AN ALTERNATIVE TO GEOLOGIC DISPOSAL OF COMMERCIAL SPENT FUEL ASSEMBLIES

S.L. Lawson
P.A. Secker
Arizona Public Service Company

ABSTRACT

This paper is written from the perspective of a U.S. electric utility.

Congress has tasked the U.S. Department of Energy (DOE) with determining whether or not the Yucca Mountain site in Nevada would be suitable for disposal of commercial spent nuclear fuel and associated high level waste (HLW). Suitability requires that DOE determine that the site will be geologically stable for a period of 10,000 years. This long isolation period is required as a result of the long-lived transuranic isotopes (actinides) in the spent fuel assemblies. Implementation of this strategy for disposal of HLW has been a difficult and complex task for DOE.

Rockwell International has performed studies on an alternate method for disposal of HLW, in which uranium, plutonium, and other actinides are extracted from the spent fuel assemblies. Instead of disposing of the non-plutonium actinides, they are fissioned in an actinide-burning fast reactor. Adoption of this strategy would require only a 200 year isolation period for the HLW generated by commercial reactors.

Arizona Public Service believes DOE should consider this disposal alternative very seriously. Too much is at stake to not have alternate plans should the current HLW program reach an impasse. The alternative appears feasible, cost-effective, and contains schedules which would appear to eliminate the backlog of commercial HLW in a timely manner.

This paper presents some of the details of the alternative, and a recommended set of actions that would help to further solidify public confidence and support for the alternative.

INTRODUCTION

The purpose of this paper is to present an electric utility perspective on spent fuel management. Arizona Public Service Company is part owner, along with six other southwest utilities, of the Palo Verde Nuclear Generating Station; a three unit, 3810 MW nuclear facility located near Wintersburg, Arizona. Arizona Public Service is the operating agent for this nuclear facility. As a generator of spent nuclear fuel, we are vitally interested in the success of our nation's high-level waste (HLW) program. The ability of the Department of Energy (DOE) to successfully implement the HLW program will directly impact the operating ability of Palo Verde.

Spent nuclear fuel continues to accumulate at nuclear plants. Under current operating plans, Arizona Public Service Company will begin to run out of spent fuel storage capacity by 2004. Expansion will be necessary if the plants are to continue to operate. Already, several utilities have been forced to spend millions of dollars to provide additional on-site storage capacity for spent fuel. On a nationwide basis, utilities will need to provide additional capacity for 60,000 fuel assemblies if a repository is operational by 2010 (assuming that a Monitored Retrievable Storage facility is not built). This is 40,000 more assemblies than would need to be stored if the repository were operational by 2003.(1)

Utilities continue to pay into the Nuclear Waste Fund at the rate of one mill per kilowatt-hour. To this date, Arizona Public Service has paid over 16 million dollars into the Nuclear Waste Fund. In return, DOE is obligated to begin accepting fuel from utilities by 1998 for disposal. If the current disposal program were to reach an impasse, it is likely that many, if not all, utilities would end up paying for life-of-plant storage capabilities. Utilities (and ultimately their ratepayers) would effectively be paying twice for storage of spent fuel. Some utilities could possibly be forced to shut down their plants because of a lack of confidence in the ability to dispose of the generated waste.

Current strategy for management of spent nuclear fuel in the U.S. calls for use of an open-ended fuel cycle. The open-ended fuel cycle does not take advantage of the potential value of the uranium, plutonium, and other transuranics remaining in the fuel assemblies at the time of disposal. Instead, the spent fuel assemblies (either consolidated or not) are directly disposed of following a specified cooling time in temporary storage.

This strategy has resulted for several reasons. The reprocessing industry had never recovered from President Carter's moratorium on reprocessing in 1977. Also, uranium prices are low enough to make reprocessing appear less attractive, even though there are no legal restraints.

In 1982, Congress passed the Nuclear Waste Policy Act (NWPA). This law assigned to the U.S. Department of Energy (DOE) the responsibility for the disposal of spent nuclear fuel and high-level waste (HLW) generated by commercial reactors in the United States. The law calls for emplacement of spent fuel/HLW in a geologic repository as the long term method of disposal.

