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Efficiency of Exterior Exposed Ductwork

Most of California's commercial buildings have thermal distribution systems, the majority (63%) of which are air-based and distribute air through ductworks. Thermal distribution ductwork systems in small commercial buildings are similar to those in residential construction [Winter 1995, p.8] and have the same leakage and conduction-loss problems. The extent of these duct-related thermal losses depends on the location of the ductwork-the largest thermal losses occur when the ducts are entirely outside the building envelope.

Leakage, conduction losses, direct solar radiation effects and solar reflection all affect the magnitude of thermal loss. Differences in the lengths of exterior ducts also affect a distribution system's energy efficiency, as well as the temperature of air delivered to interior spaces at the registers. When long duct runs are exposed to sunlight and high outdoor temperatures on roofs, the supply air can experience a significant temperature rise before reaching the registers during periods of demand for interior cooling. This configuration has a direct impact on interior thermal comfort conditions and can cause uneven temperature distribution within the building.

To examine the thermal energy issues of exposed exterior ductwork, we conducted a case study at a building on the campus of a community college in Sacramento, California. Most of the building's ductwork was located on the roof, providing an opportunity to evaluate the effects of duct leakage, conduction losses, and other issues on the energy performance and efficiency of the duct system.

The study building is a single-story brick structure with a 2,000 m^2 (21,500 ft^2) floor area containing classrooms, laboratories and office space. There is no shading from the south and east and some tree shading on the west side. The building is one of two served by a centralized chiller plant. Its systems were completely renovated in the 1980s with the installation of 15 roof-mounted, constant-volume air-handling units with chilled water coils and air-side economizers.

In 1995, the Sacramento Municipal Utility District conducted a "cool-roof" retrofit of the building, which involved improving the roof-deck insulation and increasing the surface reflectivity of the building's roof. (This strategy was developed as part of a joint research project between SMUD and Center researchers in the Heat Islands Project [Spring 1994, p.6]). A contractor sprayed a closed-cell polyurethane coating that added a 1.2- to 1.7-cm-thick coating to exposed ductwork and 10 to 15 cm to the roof. After the insulation, a highly reflective coating-reflecting up to 85% of incident solar radiation, according to the manufacturer-was added to only the top and sides of the ductwork.

For this experiment, we selected a building air-handler system serving a lecture hall with a floor area of 147 m^2 (1,580 ft^2). Diagnostic measurements included system duct leakage, system air flows, outside air flows and duct insulation and conduction efficiency. The study included short-term monitoring of temperature and solar radiation over two three-week periods in the summer of 1995.

The analysis of these measurements focuses on quantifying the magnitude of conduction losses and the effect of direct and reflected solar radiation on the ducts, the delivery effectiveness and efficiency, and the effect of the "cool-roof" retrofit on system performance and thermal-comfort issues. We developed and verified a simplified computer model to evaluate the effectiveness and efficiency of the delivery system.

The Table below summarizes conduction losses, expressed as capacity losses, measured at each air supply register studied. Conduction losses in the ducts, when in cooling mode, raise the supply air temperature. The capacity loss is the energy lost as a fraction of the capacity before cooled air reaches a room.

Despite the fact that the ducts started off with a conduction efficiency of 97%, the delivery efficiency was, on average, only 73%. (Conduction efficiency is a measure of how ducts behave as a heat exchanger; the higher the conduction efficiency number, the better. Delivery efficiency is defined as the ratio of energy delivered to the space divided by the energy put into the duct system.) This is because the ducts were located on the roof, where they gained heat from the ambient environment. The retrofit increased the delivery efficiency to an average of 89%, reducing the average energy use for conditioning by 22%. The model predicted these results, on average, within 10% or better of the measured results.

Table: Summary of average register conduction losses. Capacity loss is energy loss as a fraction of capacity before reaching the room.

	Uniformly Weighted Average			**Capacity Weighted Average**		
Supply Register	Pre-retrofit Capacity Loss	Post-retrofit Capacity Loss	Percent Change (post-retrofit in relationship to pre-retrofit)	Pre-retrofit Capacity Loss	Post-retrofit Capacity Loss	Percent Change (post-retrofit in relationship to pre-retrofit)
1	17%	9%	-46%	16%	9%	-47%
2	27%	16%	-41%	25%	15%	-40%
3	14%	5%	-64%	13%	5%	-64%
4	25%	13%	-48%	23%	12%	-45%

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An LBNL report, "Exposed Exterior Ductwork: Delivery Effectiveness and Efficiency," LBNL-39083, describes the methods and results of this study in detail.

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