



Injecting Low-Density Cellular Concrete into the Trojan Reactor Vessel

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Robert D. Morgan
Burns and Roe Enterprises, Inc.
Danen R. Heath
Leonard S. Peterson
PGE



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Robert D. Morgan (Burns and Roe, NJ),
Danen R. Heath, Leonard S. Peterson (PGE, Ranier)

The Trojan staff and its packaging contractor, Burns and Roe, have successfully completed the Reactor Vessel and Internals Removal (RVAIR) project. One of the major problems associated with the preparation of the reactor vessel as its own transportation container is the burial requirement that the void space inside the reactor be limited to <15% of the total internal volume. Additionally, the void space filler material must satisfy several other transportation, radiation, and material requirements as defined by the U.S. Nuclear Regulatory Commission and the U.S. Department of Transportation. Low-density cellular concrete (LDCC) had been used to fill similar components for transportation and burial, and LDCC was used to fill the Trojan steam generators and pressurizer as their own 10 CFR 71 transportation and disposal containers. However, using LDCC to fill the reactor vessel has presented new problems and challenges, as this 13-m (42 ft, 6 in.) vessel was filled in the vertical position, and the significant internal gamma source created problems with high internal metal temperatures and radiolytic decomposition of the water in the LDCC matrix.

LDCC is a heterogeneous mixture of organic surfactants/admixtures, portland cement, water, and air. It is very sensitive to overpressurization and degrades drastically if the wet mixture "boils" prior to curing. Approximately 130 megagrams (Mg) (143 t) of 10°C (50°F), liquid LDCC was injected into the drained reactor vessel with the 907-Mg (1000-t) vessel in the vertical position. If no compensating action had been taken to cool the vessel internals prior to LDCC injection, the LDCC would have encountered 175°C (350°F) metal temperatures inside the reactor, as neutron-activated metal components are heating themselves along with adjacent structures. To address these and other concerns, Portland General Electric Company embarked on a joint testing and development program with its architect-engineer contractor, Burns and Roe; the LDCC subcontractor, Pacific International Grout Company; and the LDCC material supplier, Master Builders. This iterative testing and analysis program addressed the foregoing issues. We present the testing program, test results, heat transfer analysis, the injection/venting process, and the results of the actual injection process.

DESCRIPTION OF THE ACTUAL WORK

Density, "off gas," and curing additive testing was performed in conjunction with field testing to establish thermal and curing profiles. With test data inputs the HEATING 7.21 models provided thermal transient profiles and steaming rates. The resulting chiller and LDCC injection procedures permitted the LDCC to cure at the proper density and to accommodate the exhaust steam driven off during the combined hydration-gamma heat evolution.

A grout chiller system was designed to circulate cold air from outside containment into the reactor vessel to remove heat from the internals. The system was designed such that the exhaust air could pass through a cooling coil, high-efficiency particulate air (HEPA) filters, and an exhaust fan prior to exiting containment via the purge exhaust system. To permit redundant equipment and HEPA filter changes, a bypass recirculation system was also provided.

The LDCC injection system operation was complicated by the aforementioned cooling requirement and the numerous fill and vent systems required to ensure a complete fill of the vessel. The LDCC was batched on-site with special foaming agents and curing additives, and then it was pumped into the reactor containment building where it was selectively routed to the proper vessel injection port. Prior to injection each batch was density tested to ensure that overall density was within the safety analysis report range of 0.721 to 1.041 g/cm³ (45 to 65 lb/ft³).

RESULTS

The chiller system was commissioned and then put into operation 1 week prior to the injection of the first "lift" or "pour" of LDCC into the reactor. The chiller system was able to lower the reactor vessel internal metal temperatures to < 75°C (170°F), thus ensuring that LDCC would "cure" before the gamma heat and heat of hydration raised the peak internals temperature to 100°C (212°F). There were sixteen 7.7-m³ (10-yd³) batches in the first pour, and the batch weighted averaged density for the first pour was 0.891 g/cm³ (55.6 lb/ft³). The chiller system was put in service in vapor removal and then the cooling mode prior to the injection of the second pour. The second pour consisted of nine 7.7-m³ (10-yd³) batches, and the overall batch weighted density of the first and second pours together was 0.902 g/cm³ (56.3 lb/ft³).

After allowing the reactor to vent and cool for 28 days, the temporary fill and drain closures were removed to verify that the vessel was full, to verify that there were no voids, and to confirm also that there was no free standing water in the vessel. ■