FACING REALITY

REPROCESSING

The U.S. Department of Energy's Wasteful, Dangerous Scheme to Resume Plutonium Separation

This report is published under the auspices of the Project for Participatory Democracy, an initiative of the Tides Center. ***Reprocessing*** is the seventh in the series of ***Facing Reality*** documents, preceded by:

Facing Reality: The Future of the U.S. Nuclear Weapons Complex; a companion

Citizens' Guide to the Future of the U.S. Nuclear Weapons Complex;

Beyond the Bomb: Dismantling Nuclear Weapons and Disposing of their Radioactive Wastes;

Nuclear Weapons "Cleanup:" Prospect Without Precedent;

Official Use Only: Ending the Culture of Secrecy in the U.S. Nuclear Weapons Complex; and

Citizen Law Enforcement: Fighting Environmental Crime at Facilities of the U.S. Departments of Energy and Defense.

Nuclear materials reprocessing is a necessary step in obtaining plutonium, a crucial ingredient of the great majority of nuclear weapons that were produced during 50 years of the Cold War. Reprocessing is also the source of a vast accumulation of highly radioactive waste that is expected to cost the United States more than 100 billion dollars and many decades of work for storage, decontamination, and eventual disposal. Any reprocessing, military or commercial, undermines efforts to control the spread of nuclear weapons, and increases the risk that crucial materials will be stolen or diverted for violent uses. These hazards motivated a U.S. decision 20 years ago to abandon civilian reprocessing and to discourage it in other countries.

Despite many compelling reasons to end it permanently, the U.S. Department of Energy recently decided to undertake reprocessing at sites in Idaho and South Carolina. Most of DOE's planned reprocessing is poorly justified and places the public interest below that of bureaucrats and contractors.

This report is an effort to help citizens understand the history and implications of reprocessing so that they can take an active role in decisions about its future.

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Introduction

In the late 1980s, the United States ended its military production of plutonium, the man-made metal that forms the essential core of nearly all U.S. nuclear weapons. The plutonium production cycle, including an activity called "reprocessing," caused extensive environmental contamination, and left the nation with a large surplus of this dangerous metal. Plutonium, and the reactors and factories that manufactured and processed it, are at the center of some of the country's most serious nuclear safety dilemmas. The Department of Energy (DOE) and some of its contractors seem dangerously close to reviving reprocessing, the separation of plutonium and/or uranium from highly radioactive material that has been taken from nuclear reactors.[1] DOE is trying to justify reprocessing as an environmental remedy, but its plans could aggravate serious threats to national security and world peace.

Any reprocessing undertaken by the United States will undermine efforts to control nuclear weapons proliferation.

Reprocessing entails a variety of safety and environmental hazards. The cleanup and waste management debt of the nuclear weapons complex is expected to cost taxpayers more than 200 billion dollars and leave contamination that lasts for thousands of years. Waste and contamination from reprocessing are responsible for the majority of this burden.

The difficulty and high cost of reprocessing make it a crucial barrier to the spread, or "proliferation," of nuclear weapons to additional countries or groups. Any reprocessing undertaken by the United States will undermine efforts to control nuclear weapons proliferation. Because of these health, safety, and proliferation hazards, any decision about reprocessing should not be based upon narrow political and economic interests. Instead, the nation needs an open and comprehensive analysis of long-term environmental and security implications. The U.S. government has not dealt with reprocessing in a consistent, rational manner.

Numerous government reports and independent analyses of the U.S. nuclear weapons complex have documented its single-minded devotion to production, frequently at the expense of health, safety, and the environment. The mission of the Department of Energy (DOE), which has managed the complex since 1977, was to help "win the Cold War," but the DOE and its contractors failed to anticipate that the nuclear arms race might eventually end. With this lack of preparation, and with a bias against ending their production activities, government officials and contractors have often added to the difficulties of managing radioactive waste and cleaning up DOE sites.

