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The Separations Technology and Transmutation Systems (STATS) Report: Implications for Nuclear Power Growth and Energy Sufficiency

Abstract

As part of the re-examination of Separations Technology and Transmutation Systems (STATS), the Department of Energy requested the National Research Council in 1991 to appoint a National Academy of Sciences (NAS) Committee to conduct a broad systems review of the application of separations and transmutation (S&T) concepts to radioactive waste disposal. The scope of the study included a peer-reviewed report evaluating the relative effects, costs, and feasibility of employing S&T for managing (1) spent nuclear fuel from power reactors, and (2) radioactive wastes from selected defense production reactor sites. The report was published in 1996.

The NAS Committee's principal recommendations include:

- None of the S&T concepts reviewed eliminates the need for a geologic repository.
- The current policy of using the once-through fuel cycle for commercial reactors, with disposal of the spent fuel as high-level waste, should be continued.
- Fuel retrievability should be extended to a reasonable time (on the order of 100 years) to avoid foreclosing alternative fuel strategies that may be in the national interest.
- Research and development should be conducted on selected topics to support the cost-effective future application of S&T to commercial spent fuel and separations for defense waste applications.

Although these recommendations are consistent with present U.S. policy, they do not address anticipated electric power demand growth in a comprehensive manner. Increased electric power demand can only be met in the long run by nuclear power plants. To prepare for this anticipated scenario, renewed research and development in the S&T area is required to address the uncertainties that utilities and the industrial sector face regarding the role of nuclear

power. These uncertainties include the difficulties in planning for the complete fuel cycle. The STATS study, unfortunately, did not include a system-wide evaluation of the advantages of spent fuel recycling: its ability to reduce the toxicity of high-level waste from hundreds of thousands of years to hundreds of years; its ability to greatly increase the repository capacity; its potential economic advantages; its resistance to proliferation; and its ability to provide a greatly expanded world energy supply.

The recommendations in the STATS report and the limitations of the study are discussed and suggested areas for future efforts to improve the usefulness of the study are identified. Study limitations are identified and grouped into three categories: (1) scope, (2) system and (3) technical.

Introduction

After reading a pre-publication version of the Separations Technology and Transmutation Systems (STATS) report that resulted from a National Academy of Sciences (NAS) study, the *Energy Daily*[1] summarized the substance of the report in a headline: "Underground Option *Only* Spent Fuel Option — NAS." Although this headline accurately reports the principal NAS recommendation, we believe that the report is so narrowly focused that it presents a distorted view to readers not generally familiar with energy resources, nuclear reactor technology, and waste management. The STATS report, if improperly used, will make it more difficult to deploy advanced nuclear power systems in the U.S. unless the limitations in its assumptions and its narrow scope are recognized and clearly understood.

As part of the re-examination the Department of Energy (DOE) requested the National Research Council in 1991 to appoint a National Academy of Sciences (NAS) Committee to conduct a broad systems review of the application of separations and transmutation (S&T) concepts to radioactive waste disposal. The scope of the study included a peer-reviewed report evaluating the relative effects, costs, and feasibility of employing S&T for managing (1) spent nuclear fuel from power reactors, and (2) radioactive wastes from selected defense production reactor sites.

We concur with the principal recommend-ations NAS Committee which include:

- None of the S&T concepts reviewed eliminates the need for a geologic repository.
- The current policy of using the once-through fuel cycle for commercial reactors, with disposal of the spent fuel as high-level waste (HLW), should be continued.
- Fuel retrievability should be extended to a reasonable time (on the order of 100 years) to avoid foreclosing alternative fuel strategies that may be in the national interest.
- Research and development should be conducted on selected topics to support the cost-effective future application of S&T to commercial spent fuel.