DOE has been directed by Congress in the 1987 amendments to the NWPA to perform site characterization studies at the Yucca Mountain site in Nevada to determine if the site would be suitable for a HLW repository. Characterization work at all the other sites was halted. Although DOE has experienced a number of delays in carrying out the first directive, recent changes outlined in the Secretary of Energy's "Report to Congress on Reassessment of the Civilian Radioactive Waste Management Program" have the potential to place the program back on track. Nevertheless, DOE should concurrently be evaluating other spent fuel management options, and in fact, is mandated to do so under Section 222 of the NWPA. This section states that

> "The Secretary shall continue and accelerate a program of research, development, and investigation of alternative means and technologies for the permanent disposal of high-level waste from civilian nuclear activities and Federal research and development activities except that funding shall be made from amounts appropriated to the Secretary for purposes of carrying out this section. Such program shall include examination of various waste disposal options."

It is our opinion that too much is at stake to place "all the eggs in one basket." Public confidence in nuclear power over the past two decades has been at an all-time low. This has been partially a result of incidents such as Three Mile Island and Chernobyl. Costly delays in nuclear plant construction have also contributed to a lack of confidence. However, from the perspective of an electric utility, it appears that the major concern on the part of the public is whether anything can be done with the waste which is generated from nuclear power plant operation. Operational safety concerns do not appear to the majority of the public as issues which would warrent removal of the nuclear power option. Nuclear power is viewed by many as an energy option to be used to mitigate the effects of global warming. Failure to implement a viable waste disposal program could very well be the only major obstacle preventing the future re-emergence of nuclear power.

Although the Yucca Mountain site currently has many characteristics which would appear to make it an ideal HLW repository site, the analytic models used to predict site behavior may be insufficient to provide "reasonable assurance" that the waste can be isolated for a 10,000 year period. The possibility also exists that some disqualifying factor(s) will be found which would prevent the repository from being sited at Yucca Mountain. Furthermore, it is not likely that siting a HLW repository at other locations would be any easier than at Yucca Mountain. Either of the situations cited above would result in further unacceptable delays in the implementation of a long-term solution to the waste disposal problem, and further erode public confidence in nuclear power.

Many disposal alternatives are possible. Among the alternatives which have been discussed in the past are subseabed disposal, disposal in ice sheets, outer space, and transmutation into less toxic substances.The disposal alternative presented in this paper provides a plan which DOE could use should the agency determine that the Yucca Mountain site cannot be licensed. This alternative consists of several facets. Uranium, plutonium, and other actinides are extracted from the spent fuel assemblies. The uranium and plutonium are reused as fuel in existing reactors, while the long-lived actinides are transmutated to short-lived nuclides by fissioning in an actinide-burning fast reactor. The remaining material, which consists of the highly radioactive but short-lived fission products,is disposed. A block diagram of this fuel management scheme is depicted in Figure 1. Adoption of this disposal method would require only a 200 year time frame for isolation of the waste, simplifying geologic disposal. This disposal alternative is attractive because it represents an engineered solution to waste disposal instead of relying on geologic predictions over the aeons. Also, much of the technology necessary to implement this alternative already exists.

This disposal alternative could prove to be more economical, particularly if, in the future, uranium market conditions become less favorable for utilities. A nuclear program with reprocessing capabilities will reduce its U_3O_8 requirements by about 35 percent.(2) This alternative also has the potential to keep DOE's HLW program on track, and restore public confidence in the industry's ability to safely dispose of its waste products.

THE ACTINIDE DISPOSAL PROCESS

In comparison to the current U.S. waste disposal strategy for commercial fuel, this disposal alternative reflects the only "true" disposal method. Burial in a geologic repository is, in reality, not a disposal method, but a storage method. Transmutation into short-lived fission products effectively removes the actinides from the environment.

The first work which was done in the area of actinide recycle investigated the possibility of fissioning recycled actinides in LWRs. After obtaining more precise data on actinide thermal fission cross-sections, it was determined that the use of thermal reactors is a poor choice for disposal of actinides. However, research has indicated that as the average neutron energy of the flux spectrum is increased, fission cross-sections for actinides begin to increase. The actinides then begin to behave more as fuels than as parisitic wastes.(3) This information indicates that disposal of actinides could be accomplished by transmutation in a fast spectrum reactor. Even though there will be some amount of actinide production in a fast reactor, the quantity of actinides in the fuel cycle will reach an equilibrium value.

Without actinide recycle, the quantity will continually increase. For transmutation to become a more effective disposal method, it is necessary for the actinide-fueled reactor to maximize the ratio of fission rate to capture rate. Otherwise, the actinide-burner will simply produce more actinides.Existing data indicates that a reactor which is fueled with neptunium, americium, plutonium, and curium can be made to go critical.