Dr. James C. Warf, who worked on the first atomic weapons and was the primary inventor of the most widely used reprocessing technology, called PUREX (Plutonium and URanium EXtraction), recently wrote:

"My experience with the Manhattan Project . . . has led me to conclude that . . . the law of unintended consequences has been strongly at work. When I demonstrated [the chemical fundamentals of PUREX], I had little idea of the full impacts that would ensue. The PUREX reprocessing technology soon spread from the United States to other countries. . . . Unfortunately, the same technology that can be used for peaceful purposes . . . can also be used to acquire materials that can be used to build nuclear weapons. The dissemination of the details of the PUREX reprocessing technology contributed to the acceleration of the proliferation of nuclear weapons.

Additionally, few in the Manhattan Project or in the early years of the post-war nuclear program gave much thought to the environmental effects of the radioactive waste that was being created. Reprocessing produced large amounts of high level radioactive waste, without much thought given to how it could be permanently disposed of. . . . I have thus come to learn that there are often large proliferation and other environmental impacts from such endeavors as reprocessing, despite the initial paper proposals that promise smooth operations." [2]

"There are often large proliferation and other environmental impacts from such endeavors as reprocessing, despite the initial paper proposals that promise smooth operations."

The "law of unintended consequences" is no doubt still in effect. Despite its many unanticipated environmental, safety, and proliferation consequences, the DOE and its contractors have been looking for excuses to keep reprocessing alive for as long as possible. "Environmental Management" is the latest justification.

This report, the seventh in a series about the U.S. nuclear weapons complex, analyzes the DOE's problems with "spent nuclear fuel" and related materials, describes short-sighted decisions to resume reprocessing by the government and its contractors, and recommends alternatives. For those interested in more extensive analyses, two reports from the Institute for Energy and Environmental Research would be a good place to start.[3] These and other documents (see endnotes) informed this report. A list of contacts is provided for people interested in joining the debate about the future of nuclear materials reprocessing in the United States.

Robert Del Tredici

The F Area - *One of two reprocessing areas at the Savannah River Site, South Carolina. The F-Canyon is in the upper left. Most of the other structures, including a "tank farm" for highly radioactive waste (foreground) are for managing reprocessing wastes.*

The End of Plutonium Mass Production

Several factors contributed to the 1988 shutdown of U.S. plutonium production reactors, where uranium components were irradiated before being moved into reprocessing plants, and to the proposed, but not fully implemented, phase-out of reprocessing in 1992:

- The devastating 1986 Chernobyl nuclear reactor accident in the Ukraine inspired investigations into U.S. reactors of similar design. This probe revealed the fact that the DOE's reactors lacked adequate containment buildings and other essential safety features.
- Citizens in nearby communities demanded information on the safety and purpose of DOE sites. The emerging facts exposed serious negligence throughout the nuclear weapons complex.
- John S. Herrington, a Secretary of Energy under President Reagan, belatedly recognized that the United States had a large surplus of military plutonium. Until Herrington's famous remark that the nation was "awash in plutonium," DOE officials had insisted that a dire shortage was imminent.

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U.S. decisions are seen by other countries as crucial endorsements or condemnations of their nuclear weapons-usable programs.

These events did not occur without some warning, but some DOE officials believed that the nation could still be persuaded that more plutonium was needed, and they expected any production shutdown to be brief. As a result, reactor and reprocessing operations were not halted with the long term in mind. Several thousand tons of nuclear fuel and various solutions containing plutonium were left "in the pipeline." The facilities for handling them, and the materials themselves, had been designed for production cycles measured in months. The "spent fuel" and related materials for making plutonium were not suitable for "temporary storage" that would span years or decades.

Plutonium can be used as fuel for nuclear power reactors, but it is very uneconomical compared to uranium fuel. Its proliferation dangers, as well as its health and safety hazards, make a plutonium-based energy system a costly and risky proposition. Despite its poor economic prospects, Japan, Russia, and several European countries are still pursuing the civilian "plutonium fuel cycle." While the intent of a plutonium-based energy economy might be peaceful, the technologies and materials involved can readily be applied to nuclear arms.

