The EPRI DFDX Chemical Decontamination Process

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Abstract
Decommissioning of retired nuclear plants and components demands the proper management of the process, both for economic reasons and for retaining public confidence in the continued use of nuclear power for electricity generation. The cost and ease of management of radioactively contaminated components can be greatly assisted by the application of decontamination technology.

EPRI initiated a program of research and development work in collaboration with Bradtec, which has led to the "EPRI DFD" (Decontamination for Decommissioning) Process. The Process has been patented and licensed to six companies worldwide. The purpose of this process is to achieve efficient removal of radioactivity with minimum waste from retired nuclear components and plant systems. The process uses dilute fluoroboric acid with controlled oxidation potential. By removing all the outer scale and a thin layer of base metal from the surfaces, contamination can in many cases be reduced below the levels required to allow clearance (free-release) or recycle to form new components for the nuclear industry. This reduces the need for on-site storage or burial of large amounts of contaminated material at low level radioactive disposal facilities. An additional benefit is that residual radiation fields can be reduced by a large factor, which reduces the worker radiation exposure associated with decommissioning. Furthermore, this dose rate reduction improves the viability of early dismantlement following plant closure, as opposed to waiting for a prolonged period for radioactive decay to occur. The results obtained in early applications of the EPRI DFD process demonstrated the benefits of taking this approach (reference 1).

Introduction
The EPRI DFD process has been applied successfully by EPRI licensees to many different components, in addition to the primary coolant systems of Big Rock Point BWR and Maine Yankee PWR, including pumps and heat exchangers, and material from DOE facilities. A key aspect of the existing technology that required further development for new applications of the DFD process is the management of secondary waste. Essentially, the disposal of the resulting radioactive ion exchange resin is unpopular and expensive, and is therefore the main constraint limiting further applications. For this reason, market penetration has been relatively slow.

Electrochemical Ion Exchange
A development to overcome this disadvantage has been demonstrated in laboratory tests, and a patent application has been made. The new process is termed EPRI DFDX. This is

the adaptation of the technology of electrochemical ion exchange, previously developed by EPRI for application with the LOMI decontamination process.

In the work with the LOMI process, EPRI sponsored research by Bradtec into a system of Electrochemical Ion Exchange for regenerating ion exchange resin and converting the metal ions held on the ion exchange resin into metal particles. A considerable amount of work was done on this system, including two plant demonstrations at Dresden and River Bend BWRs. The process was called ELOMIX (LOMI Electrochemical Ion Exchange). Technically the process performed well, although it has never been used at full scale with the LOMI process, mainly for economic reasons. The LOMI process is designed to be carried out during the refuelling outage at operating nuclear power plants, and is therefore extremely fast. A large electrochemical cell, with high electrical demand, would be required to keep pace with the generation of the radioactive solution from the decontamination process. For this reason, the ELOMIX process was not applied commercially.

In electrochemical ion exchange, conventional cation exchange resin is used to take the metallic and radioactive ions out of the decontamination solution. However, instead of the resin being in a self standing column, it is "sandwiched" between a cathode and anode compartment. The boundaries between the cathode, resin and anion compartments are formed by cation selective ion exchange membrane, which only permits the passage of cations. Electrodes are placed in the cathode and anode compartments, and electric current is passed through the cell while the solution is flowing through the resin compartment. At the anode protons are formed, which travel through the cation membrane. These protons displace metal cations held on the ion exchange resin, and the metal cations then pass through into the cathode compartment, where the metal ions are deposited as metal (Figure 1).