If the backlog of commercial spent fuel is to be eliminated in a reasonable time frame, it will be necessary to have a sufficient number of actinide burners to dispose of the actinides. A single fast spectrum reactor can transmute the waste actinides generated by approximately 50 equivalently sized LWRs.(4)

A reactor which is capable of actinide disposal is under development at Argonne National Laboratory. This Integral Fast Reactor (IFR), which is actually a breeder reactor, could be operational by the turn of the century. An actinide-burning reactor would also have the characteristic of being inherently safe. The IFR uses liquid sodium as a coolant. Sodium has a boiling point of 1650 degrees and is capable of removing the reactor's heat at normal atmospheric pressure. Also, as the metallic fuel heats up, it expands, driving fuel atoms apart and slowing down the chain reaction.(5)

PREVIOUS EXPERIENCE WITH EXTRACTION OF SPENT FUEL COMPONENTS

Chemical extraction of the various spent fuel components is not a new technology. Experience has been obtained in the United States and abroad with chemical reprocessing. United States military waste is stored primarily in the form of aqueous solutions, a result from the first step in reprocessing. A small amount of commercial fuel was reprocessed at the West Valley Reprocessing Plant in the early 1970's. This waste is also being stored as a neutralized aqueous solution.(6)

The People's Republic of China has a waste disposal policy which calls for reprocessing of spent fuel from light water reactors (LWRs), removal of over 99.9 percent of the actinides in HLW, and burial of the HLW in suitable geologic formations. China has deferred however, on an immediate solution to the actinide disposal problem, opting for temporary storage of actinides in a retrievable depository.(2)

France has taken a long-term perspective of energy resources, and as a result, has become a leader in the development of reprocessing technology. France has reprocessed more than 1700 tons of LWR fuel at the La Hague reprocessing plant. In addition to the recycling of uranium, the French have introduced plutonium into several LWR's. Electricite de France has now decided to use plutonium on a large scale.(2)

The United Kingdom has had extensive experience with the reprocessing of Magnox fuel. Although the British have not yet had any experience with the reprocessing of LWR assemblies, they will gain this experience with the spent fuel generated from the Sizewell Nuclear Power PLant. The British have determined that the performance of recycled fuel has been equal to that of fuel manufactured from natural uranium.(2)

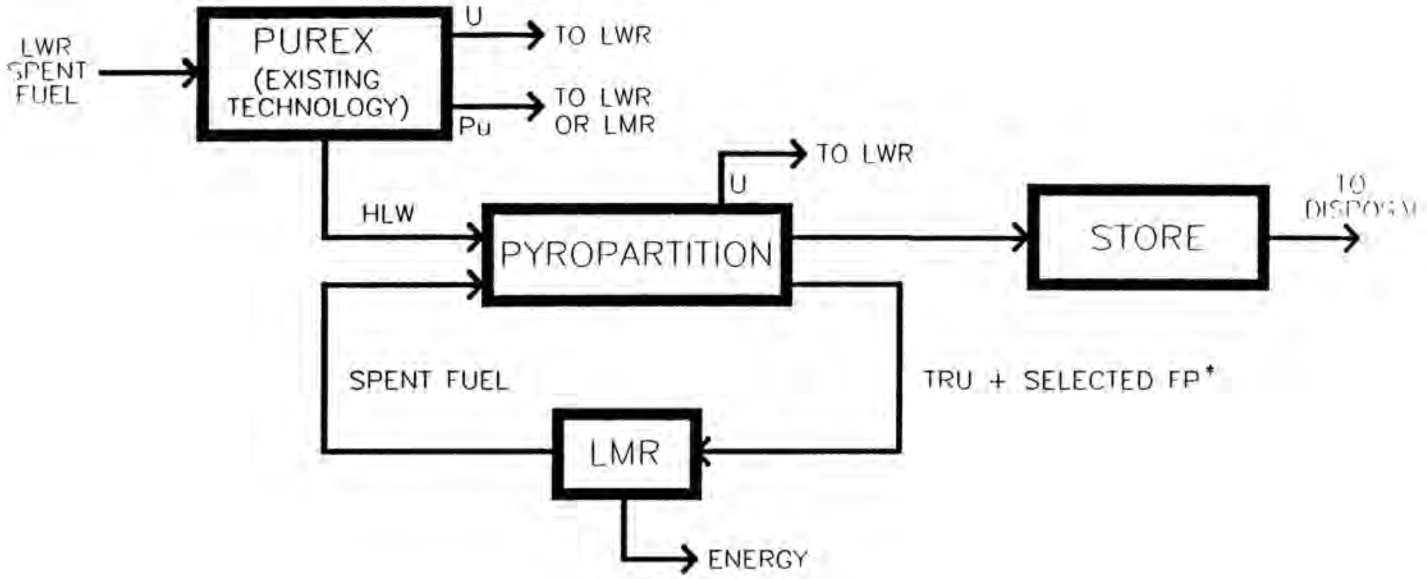
If this disposal alternative were to be implemented in the U.S., it would be necessary to improve the PUREX process for chemical extraction. The improvements need to be made in several areas. The areas involve actinide partitioning, occupational radiation exposures, and safeguards concerns. It would also be necessary to insure that the HLW which is to be disposed is in a stable form.

