. The angle clips in the northeast valley on Building 10150 were adhered with a *gray*-colored *high-strength* neutral-curing silicone.
10. The number of attachment failures is given in parenthesis below the number of attachments (five ties means that five cable ties broke). If there is nothing in parenthesis, nothing failed.

Table 2. Electric heaters installed during winter of 1992-'93.

Findings After the First Winter

All six electric heater systems provided melt paths through the ice dams in their valleys and prevented ponding from occurring there (*Figure 8*). In most cases, this greatly reduced the size of the icings and the risk of roof leaks. Roof leaks were reported under control valleys that winter but not under the heated valleys.

The weak link on all six electric heater systems was that not enough heat had been provided at their fascias and drip edges. Our systems did not prevent ice from forming on either side of heaters placed on the fascia. Ice accumulated there resulting in large icicles and icings hanging from the fascia and drip edge (*Figure 9a*). When those icicles broke free, they pulled the heater off the fascia and drip edge. Some icicles hung from the heaters as they melted free (*Figure 9b*). This damaged the plastic sheathing on those heaters as they were pulled through the well-secured mechanical fasteners.

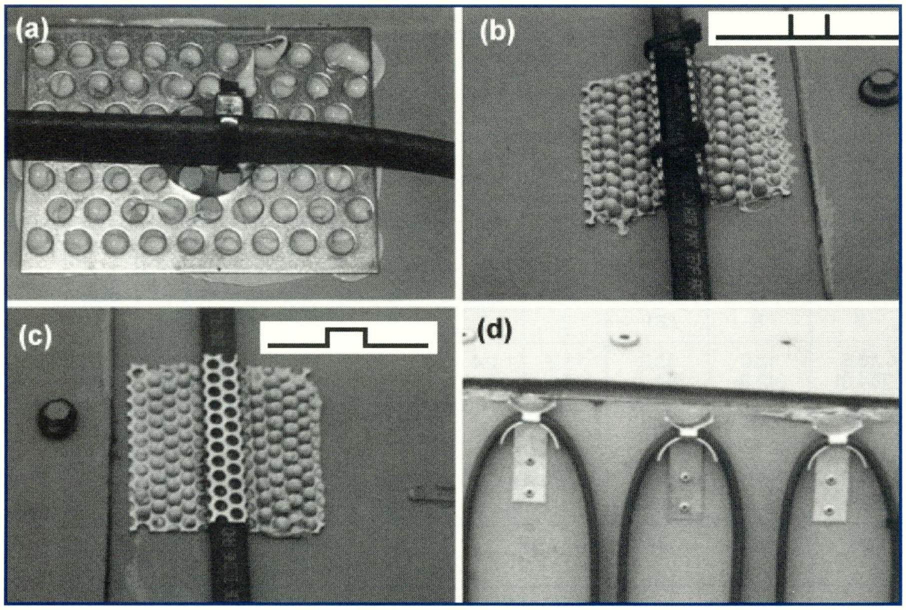

Figure 10. Heater attachments adhered with high-strength, neutral-curing silicone are: (a) dome, (b) channel, and (c) tunnel clips. The commercially-available butterfly clip (d) was mechanically attached with rivets or screws.

The weakest attachment method was the nylon mounts adhered with epoxy. By the end of the winter, 73 percent of them had failed (*Table 1*) and heaters were hanging down from all six test valleys. Some of the epoxy failed adhesively at the nylon mount, but most failed at the coated metal roof. The mechanically-attached loop clamps worked quite well and can be used wherever holes can be accepted. One mechanical loop clamp failed when a large icicle with a fascia heater embedded in it fell off the roof, pulling that clamp out of the weak soffit screening. The adhesively-attached perforated angle clips also worked well. Sliding snow and ice bent them over, but most remained in place. Two failed adhesively when sliding snow and ice from the roofs above took them out. A lower profile clip may have survived. None of the silicone puddles holding a heater loop on the roof behind a parapet failed. Their success was related to three angle clips (one which failed due to sliding snow) on the same heater loop that provided most of the resistance.

