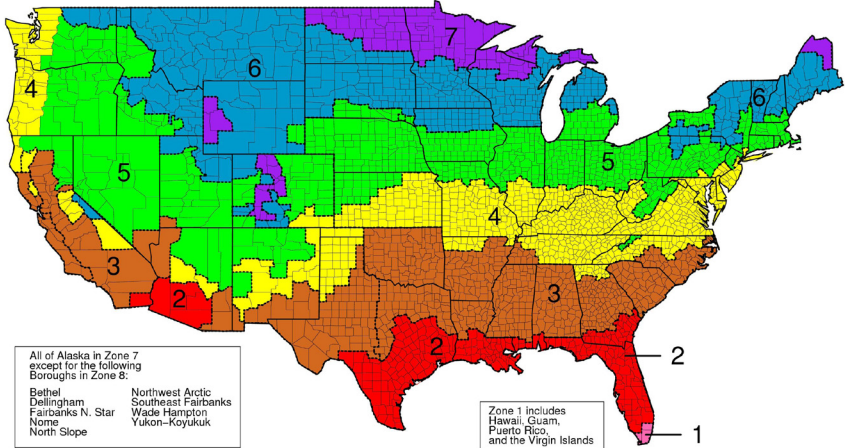


**TECHNICAL BULLETIN 19:  
OAK RIDGE NATIONAL LABORATORY HOT BOX TEST RESULTS**

The Buildings Technology Center at the Oak Ridge National Laboratory (ORNL) did steady-state guarded hot box tests in its Large Scale Climate Simulator (LSCS) in August 2006 to compare the thermal performance of a 6", R-19 draped insulation installed "over the purlin" and Thermal Design's Simple Saver System® in standing-seam metal roofs with purlins 5 ft oc. The hot box tests conclude that the "over the purlin" configuration's overall performance is only 45% of that for the Simple Saver configuration. It also confirms that the 6", R-19 draped insulation does not meet ASHRAE 90.1-2004 minimum U-value roof requirements of 0.065 (installed R-value of R-15.3) in heated and cooled metal buildings.

<b>ASHRAE 90.1-2004 BUILDING ENVELOPE REQUIREMENTS FOR CLIMATE ZONE 1-8 TABLES: 5.5-1 TO 5.5-8</b>			
<b>Nonresidential Roofs</b>			
Climate Zones	Opaque Elements	Assembly Maximum	Insulation Minimum R-value
Climate Zone 1	Metal Building	U-0.065	R-19.0
Climate Zone 2	Metal Building	U-0.065	R-19.0
Climate Zone 3	Metal Building	U-0.065	R-19.0
Climate Zone 4	Metal Building	U-0.065	R-19.0
Climate Zone 5	Metal Building	U-0.065	R-19.0
Climate Zone 6	Metal Building	U-0.065	R-19.0
Climate Zone 7	Metal Building	U-0.065	R-19.0
Climate Zone 8	Metal Building	U-0.049	R-13.0 + R-19.0

All of Alaska in Zone 7 except for the following Boroughs in Zone 8:  
Bethel, Deeringham, Fairbanks N. Star, Nome, North Slope, Northwest Arctic, Southeast Fairbanks, Wade Hampton, Yukon-Koyukuk

Zone 1 includes Hawaii, Guam, Puerto Rico, and the Virgin Islands

## Details of Test Section Construction

The test assemblies used 14 gauge steel purlins nominally 8-in. high with 2-in.-wide flanges. Two assemblies were constructed outside the LSCS to suit the 8 ft by 8 ft metered area. ORNL personnel moved the tests sections into the LSCS, instrumented them, and conducted the tests for thermal performance. The first assembly tested was the Simple Saver System with R-30 fiberglass insulation and the second assembly tested was a single 6" R-19 fiberglass blanket draped across the purlins, commonly know as "over the purlin". Post-test measurements were done of insulation thickness in the metered area and insulation thermal conductivity as a function of density. These measurements allowed the heat flow through the 8 ft x 8 ft metered area of the assemblies to be corrected to heat flow for an 8 ft x 10 ft area, yielding U-values corresponding to purlins spaced 5 ft oc in the field of a large roof.

