EPRI

case study

Transport Refrigeration Units

Electric Transportation Program

Transport refrigeration units (TRUs) are used to control temperature in truck containers that carry perishable food, medications, and other commodities. Most TRUs are powered by small diesel engines whose emissions contribute to air pollution and local health concerns especially in and near distribution centers and warehouse parking lots where exhaust accumulates. Concern about these concentrated emissions has prompted the California Air Resources Board (ARB) to pursue air toxics control measures targeting TRUs. Federal regulators, also, are reviewing options for controlling emissions.

One way to significantly reduce emissions is to power TRUs with grid-powered electric motors when they are stationary – or in standby mode – for extended periods. The Sacramento Municipal Utility District (SMUD) evaluated existing technology and potential improvements to electrically powered TRUs (e-TRUs), analyzed capital and operating costs, and examined operational barriers to widespread use of e-TRUs. This full report is entitled *Transport Refrigeration Units: A Technical Assessment* [EPRI Product ID 1009992].

State of Technology

Truck-trailer TRUs are vapor compression cycle refrigeration systems, typically diesel driven. They are made by outside manufacturers and installed in trailers by trailer manufacturers. These refrigeration systems have four main components: evaporator, compressor, condenser, and control valve.

Today's trailer-mounted TRUs typically are powered by 2-liter, 1,800 to 2,200 RPM diesel engines that produce 30–40 peak horsepower. Low engine speed and low combustion temperatures result in long life and low cost. The engine drives the compressor directly and, through v-belts, also drives condenser and evaporator fans and a 12-V alternator. The engine operates in high speed mode when temperature falls below a certain set point, and in standby mode for temperature maintenance.

In today's e-TRUs, a clutch disengages the engine and a 10- to 15-horsepower industrial induction electric motor drives the compressor and fans through v-belts. One drawback is that the motor is too low-powered to lower the trailer interior from hot ambient temperature to operating temperature (a process known as pull-down) in the industry-required 20- to 30-minute period. Additionally, retrofit of electric standby on TRUs has proven to be an expensive proposition; it is much cheaper to install the electric motor capability when the system is first manufactured.

All TRUs have the ability to operate as heat pumps either to defrost the evaporator coil or to warm up the refrigerated space for loads that require a higher set point in cold weather. Certain kinds of fresh produce frequently require this

Figure 1. Front View of Refrigerated Highway Trailers With Transport Refrigeration Units (TRUs) Installed.

treatment, and may require fans to run regardless of ambient temperature because of product out-gassing, which can lead to spoilage.

The operational need for fast pull-down, the capability to cope with door openings during deliveries, and the trend towards lighter, less insulated trailers to maximize internal volume, have led industry to compensate with higher capacity, higher power refrigeration systems.

Possibilities for improving transport refrigeration technology could include introduction of efficiency standards for transport refrigeration systems. This approach has been effective in other refrigeration equipment sectors. Testing to

enforce the standards should include both the refrigeration unit and the insulated trailer. Most transport refrigeration systems appear to be much less energy efficient than other refrigeration equipment – primarily because of engineering tradeoffs between efficiency and the ability to adapt to temperature extremes, to cool as well as heat, to control humidity, to ventilate cargo gas buildup, and to provide fast pull-down.

One way to improve energy efficiency is to increase the insulation in the TRU. However, better insulation usually means thicker container walls. Because the external dimensions of trailers are fixed by the Department of Transportation, any increase in wall thickness due to insulation results in a decrease in internal volume and less cargo capacity. Because the payloads are typically not high density, TRUs usually fill completely before their weight limits are reached, making any decrease in internal volume a decrease in cargo capacity.

The grocery industry typically uses standard pallet sizes, which fit exactly inside existing trailers with 2.5 inch wall thickness

Equipment Capital and Operating Cost

A detailed analysis of first cost, infrastructure cost, and fuel and maintenance costs of e-TRUs concludes that overall costs would increase 10% when compared to diesel, assuming the use of presently available technology. The analysis found that e-TRU technology does not appear viable on a purely economic basis when all costs are included, unless diesel costs reach about $2.50 per gallon at the pump.

Profit margins are narrow in the food handling business. As a result, there is little capital investment in new technology unless government mandates require it. Because of the narrow profit margins, purchase decisions for equipment are often based on small differences in equipment cost, and infrequently take into account future energy costs. The level of system integration is relatively low, and the study could identify no industry standards for testing complete refrigerated trailers.

If public funds were used to partly finance infrastructure costs or electric energy costs, the analysis would change, and electric standby could offer a better economic package for the refrigerated transport industry. Mechanisms to finance infrastructure or energy may also be available based on the emissions reductions realized with electric standby. Such mechanisms are described in the ARB's report on TRUs.

Barriers to User Acceptance

Replacing today's conventional TRUs with e-TRUs is technically feasible, however barriers to widespread acceptance remain, chief among them user objections on economic grounds.

To understand the barriers, SMUD interviewed decision makers from representative TRU users in the food supply industry, including two major grocery warehouse operations, one distributor of restaurant specialty foods and supplies, one dairy products company, and one frozen food warehouse. The interviews revealed perceptions and operational constraints that prevented users from adopting e-TRUs.

Perceptual Barriers

Many fleets based outside of California do not understand or recognize the state's high population density and climate conditions or its need to reduce emissions. For them, emissions mandates represent unwarranted regulatory intrusion.

Operational Barriers

Users also voiced several operational concerns. Three factors dominate the economics of transporting food and other perishables: the ability to maximize the amount of cargo in each vehicle, the ability to minimize the time that each vehicle is idle and empty, and the reliability of systems that can minimize waste and down time. Of lesser concern is the cost of fuel.