A need exists for effective partitioning of the actinides. A fission product stream containing even one percent of the actinide inventory would necessitate a long isolation period for confinement of the waste. If the actinides are sufficiently segregated, the long-term radiological hazards associated with geologic disposal can be reduced by a factor of 1000. China has found solvents which are capable of removing over 99 percent of the plutonium, americium, and curium from the HLW.(2) An electrochemical process called pyropartitioning also holds the promise of being capable of removing 99.9 percent of the actinides from the HLW. Developments must continue in this area.

There may also be some long-lived isotopes found in HLW which cannot be removed by transmutation. Niobium-94 is a long-lived isotope which is an activation product from Inconel. Future production could be reduced by limiting the use of Inconel in the reactor core region. However, that which is existing could still create problems in terms of complying with long-term disposal limits. It is not yet certain how this problem would be handled.

Also essential is efficient separation of the lanthanide isotopes from the actinides. The lanthanide elements are effective neutron absorbers which will compete with the actinides and lower the effectiveness of the actinides as potential fuel. Because of chemical similarities between actinide and lanthanide elements, they are difficult to separate. Methods have been investigated in the laboratory for effective partitioning of the lanthanides. However, it would still be necessary to develop these methods on a commercial scale.

Another problem associated with the reprocessing of spent fuel is exposure of workers to radiation, particularly during maintenance operations. However, the open-ended fuel cycle involves greater exposures during uranium mining and milling, so it is difficult to cite any particular radiological advantage of one disposal method over the other. In



*Note: Selected fission products (such as Tc$_{29}$ or I$_{129}$) could be transmuted in LWRs under certain conditions

Fig. 1. Basic Concept for Spent Fuel Management.

addition, advances have been made in the design of remote-handling equipment and maintenance techniques for reprocessing plants to minimize these radiation exposures.

The reprocessing of the spent fuel generated from nuclear weapons plants has produced plutonium in a state of high purity following its chemical separation from uranium. Because of the low radioactivity associated with plutonium, this plutonium could be stored and moved about in simple containers. These facts led to a large scale concern on the part of the public that the plutonium could be easily diverted and used by terrorists to create nuclear bombs.A potential end product of reprocessing which would allay these fears is a uranium-plutonium mixed oxide which is unsuitable for use in nuclear weapons. This would provide further deterrence to potential terrorists. Also, the recycled plutonium will always be part of the fuel cycle. Therefore, material accountability standards for recycled fuel will be the same as for new fuel.

It is important that the high-level waste which is generated by reprocessing be conditioned prior to disposal. The initial form of the high-level waste following the first reprocessing step is an aqueous solution containing fission products. U.S. military waste has been stored in underground tanks as radioactive liquid waste. This storage method has been found to be unsatisfactory, because of leaking storage tanks. The structural integrity of the tanks must last for hundreds of years. Also, in some instances, a heat removal system is necessary because of the decay heat which is produced. Certainly, this type of storage represents an interim solution at best. Conditioning is accomplished by converting the waste into a solid form. This is done to minimize the chances of radioactive nuclide migration to the environment following disposal. Disposal is thus, simplified and risk is lowered. The waste form which has generally been adopted for disposal of HLW in other countries and military HLW in the United States is borosilicate glass. The vitrification techniques in use today have demonstrated a high level of safety and reliability. This does not mean that further developments can't be made to further reduce the volume of generated HLW, and to further enhance safety.