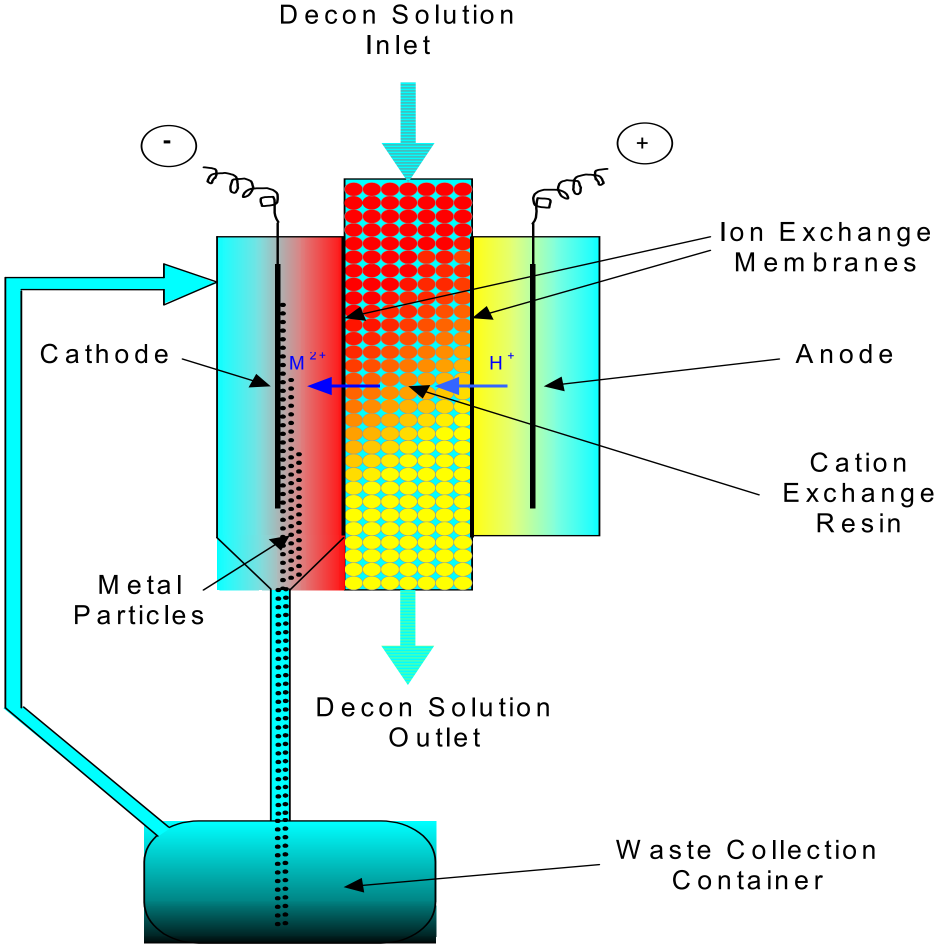

Fig 1: Schematic diagram of the ELOMIX process

The principal drawback of the ELOMIX Process was found to be the available time to apply the process. The metal ions have to be migrated and reduced to metal by the passage of the necessary electric charge. This requires large equipment and considerable electric power if it must be achieved quickly.

A type of Electrochemical Ion Exchange Process can also be used effectively with EPRI DFD, as during applications more time is available, which reduces considerably the capital equipment required to achieve on-line processing of the radioactive solutions.

Results

The development of the electrochemical ion exchange process to work with the EPRI DFD Process resulted in a simplified cell design, compared to the ELOMIX cell. The central compartment was eliminated, as it proved to be unnecessary for the fluoroboric acid system. This has the advantage of permitting a higher current density, thereby increasing the overall efficiency of the system.

The overall process enables the collection of radioactive contamination from a thin layer of the surface of components and systems and its conversion into metal powder for disposal, driven by electrical energy. The metal powder, consisting primarily of iron, nickel and cobalt (including cobalt-58 and cobalt-60 radioisotopes) is easily collected. No other wastes are generated, and thus the new development will represent almost theoretical efficiency of decontamination.

The DFDX process has been demonstrated in laboratory tests, and a pilot-scale portable equipment skid has been constructed. It was possible to achieve electrochemical ion exchange with a high degree of efficiency using the fluoroboric acid system. Metallic flakes created at the cathode are several millimetres across and have good mechanical handling properties. The surface analysis spectrum of the metallic flakes show iron, chrome and nickel with an small oxygen peak indicative of surface oxygen.