Electric heaters placed under the metal roofing of one valley (*Figure 5*) kept a wide, clear melt path down the valley. However, the 1649 watts provided in that valley (*Table 1*) was too much and it melted more snow than was necessary. That extra meltwater refroze on cold portions of the fascia and created a large, dangerous icicle (*Figure 9a*), even when no icings were forming on the control valley. The authors concluded that too much heat was provided in all valleys. Meltwater was produced by the heaters even when it was too cold outside for the warm roofs of these buildings to be producing meltwater. The low output heater used on one roof provided enough heat to create a melt path through the ice dam and to avoid ponding there.

The authors found that meltwater rarely flows off the roof along the heater. It flows along the cold edges of the melt path and under any ice near those edges. If the meltwater was not directed where it was intended to go, it refroze on the fascia, which was undesirable.

Electric Heaters Installed for the Winter of 1992-'93

Based on the findings from the previous winter, the authors tested alternative methods of adhesively attaching heaters, better methods of heating the fascia, and ways to direct meltwater down the fascia to a heated drip edge and then away from the walls below. Valley heater runs were shortened to reduce their contribution to the meltwater produced on the roof. Additionally, methods of placing heaters under the metal roofing were investigated further.

The authors installed nine heating systems from Oct. 21 to Nov. 20, 1992. They had various power outputs, layouts and attachment methods as summarized in *Table 2* (Note: power outputs are defined in Note 1 on *Table 1*). New heater systems replaced all or portions of the six systems used in 1991-'92. New systems were installed in three constricted valleys of a dining facility with its fourth valley used as a control. Roof slopes on the dining facility were 18° or 4:12. Thermostatic control for all systems was the same as that used during the previous winter (i.e., "off" when it was warmer than 4.4°C (40°F) outside). Air and roof surface temperatures and power consumption were again measured using dataloggers. Periodic photos were taken by the authors and Public Works personnel.

Stainless steel loop clamps fastened with screws were again used to fasten heaters to fascias and soffits. An even higher-strength, neutral-curing silicone was used for all adhesive attachments. Its gray color more closely matched the color of these metal roofs. The heater on one fascia was attached with this silicone using the same black nylon mounts which had previously failed when adhered with epoxy. After four winters, none of them had failed. *Figure 10* shows the four new attachment methods used in 1992 to secure electric heaters to the metal roof and fascia. Three new perforated stainless steel clips were designed and built for attachment with the higher-strength, neutral-curing silicone. The authors called one the "dome" clip (*Figure 10a*), as it has a 25-mm- (1 in.-) diameter, 6-mm- (1/4 in.-) high dome in the center of a flat, 66 by 89-mm (2.6 by 3.5-in.) perforated plate made from the same material as the angle clips used the previous year. The other two clips were made from perforated 1-mm-thick (20-gauge) stainless steel with 5-mm- (3/16 in.-) diameter holes on 6-mm (1/4 in.) staggered centers. One clip was bent into a channel shape with walls sticking up 16 mm (5/8 in.) on both sides of the channel where the heater was placed (*Figure 10b*). The other clip was bent into a 5-mm- (3/16 in.-) high, 13-mm- (1/2 in.-) wide tunnel that just fit over the electric heater (*Figure 10c*). The bottom of both clips was about 76 mm (3 in.) square. The surface adhered to the metal roof on both clips was somewhat less, as silicone was not placed under the heater.

During installation of the tunnel clips, adhesive was applied to them, they were placed over the heater, and the assembly temporally held in place with tape until the adhesive cured. All other adhesively-applied clips and mounts could be placed on the metal roof and the adhesive allowed to cure before the heater was attached to them with one or two black nylon cable ties. The last attachment method shown in *Figure 10d*, the butterfly clip, is a commercially-available soft steel clip used to secure heaters to asphalt shingled roofs. The authors used it to loop heaters up and down across the face of fascias. The butterfly clips were attached with screws or rivets, depending on the fascia material.

Heater loops installed under the metal roofing were sometimes taped in place with aluminum foil tape. The authors used a variety of methods to secure heaters as the situation demanded (e.g., duct tape, tucking the heater behind parapet flashing, and cable ties to secure heater loops to each other).

