AN ENERGY AND ECONOMIC ANALYSIS OF THE BENEFITS OF RESIDENTIAL DUCT INSULATION

Robert Lucas **Mark Modera**

Burke Treidler **Jim Miller**

ABSTRACT

A significant percentage of energy expended to condition buildings can be consumed or lost in the process of distributing conditioned air to the conditioned space. This portion of building energy consumption can be categorized into three main components: (1) direct thermal losses from ducts in unconditioned spaces, either from conduction or leakage through seams and holes in the ducts; (2) associated thermal losses from interactions between the building envelope, furnace/air conditioner, and distribution system; and (3) fan motor electricity consumption.

In residential buildings, components 1 and 2 are the dominant modes and are estimated at 25% of total building heating, ventilating, and air-conditioning (HVAC) system energy use in a typical home with an air-ducted distribution system. In conduction losses, the air in the duct exchanges energy with the surroundings through the skin of the duct system. Leakage losses affect space-conditioning energy use in three ways: (1) air lost by the supply ducts is not delivered to the conditioned space, (2) the HVAC system equipment must heat or cool the air that is pulled in through leaks in the return ducts, and (3) if supply leakage exceeds return leakage, the infiltration of the house is increased. These thermal distribution system losses have been noted by many investigators. This presentation gives the findings of an extensive analysis of energy losses from ducts as a result of conduction.

In spite of the magnitude of this energy loss, current U.S. standards and codes do not yet reflect the considerable body of research pointing to the need for higher quality and efficiency in duct construction. To address these issues, a cooperative research effort between two U.S. laboratories was undertaken to identify minimum-cost duct insulation levels for residential structures in the United States. The initial phase of this project focuses on insulation levels because conduction represents a significant fraction (approximately 30%) of the thermal losses from distribution systems. This work involves two primary components: the thermal simulations that determine distribution system efficiency, and cost minimization analysis that identifies the costs of duct insulation and then establishes the minimum cost levels for U.S. climates.

The simulation tools are used to estimate the distribution system efficiencies and their sensitivities to influencing factors. Investigated factors include duct insulation R-value, duct system type and location in the prototype houses, climate and season, duct system mass, HVAC system oversizing, buffer zone ventilation, and equipment type. Approximately 150 simulations of heating and cooling a house for one year were performed in the analyses. The results of this study indicate that the duct insulation levels, duct location in the house, equipment type, climate, and degree of equipment oversizing (relative to design loads) have the most influence on the duct efficiencies.

Based on the results of the thermal analyses, a life-style cost analysis was performed using a database of distribution system efficiencies resolved by R-value, location in the building (attic, crawlspace, or basement), and equipment type for the heating and cooling season. This economic analysis was used to determine the minimum-cost duct insulation levels.

Cost data were collected on the four primary types of duct insulation sold in the United Staes: duct board, duct liner, duct wrap, and flexduct. Data were obtained from nine sources on construction costs in buildings. These data were aggregated by source and also by product type to produce an estimate of national average costs as a function of R-value per m^2 (ft^2) of duct area for a builder in 1993. Costs include materials, labor, equipment, overhead, and profit for the general contractor or builder. The cost data are merged (by R-value) with the efficiency data to establish the relationship between cost and performance. The cost/performance data set serves as input to the cost minimization.

The life-cycle cost analysis of ducts was conducted for 881 cities and five heating fuel/equipment types: oil, natural gas, liquefied petroleum gas, electric resistance, and electric heat pumps. In residential buildings, ducts are often placed in one or more of three locations outside the conditioned space: attics, unheated basements, and crawlspaces. The cost-effective insulation levels for all three of these duct locations were determined and aggregated across fuel types and locations. The cost-effective insulation levels were determined to be primarily a function of heating degree-days. The cost-effective levels and other findings of interest will be presented.

Robert Lucas and **Jim Miller** are in the Energy Technologies Department of the Pacific Northwest Laboratory, Richland, Wash. **Mark Modera** and **Burke Treidler** are in the Energy and Environment Division of Lawrence Berkeley Laboratory, Berkeley, Calif.