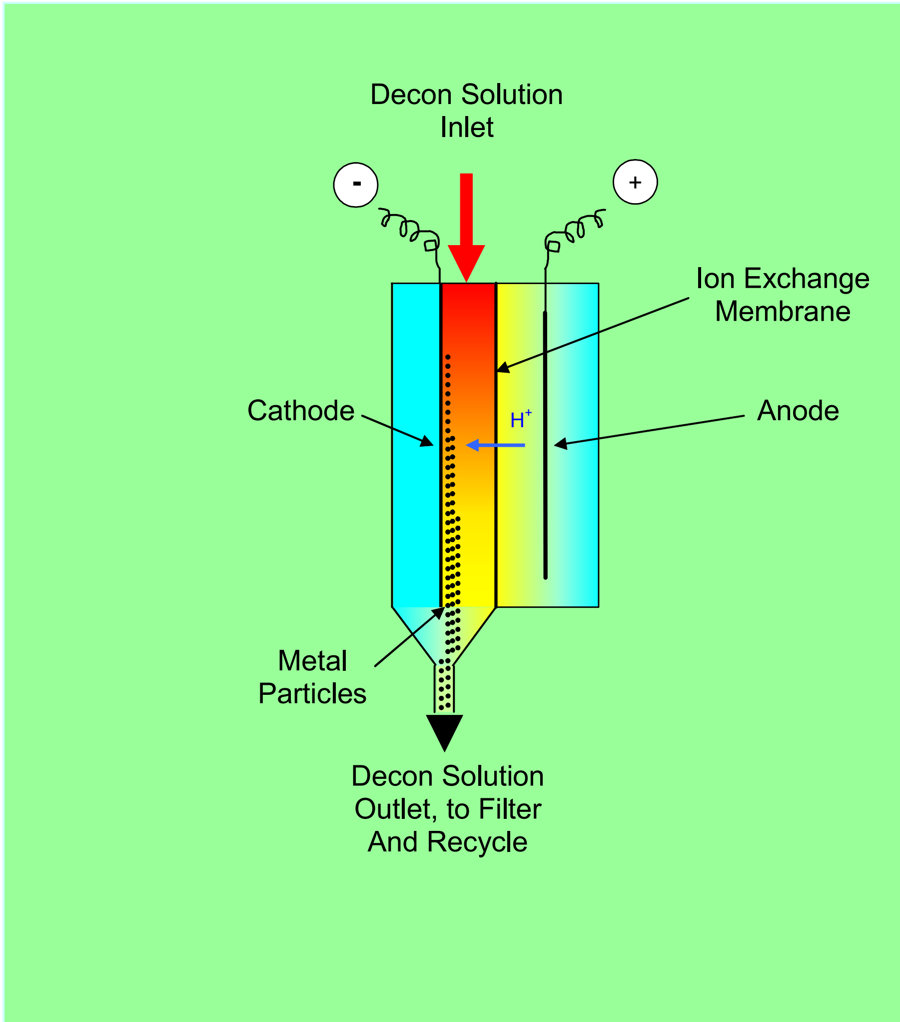

Fig 2: Schematic diagram of the DFDX process

Application of the electrochemical technology with DFD requires much smaller equipment than the ELOMIX system, and the economics are favorable. This development can reduce the volume of waste arising from the DFD Process, by a factor of 10. Waste volume reduction achieved by electrochemical ion exchange permits collection of the radioactive residue as metal particles, which can conveniently be fluidized into a small container for storage or disposal as radioactive waste. The volume of the metallic waste is sufficiently small that storage, for example, in a reactor's fuel pool, to take advantage of radioactive decay, is technically feasible.

The development of DFDX is complete, and potential applications for the process are under evaluation, including replaced components from operating nuclear power plants (for example, retired steam generators), and material from DOE facilities and decommissioned power plants to allow disposal or storage with minimal LLW generation. The controlled reuse of the decontaminated material is also being considered.

Discussion and Conclusions

The laboratory-testing phase of the development process for EPRI DFDX has been successfully completed. During 2002, field tests of the process are planned to start, at a number of nuclear sites, both in Europe and USA. These tests will decontaminate a variety of discarded contaminated components. Ultimately, the technology will be made available to the current EPRI DFD licensees for commercial applications.

In the longer term the new process may have an important role in allowing new reactor plant to adopt a "zero-waste" approach, in which the plant does not require off-site radioactive waste disposal facilities during its operational life.

References

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