## *Session I-A: Roof and Attic Systems*

**Monday, December 6, 2004**
**10:30 a.m. to 12 noon**
**Grand Ballroom – Beach**

*Session Chair:*

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10:30 a.m. to 10:40 a.m. Introduction
Gerry Miller

10:40 a.m. to 11:00 a.m. *"Convection in Loose-Fill Attic Insulation—Measurements and Numerical Simulations"*
Paula Wahlgren

11:00 a.m. to 11:20 a.m. *"The Impact of Airflow on the Hygrothermal Behavior of Highly Insulated Pitched Roof Systems"*
Geert Houvenaghel

11:20 a.m. to 11:40 a.m. *"Cathedral Ceilings: A Test Building Evaluation in a Cool, Humid Climate"*
Hugo Hens

11:40 a.m. to 12:00 p.m. *"Exterior Surface Temperature and Humidity of Walls—Comparison of Experiment and Numerical Simulation"*
Andreas Holm

## Convection in Loose-Fill Attic Insulation—Measurements and Numerical Simulations

Paula Wahlgren – *Chalmers University of Technology*

The objective of this study is to investigate the influence of convection on the thermal performance of loose-fill attic insulation under realistic climatic conditions. Measurements have been performed in a large-scale attic test model to determine heat transfer through the attic floor due to convection. Natural convection occurs in low-density materials only, leading to an increase in heat flow through the insulation and, thus, to a decrease in the thermal resistance of the insulation. The measurements show that the critical modified Rayleigh number for the low-density attic insulation in the studied setup is 22 to 25. At a modified Rayleigh number of 34, the thermal resistance of the insulation in the attic test model is only 75% of the highest measured thermal resistance.

## The Impact of Airflow on the Hygrothermal Behavior of Highly Insulated Pitched Roof Systems

Geert Houvenaghel and Hugo Hens – *Catholic University of Leuven*

Arturo Horta – *DuPont de Nemours Non-wovens*

Two important design parameters in insulated sloped roofs are (1) vapor-permeable versus vapor-tight underlays and (2) ventilated versus nonventilated roof constructions. In order to study the influence of both parameters on the hygrothermal performance, highly insulated pitched roof systems were constructed at the K.U.Leuven Vliet test building. During two years of testing, their hygrothermal response has been studied in detail. The roof eaves were redesigned between the first and the second year, with the main objective being to increase their wind-tightness.

The temperature and heat flux distributions show the importance of natural and forced air convection. The impact of air transfer shows that traditional thermal performance, such as the conduction-related U-factor, no longer has a clear physical meaning. Measurements of the relative humidity fields, the moisture content in the rafters, and the occurrence of condensation confirmed the importance of air flow, not only for thermal but also for hygric performance. Air leakage measurements reveal the impact of minor perforations, with the leakage linked to the inside-outside temperature difference, wind direction, and wind speed. The air infiltration experiments show a clear relation between wind speed and direction and the magnitude and direction of the air flows in the roof sections.

The performance differences between the ventilated and the nonventilated roofs and between the roofs with a vapor-permeable underlay and those with a vapor-tight underlay are overshadowed by these air and wind flow effects. A comparison with previous test roof results also indicates that the very low density of the mineral wool used increases the importance of wind and air flow in and through the roof sections.

## Cathedral Ceilings: A Test Building Evaluation in a Cool, Humid Climate

Hugo Hens – *Catholic University of Leuven*

Arnold Janssens – *University of Gent*

This paper describes a series of field tests on four types of cathedral ceilings with six different designs. During the two years of testing, airtightness, wind washing, thermal performance, and moisture were monitored. The outside environment at the test site was representative of a cool, humid climate. Indoors, a normally heated, moderately humid environment was maintained. The test results show that airtightness and wind washing are the main elements fixing hygrothermal response. The tests nevertheless confirm that a compact cathedral ceiling, with a windtight but vapor permeable underlay, no airspace above the thermal insulation and an effective airflow retarder below, is the best choice in a cool, humid climate.

## Exterior Surface Temperature and Humidity of Walls—Comparison of Experiment and Numerical Simulation

Andreas Holm, Wolfgang Zillig, and Hartwig M. Küenzel

*Fraunhofer Institute of Building Physics*

The conditions at the exterior surface of building components with high insulation are almost independent of the indoor climate. The tiny heat flow from the interior is generally not sufficient to prevent a temperature drop below ambient conditions by long-wave emission during nighttime. Apart from energetic consequences, this temperature drop may lead to surface condensation and subsequently to soiling or microbial growth. Another factor resulting in surface temperatures below ambient conditions is the evaporation of precipitation moisture.

In order to obtain realistic surface conditions by numerical simulation, the heat and moisture transfer processes at the surface have to be modeled accurately, taking into account convective and radiative exchange as well as evaporation and condensation heat. This requires hourly climatic data including air temperature and humidity, solar and sky radiation, precipitation, wind speed and direction. These data from selected years recorded at the meteorological station of the Fraunhofer-IBP in Holzkirchen serve as input for a hygrothermal simulation tool called WUFI®. The calculated results are compared with measured surface temperatures of walls and roofs with different orientation at the Fraunhofer-IBP test site. From this comparison appropriate surface transfer coefficients for simulation tools can be deduced and the different surface humidity sources may be quantified.