DECONTAMINATION AND PROVENANCE TRACKING

The key to acceptable recycle of nuclear materials

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Abstract. Decommissioning of 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. Surface decontamination has an important role to play in decommissioning. A new development, the EPRI DFDX process, produces secondary waste from decontamination in the form of powdered metal rather than ion exchange resin, thereby reducing the volume of secondary waste for storage and eventual disposal. The process has been patented and licensed and is due to be field-tested on a number of sites starting in 2002. Although the purpose of the process is to clean materials sufficiently to achieve unrestricted release, in practice there is some public unease at the prospect of formerly contaminated materials passing into unrestricted use. Greater public support for recycle can be achieved by recording the provenance of decontaminated materials and recycling them back into restricted uses in the nuclear industry. Because the materials have first been decontaminated to below free release levels, there is no objection to using non-radioactive facilities for the recycling and manufacturing activities, provided that the materials are properly tracked to prevent their uncontrolled release.

INTRODUCTION

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.

Much of the material which requires to be managed in retired facilities is contaminated with radioactivity on the surface only. The efficient removal of the surface radioactivity makes the dismantling task easier and provides savings in the cost of waste management. If the decontamination is efficient enough the material may even be recycled rather than disposed of as waste.

Decontamination technology has been extensively developed for use in LWR reactors for reducing operational radiation exposure during maintenance of the plants. The decontamination process is applied to the reactor circuit or sub-circuit at the beginning of the maintenance outage to remove the majority of the radioactivity present on circuit surfaces. One such process, which was developed with EPRI support and has been extensively applied commercially, is the LOMI process. These processes developed for operational use are designed to avoid any possible damage to plant materials (to ensure further safe operation) and are not sufficiently aggressive for the purpose cleaning materials for decommissioning.

DECONTAMINATION

The EPRI DFD Process

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, described in a paper at Spectrum '98, [1] demonstrated the benefits of taking this approach.

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. The process produces ion exchange resin as the final waste form and 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.

The EPRI DFDX Process

A new development to overcome this disadvantage has been demonstrated in laboratory tests, and a patent application has been made. This is an adaptation of the technology of electrochemical ion exchange, previously developed by EPRI for application with the LOMI decontamination process.

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). 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.

This development of the electrochemical ion exchange process to work with the EPRI DFD Process (called "EPRI DFDX") is almost finished, with only the optimization of the cell design to maximize efficiency remaining to be completed. 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.

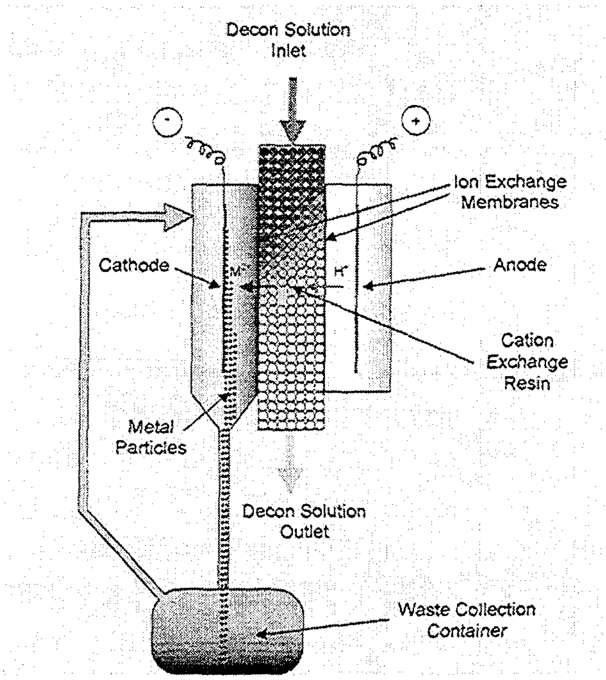

Figure 1 – DFDX Cell Schematic

Application of EPRI DFDX is possible with small equipment, and the economics are favorable. This development can reduce the volume of waste arising from the EPRI 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 nuclear facility's fuel pool, to take advantage of radioactive decay, is technically feasible.

Potential applications for the process include replaced components from operating nuclear power plants (such as 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 in other nuclear applications appears to be economically attractive..

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. In 2003, the technology will be made available to EPRI DFD licensees for commercial applications.

PROVENANCE TRACKING

The recycle and reuse of materials has obvious environmental benefits. If materials can be cleaned and reused this provides an alternative route to disposal of the material and obviates the need to obtain fresh materials for the new product. The benefits of recycling in conventional (non-nuclear) industry are well recognized. In a nuclear context the availability of a recycling route can sometimes allow the early management of facilities or equipment for which no other route is available.

As referred to above, there is ample evidence that decontamination technology is capable of efficiently removing surface contamination from nuclear materials to meet almost any desired standard of cleanliness.

It may seem surprising, therefore, that the cleaning and unrestricted recycle of nuclear materials is not a more widespread practice. The reservations which hold back this practice are not necessarily economic and technical, but more social in origin.

