FULL REACTOR COOLANT SYSTEM CHEMICAL DECONTAMINATION QUALIFICATION PROGRAMS

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INTRODUCTION

Corrosion and wear products are found throughout the reactor coolant system (RCS), or primary loop, of a PWR power plant. These products circulate with the primary coolant through the reactor where they may become activated. An oxide layer including these activated products forms on the surfaces of the RCS (including the fuel elements). The amount of radioactivity deposited on the different surfaces varies and depends primarily on the corrosion rate of the materials concerned, the amount of cobalt in the coolant and the chemistry of the coolant. The oxide layer, commonly called crud, on the surfaces of nuclear plant systems leads to personnel radiation exposure. The level of the radiation fields from the crud increases with time from initial plant startup and typically levels off after 4 to 6 cycles of plant operation. Thereafter, significant personnel radiation exposure may be incurred whenever major maintenance is performed. Personnel exposure is highest during refueling outages when routine maintenance on major plant components, such as steam generators and reactor coolant pumps, is performed. Administrative controls are established at nuclear plants to minimize the exposure incurred by an individual and the plant workers as a whole.

A critical objective for the U.S. nuclear industry is the reduction of personnel exposure to radiation, both for continued safe operation of currently licensed plants and for long term acceptance by the public of the nuclear option for power generation. While reductions in personnel exposure to radiation have been achieved through the industry's aggressive radiation management programs, increased plant maintenance and high radiation fields at many sites continue to raise concerns. Unexpected maintenance problems and major equipment replacements have resulted in significant personnel exposure for many plants. In addition, it is likely that new regulations will be forthcoming which could reduce the allowable limits for quarterly and annual exposure. Such restrictions would have a significant impact on productivity and performance. To alleviate the radiation exposure problem, the sources of radiation which contribute to personnel exposure must be removed from the plant. The only economically feasible way of significantly reducing the source term of a pressurized water reactor (PWR) is to chemically decontaminate the entire primary system.

Full RCS Chemical Decontamination Qualification Program - Description and Results

Beginning in 1989 and continuing through 1993, the Electric Power Research Institute (EPRI) and 11 PWR utilities sponsored a program to verify the technical acceptability of using dilute chemical solvent processes for primary system decontamination. Two processes, AP/CAN-DEREM and AP/LOMI, were qualified for use in the RCS of a W PWR. This laboratory research and engineering evaluation program was completed in 1992 and a topical report was approved by the Nuclear Regulatory Commission (NRC) in 1993.

The purpose of the program was to define and complete a systematic evaluation of the major issues that need to be addressed for the successful decontamination of the entire primary system of a Westinghouse pressurized water reactor system with all fuel removed. The workscope of the overall program was large and encompassed a broad spectrum of engineering evaluations, materials and chemistry evaluations, radiological assessments, and equipment designs.

The program was structured in three major phases: Phase 1 - Initial Parametric Studies, Phase 2 - Decontamination Process Qualification and Detail Engineering Evaluations, and Phase 3 - Detailed Design and Implementation.

Phase 1 of the Program constituted the initial parametric studies to address the major issues related to full RCS decontamination. This evaluation included critical process screening of two commercially available chemical decontamination processes. This evaluation also included consideration of decontamination application with the fuel in and fuel out and basic configuration of the reactor coolant system and auxiliary systems for decontamination application.

Phase 2 of the program entailed detailed engineering and testing evaluations to verify the technical feasibility of applying the two chemical decontamination processes to the generic Westinghouse full reactor coolant system. Phase 2 was divided into seven tasks, as follows:

- Task 1 - Process Qualification Test Program
- Task 2 - Fluid Systems Evaluation of Decontamination Process Integration with RCS and Auxiliary Systems
- Task 3 - Engineering Evaluation of RCS Components and Systems
- Task 4 - Waste Management Methodology and Waste Characteristics
- Task 5 - Evaluation of Long-Term Benefit of Full RCS Decontamination
- Task 6 - Preparation of Topical Report Addressing Industrial and Nuclear Safety Issues
- Task 7 - Full RCS Decontamination Project Conceptual Design

Phase 3 of the program encompasses the detailed design and design implementation effort required to perform the chemical decontamination on a specific demonstration plant. The generic plant evaluation data generated in Phases 1 and 2 is being utilized to perform the plant-specific design effort for a demonstration plant application. Details of this Full RCS Chemical Decontamination National Demonstration, which will be conducted at Con Edison's Indian Point 2 plant in 1995, will be provided in the paper which follows.