IMPLEMENTATION

This disposal alternative can be implemented in several small stages using existing defense facilities, and existing defense waste. Rockwell International has proposed some very reasonable time frames in which this disposal alternative can be implemented.(4)

Fuel performance of the actinides can be verified using the FFTF reactor at the Hanford site in Washington. Chemical extraction and pyropartitioning of spent fuel components can also be tested at the Hanford site using the existing PUREX plant with some modifications. These modifications would include construction of a pyropartioning plant. These activities would occur during the mid 1990s.

The PUREX plant can then be adapted to begin acceptance of commercial spent fuel (1000 MTU per year). This could be done by 2000. It is projected that a full scale actinide burner could be brought on line by 2003. If an additional reprocessing plant were operational by 2008, and a second actinide burner were brought on line by 2013, the spent fuel backlog could be eliminated by 2035 (assuming a no nuclear growth scenario). Other reprocessing plants exist which could also be used as part of this disposal strategy. The General Electric Midwest Fuel Reprocessing Plant in Illinois and the Allied General Nuclear Services Reprocessing Plant in Barnwell, South Carolina were built, but never placed into operation.

COSTS

The projected costs associated with this disposal strategy appear to be reasonable, with the first expenditures in the billion dollar region not occuring until development of the full-scale actinide burner. In fact, the disposal alternative could represent a 15 billion dollar savings over the current waste disposal plan to the year in which the spent fuel backlog is worked off.(4)

However, because of the lack of precision involved with these type of economic predictions, any decisions which DOE should make regarding waste management strategy should not be based upon economics alone. Decisions should also take into account long-term considerations, and not just the short-term.

UNCERTAINTIES

Many issues would still need to be resolved prior to making a decision as to whether this disposal strategy should be implemented. Laboratories would need to develop more reliable cross section data on actinides. It will be necessary to verify fuel performance of the actinides. Uncertainties exist in terms of the requirements necessary for the licensing of reprocessing/pyropartitioning facilities. It is not yet known whether effective actinide partitioning will be able to performed on a commercial scale. Adoption of this strategy involves the processing of highly radioactive materials, and the re-birth of an entire industry.

CONCLUSIONS

Arizona Public Service believes that DOE should seriously evaluate the alternative disposal strategy presented by Rockwell. A backup disposal method is desparately needed, particularly if the current program were to reach an impasse.

It is essential that any decisions which are made regarding waste management strategy be guided by more than politics alone. Currently, there appears to be a widespread tendency to avoid "rocking the boat." However, limiting our options for future waste management strategy will only be to our detriment and not to our advantage.

Should our nation's waste disposal program reach an impasse,this disposal alternative has the potential to stimulate the program and restore public confidence in the ability of the nuclear industry to safely dispose of its waste products. The alternative also provides a mechanism for early development of breeder reactor technology. This will become important by the turn of the century, particularly if nuclear power is to be revitalized and play a significant role as part of our nation's energy supply.

REFERENCES

1. Focus - Quarterly Report on the Nuclear Fuel Cycle, Nuclear Assurance Corporation, Issue 11 (December 1989).
2. International Symposium on the Back End of the Nuclear Fuel Cycle, Vienna, Austria, May 11-15, 1987, STI/PUB/758, International Atomic Energy Agency (1987).
3. W.M. FARR and D.J. MURPHY, "Final Report - Actinide Burner Studies," Contract No. 02-8859, Sandia Laboratories (July 1978).
4. Rockwell International, "An Alternative to Geologic Disposal of High Level Waste (December 1988), Unpublished.
5. R. WINSLOW, "New Breeder Reactor May Operate More Safely, Produce Less Waste," Wall Street Journal (December 1, 1988).
6. C.A. WALKER, L.C. GOULD, and E.J. WOODHOUSE, "Too Hot to Handle," Yale University (1983).
7. U.S. DEPARTMENT OF ENERGY, "Report to Congress on Reassessment of the Civilian Radioactive Waste Management Program,"(November, 1989).
8. Proceedings of the Twenty - first Annual Meeting of the National Council on Radiation Protection and Measurements, Washington, D.C., April 3-4, 1985,

ISSN0195-7740, No.7, National Council on Radiation Protection and Measurements (1986).

9. E.W. COLGLAZIER, "The Politics of Nuclear Waste," Pergamon Press (1982).