Unless concrete action is taken on the last two recommendations, uncertainties that the U.S. utilities and the supporting nuclear industrial sector face in long-term planning regarding the role of nuclear power in the U.S. energy equation will remain. These uncertainties include the difficulties in planning the complete fuel cycle or its components such as:

- The extent that additional uranium mining, milling, conversion and enrichment will be required and the effect of these activities will have on uranium reserves and the price of uranium.
- The degree which plutonium will be utilized to offset the diminishing uranium resources and to support continued use of nuclear power.
- The establishment of interim storage of spent fuel.

- The size, number and environmental risk associated with spent-fuel repositories.

We obtained a copy of the draft STATS report when alerted to its existence by the *Energy Daily* article in September 1995. We were told that the report had not been published and that there was opportunity to incorporate appropriate comments. (Indeed, the published report[2] was not available prior to mid-March 1996.) We were unsuccessful in persuading Dr. Rasmussen, Chairman of the STATS Committee and Dr. Thomas, Study Director for the National Research Council, to adjust the report to accommodate our concerns and comments. Dr. Rasmussen indicated that the Committee had already completed their information gathering phase and that changes in the scope of the study or recent progress in reprocessing should be considered by a new committee under a new charter. Dr. Rasmussen believes that the Committee's conclusions are appropriate considering their charter and the information that was available at the time they completed gathering information for the report at the end of 1992.

We continue to believe that our concerns with the STATS report are well founded. We are hopeful that the DOE will charter a new committee to review the question of spent fuel management on a broader overall system basis that includes the complete nuclear fuel cycle as well as the availability and conservation of all energy resources in the U.S. A list of specific issues that should have been more completely addressed in the STATS report, or addressed with current information, is included at the end of this introduction.

Although we agree that investigation of the Yucca Mountain repository for HLW is appropriate, the report would have made a much more valuable contribution if it had assessed the system wide advantages of closing the nuclear fuel cycle including: its ability to reduce the toxicity of HLW from hundreds of thousands of years to hundreds of years; its ability to greatly increase the repository capacity; its potential economic advantages; its resistance to proliferation; and its ability to provide a greatly expanded energy supply for the U.S. and the world. None of the advances in the design of the Advanced Liquid Metal Reactor (ALMR) or in pyro metallurgical processing technology that occurred after 1992 was factored into the NAS assessment. Without including the recent advances in fuel recycle technology, and advances in the ALMR/Fuel Recycle System, the STATS report provides an out-of-date perspective on what we believe is today's leading nuclear technology.

The ability of nuclear power to reduce the potential for global warning and air pollution, in itself, does not provide incentive for the utility companies to order new nuclear plants. On the other hand, there is a clear incentive for our Government to reduce air pollution to meet its national goals and international treaty obligations. To meet these environmental commitments our Government must provide legislation that supports the continued research and development of advanced nuclear power technologies (as enacted in the 1992 Energy Policy Act but not executed) and supports the first utility that takes the risk required to go forward with the construction of a nuclear plant using the new one-step licensing procedure that has been instituted, but is untried, in the U.S.; and/or levying environmental burden taxes on fossil plants.

The STATS report should have included a thorough discussion of the use of the ALMR and its associated pyro metallurgical processing fuel cycle. Our government has supported the development of a repository for LWR spent fuel as the alternative to aqueous reprocessing (banned by President Carter, but later reinstated by President Reagan) as well as the development of the ALMR and its pyro metallurgical processing fuel cycle. Support for both of these activities has diminished in the case of the repository and disappeared in the case of the ALMR/Fuel Recycle System. The economic advantage of the ALMR and its pyro metallurgical processing fuel cycle over the use of geologic repositories for direct disposal of spent fuel and over the use of an aqueous reprocessing plant to perform S&T became more clearly understood during 1994 when a definitive fuel cycle facility design and cost estimate were completed.[3,4,5,6] As the STATS Committee completed their "information gathering' phase in 1992, the STATS report provides an out-of-date perspective on what appears to be today's most promising nuclear power technology.