To keep meltwater from reaching cold portions of the metal roof (fascias in particular), water diverters of aluminum angles were made. Drip edge extensions were made from metal roofing to "kick" water further away from the building. Cable ties were used to secure heaters to water diverters on the sloped metal roofs and to drip edges or drip edge extensions at the base of fascias.

Two valley heaters were reattached to some of the remaining angle clips that had been adhered with white silicone the previous winter. Other valley heaters were adhesively secured with channel, dome or tunnel clips using the high-strength gray silicone after the roof surface was cleaned as mentioned before. Three valley heaters were placed below the metal roofing, either in the downslope-oriented flutes of the metal decking directly below or between the metal roofing and another layer of metal valley flashing placed over the cross-slope-oriented metal decking on the dining facility. It was quite easy to feed the heater down the flutes of the metal decking, but very hard to place it between the metal surfaces in the valley of the dining facility.

For aesthetic and thermal efficiency reasons, some heaters were placed behind the metal fascia. On two buildings, plywood sheathing behind the metal fascia was routed out and the heater carefully stapled in these channels (*Figure 11*). Upper loops from the heater's fascia runs were held tightly to the sloped metal roofing. The end of the heater ran horizontally at the bottom of the fascia to warm the drip edge. When the metal roofing was replaced, these two buildings had all their heaters located below the metal roofing. This was difficult to do but it was tried for the aesthetic, maintenance and thermal efficiency benefits gained.

Heater runs on the fascias of three buildings were looped over butterfly clips mechanically attached to the metal fascia (*Figure 12*) and then covered with a false fascia, either closed at the top as shown in *Figure 13* (Buildings 10150 NW and 10210) or open at the top like a chimney (Building 10230). Installation of heaters and false fascias was much easier than placing heaters behind existing fascias. False fascias also allow for easier access if repairs are necessary. Heated water diverters were used on all roofs to direct meltwater flow over the heated fascia and drip edge. A diverter is shown at each end of the false fascia in *Figure 13*. Diverters were able to prevent icings just beyond heated portions of fascias.

A small gutter (open at one end) was installed near the top of the fascia on one building, and a high-power heater was placed within a box under the gutter to keep it warm. This assembly was relatively easy to construct and install. It redirected meltwater away from the cold fascia but looked out of place on this building.

Figure 11. Heater laid in channels routed in the plywood sheathing behind the fascia metal.

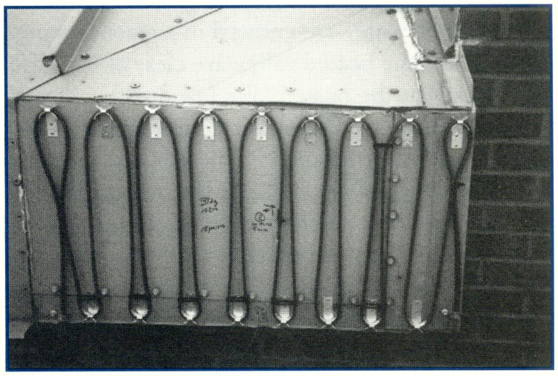

Figure 12. Heater looped over butterfly clips mechanically attached to fascia.

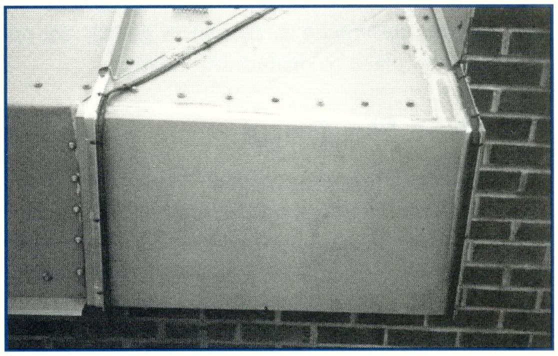

Figure 13. False closed-top fascia installed over heater shown in Figure 12. Note heated vertical baffles (water diverters) at each end.