There is public unease about the practice of taking formerly contaminated materials, albeit efficiently decontaminated, into the unrestricted public domain. The unease centres on the potential for mistakes, (ie materials released accidentally which contravene the required standards) and a concern in some quarters that even tiny amounts of residual man-made contamination in recycled products could create health consequences. This latter point might seem inappropriate to many people – evidence continues to accumulate that small doses of radiation (whether from natural or man-made sources) probably cause no harm. It can even be argued that over-caution with regulating small doses of radiation has led to societal costs, which far exceed the benefits. However, fear of radioactivity runs very deep in the public mind, and thus there is a degree of public support for scientists who are sceptical and put forward technical justification for continuing caution. Thus the stage is set for a classic confrontation. First the industry says that the proposed unrestricted recycle practice is economically justified, beneficial for the environment and reduces overall risks. The pressure groups state that the practice allows radioactive poisons into the public domain and is merely being proposed for the economic benefit of the industry. The public does not know whom to believe but instinctively falls on the side of caution. The result is impasse and no progress.

Another weakness of the current situation is the lack of agreement on international standards for unrestricted release. While different countries follow slightly different practices there is ample scope for confusion and dissent, particularly when material crosses frontiers. The continuing uncertainty is also a barrier to setting up serious recycle facilities and operations. The sudden moratorium on recycling materials from the USDOE complex caused significant problems due to the significant time and effort, which had been expended preparing to do this. Without legally agreed international standards for releasing materials from radioactive controls such government moratoria could happen anywhere, which makes the setting up of a business based on unrestricted recycling of nuclear materials a very risky venture.

The answer to these problems may be to try to find a consensus which steers both sides away from the "no-action" solution. Private discussions have revealed that many of the reservations the pressure groups (and indeed the public at large) have about recycling nuclear materials are removed if the material is recycled into a restricted use in the nuclear industry. Whether or not new nuclear power plants are built, the industry will require large amounts of materials for various facilities in the coming years (eg waste containers, structural steel, plant and building materials). The idea that these components should, where possible, be built out of recycled materials appears to command widespread support. The industry would also be likely to accept this practice if a route could be identified for a significant proportion of its materials to be treated in an economic manner.

Of course this practice is well established already for certain types of product (shielding blocks etc). However, the practice has so far been limited because it involves using specific manufacturing processes set up within the nuclear industry. In most cases the facilities are radiologically controlled and thus are inevitably expensive, small scale and rather inflexible. It would never be possible to manufacture the full range of products the industry needs in facilities of this kind.

An alternative approach is to clean materials to free release standards and then pass them through the normal (non-radioactive) manufacturing chain to form products for the nuclear industry. The provenance of the materials is "tracked" through the manufacturing chain to ensure compliance with the restriction to end-use in the nuclear industry. Such an approach will be *a priori* less economic than unconditional release of the same material, since the various supply chain organisations have to be compensated for maintaining the provenance of the material. However, the economic loss may be quite small and indeed may be reversed by upstream savings (eg more relaxed standards of survey required). There are several advantages of this approach. Because existing manufacturing facilities are used there is no need for extensive investment, and there is the flexibility to convert a wide variety of cleaned material to recycle into almost any nuclear industry product (pipes, valves, fasteners, waste containers etc). Finally, the provenance-tracking route may provide an option for management of materials from a decommissioned facility where currently no other option exists.

Clearly the greatest benefit will be obtained when the material in question has high value. High value can either be the intrinsic value of the material itself (eg nickel, platinum) or the payment receivable from the material's initial owner for management of the material. In other words the recycler can make his money either from selling the material to the end-user, or by charging the initial owner to manage the material, or both. There is no universal economic solution – just a whole series of options optimized by the recycler to make money from getting waste materials into nuclear industry products. This is an ideal activity not so much for the big nuclear companies, but for entrepreneurial small and medium size enterprises, which have the dexterity to find the routes, which make money.

An example of options is given in Table 1 below for contaminated nickel metal. The numbers are broadly based on an actual "real life" case. As can be seen the unrestricted release option is the cheapest, but if this is not permitted, the restricted recycle route is still much better economic value than direct disposal, and can be done in a way that actually generates net cash for the original owner.

Table 1. Nickel Disposal and Recycling Option Costs (US\$ kg^{-1})

	Direct Disposal	Unrestricted Release	Restricted Recycle
Disposal	1.75	0	0
Decontamination	0	3.2	2.2
Secondary Waste	0	0.5	0.3
Survey	0	0.1	0.1
Sale	0	-6.9	-6.9
Tracking / Special Treatment Cost	0	0	2.1
Total	**1.75**	**-3.1**	**-2.2**

CONCLUSIONS

- Decontamination can make a useful contribution to the management of materials from decommissioning of nuclear facilities, both in assisting dismantling and reducing waste costs.
- The EPRI DFDX Process represents a new development in decontamination, which reduces secondary waste problems to a minimum.
- Public concern with unrestricted release has limited the market penetration of decontamination/ unrestricted recycle scenarios.
- Provenance tracking provides a means to allow material released from radioactive controls to be recycled back into the nuclear industry in an economic way. Although there is a small economic penalty this method is likely to be more acceptable to the public than unrestricted release.

REFERENCES

[1] C.J.WOOD, D. BRADBURY, G.R. ELDER, The EPRI DFD Process – Decontamination for Decommissioning, Proceedings of Spectrum '98, pages 65-67, 1998.