Major Concerns

We identified a number of important concerns in the final draft STATS report and grouped them into three categories: scope, system and technical. A more detailed discussion of some of these concerns according to this grouping follows. Although our analysis is based on the pre-publication version of the report, our spot comparisons uncovered no substantive changes in the published report. Where we make reference in our discussion to a specific page, we use the published report page number. The list below includes the concerns that are discussed in the following sections.

Scope Type Concerns

1. Increasing Nuclear Power Generation Scenario
2. Report Objectivity
3. Ethical Considerations
4. Energy Resource Conservation
5. Mortality Risk Reduction
6. Report Timeliness

System Type Concerns

1. Fuel Cycle System Analysis
2. Long-term Repository Safeguards
3. TRU Inventory Fraction
4. Reprocessing Cost
5. Repository Capacity
6. Mixed Missions: Defense Waste/Spent Fuel

Technical Type Concerns

1. Environmental Hazard Reduction
2. TRU Burning Rates
3. Fission Product Transmutation
4. Process Losses

Scope Type Concerns

1. *Increasing Nuclear Power Generation Scenario* The STATS report (p. 13) states that: "The National Energy Strategy U.S. DOE 1991/1992, projects that a substantial amount of new generating capacity — from 190 to more than 275 GW — would be added through nuclear power between 1991 and 2010." If the latter DOE nuclear power capacity forecasts are accurate, they represent an increasing nuclear power generation scenario. As the current nuclear power capacity is about 100 GW, the projections quoted in the STATS report represent increases in nuclear power of 95 to 190% over a 35-year period, an annual growth rate of 2-3%.

The report also states (p. 13) that the implications of the projected increasing nuclear power component are important in determining the role of S&T. But despite recognition of an increasing need for electric power, the report addresses only declining and continuing (constant) low power generation scenarios. The conclusions in the report would have been different if an increasing power generation scenario had been evaluated. For example, the cost of investigating and certifying four to five additional repositories similar to Yucca Mountain could be avoided by applying S&T that offers a capacity increase of four to five (as stated in the report, p. 7). The report is clearly deficient by not addressing long-range use of increased nuclear electric power.

2. *Report Objectivity* The STATS Committee was established under the direction of the National Research Council, Board of Radioactive Waste Management (BRWM) at the request of DOE. DOE essentially suspended research and development on S&T late in the period of the Committee study and gave S&T proponents little or no opportunity to describe recent advances in their approaches. Instead, DOE focused its attention on site remediation and waste disposal. Also, as the charter of the BRWM is to oversee the repository program, basically at the exclusion of alternatives, it is

not surprising that the STATS report would discount the significant advantages of S&T.

The scope of the STATS Study included preparation of a report reviewed according to standing policies of the National Research Council (p. 131). ALMR input to the STATS Committee, at their request, was discontinued at the end of 1992. The Committee last met on August 5, 1993. During the period, 1992-1995, considerable development of the ALMR/Fuel Recycle System was accomplished. The Committee did not provide the ALMR team an opportunity to review the STATS report.

3. *Ethical Considerations* In the past, technology has often been developed without regard for its ethical consequences. Lately, a closer tie is being made between technology use and its environmental and societal consequences. Perhaps ethics was not a proper consideration to include in a technical study begun in 1991, but in 1996 (the publication date of the STATS report), it would appear to be an omission. The Radioactive Waste Management Committee of the NEA/OECD recently published its collective opinions on the ethical aspects of geologic disposal.[7] Some of the collective opinions of this body are listed below, along with parenthetical statements indicating how these opinions on ethics appear to be violated in the STATS report.

- The distinction between radioactive waste that can and cannot be recycled must be made. (Placing spent fuel that can be recycled in a repository violates this principle.)

- Generation of radioactive waste shall be minimized. (Placing spent fuel that can be recycled in a repository appears to violate this principle.)

- Future populations must not be committed to continued expenditure of resources to provide future population protection. (Concern about future diversion of materials with high plutonium content will require continued surveillance and expenditure of resources. Advocating a once-through cycle violates this principle.)

