

ensure that no toxic wastes are introduced into the gray waste-water stream. One manufacturer stated that today's ships operating with direct water injection carry the amount needed to operate the system between ports (two to four days).

Depending on the amount of water necessary, other vessels that use Category 3 marine engines may not be able to generate sufficient amounts of water for this technology, especially at low loads where less heat is available from the engine. These ships would have to carry the water or be outfitted with new or larger distillation systems. Both of these options could displace cargo space. Finally, it should be noted that vessels currently equipped with water-based NO_x-reduction technologies are four-stroke engines and include fast ferries, cruise ships, and cargo ships. The specific vessels travel relatively short distances between stops and need a much smaller volume of fresh water for a trip than would be required for crossing an ocean. More information is needed regarding operation on ocean-going vessels. If the ships were to use this technology only while traveling from 175 nautical miles of the U.S. coast to port, less water-storage capacity would be needed than if the ship used this NO_x reduction strategy at all times. However, ships operating primarily within 175 nautical miles of the U.S. coast would need to be able to carry a volume of water of about one-half the volume of fuel they carry if they wish to keep the same refueling schedule. Ships making long runs, such as from California to Alaska, would have to be able to store enough water for that trip even if the ship travels that route infrequently. Because the standards would not be retroactive to existing vessels, ships could be designed to carry this water, however, this space would not be available to carry cargo or fuel. Lastly, if this technology were applied to two-stroke engines there may be lubricity concerns with the cylinder liner. One manufacturer is developing a strategy to use direct water injection with exhaust gas recirculation to minimize water requirements on such engines.

b. Selective catalytic reduction.

Selective catalytic reduction is one of the most effective means of reducing NO_x from large diesel engines. In SCR systems, a reducing agent such as ammonia, is injected into the exhaust. The exhaust then goes through a catalyst where NO_x emissions are reduced. As discussed in the Final Regulatory Support Document, SCR can be used to achieve NO_x reductions of 90 percent or more below the Tier 1 limits, at exhaust

temperatures above 300 °C. Lower-cost SCR systems can also be designed for less effective control of NO_x emissions by reducing the amount of reducing agent used in the SCR unit. These systems are being successfully used for stationary applications, which operate under constant, high-load conditions. These systems are also installed in Category 3 engines used on ferries and cruise ships where they operate largely at high loads and over short distances so exhaust temperature and urea storage are not primary issues.

As discussed in the Final Regulatory Support Document, manufacturers are demonstrating similar NO_x reduction using SCR technology for marine applications. These SCR demonstrations include both test systems and in-use vessels. One manufacturer has demonstrated a standard SCR system on eight vessels and a compact SCR system, which uses an oxidation catalyst upstream of the SCR reactor to reduce reactor size, on four vessels. Combined, these twelve vessels are equipped with a total of 40 medium-speed Category 3 marine engines. Another manufacturer has installed systems on 56 Category 2 or Category 3 marine engines. The majority of these engines were in ferries and ro-ros operating in European waters where there are economic incentives to use SCR. In addition, these engines are four-stroke medium-speed engines, which have higher exhaust temperatures than two-stroke low-speed engines which better enables the use of SCR. To prevent sulfur poisoning of the catalysts, the fuel used by these vessels ranges from 0.1 to 1.0 percent sulfur. This fuel includes both residual fuel and marine distillate fuel. In addition, they make relatively short trips between European ports, so urea availability and storage are not significant issues. Also, the relatively short trips allow time for maintenance and provide better access to any needed parts compared with ocean-going trips.

In one case, SCR was equipped on vessels with two-stroke low-speed engines. The goal of this program was to reduce the emissions emitted during the transportation of steel to a facility in Pittsburg, California. Because the vessels were equipped with two-stroke low-speed engines, the exhaust temperatures were low. In addition, the vessels operate at low load near the coast; therefore, certain modifications to the system were necessary. Primarily, the exhaust system was reconfigured to provide the maximum heat to the reactor, which had negative impacts on transient response and efficiency. Also, the catalyst was formulated to be effective at temperatures as low as

270°C. Because such a reactive catalyst is vulnerable to sulfur poisoning, the vessels operate only on 0.05 percent sulfur fuel when the SCR unit is active. These vessels make about 6 calls to California per year and the SCR unit is active for about 12 hours per call, when the vessel is within about 50 miles from the port.

We believe that the results from initial applications of SCR systems are encouraging. We will continue to evaluate this technology in the future. However, we believe there are still outstanding technical issues concerning the use of SCR for widespread application on marine engines. These issues are discussed below.

Lower-sulfur fuel is necessary to ensure the durability of the SCR system because sulfur can be trapped in the active catalyst sites and reduce the effectiveness of the catalyst. This sulfur poisoning can require additional maintenance of the system. We need more information on the impacts of fuel sulfur on SCR. As discussed above, SCR units in service today are operating on fuel ranging from 500 to 10,000 ppmS. Even if these systems can be made to operate on 15,000 ppmS fuel, an infrastructure would be necessary to ensure that ships could refuel with 15,000 ppmS fuel at ports they visit. Lower-sulfur residual fuel is available in areas that provide incentives for using such fuel, including the Baltic Sea; however, such fuel is not yet available at ports throughout the United States. During the next few years we expect to develop a better understanding of the availability of lower-sulfur fuels through the process related to designating SO_x Emission Control Areas under Annex VI. We also intend to learn more about the sensitivity of SCR systems to fuel-sulfur concentrations.

Another issue is the effectiveness of SCR during low-load engine operation. SCR systems available today are effective only over a narrow range of exhaust temperatures (generally above 300 °C). The effectiveness of the SCR system is decreased at reduced temperatures that occur during engine operation at partial loads. Most of the engine operation in and near commercial ports and waterways close to shore is likely to be at these partial loads. In fact, reduced-speed zones can be as large as 100 miles for some ports. Because of the cubic relationship between ship speed and engine power required, engines may operate at less than 25 percent power in a reduced-speed zone. During this low-load operation, no NO_x reduction would be expected, so SCR would be less effective while operating near ports. Some