For the fiberglass-insulated Simple Saver configuration, the fabric supported nominal R-19 unfaced blanket insulation of proper width to fit between the purlins. An additional layer of nominal R-11 unfaced blanket insulation was installed over the entire assembly, including the purlins. To form the standing-seam system, 24 gauge steel roof panels, 2-ft wide, were attached at their edges to clips and to each other. The clips were attached by screws through compressed R-11 insulation to the purlins. Standard expanded polystyrene (EPS) thermal blocks, 3/4 in. thick by 3 in. wide by 23 in. long, were laid over the purlins on top of the insulation between the clips. The R-11 insulation was also compressed between the purlins and the bottom of these thermal blocks in this assembly.

For the 6" R-19 "over the purlin" configuration, the insulation draped over the purlins was faced NAIMA 202-96 blanket insulation. The facing on nominal R-19 insulation was stretched tautly across the purlins and secured at the edges. Clips were attached by screws through the compressed R-19 insulation to the purlins. EPS thermal blocks were laid over the purlins on top of the insulation and roof panels were put in place.

Care was taken in both these assemblies to achieve the amount of sag between purlins as typically installed in the field. The amount of sag was measured by Thermal Design at seven buildings and installed in the configurations as closely as possible. Measurement of the actual sag that was achieved was not done accurately until after the tests as part of the post-test analysis.

## Instrumentation and Test Procedures

Each test assembly was lifted by crane into the LSCS. A sketch of the LSCS is shown in Fig. 3 to illustrate the placement of an assembly with the climate chamber above it and the metering and guard chambers below it. Each assembly was fully instrumented with the same set of thermocouples on the upper and lower surfaces. Within the vertical projection of the metered area, nine thermocouples were fixed to the upper surface and another nine to the lower surface. An additional four thermocouples on the upper surface and four on the lower surface were placed outside the vertical projection of the metered area near the corners of the metering chamber walls. An array of 21 thermocouples measured metering chamber air temperature about 3 in. below the top of the metering chamber. Nine thermocouples in the air 3 in. below the bottom surface of each assembly corroborated these data. They were placed at the locations of the thermocouples in the metered area on the bottom surface. An array of 25 thermocouples measured the air temperature in the climate chamber about 3 in. above the roof surface.

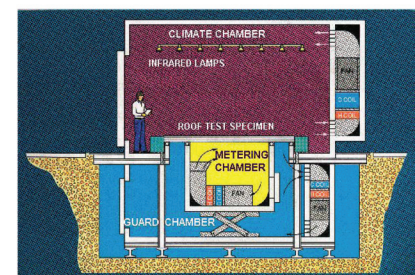
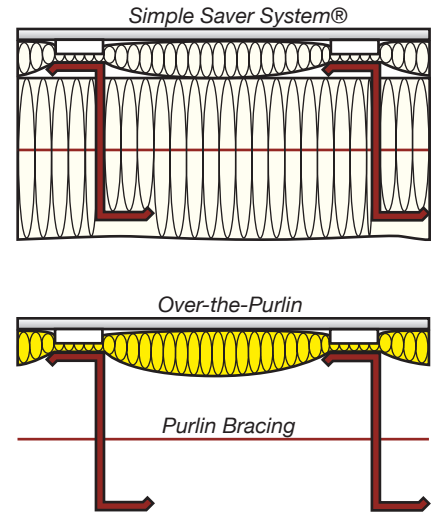


Fig. 3 Sketch of the Large Scale Climate Simulator

The purpose of the metering chamber is to obtain the energy flow through the 64 ft<sup>2</sup> of open area at its top as a result of the temperature difference imposed between the climate and metering chambers and across the test section. This energy flow is obtained by measuring all other energy flows into the metering chamber in accordance with ASTM C-1363, Standard Test Method for the Thermal Performance of Building Assemblies by Means of a Hot Box Apparatus. The energy flows include the amount across the metering chamber walls and floor due to any imbalance between the metering and guard chamber air temperatures. This energy flow was determined as a function of the temperature imbalance by previous use of a calibration panel. The energy flow through the metering chamber walls and floor is given by the sum over each face. On each wall and the floor, the average temperature difference measured by nine differential thermocouples is multiplied by the component's area and divided by its R-value. The same calibration panel is used periodically to establish the overall accuracy and precision of energy balances for the metering chamber (1). The accuracy is generally of the order of  $\pm 10\%$ . The precision is generally of the order of  $\pm 1\%$  as a result of excellent control of imposed conditions by the control system.