- Interdependencies among all steps in radioactive waste generation and management must be appropriately addressed. (Lack of consideration of the interdependency between national energy resources and once-through fuel cycles violates this principle.)

4. *Energy Resource Conservation* The STATS report recognizes the value of the energy resource in spent fuel by concluding (p. 2) that access to the geologic repository for spent fuel should be maintained "....for a reasonable period of time, say about 100 years..." and recommending (p. 10) that "Fuel retrievability should be extended to a reasonable time (on the order of 100 years) to avoid foreclosing alternative fuel strategies that may be in the national interest."

Recognition of the energy value remaining in LWR once-through spent fuel was not considered in formulating the Committee's recommendations. If utilization of its energy potential in about 100 years is a valid consideration, interim placement of the spent fuel in a repository designed for perpetuity seems illogical. Certainly, the economic arguments presented in the STATS report (notwithstanding that they are based on obsolete data) can not reasonably be expected to apply 100 years from now. Moreover, the STATS report does not quantify the energy potential of uranium in the U.S. if used in the once-through LWR cycle compared with its energy potential in an ALMR/Fuel Recycle System.

We have calculated the enormous energy potential that can be realized through utilization of the ALMR/Fuel Recycle System, the energy potential of the LWR once-through fuel cycle, and for comparison on the same basis, the energy potentials of indigenous (U.S.) fossil fuels. These values, based on current DOE energy resource information are given in the following table. Our analysis indicates that the U.S. would be about 350 times more energy sufficient using ALMRs vs. LWRs. In comparison, the large U.S. coal resource, generally considered to be vast, contains only about one-tenth the energy that could be provided by ALMRs with fuel recycle. In assessing the ALMR value, we utilize the depleted uranium (as make-up "fuel") that already exists and that will be produced in the process of enriching fuel for existing LWRs during their design life.

Fuel System	Thermal Energy, TWy*	Relative Energy
ALMR/Fuel Recycle	1900.0	345.
Coal	193.1	35.0
Gas	29.3	5.3
Oil	23.1	4.2
LWR/Once-through	5.5	1.0

*Energy estimates for fossil fuels are based on "International Energy Outlook 1995," DOE/EIA-0484(95). The amount of depleted uranium in the U.S. includes the existing stockpile and that expected to result from enrichment of uranium to fuel existing LWRs operated over their 40-y design life. The amount of uranium available for LWR/Once-Through is assumed to be the reasonably assured resource less than $130/kg in the U.S. taken from the uranium "Red Book."

5. *Mortality Risk Reduction* The STATS report should have included a table similar to Table 6-4 (p. 110) for the case of an all-ALMR nuclear-electric sector. The total potential health risk (more precisely *mortality risk* as quantified in the tables) for such a scenario would drop by a factor of two as uranium mining, milling, conversion and enrichment would not be required. Table 6-4 considers only a 20% (power) replacement of the LWR once-through cycle with the ALMR/Fuel Recycle System. The mortality risk advantage of ALMRs, therefore, was not fully demonstrated in the report.

6. *Report Timeliness* We recommend that in future studies, NAS publish their study reports in a reasonably short time after their last committee meetings. The STATS report has been passed-up by current events including:

- The 1996 Yucca Mountain budget was severely cut and it is no longer likely that spent fuel could be emplaced there before 2010.
- Serious attention is being given to bills in the House and Senate for interim surface storage of spent fuel.
- U.S. energy independence requires that we become less dependent on foreign oil — and we have very little of our own.
- U.S. uranium resources are very limited.
- Uranium separated from LWR spent fuel in the ALMR would be recycled to LWRs for use in fresh fuel fabrication, thus reducing requirements for uranium mining and enrichment separative work.
- There are large amounts of depleted uranium in the U.S. that could fuel ALMRs that would initially be fueled with actinides from LWR spent fuel. Used in this manner, depleted uranium and plutonium become the largest energy resource in the U.S. The environmental burden of depleted uranium would be gradually reduced.
- The program for development of the ALMR/Fuel Recycle System was making excellent progress before it was terminated for non-technical reasons. The potential of this

technology surpasses any existing electric power generating system.