Findings After the Second Winter (1992-'93)

All nine electric heater systems provided meltwater paths at the lower ends of their valleys. However, on the dining facility with its very hot attic, meltwater froze all along the unheated eaves, creating large ice dams and icicles (similar to those in *Figure 1*) that encroached upon the heated meltwater paths down the valleys. Meltwater that left the roof at the heated valleys dripped onto the encroaching icicles, causing them to grow much larger. This resulted in a massive icing that descended from the eaves to the ground at the southeast valley of the dining facility even though the heated path at that valley remained open essentially all the time. The dining facilities needed heaters all along their eaves, not just in their valleys, or they needed much improved attic ventilation.

There were no adhesive failures of any clip or mount during the second winter. The only failures were several broken cable ties, mostly on dome clips on the dining facility which experienced severe icing.

Electric heaters installed under the metal roof worked well, as did all false fascia systems. False fascias that are closed at the top worked better than the open "chimney" type and were also more robust. *Figure 14* shows a typical comparison of heated and unheated (control) valleys on a test building. The eaves below the unheated valley are encased in a massive icing. The eaves below the heated valley are clear of ice. The ice-free fascia was the heated false fascia with a closed top, shown in *Figure 13*. The gutter design also worked fine but did not fit the aesthetic look required for these buildings. The exposed fascia heater looked unattractive (*Figure 15*), but it also performed well. The ability of all of the heater systems to prevent icicles suffered when snow and ice overhung the heaters as shown in *Figure 15*. The overhangs were created by creep of snow and ice extending beyond the fascia 0.3m (a foot) or more. Meltwater tended to flow within and on the underside of these overhangs instead of over the heated path down the fascia. This bypassed the heating system and created dangerously large icings. These observations convinced us that snow guards are needed to hold snow in place to protect the heaters.

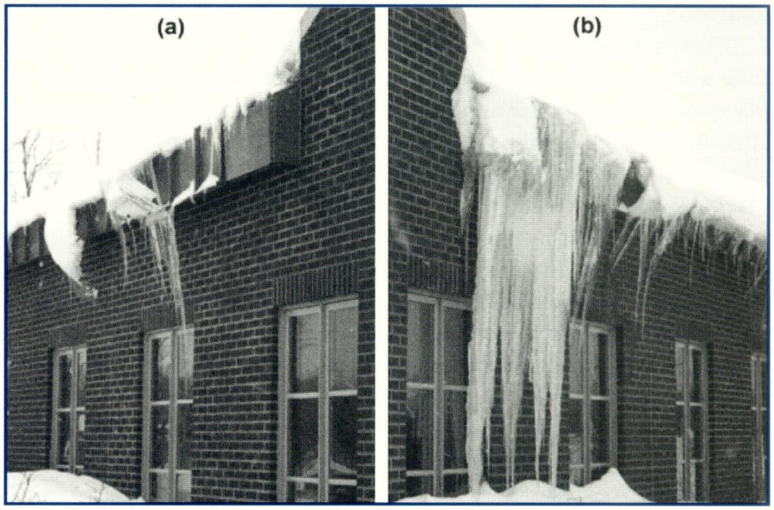

Figure 14. Comparison of heated and unheated valleys at Building 10210 on Feb. 22, 1993: (a) Heated valley and heated false fascia clear of ice. (b) Adjacent unheated valley and fascia encased in ice.

Figure 15. Icings forming on a creeping, overhanging mass of snow and ice, bypass the heated fascia on this building. Note exposed heaters at near end of fascia.

Further Findings

Attic ventilation improvements recommended by CRREL were completed on the dining facility (Building 10150) during the summer of 1993. The following winter, the three electric heater systems on that roof were able to cope with the greatly reduced rate of meltwater production from the much cooler roof. Large icicles and ice dams did not form all along the eaves as in the past. This clearly illustrates how effectively a "cold" ventilated roof can reduce icings and ice dams, at times obviating the need for electrical heaters. The three valley heaters on this roof have been left on to provide comparisons with unheated valleys of nearby dining facilities now having improved attic ventilation. Those studies suggest that electric heaters are no longer needed in any of these valleys.

Snow guards were added to several electric heater systems over the next two winters[3,5,6] All nine heating systems and their snow guards were maintained and studied every year through the winter of 1995-'96 (i.e., three more winters). All externally-attached heaters at Fort Drum required some repair after each winter. Sliding snow and ice was the main problem. Snow guards were effective in reducing damage to heaters. However, maintenance and contractor personnel also caused damage when fixing roof leaks or climbing up on the roof over the heaters. Heaters installed under the metal roofing required no repairs.