Because the use of plutonium in power reactors is so controversial, other countries see U.S. decisions as crucial endorsements or condemnations of their nuclear weapons-usable programs. For example, a recent French Embassy newsletter, referring to a proposal to build a plant for fabricating plutonium reactor fuel, said: "If the United States were to lend its support to such a project, it would certainly mean a great deal to the international community and would definitely be a symbolic success for France."[4]

What is Reprocessing?

The fissile materials (plutonium and/or uranium, see pp. 6 and 26) contained in "spent fuel" cannot be used in nuclear weapons or as reactor fuel until they have been separated from the highly radioactive "fission products" with which they are mixed. Reprocessing is the term for a variety of methods for accomplishing this separation. Historically, this has required a "chemical separation" or "reprocessing" plant. The "re" in the term refers to the fact that some of the material involved can be incorporated into new reactor fuel and used again. Reprocessing has been a costly, hazardous, and messy operation for several reasons:

- The materials involved are extremely radioactive and must be handled robotically behind heavy shielding.
- Uranium and plutonium are chemically similar; therefore, many complicated steps and large quantities of toxic and corrosive chemicals are used to separate them.
- Large volumes of toxic and radioactive waste are generated. These wastes are difficult to manage, store, and dispose.
- Relatively small amounts of plutonium can form a "critical mass," leading to a dangerous accidental chain reaction. All plutonium processing methods and equipment must be designed carefully to avoid, or at least contain, such accidents. Enriched uranium can also chain-react, but somewhat larger quantities of it are needed to form a critical mass.
- The nature of reprocessing makes it virtually impossible to account for every kilogram of separated plutonium: the risk of diversion or theft cannot be avoided.

"Pyroprocessing," a newer method for separating the components of spent fuel, now operates on a pilot scale at the Idaho National Engineering and Environmental Laboratory (INEEL, known until recently as the Idaho National Engineering Laboratory, or INEL).

Pyroprocessing, or "electrometallurgical processing," is a high-temperature operation that requires a much smaller facility than the more traditional methods. The technology's proponents point to this feature as an advantage, but the fact that pyroprocessing can be carried out in a smaller, more easily concealed plant raises serious proliferation concerns.

What is "Spent Nuclear Fuel"?

The highly radioactive metallic or "ceramic" (metal oxide) rods, cylinders, and flat plates taken from nuclear reactors are loosely known as "spent nuclear fuel." Spent fuel can be stored in special facilities and eventually disposed of as radioactive waste, or it can be reprocessed to extract the plutonium and/or uranium it contains.

In the commercial nuclear power industry, "spent" fuel has produced all the energy that can economically be extracted from it, although its weight, volume, and appearance remain essentially unchanged. After a period of irradiation, nuclear fuel becomes immensely more radioactive than it was before it was placed in a reactor. In addition to uranium and plutonium, spent fuel contains numerous highly radioactive lighter isotopes called "fission products" that result from atoms splitting. The presence of fission products means that spent fuel must be handled by remote control behind heavy shielding.

Spent fuel from commercial and military reactors gives off heat and intense radiation. It must be stored so that people are shielded from the radiation and so that heat can be dissipated. Civilian spent fuel is designed so that it can be stored for many years in basins, or "swimming pools," full of water that absorbs radiation and circulates to carry away heat. After the heat and radioactivity have declined through radioactive decay, the fuel is commonly put into longer-term dry storage.

In the nuclear weapons field, "spent fuel" is commonly used as shorthand for "reactor-irradiated nuclear materials," which can include both fuel and "targets" that have been discharged from reactors. Reactor fuel contains enough fissile material (see Appendix on fissile materials) to support a chain reaction that releases energy and particles called neutrons. Targets for plutonium production, made of nearly pure uranium-238, are placed in the reactor where they can absorb neutrons, which changes some of the uranium to plutonium. To keep proportions of the most desirable type of plutonium high, fuel and targets are typically withdrawn from military reactors long before the maximum possible quantity of plutonium has formed within them.