System Type Concerns

1. *Fuel Cycle System Analysis* While allegedly taking a systems point of view (p. 49), the report does not treat the nuclear fuel cycle for the generation of electricity on a system basis. Only when this is done, can one make societal, environmental, health, economic, and technical assessments of how to treat spent fuel. Although the study was started in January 1992, the Integration Subcommittee soon disbanded (May 1992). Presumably, this subcommittee was responsible for the system analysis, but was not in existence as a subcommittee to review the study conclusions. A thorough system analysis would look at the entire U.S. indigenous energy base and conclude that it is imprudent to bury spent fuel in a geologic repository. The STATS report does not consider this fundamental issue.

We are astonished that the report does not include the "repository" in its system description as part of the nuclear fuel cycle! Also missing from the description, in the list of key system components, are uranium mining, milling, enrichment, tails disposal and fuel fabrication facilities. The report conclusions appear to have been made on the basis of arbitrary assumptions and incomplete system analysis for a declining or a continuing (constant) low-power scenario, with no consideration of increased generating capacity in the future.

2. *Long-term Repository Safeguards* The difficulties, cost, and institutional barriers to reprocessing are stated frequently in the STATS report. However, the report fails to address the cost for safeguarding (and associated issues) for times exceeding 2000 centuries, the 600 t of plutonium that would be placed in the repository as a result of LWR operation on a once-through cycle. With S&T, as would be practiced with ALMR operation, the amount of plutonium in the repository would be reduced by a factor of 1000, to 600 kg, pessimistically, or by up to a factor of 100,000, to 6 kg. At either of these lower amounts of plutonium in a dilute waste form, safeguarding may not be required because of the dilute characteristic of the plutonium resource, and therefore its greatly diminished attractiveness as a source of weapon material. The cost of a minimal safeguard program for once-through spent fuel at Yucca Mountain could easily exceed the $62B cost estimated (which we consider to be greatly over-estimated) in the report for reprocessing 62,000 t of LWR spent fuel and avoiding its placement in the repository. In fact, the ALMR development team found that the total cost of reprocessing LWR spent fuel would be covered by the sale of electricity from the ALMRs.[3]

3. *TRU Inventory Fraction* In evaluating the S&T options, the STATS report relies on a parameter that is referred to as the Transuranic (TRU) Inventory Fraction. This parameter compares, for equal electrical energy output, the total inventory of TRU contained in the transmuter, fuel cycle, and waste for the particular S&T option considered with the inventory of TRU in spent fuel of the LWR once-through fuel cycle. The parameter is misleading because it considers the entire TRU inventory of the S&T option during operation as waste, destined for the repository as though it is all spent fuel. This entire inventory for an S&T option is represented by three terms in the denominator of the parameter-defining equation. There is a large (several orders of magnitude) disparity in size of the first two terms (TRU in the reactor and TRU in the fuel cycle) compared with the third term (TRU in the waste). Unless an immediate demise of nuclear power is assumed, the inventory of an all-ALMR S&T system would have only a negligible content of TRU in the waste destined for the repository. The appropriate comparison parameter for a continuing or increasing nuclear power scenario should consider only the material destined for the repository: the spent fuel for the once-through LWR system, and the waste for the ALMR S&T system.

A simple approximate calculation shows that for equal power generation from these two "pure" systems, the ratio of TRU content in material destined for the repository from an ALMR with fuel recycling to that from an LWR once-through cycle is 0.008 (pessimistic) or to as low as 0.00008. These ratios correspond to an actinide separation factor in the ALMR recycling process of 0.1% or 0.001%, respectively. The same ratios could be achieved for a roughly 50% power mix of ALMRs and LWRs (compared to the all-LWR once-through system) by adjusting the conversion ratio and thus consuming all the spent fuel from the LWRs. The STATS report (p. 6 , p. 110) appears to consider at most a power mix of 20% ALMRs, but does not provide the rationale for this choice. Clearly, the less S&T that is performed, the less the advantage that can be derived from S&T.