The dome clip attachment method continued to suffer from broken cable ties which had to be replaced often. The angle, channel, and tunnel clips provided better mechanical support and resisted downslope movement of the heater, even when a cable tie broke. These perforated clips let the silicone adhesive squeeze through their perforations as shown in *Figures 10a, 10b and 10c*. This allowed the adhesive to cure better and provided some mechanical connection between the adhesive and clip.

The leaky valley-parapet intersections on the test buildings all required repairs to stop leaks. They were patched with roofing cement, special coatings, and rubber (EPDM) membranes. The heaters were inadvertently embedded in roofing cement, which is not acceptable (the authors pulled them out). If a heater was in the way of maintenance work, it was removed and replaced after the leak was fixed. White cable ties and ordinary "hardware store" acid-curing silicone were used to reattach the heaters. None of these replacements lasted more than two winters. The leaky valley-parapet intersections at Fort Drum still require maintenance that interferes with the surface-mounted electric heaters used there. Attic ventilation improvements[3] were so successful that the need for electric heaters was largely eliminated. Small ice dams and icicles still occur occasionally on these roofs, but they are no longer problematic and can be tolerated.

Conclusions and Recommendations

- Meltwater is produced when snow melts on warm portions of roofs. If it can freeze at cold eaves, icings and ice dams are produced. Meltwater that backs up behind these dams may leak into buildings, causing serious damage.
- Adding insulation will reduce icings and ice dams on a sloped metal roof, but the most effective measure is to provide ventilation to cool the underside of the roof with outside air, creating a "cold" ventilated roof.
- Electric heating systems do not prevent icings from occurring. They prevent ponding behind the icings by providing a path through the ice for meltwater to drain off such roofs.
- Meltwater must be kept from freezing until it leaves the roof. Consequently, fascias and drip edges over which meltwater flows must be heated. Warm baffles (water diverters) are often needed within heated zones to prevent lateral movement of meltwater to cold areas where icicles will form. Heater intensities of 225 to 591 W/m^2 (21 to 55 W/ft^2) were used with success on fascias at Fort Drum. Heaters were run directly on or under drip edges.
- Meltwater control should continue beyond the eaves to avoid problems such as icings on walls, walkways, and parking areas. In some instances, this may require the use of electrically-heated gutters and downspouts.
- Large arrays of heaters or high-powered heaters are not needed in valleys. When too much heat is generated in a valley, excess meltwater is produced and problems may increase. One run or a single loop of low to medium-wattage heater is enough. It should run up the valley until it is, at least, upslope of vertical planes located 0.3m (1 ft) inside the interior surfaces of the heated exterior walls of the building.
- If heaters are needed all along eaves, low to medium-wattage heaters are usually sufficient. They should extend upward over the heated portion of the building (see above bullet on valley heaters) and may be best placed on either side of every other seam to provide one drainage path at the base of each metal panel. Methods for creating a proper drip loop at the lower ends of each heater and preventing icicle formation at the eaves or on the fascia on either side of such heaters are being studied.
- It is usually difficult to place heaters under metal roofing after it is constructed, but for aesthetic, durability and thermal-efficiency reasons, that is the preferred location.
- Plastic-coated, self-regulating heaters can be cut to length on the job and overlapped without burning out. During startup, such heaters use up to three times as much electricity as they do once warm. Even when warm, out on a cold, windy roof, their power consumption may be somewhat more than their rated capacity. These increases must be considered when determining the amount of heater each electrical circuit can carry. Design charts of some manufacturers account for this.
- Electric heaters can be used on the top side of metal roofs. They can be attached with penetrating mechanical fasteners, but holes for such fasteners should not be placed where meltwater flows on the sloped metal roof. They should be placed up on the standing seams. Because of the flexible nature of metal roofing, rigid adhesives such as epoxy should not be used. Common "hardware store" acid-curing silicone rubber adhesive (about $4 per tube) is weak and chemically inappropriate. It seldom lasts long. Special "neutral-curing" silicone (about $40 per tube) works well. Direct attachment of the heater in puddles of silicone is difficult. No failures were experienced, but our test of this attachment system was in a relatively protected area so we are reluctant to recommend it. Use of plastic mounts or perforated metal clips about 0.3 m (1 ft) apart to hold the heaters on the roof is recommended. Low profile clips that grip the heater, provide lateral support and keep it in contact with the metal (e.g., those shown in Figures 10b and 10c) are preferred over clips that use cable ties to hold the heater up off the ro of (e.g., those in Figures 7b and 10a). Cable ties resistant to UV deterioration (i.e., black, not white) should be used to attach heaters.
- Our inexpensive thermostats were used to turn heaters off when the outside temperature was above 4.4°C (40°F). That avoided having them on during warm periods but kept them on during most of the winter. The heaters were on 74 to 93 percent of the time during the winter of 1992-93, as shown in Table 2. Our concurrent attic ventilation studies on these same buildings suggest that more accurate, dual-sensor thermostats [that turn heaters on only when it is colder than about -5.6°C (22°F) outside and the metal roofing is warmer than about -1.1°C (30°F)] would result in heaters being on less than one third of the time while still solving icing problems[3]. This would save considerable electrical energy. However, since these dual-sensor thermostat settings have not been tested for control of electrical heaters, we are uncomfortable with an outside air temperature setting as low as -5.6°C (22°F). Until tests are conducted, we feel it is prudent to use an outside air temperature setting no lower than -1.1°C (30°F).
- When snow and ice protrude beyond the eaves due to creep, meltwater will run out in it and on its underside, creating large icings there until the extra weight causes the mass to break away. Snow guards are needed to hold the snow on the roof to avoid this problem and to protect the heaters.
- The roofs of most buildings in cold regions can be designed to function properly without the need of electric heating systems. However, there are situations when electric heaters can be used to solve localized icing problems anticipated on new roofs and chronic icing problems on existing roofs.

