System Measures Corrosion Condition of Shipboard Tanks

NRL Improves Upon Time-Based Inspection

By Kathy Riggs Larsen

The cost of preserving shipboard tanks and voids is a significant expense for the U.S. Navy. Shipboard tanks, including seawater ballast control tanks, fuel storage tanks, and potable water tanks, are constructed of carbon steel in spite of the material’s propensity to corrode in marine applications.

Barrier coatings are used to protect the tanks, and the coating protection is complemented with a sacrificial cathodic protection (CP) system. If the coatings and CP should fail, extensive structural damage can occur due to corrosion.

Tanks and enclosures were named as the top corrosion expense on Navy ships, accounting for $204 million annually in direct costs, according to a 2006 report commissioned by the DoD Corrosion Policy and Oversight Office titled “The Annual Cost of Corrosion for Army Ground Vehicles and Navy Ships.”

The Navy’s traditional tank preservation philosophy uses a time-based maintenance program to inspect tanks and monitor their condition for corrosion. When a tank is scheduled for an inspection, it must be drained of fluids, opened, vented, and certified as gas-free by a marine chemist; then trained inspectors enter the tank to conduct visual inspections and make an estimation of the extent of any damage.

To reduce inspection-related costs, the Naval Research Laboratory developed and is helping implement a tank-monitoring system that measures the condition of tanks and voids using corrosion sensor technology.

Improving Upon Time-Based Inspections

Because tank maintenance can vary widely depending on the contents, size, ship operation location, and numerous other factors, uniform, time-based inspections are not considered optimum tools for identifying tanks in need of repairs, said Edward Lemieux, head of the corrosion engineering section at the Naval Research Laboratory’s Center for Corrosion Science and Engineering.
Lemieux added that the Navy inspects approximately 4,000 tanks a year, and the inspection process costs $8,000 to $12,000 per tank. The process of physically entering the tanks and visually inspecting the coatings is expensive, subjective, and involves numerous safety concerns. In addition, tanks that do not need restoration may be opened unnecessarily and refurbished according to an existing maintenance program, while tanks that do need reconditioning to mitigate corrosion may go unchecked and ultimately cost DoD hundreds of thousands of dollars in structural damage repairs.

“Fundamentally, the problem with time-based inspections is that there are no criteria that identify to Fleet maintenance personnel which tanks should be opened for inspection on the basis of their condition. As a result, coating preservation and preventative maintenance may not be conducted in the necessary spaces that are not inspected,” Lemieux noted.

**Navy Uses Sensors to Monitor Tanks**

The tank-monitoring system provides maintenance personnel with a tool to assess the current condition of the tank and identify those tanks that should be earmarked for further inspection. The monitoring equipment, now licensed to and manufactured by Battenkill Technologies of Manchester Center, Vermont, was recently installed in eight tanks on the USS *San Antonio* amphibious transport dock ship.

Plans call for installing tank-monitoring systems on the other LPD 17 class of amphibious transport dock ships as well as the DDG 1000 class of destroyers during new construction.

The tank-monitoring system is a condition-based inspection technology that provides data to determine the risk or presence of corrosion. The sensor system measures tank condition data and stores them in a data logger without requiring maintenance personnel to physically enter the tank. The sensor system is composed of three major components: silver/silver chloride reference electrodes that sense the tank’s electrochemical corrosion potential in volts; an instrumented anode (either aluminum or zinc, depending on the anodes used in the CP system for the tank) that measures demand placed on the CP system (in amps); and a battery-operated data logger system that stores and downloads data.

“By measuring the voltage difference between the reference cells and ship’s structure, we can determine the corrosion potential of the metals (predominantly steel) in the tank,” Lemieux explained. “This, in turn, allows us to characterize the corrosion state of the tank—specifically, whether it is protected adequately by the CP system or if it is actively corroding. The instrumented anode is used to measure the current demand by measuring the amount of current delivered by the anode to the tank. The current demand is proportional to the amount of exposed steel in the tank, so higher currents are indicative of more damage.”

Output from the sensors and the instrumented anodes are fed to and recorded every 30 minutes by a data logger mounted on the tank’s exterior. Maintenance personnel are able to easily download the data from the data logger onto a pocket-sized personal computer. There, data is processed by corrosion analysis software to help personnel ascertain conditions of the actual tank coating and CP system. Such data helps them decide what the next maintenance steps should be.

“It’s important to note that the monitoring system is more than just sensor components collecting data,” commented Bruce N. Nelson, president of Battenkill Technologies. “The sensor data is processed by a unique, advanced algorithm that interprets the data in a reliable and repeatable way, and maintenance decisions are based on this data interpretation.”

As Nelson explained, the software algorithm measures the collected sensor data against several parameters, and generates a report that provides a score associated with the measured parameters as well as an overall score. He added that Navy ships have significant environmental variations, such as tank usage (how long and how often tanks are filled) and duty cycles, and the algorithm accommodates these variations when interpreting data. Data scores then determine maintenance action. For example, if the scores don’t indicate a corrosion problem, the maintenance action may call for a download and review of the data after 18 months. If one particular score is low or the overall score falls below a certain specified level, personnel may need to conduct a video inspection of the tank and manually inspect it.
“With this monitoring system, maintenance personnel open the tanks only when physical inspections are necessary,” Nelson said.

The corrosion sensors installed on the USS San Antonio are being used as a springboard to implement a tank-monitoring system in all amphibious class vessels, Lemieux added. If eight tanks on eight ships in the LPD 17 class are outfitted with the system, he said, total life-cycle cost savings are estimated to be $11 million. Implementing the system on other amphibious ships is expected to yield much larger cost avoidances.

Editor’s note: This article originally appeared in the March 2009 issue of Material Performance magazine.

Shown (top) are three sensors and the instrumented anode in a ballast tank on the USS San Antonio, and (bottom) a close-up of the sensor. Photos by Paul Slebodnick, U.S. Naval Research Laboratory Center for Corrosion Science and Engineering.