A pure ALMR system would retain all the TRU inventory in the reactor and fuel cycle to produce energy for as long as it was needed, discharging only processed waste with minimal TRU content to the repository. At the end of the "ALMR era," unless the TRU in the reactor and fuel cycle were needed to fuel another energy producer, the TRU inventory could be eliminated by recycling in "burner" ALMRs. The number of ALMRs in operation would decrease over time to a single reactor. The final core might need to be disposed of in a repository, but more likely would be disposed of in methods not yet devised that would not require geologic disposal. We disagree with the statement in the STATS report (p. 59): "This residual inventory must be accounted for as potential high-level waste." That statement is only valid if the objective is to shut down nuclear power generation on a short time scale.

4. *Reprocessing Cost* The STATS report concludes that reprocessing is not economical and therefore is not appropriate to use in the U.S. In fact, the report arbitrarily adopted the high value of a "possible" cost range of $810-2110/kg. It appears that all "reasonable" or "low" cost estimates were discounted.

It may have been appropriate to discount pyro metallurgical processing facility designs and costs in the 1992 time frame because of the early developmental stage of the process. However, the pyro metallurgical process was significantly more developed by 1994 and an extensive preliminary design/cost report of pyro metallurgical processing facilities was prepared by the ALMR team.[6,8] It is ironic that the general bibliography includes several 1993, 1994, and 1995 references, but none of these includes current pyro metallurgical processing facility design and cost information.

The STATS Committee also ignored or did not have access to European and ORNL reports that determine lower reprocessing costs. For example, OECD/NEA estimated a future reprocessing cost of $540/kg.[9] This cost estimate was not acknowledged in the STATS report. The report (p. 117 or p. 435) forecasts increasing reprocessing costs (constant dollars) in the future with an unexplained extrapolation algorithm. The data (individual data points on the graph, Fig, 6-2 or J-2 are not uniquely defined) that are extrapolated apply to various processing methods, plant throughputs, and other assumptions. It is not reasonable to expect that it is valid to extrapolate these data as a group with one algorithm. The resulting forecast of reprocessing cost is generally contrary to normally decreasing unit costs that are representative of maturing industries. There are several reasons for decreasing unit costs to occur (e.g. replication, process improvements, waste reduction, improved hardware, new processes). It seems reasonable to assume that the curves would level out well below the costs assumed for the STATS study.

The STATS report (p. 7, p. 77) indicates that in the U.S., reprocessing plants would be financed by private companies with an elevated rate of return. However no private company is likely to venture into this type business until after it becomes protected against governmental/regulatory policy uncertainties. Therefore, at least initial reprocessing plants would likely be financed either by utilities or the government, with their correspondingly lower discount financing rates, and thus lower unit reprocessing costs.

A highly credible review[10] of nuclear fuel cycle costs conducted in 1987 indicates a 37% reduction in reprocessing cost for fast reactor fuel between the first demonstration plant and the first commercial plant. LWR spent fuel reprocessing costs were projected in this review at a level near the low end of the range indicated in the STATS report. It seems clear that additional, larger plants would have significantly lower unit reprocessing costs.

The STATS report based its reprocessing costs on relatively low throughput, first-of-a-kind British (Thorp), French (UP-3) and an unconstructed Japanese (Rokkasho-mura) plant. If the U.S. were to build a large reprocessing plant, the lessons learned from development of these three plants should be applied and would result in significantly lower unit reprocessing costs. Subsequent plants should provide even lower unit costs.