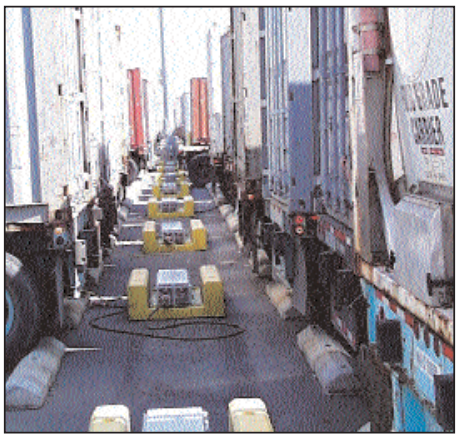

Figure 2. Container Refrigeration Systems Plugged in at Port.

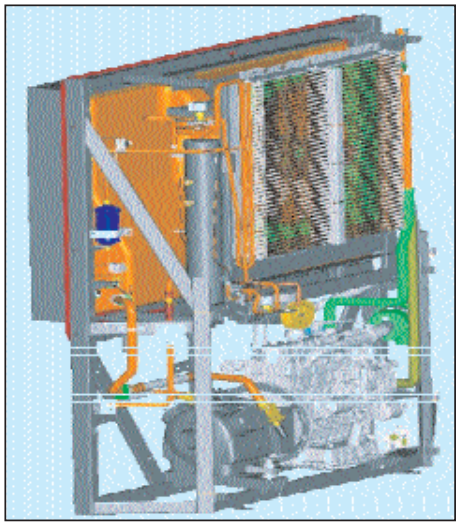

Figure 3. Trailer Mounted Truck Refrigeration Unit.

Equipment Capital and Operating Cost

Because profit margins are slim across the industry, an upgrade to e-TRUs must provide economic payback. An equipment capital expense must be offset by decreased operating costs, with as short a payback time as possible.

Reliability

High reliability is an imperative for protecting cargo, which in the case of pharmaceuticals and certain food products is high-value. Interviewees expressed concern about reliability of the equipment and of electric power.

High Performance

In the industry, high performance translates to the ability to minimize the time required to bring a TRU's temperature down to the value required for loading with perishable cargo. High performance does not necessarily equate to high efficiency because time to market and cargo capacity often outweigh efficiency in the overall cost equation.

TRU users interviewed expressed concern that e-TRUs in standby mode would not be able to provide enough power to accomplish pull-down in 30 minutes or less. Indeed, present TRU design appears to be dominated by the requirement for fast pull-down to keep pace with just-in-time deliveries and minimum waiting time.

Low Maintenance

Frequency of maintenance is a factor in overall cost of ownership. Longer maintenance intervals mean less down-time and lower cost of operation. Electric drive holds an advantage in this area because electric motors have fewer moving parts and lubrication requirements, and do not leak fuel or lubricant. Also, electric drives on the evaporator and condenser fans would eliminate the belts, and thereby reduce maintenance intervals and improve efficiency.

Low Weight

Lighter refrigeration equipment translates to lower transportation costs. To the extent that e-TRUs require electric motors in addition to the diesel engines required for use during transport, they increase weight.

Safety Issues

Interviewees were concerned about the safety of dismounting from the vehicle cabin to connect high-voltage cables to e-TRUs. Special training to use the equipment would represent an additional expense. Without a safety interlock between the electrical system and the vehicle's motive engine, the potential exists for driving away without disconnecting the power cable. Such drive-offs could result in damaged equipment and dangerous contact with ruptured high-voltage lines.

Cost and Reliability of Fuel

Although the cost of diesel fuel is borne by the carrier, the cost of electricity is generally borne by the owner of the warehouse or distribution center. These two entities are often not the same, so the warehouse or distribution center owner expects increased expense associated with e-TRU operation unless an arrangement is made to share the cost of electricity with shippers. In addition, scheduling constraints could keep customers from taking advantage of off-peak power discounts.

Interviewees also worried that unforeseen demands for additional power may not be met. They perceived that the electric utility industry is near its limit of generating capacity, and that the distribution system was vulnerable to choke points in the distribution grid.

Economic forces in the industry demand that participants show more concern for maximizing the amount of cargo in a trailer and protecting it from spoilage than for minimizing operating costs. These forces suggest that TRU operators are not likely to lower their electricity usage to accommodate electric utility peak demand constraints. In fact, they are more likely to demand more power during summer peak usage times. Diesel usage would be seen as a backup during such times, even though air quality concerns during these periods are typically high also.

Emissions Considerations

The daily duty cycle of TRU refrigeration units is an important factor in considering the emissions reductions possible with e-TRUs.

One interviewee reported that its TRUs are turned on about one half-hour before being loaded, and remain running until the load is delivered. Analysis of data provided by the interviewee showed that the switched-on time for a TRU was approximately half of the clock time. Dividing the remaining 12 hours into stage-and-load, transport-cargo, and return-to-base times, it is reasonable to believe that grocery operations TRUs are switched on 8–12 hours per day, and actually operate on the order of 4–6 hours per day. Industry users typically track only total engine time; they do not distinguish between time spent in transport or while stationary at the home facility. ARB estimates, however, that TRUs spend most of their operating time while stationary. Therefore, use of e-TRUs would eliminate half of the total emissions and all of the emissions concentrated at the facility.

Future Research Need: Evaluate Real-World Operation

Future research projects should seek to identify actual operating habits and the location of systems during operation. For example, some TRUs, often the older and least insulated, are sometimes used for extra food storage at warehouses and distribution centers. This practice might be well served with electric power, particularly if thermal insulating blankets were used to better insulate stationary trailers to decrease overall energy use.

For More Information

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