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A quasi-steady-state model of attic heat transfer with radiant barriers

David W. Winiarski [a], Dennis L. O'Neal [b]

[a] *Battelle Pacific Northwest Laboratory, Richland, WA 99352, USA*

[b] *Department of Mechanical Engineering, Texas A&M University, College Station, TX 77843-3123, USA*

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Abstract

During the cooling season, heat transfer from the attic into the conditioned space of a residence can represent a significant portion of the total envelope heat transfer. Radiant barriers are one method used to reduce this heat transfer. A quasi-steady-state model was developed for predicting attic heat transfer in residences with radiant barrier systems. The model was used to estimate the reduction in cooling load that would occur with a radiant barrier and to identify important construction and environmental parameters that influence this cooling load reduction. The model's output consisted of hourly ceiling heat fluxes inside the house based on hourly weather data inputs. Model results were compared with detailed experimental results from two small test houses. The model predicted typical summer heat flux reductions of between 35 and 43% with different radiant barrier configurations and levels of insulation. These compared to measured heat flux reductions of between 29 and 37% in attics under the same conditions. Sensitivity studies were also conducted to show the effect of uncertainty in several of the important physical attic parameters on the final heat flow predictions of the model.

Keywords: Residential buildings; Envelope; Heat transfer; Computer simulation; Radiant barrier

1. Introduction

Radiant barriers are designed to reduce the radiant heat transfer that occurs between the roof deck and attic floor of a residence or commercial building. Radiant barriers are thin sheets of material having at least one low-emissivity surface. Typically, this is an aluminized foil surface bonded to paper, plastic or a reinforcing mesh for strength. The emissivity of the clean foil surface is typically less than 0.05. The barrier is placed in the attic with the low-emissivity surface facing the attic airspace. The average distance between roof deck and attic floor typically varies between 1 and 3 m in most residential buildings. Because of this, thermal radiation is the primary method of heat transfer between a hot roof deck and the attic floor. Because the heated attic air tends to stratify next to the roof deck, natural convection can usually play only a minor role in removing heat from the roof deck. The radiation blockage obtained through the use of a radiant barrier can dramatically reduce the radiant heat transfer across this airspace and thus also reduce the heat transferred to the living space.

At each attic surface, there is a complicated interplay between the heat that is conducted, radiated or convected to that surface. During daytime periods in the cooling season, heat is radiated from the roof deck downwards to the attic floor and then either convected upwards from the floor into the attic ventilating air or conducted down to the living space below. The net impact of a radiant barrier on the heat conducted into the living space depends on such variables as the conditioned space temperature, ambient air temperature, ventilation rate, solar insolation, and the absorptivities, emissivities and thermal resistances of the other attic surfaces. Accurate modeling of attic heat transfer allows prediction of the impact or radiant barriers under varying conditions.

Modeling work on attic heat transfer and radiant barrier systems began with a single, steady-state equation developed by Joy [1]. This equation assumed a flat roof and required constant values for the ventilation rate, all convection coefficients and all radiative heat transfer coefficients. The work by Joy forms the basis of the tables for effective attic resistance suggested by ASHRAE [2]. Peavy [3] developed a computer model to predict ceiling heat transfer in residential attics under different ventilation conditions. Peavy's model calculated the transient heat flow using conduction transfer functions for three attic surfaces, two roof sections and the attic floor. The gable ends were assumed to be refractory surfaces. An average sol–air temperature was used to calculate the roof temperature, and an average attic air temperature was used in calculating the heat convected to the attic ventilating air. Wilkes [4] expanded upon Peavy's model to

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