PARTITIONING AND TRANSMUTATION: NEAR-TERM SOLUTION OR LONG-TERM OPTION?*

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ABSTRACT

Starting in 1989, the concept that partitioning and transmuting actinides from spent nuclear fuel could be a "solution" to the apparent lack of progress in the high-level waste disposal program began to be heard from a variety of sources, both in the U. S and internationally. There have been numerous papers and sessions at scientific conferences and several conferences devoted to this subject in the last three years. At the request of the U. S. Department of Energy, the National Research Council is evaluating the feasibility of this concept.

Because either plutonium or highly enriched uranium is needed to start-up breeder reactors, there is a sound rationale for using Pu from reprocessing spent light-water reactor fuel to start a conversion to Pu-breeding liquid metal reactors (LMRs), once society makes the determination that adding a large component of LMRs to the electricity-generating grid is desirable. This is the long-term option referred to in the title. It is compatible with the current and likely future high-level waste program, as well as the current nuclear power industry in the U. S.

However, the thesis of this paper is that partitioning and transmutation (P-T) does not offer a near term solution to high-level waste disposal in the U. S. for numerous reasons, the most important of which is that a repository will be needed even with P-T. Other important reasons include:

- lack of evidence that the public will be more likely to accept a repository that has a reduced inventory
- the waste disposal program delays do not result from technical evidence of lack of safety
- the economics of reprocessing and/or P-T are unfavorable
- obtaining the benefits from P-T requires a long-term commitment to nuclear power

INTRODUCTION

After 1978 the policy in the U. S., either official or unofficial, has been to forego reprocessing of spent nuclear reactor fuel in favor of direct disposal. This was an Executive Policy under President Carter, and although the official policy was rescinded under President Reagan, the economics have continued to favor the once-through nuclear fuel cycle (direct disposal of spent fuel). The Nuclear Waste Policy Act of 1982 and subsequent amendments provide for disposal of both solid reprocessing waste and spent fuel and are neutral toward the issue of reprocessing.

The technology of reprocessing was developed in the nuclear weapons program to recover Pu from reactor fuel. The role of reprocessing in the civilian power program prior to 1989 was seen in terms of extension of a limited uranium resource by recovering and recycling Pu in mixed oxide fuel in light water reactors, a technology that operates in other countries today. The waste management benefits of this technology were not the primary motive, and in fact were not regarded as a significant incentive (1,2).

As proposed starting about 1989, the concept of Partitioning and Transmutation (P-T) addresses all transuranic actinides, as well as possible transmutation or immobilization of selected long-lived fission products. In at least some presentations, the waste management benefits are seen as primary, with electricity production a beneficial by-product. P-T is also seen as a solution to a seemingly intractable lack of disposal for high level waste and spent fuel. These latter views are the subject of this paper.

This paper addresses only a few major issues. Details of the concepts discussed and additional issues not noted here are given in Ref. 3. The discussion in this paper is confined to actinide burning in liquid metal reactors, because this is the most mature technology and is funded for research in the United States and in other countries.

NEAR-TERM SOLUTION

Although there is debate about the maturity and technical readiness of the P-T concepts, for this paper the assumption is made that the technology can be demonstrated to function as stated by the various proponents of P-T. The issues addressed here are the technical interaction of P-T with the disposal program, and the economic, sociological, political, and fuel cycle system implications of the introduction of P-T as an integral part of the nuclear waste management system.

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Technical Interaction of P-T with the Disposal Program

Most important is the fact that a repository will be needed regardless of whether P-T is adopted as national policy. First, there exists a large amount of high-level waste from the defense program. Second, there are many special categories of waste existing in small amounts from both the defense and civilian programs that will require disposal in a HLW repository. Finally, it is not technically feasible to decontaminate the waste from P-T sufficiently to avoid producing high-level waste (3). Thus it will remain necessary to develop a geologic repository on an expeditious schedule. P-T does not "solve" the need for a repository.

All technical studies to date, including the most recent official Yucca Mountain performance assessment (4), indicate that spent reactor fuel can be disposed of within the safety guidelines set by regulatory agencies in the U.S. and internationally. A recent study (5) compared waste from actinide burning (AB) at Yucca Mountain with spent reactor fuel and concluded "Although most of the releases from a repository containing partitioned/transmuted waste are lower than those from a repository containing conventional spent fuel, the maximum releases are not significantly different". The lack of progress in establishing a high level waste repository is not based on technical issues of safety. If there is no technical issue of safety, it is difficult to understand how an improvement in safety will help the program.

The radionuclide inventory that remains in the reprocessing waste is non-negligible for several reasons. First, there is some loss of radioactive material to the waste stream in each reprocessing cycle within the transmutation device. Even if decontamination factors of 10^{-3} to 10^{-5} can be achieved as postulated, over dozens of cycles a significant amount of material passes to waste.

Second, a presumption by advocates of actinide burning is that a postulated reduction in actinide inventory of 10^{-3} to 10^{-5} will reduce actinide release, and therefore risk, by a similar amount. Pigford (6) points out that this is not the case, because the fractional dissolution rate of the waste is about 10^{-10}. Therefore, the decontamination factors would have to be 5 to 7 orders of magnitude better than projected before the low inventory became the controlling factor for actinide release.