Acknowledgments

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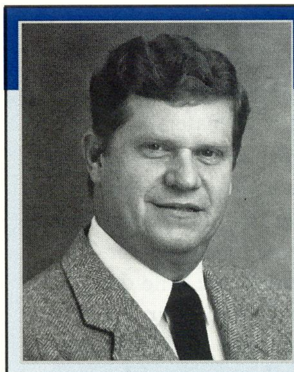
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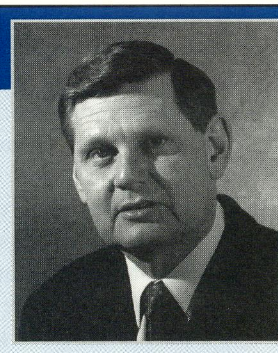
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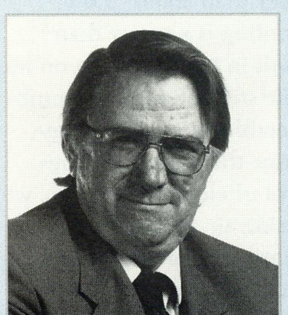
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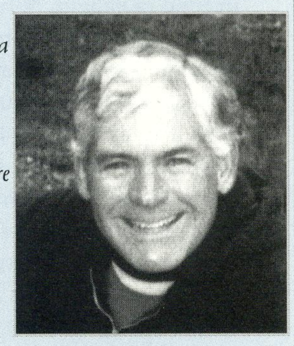
William Fyall

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RCI Interface

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RCI was chartered, in part, to bridge the gap between the seemingly disparate elements of the roofing profession. It is the intent of *Interface* to connect with these elements, educate and inform about roofing-related topics, establish a common ground for discussion, promote Institute programs, and branch out toward even more people. *Interface* is circulated monthly to over 3,000 people (nationwide and overseas) including RCI members, specifiers, facility managers, owners, industry contacts, and a growing number of highly placed professionals. *Interface* is frequently distributed at various trade shows, as well as educational and institutional functions.

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On the Cover: Dangerous ice dams form on the Cobblestone Shopping Center, Tahoe City, CA. © Rob Mackinlay. See article, page 5.

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