5. *Repository Capacity* The STATS report (p. 7) states that: "Transmutation of the TRUs would reduce significantly the waste heat generation..., offering possibilities of increasing repository loading by a factor of four to five." (a conclusion also supported by A. Croff[11]) and "Transmutation could increase the effective capacity of the first repository and thus delay the need for a second repository. In most cases, however, there are other ways to achieve the same end without using transmutation." However, the other ways of achieving the four to five capacity advantage without actinide removal are not described. Moreover, the report (p. 8) also states: "...but the presence of actinides limits this increase to about 20%." Not only are these statements contradictory, they are misleading by indicating that the repository capacity could be increased without S&T. It does not seem likely that any other approach would have the same impact. The STATS report appears to focus on an imminent end to nuclear power, as it avoids consideration of more than a "second" repository.

6. *Mixed Missions: Defense Waste and Spent Fuel* The need for a TRU geologic repository for spent fuel and defense waste is driven by considerations of defense waste (Chapter 5). The two sources of repository material, as well as the societal, economic, and environmental considerations governing these material sources are so different, that a repository recommendation resulting from a system analysis is likely to be non-optimal for either. The optimal solution for disposal of waste and spent fuel from the commercial nuclear fuel cycle should not be modified by the defense-waste issue. The STATS report (p. 97) appears to use a circular argument in concluding that because the TRU content in defense waste is very small in comparison with the TRU content in spent LWR fuel for the first repository (assuming that it is not transmuted), it does not appear to be justified to remove TRUs from the defense waste. Accordingly, it does not appear that the Committee truly addressed the benefits of S&T as applied to defense waste.

Technical Type Concerns

1. *Environmental Hazard Reduction* - NAS has been considering the requirements for geologic disposal of high-level nuclear waste for about forty years, beginning in 1955. At that time, it was assumed that all spent fuel would be reprocessed. About twenty years ago, as a result of President Carter's ban on reprocessing (April 1977), it was realized that spent fuel might also need to be considered for geologic disposal. Not much was done about it, however, and President Reagan rescinded the ban in 1981. By this time, having suffered great financial losses that resulted from canceled facility plans, the industry did not reinitiate construction of the infrastructure for spent-fuel reprocessing. This industry perspective, coupled with a generally low uranium price, electric utility deregulation, and minority but powerful anti-nuclear voices have produced a risky investment environment for new nuclear facilities. As a result, no new reactors have been ordered recently in the U.S.

This historical background of geologic disposal, strongly influenced by political factors, has resulted in ever changing waste forms and geologic repository performance requirements. The proposed time of isolation has increased from 600 years to 10 million years during the 40-year time of the geologic repository "program." Now, the performance requirements are leaning toward assuring that water immediately adjacent to the repository remain potable *forever*. Also, there is no general agreement within the "program" as to what the metrics of performance should be: *e.g*., dose, release, risk, or concentration.

The current performance model for the Yucca Mountain repository predicts the peak dose rate resulting from each radioisotope in the "waste" received by a person at the accessible environment (AE). The dose to this individual, on an annual basis, is assumed to result from drinking two liters per day of water drawn from the water table below the repository at a well located 5 km from the "waste" package. The model contains various assumptions, not generally based on experimental data. Given all the variables that are involved, and the difficulties in quantifying them and their associated uncertainties, there is, as yet, no published prediction of the nominal repository performance.

Faced with this quandary of repository objectives and analytical issues, it is difficult to credibly assert, one way or another, that removing more than 99.9% of a specific isotope (*e.g.* Np-237) from the nuclear material placed in the repository makes a dose difference at the AE. Until now, the repository performance calculations have assumed the solubility limit of Np-237 (as an Np IV phase) to be 24 parts per 10^{15}. With this low solubility assumption, the predicted dose is apparently within the "regulatory" limit. However, recent solubility measurements indicate that the solubility concentration, as an Np V phase, can be ten orders of magnitude higher (240 ppm), leading to a dose at the AE in excess of the "regulatory" limit.