### Test Results

The air temperatures of 50°F imposed in the climate chamber and 100°F imposed in the metering chamber yielded a mean insulation temperature of about 75°F and a temperature difference of 45°F to 48°F from the bottom to the top of the insulation. Depending upon the configuration, 125 Btu/h to 270 Btu/h flowed upwards through the test sections.

The severe thermal bridges present in the “over the purlin” configuration are evident not only in the large heat losses, low R-values and high U-values, but also in the relatively higher temperatures of the top surface over insulation, the top surface over purlins, and the bottom surface under purlins compared to these temperatures for the Simple Saver configuration. The Simple Saver configuration had the bottom surface of the liner at the level of the bottom of the purlins. The “over the purlin” configuration had the bottom surface of the liner closer to the top of the purlins. Therefore, the temperatures of the bottom surface under insulation for the “over the purlin” configuration are slightly cooler than for the Simple Saver configuration.

At the conclusion of each test, before the test section was moved out of the LSCS, holes were drilled through the roof panels to admit a pin probe. It was used to determine depth from the bottom of the roof panels to the top of the liner or purlins. Eight holes were drilled parallel to the purlins at each location shown in Fig. 4. Each set was two holes in flat parts of each of the four roof panels within the vertical projection of the metered area. The numbers in Fig. 4 are the average of the eight measurements at each location for the fiberglass insulated Simple Saver configuration. The results are added to Fig. 4. It is assumed that the entire cavity was filled by the fiberglass insulation since it was free to expand.

Figure 5 shows the depth from the bottom of the roof panels to the top of the liner for the “over the purlin” configuration. Again, eight holes were drilled parallel to the purlins at each location shown in Fig. 5, with two of each set in flat parts of each of the four roof panels in the metered area. The numbers in Fig. 5 are the average of the eight measurements at each location for this configuration with fiberglass insulation. Unlike in the fiberglass-insulated Simple

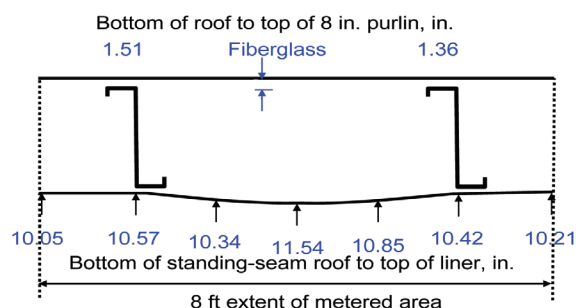


Fig. 4 Results of Pin Probe Measurements for the Simple Saver Configurations

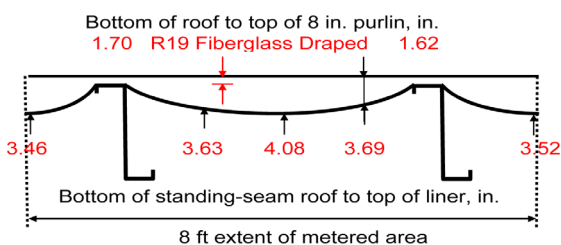


Fig. 5 Results of Pin Probe Measurements for the non-Simple Saver Configurations

Saver configuration, the insulation is severely compressed between the roof panels and the liner. The average gap from the roof to the purlins is 1.43 in. for the R-30 Simple Saver and 1.66 in. for the R-19 fiberglass draped over the purlins. The Simple Saver with fiberglass has an R-11 blanket between the clips and purlins. The draped R-19 fiberglass is between the clips and purlins. Therefore, the average gaps of 1.43 in. and 1.66 in., respectively, are also reasonable.

**Conclusion**

The hot box tests conclude that the “over the purlin” configuration's overall performance is only 45% of that for the Simple Saver configuration. It also confirms that the 6”, R-19 draped insulation does not meet ASHRAE 90.1-2004 minimum U-value roof requirements of 0.065 (installed R-value of R-15.3) in heated and cooled metal buildings.