All of the tasks described in Phases 1 and 2 above have been completed. The comprehensive process testing program and extensive engineering evaluations of the results of the tests clearly indicate that there are no significant detrimental effects of the chemicals employed in the two proprietary processes tested on primary system materials and components. For most materials of construction, the expected corrosion rates are very low and there is no evidence of intergranular attack (IGA) or stress-corrosion cracking (SCS).

As a result of noted material effects on chrome-plated surfaces, 410 SST and stellite materials, however, certain minimal critical system and component recommended pre- and post-decon inspections and equipment modifications are required during a Full RCS Chemical Decontamination. These highly encouraging results are reported in the Phase 2 Qualification Program Final Report for the subject program.

Based on the success of the Phase 2 Qualification portion of the program, EPRI and Con Edison working with Westinghouse and others are currently completing the detail design and fabrication of equipment and facilities as well as defining the detail operational procedures to perform a first Full RCS Chemical Decontamination in

1995. Efforts are well underway to form a National PWR Demonstration Program for the purpose of funding and managing this important demonstration project.

Fuel Decontamination Qualification Program at V. C. Summer - Description and Results

As noted above, the Indian Point 2 full system decontamination will be done with the fuel removed. Looking beyond this, Westinghouse, at the request of South Carolina Electric and Gas Company, developed a separate program in 1989 to qualify nuclear fuel for full reactor coolant system decon application.

This program involved the chemical decontamination of actual fuel assemblies in a specialized canister in the fuel handling building at the V. C. Summer nuclear station with the same dilute chemical solvent parameters as were employed in the full-RCS qualification program.

To take account of current generation fuel and also future generation fuel designs, one assembly of Vantage 5 and one assembly of Vantage-Plus type fuel were exposed to CAN-DEREM solvents and one assembly each was exposed to LOMI solvents.

Conduct of the Fuel Decontamination Qualification Program (FDQP) necessitated the design and fabrication of a specialized qualification test loop for decontamination of each fuel assembly at the same conditions of flow, temperature, pressure and chemical environment as would exist for the fuel in the reactor vessel during full-RCS decontamination. The specialized loop was designed, fabricated, tested and installed in the fuel handling building at V. C. Summer during 1991.

In August 1991, the two Vantage-Plus assemblies were decontaminated and in October 1991, the two twice-burned Vantage 5 assemblies were decontaminated. All four assemblies plus two twice-burned control assemblies underwent extensive TV visual and eddy current cladding oxide thickness inspections before and after being exposed to the solvent processes, with the same inspections planned after one full cycle of operation in the V. C. Summer plant.

The Summer operating cycle was completed on 6 March 1993 and TV visual and eddy current cladding oxide thickness inspections were performed on the fuel assemblies which had been subjected to decontamination treatment and the non-decontaminated control assemblies. Evaluation of the cladding oxide thickness data showed no significant cladding corrosion performance differences between any of the assemblies. High magnification TV visual examination of the girds, grid springs and assembly nozzles and hold down springs showed no adverse effects of the decontamination processes.

Overall, the fuel material post-decontamination inspection results showed no deleterious effects, with excellent decontamination effectiveness. Preliminary evaluation of the cladding corrosion oxide thickness measurements on the decontaminated and control assemblies indicates that the decontamination treatments have had no adverse affect on the post-decontamination cladding corrosion behavior. In addition, a number of decontamination process application anomalies resulted in recommendations for further study of boron control, ion exchange resin utilization, carbon dioxide generation, EDTA chemical analysis and decomposition, picolinic acid analysis and decomposition, vanadous formate oxidation and reassessment of metals and radioisotopes removed.

Other general recommendations included revisiting each facet of the study to extend the evaluations to include the "fuel-in" full-RCS decontamination scenario and submittal of a second Topical Report to the US Nuclear Regulatory Commission for its approval. To this end, W has developed a Fuel-In Full RCS Chemical Decontamination Qualification Program, which has as its objective, NRC approval of a second comprehensive Topical Report for the Fuel-In Case. Completion of this work and subsequent NRC approval will provide utilities with another key option which provides significant additional benefit in terms of reduced critical path time and lower recontamination rates during a Full RCS Chemical Decontamination. Development of the work scope and schedule for this program has been completed and W is in process of obtaining necessary funding to complete this program. It is anticipated that key results will be available early in 1995.

Author Biography

Phillip E. Miller is Manager of Plant Application in the Nuclear Technology Division of Westinghouse Electric Corp. Mr. Miller acted as Program Manager for the two programs completed as described in this paper and will also be in charge of the Fuel-In Qualification Program. He has 22 years experience with Westinghouse and has managed numerous large, multidisciplined projects. Mr. Miller holds a B.S. Degree in Civil Engineering and has received 9 U.S. Patents to date, many of them in chemical decontamination related technologies.

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