CoolCab: Reducing Thermal Loads in Long-Haul Trucks

Ken Proc/PIX 15738

The CoolCab project used these trucks to test and model the effects of thermal-load reduction strategies applied to long-haul truck cabs.

An average long-haul truck with a sleeper cabin idles more than 1,400 hours annually to supply heating, cooling, and electricity during driver rest periods. Nationwide, long-haul truck idling consumes more than 800 million gallons of fuel annually. Reducing idling time can cut fuel consumption and tailpipe emissions while saving money for truckers. Reducing thermal loads—the amount of heating and cooling energy required to keep a truck's occupants comfortable—is vital for reducing idling. As part of the U.S. Department of Energy's (DOE) Advanced Vehicle Testing Activity (AVTA), the National Renewable Energy Laboratory's (NREL) CoolCab project tested and modeled the effects of several thermal-load reduction strategies applied to long-haul truck cabs.

Project Design and Data Collection

NREL partnered with two major truck manufacturers to evaluate three long-haul trucks at NREL's outdoor test facility in Golden, Colorado. Two test trucks were configured with various thermal-load reduction strategies, and one control truck was left unmodified for comparison.

Three thermal-load reduction configurations were applied to both test trucks: base case (no modifications), sleeper curtain closed and standard window shades installed, and windows insulated. The sleeper-curtain-and-window-shades configuration applied the factory-supplied, snap-in window shades and sleeper privacy curtain during testing to measure the effects of isolating the sleeper compartment. The windows-insulated configuration included the application of foiled bubble insulation on the inside of the cab windows; the factory sleeper curtain and shades were not applied in this configuration. A fourth configuration, tested in the second test truck only, replaced the standard curtain with a foam-insulated (arctic) curtain in the closed position (with standard window shades applied).

All the trucks were instrumented and subjected to tests that measured heat transfer and identified high-heat-loss areas. Results from the real-world testing were used to create and validate a computer model of thermal loads. This model was used to estimate energy used for climate control in long-haul trucks.

Results

Testing was performed to determine the heat-transfer coefficient of the test trucks using the different thermal-load reduction configurations. The heat-transfer coefficient represents the amount of power required to change the temperature of the truck cab by 1°C. For example, the heat-transfer coefficient for the first test truck in the base configuration was 65 W/°C. Therefore, in a typical overnight cab-heating situation with an outside temperature of 0°C, heating the cab to 20°C would require 1,300 W of power (65 W/°C × 20°C = 1,300 W). The lower the heat-transfer coefficient, the lower the amount of power—and fuel—required to change the temperature of the cab.

Closing the sleeper curtain and applying the window shades reduced the heat-transfer coefficient by 16% in the first test truck and 21% in the second test truck (compared with the base case). Insulating the windows reduced the heat-transfer coefficient by 16% in the first test truck and 14% in the second. Insulated window shades could reduce heat loss further when used in conjunction with the sleeper curtain, but this configuration was not tested. Use of the arctic curtain and window shades in the second test truck reduced the heat-transfer coefficient by 26%.

"Solar soak" tests were conducted to quantify how hot the trucks would get in each configuration while facing south during the sunniest part of the day (from about 12 p.m. to 2 p.m.). In the base configuration, the interior cab temperature rose by 13°C above the outdoor temperature for the first test truck and 11°C for the second test truck. Insulating the windows reduced the temperature rise by 8°C in the first test truck and 4°C in the

Heat-Transfer Coefficient Test

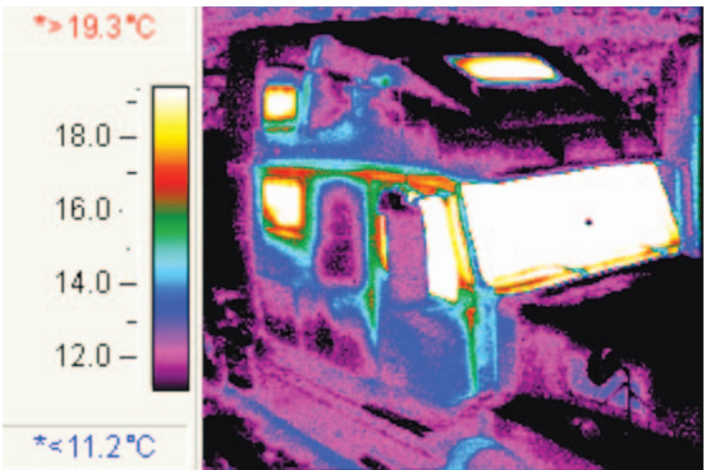
Test Vehicle	Base Case (Unmodified)	Change from Base Case		
		Sleeper Curtain and Window Shades	Arctic Curtain and Window Shades	Windows Insulated
Truck 1	65 W/°C	–16%	N/A	–16%
Truck 2	51 W/°C	–21%	–26%	–14%