The Committee position appears to be that Np-237 transport is limited by low solubility so that the amount transported is independent of the amount of Np-237 in the waste form. The 63,000 t of spent fuel currently planned for the Yucca Mountain repository is estimated to contain 30,000 kg of Np-237. But the Committee position is that the risk to a person at some future time would be the same as if the amount of Np-237 were 300 kg. Based on the recent data on solubility, the Committee now has no viable basis for such an assertion.

To evaluate the effect of large reductions in the "waste" content of the actinides, a simple model was analyzed for the transport of Np-237. The highest solubility state of Np-237 was assumed. A reduction in dose proportional to a 1000-fold reduction in Np-237 content at the waste site was obtained. The peak dose occurs at 100,000 years or later in both cases. Under the assumptions made in this model, in either case the dose exceeded what would be considered to be an acceptable dose. These results indicate that there is a strong incentive for eliminating, to a very high degree, troublesome isotopes such as Np-237 from the repository by means of efficient S&T methods. That seems to us to be a more reasonable approach than guessing what solubility conditions will persist for over 100,000 years.

2. *Fission Product Transmutation* The STATS report is contradictory on whether or not it is practical to burn fission products in an ALMR. On p. 3 the report states: "...modifications of [ALMR] core design involving specially moderated fuel assemblies could reduce the fission product inventories of these two fission products" [Tc-99 and I-129], but on p. 5 it states: "Transmutation of fission products is not practical with an ALMR." In fact, although not an optimum situation, it appears viable to thermalize neutrons in a target blanket in the ALMR and thus transmute significant quantities of fission products. In addition, it must be understood that with the proposed ALMR infrastructure, reprocessing is an important component, and improved waste forms for fission products is imminent. Therefore, the need to transmute fission products in an ALMR, especially those with a low neutron absorption cross section, could be replaced by an improved waste form.

3. *Process Losses* The STATS report recognizes that the ALMR target for process losses is 0.1% or possibly 0.001%. The report appears confused, however, about how to apply this processing performance in relation to the energy produced. Each waste package (exhibiting the process loss achieved within the above range) would be

associated with a given amount of energy produced. Subsequent (identical) waste packages would be associated with a subsequent (identical) unit of energy produced.

The report (p. 59) states: "Consequently, even with new separations that would reduce losses to waste to 0.001 or 0.00001 of the amount processed, the inventories of TRUs in the waste would be far greater than what might be expected by multiplying the TRU inventories in LWR spent fuel by the process loss fraction." This statement is unfounded because the process losses for a given unit of energy would be 0.1% (or the achievable level), not a multiple of this value as indicated in the above statement. A repository loading of 0.1% TRU in processed waste from the ALMR is significantly less than 100% TRU in LWR spent fuel for the same unit of energy.

Conclusions

It is time for the U.S. to re-evaluate its policy on spent fuel processing as the nuclear genie is already out of the bottle and proliferation risks must be addressed on an international basis. Other nations that are less fortunate with respect to their fossil energy reserves and are more dependent on nuclear power will proceed with processing whether or not the U.S. continues its self imposed "ban." An in-depth assessment of these complex issues is needed now so that the U.S. can complete the necessary research and development work on a schedule that will allow its introduction when needed for low-cost energy and low-cost waste disposal. It is anticipated that the assessment will confirm that an ALMR/Fuel Recycle System will significantly reduce the demand on the uranium supply and stabilize the price of uranium for future LWRs and that the system will save the U.S. taxpayers billions of dollars in ultimate disposal costs by reducing the size and complexity of the Yucca Mountain repository. The development programs for the ALMR and for the pyro metallurgical processing system should be continued so that commercialization of the integrated ALMR/Fuel Recycle System can begin as close to the original 2010 target date as possible. This will allow the U.S. to take advantage of: (1) the vast energy potential of the fissile material contained in present and future inventories of LWR spent fuel, and (2) the benefits derived by conditioning the waste prior to placing it in an ultimate repository.[12]

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