Fuel Cycle System Implications

Part of the inventory reduction in high-level waste is converted to low-level waste, for which there continue to be public acceptance problems in siting disposal facilities. Essentially all of the LLW generated by reprocessing LWR spent fuel is new to the system—that is, it would not be there in a once through cycle. Based on information in an EPRI report (7), it can be calculated that the reprocessing of spent LWR fuel adds about 12% to the LLW volume expected from a once-though cycle (3). The EPRI report (7) also indicates that reprocessing LMR spent fuel appears to generate about 10 to 30% more LLW than reprocessing LWR spent fuel.

Very large amounts of U-238 (95% of the spent fuel) are produced by the reprocessing, and except for recycle in light water reactors (not advocated by P-T proponents) and initial fuel makeup in the LMR, there is little use for this uranium. At actinide-burning conversion ratios, it is not needed for blanket material in the LMR.

Economics

Ignoring all of the other costs of P-T, the cost just to reprocess LWR fuel to feed a P-T system is enormous. The simplest way to illustrate this is to postulate approximately $1000/kg reprocessing costs (8), in which case the 84,000 MTIHM of spent fuel projected to be disposed would cost $84 billion to reprocess (3). Because of excess capacity, it is possible that commercial prices as low as $500/kg might be available internationally. However, the resulting $42 billion exceeds the projected $28-35 billion cost of a repository, which as noted above would still be needed.

In addition to the cost of reprocessing LWR fuel, a large infrastructure of LMR reactors, reprocessing facilities, and fuel fabrication facilities would be needed. At present an LMR system could not compete economically with LWRs operating on a once-through fuel cycle. Even if the reprocessing costs were paid by the government or a special tax, LMRs are not currently competitive with LWRs.

Sociological and Political Considerations

From the viewpoint of establishing a repository, perhaps the greatest weakness of the P-T concept is the lack of evidence that the public will accept a facility with a low inventory of radionuclides any more readily than one with a high inventory. In a study undertaken to evaluate this issue, McCabe and Colglazier (9) conclude that "The DOE should not expect, nor is it likely, that the public would be more inclined to host a nuclear waste facility because of a reduction in the amount of waste to be emplaced". They also state "An analysis of public opinion literature suggests that those issues that dominate – public knowledge of nuclear waste issues, nuclear waste as a reason for opposing nuclear power, issues of trust and confidence, transportation, and opposition to facility siting – are largely unaffected by transmuting waste prior to disposal".

Because of the unfavorable economics, the public that presently objects to perceived small indirect subsidies for nuclear power derived from LWRs would be asked to accept large and direct tax subsidies for nuclear power derived from LMRs. Acceptance of such a subsidy appears unlikely under current conditions.

For a variety of reasons, including economics, proliferation concerns, the deployment of untested technology, and the need for a centrally coordinated system, the Federal government would have to own, manage, and possibly operate a P-T program. With a few exceptions such as TVA and BPA, the role of the Federal government in the energy sector of the economy is restricted to regulation and sponsorship of R&D. Ignoring the question of intrinsic merit of government ownership, such a conversion of a substantial part of the nuclear power industry would be an immense change to the economic and political infrastructure in the U.S. The Energy Policy Act of 1992 has recently moved in the opposite direction by partially privatizing uranium enrichment.

It is commonly stated in the United States that new nuclear reactors will not be built until the waste problem is "solved". The solution proposed by advocates of P-T involves a commitment to nuclear power, with dozens of new reactors that have to run for centuries to burn the actinides even at non-breeding conversion ratios. In other words, we need more and better nuclear power as a solution to our waste disposal problem, which today blocks the way to further nuclear power.

Whereas today's nuclear power system could be shut down immediately with the result being disposal of a smaller than planned inventory of waste, a system involving P-T would require centuries to reduce the inventory to the expected level (10). Thus an early shutdown of a P-T system would lead to disposal of much larger than expected waste inventories that would include spent fuel, which is supposed to have been eliminated from the disposal system by P-T.

The perceived link between nuclear power and waste disposal would continue to impact the disposal program even with P-T. The National Research Council (11) identifies "the controversy over nuclear energy and radioactive waste disposal as part of nuclear energy development" as the first of two main reasons for failing to reach a "socially satisfactory resolution of the problem of HLW management and disposal". This linkage and the opposition to waste disposal that it generates will not disappear with P-T. In fact, if the offered solution is to increase nuclear power to solve the waste disposal issue, the opposition will likely intensify.

LONG-TERM OPTION

Despite the large number of reasons (3,8) that P-T is not a near-term solution to the disposal of spent fuel from LWR's, there are also reasons why research on the concept as a long-term option has been continued. Over a very long timeframe when energy resources become scarce and/or if emissions from carbon fuels become unacceptable, liquid metal reactors operated at a breeding conversion ratio offer a virtually inexhaustible source of energy.

The economics of actinide burning within the IFR fuel cycle in the LMR would be considerably better than for burning actinides derived from reprocessing LWR spent fuel (8). Thus the IFR might produce an improved waste stream within its own fuel cycle at no economic penalty. Furthermore, operation of LMR's at a breeding conversion ratio could provide several additional environmental benefits:

- By using excess U-238 as blanket material, a potential waste would be converted to beneficial use
- Recycle of plutonium would obviate the need for additional uranium mining, milling, and enrichment.

Finally, although no technical flaws have been identified in the repository program at this time, it is always possible that one or more could develop. In such a case, P-T might assist in overcoming a specific technical deficiency in the disposal program.

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