Solar Soak Test

Test Vehicle	Base Case (Unmodified)	Change from Base Case		
		Sleeper Curtain and Window Shades	Arctic Curtain and Window Shades	Windows Insulated
Truck 1	ΔT = 13°C	N/A	N/A	–8°C
Truck 2	ΔT = 11°C	–1°C	–3°C	–4°C

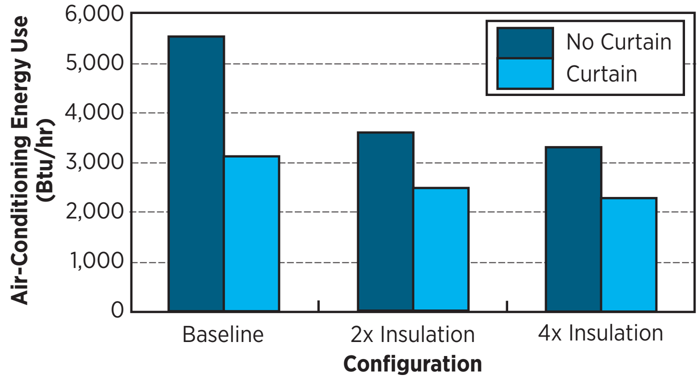
second; the greater reduction for the first test truck can be attributed to that truck's larger glass area, including a sunroof, which the second test truck did not have. Closing the sleeper curtain and applying window shades reduced the temperature rise by about 1°C for the second test truck; substituting the arctic curtain reduced the temperature rise by 3°C.

Infrared images of the trucks were taken at night—with the cab interiors heated—to identify potential sources of high heat loss. The images revealed expected heat loss around door and window seals and at the seam joining the roof to the lower cab, and some heat loss was noted at the roof structural members where insulation may have been lacking. Images of the second test truck revealed heat loss from the upper left and right corners at the rear of the truck cab, possibly due to a lack of insulation in air duct areas.



Infrared image of Test Truck 1

Computer modeling was used to predict how much air-conditioning energy would be required to cool a sleeper cab during a hot day in Phoenix. As expected, partitioning the cab with a sleeper curtain and cooling only part of the air resulted in a lower predicted energy requirement, as did adding cab insulation (see graph at upper right). Covering the windows with insulated, reflective shades reduced air-conditioning energy use by 34% with the curtain open and 14% with the curtain closed. The reduction with the curtain closed is much less than with it open because the shades primarily keep the solar load out of the front of the cabin where most of the glass area is.



Computer-modeling predictions of air-conditioning energy use with and without the use of a sleeper curtain and with varying amounts of cab insulation

Conclusions

Testing of long-haul truck cabs demonstrated reduced thermal loads due to use of standard configurations (sleeper curtain and window shades) and some optional configurations (insulated curtain and window insulation). Computer modeling predicted reductions in air-conditioning loads due to closing the sleeper curtain, improving cab insulation, and covering windows with insulated, reflective shades. Download the full report for this project at *www.nrel.gov/vehiclesandfuels/fleettest/pdfs/43402.pdf*.

For more information, visit the CoolCab Truck Efficiency Web site at *www.nrel.gov/vehiclesandfuels/truckefficiency*, read National Idling Reduction Network News at *www.eere.energy.gov/vehiclesandfuels/resources/fcvt_national_idling.html*, or visit the Idle Reduction section of the Alternative Fuels and Advanced Vehicles Data Center at *www.afdc.energy.gov/afdc/vehicles/idle_reduction.html*.

The CoolCab Project

The National Renewable Energy Laboratory leads the CoolCab project for DOE's Advanced Vehicle Testing Activity, part of the Vehicle Technologies Program. AVTA bridges the gap between research and development and the commercial availability of advanced vehicle technologies that reduce petroleum use and improve air quality in the United States. The CoolCab project's main goal is to identify design opportunities for reducing thermal loads inside truck cabs during rest periods. Reducing the thermal loads will enable efficient use of idle-reduction technologies and reduce fuel consumed due to idling while maintaining driver comfort. A secondary goal is to reduce thermal loads in moving vehicles—both light- and heavy-duty—to provide additional opportunities for increased fuel efficiency. CoolCab works with DOE's 21st Century Truck Partnership for industry support and partnerships to improve truck efficiency.

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