Plutonium production reactor fuel was designed to be stored only a few months before being reprocessed to extract the plutonium and/or uranium. After storage underwater for years in poorly maintained facilities, some of the DOE's spent fuel began to corrode, contaminating the water, increasing workers' radiation exposure, and posing the risk of accidental chain reactions.

Putting the Cold War on Ice . . .

Since the early 1990s, Russia and the United States have taken a number of positive steps to reduce the risks to humanity posed by their large arsenals of nuclear weapons. Both countries have taken many thousands of nuclear arms out of service, and they have negotiated for further cuts in their arsenals.

While arms control treaties and other confidence-building measures have by no means eliminated the possibility of nuclear holocaust, they have reduced its likelihood. In addition to ending the nuclear arms race, however, the world faces a related set of challenges:

- Nuclear weapons production created an environmental legacy that will require decades of costly decontamination and radioactive waste storage and disposal work.
- Leftover nuclear weapons and the essential materials and technologies for building them, particularly in the former Soviet Union, must be controlled and kept off the black market.
- Effective international "nonproliferation" agreements, monitoring systems, and cooperative security measures must be developed to help slow or stop the spread of nuclear arms.

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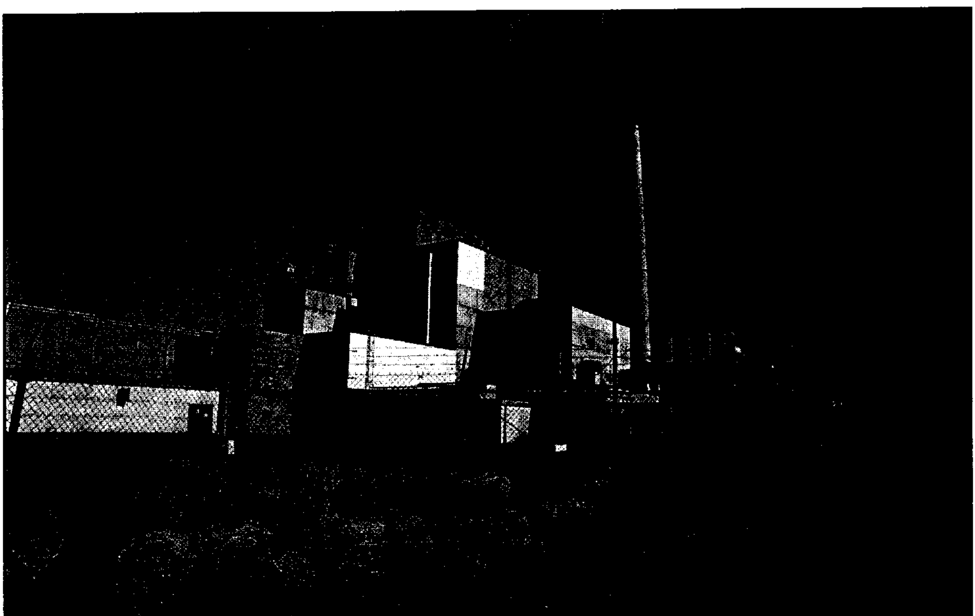

Robert Del Tredici

The B Reactor *- Hanford, Washington. This was the world's first plutonium production reactor. It began operations in late 1944, produced plutonium for the Trinity test bomb and the Nagasaki bomb. The B Reactor was shut down in 1968.*

The United States has a unique opportunity to lead the way in solving these problems. Leadership should be demonstrated by setting the right examples and by complying with and advocating international monitoring and verification.

In some areas, the United States has lived up to this leadership challenge. The Department of Energy (DOE) has largely changed the mission of the nuclear weapons complex from warhead production to environmental management. The nation has ended mass production of nuclear weapons and all military production of two crucial materials, plutonium and highly enriched uranium (although civilian spent fuel accumulates large quantities of plutonium that would be weapons-usable if it were reprocessed). The United States has also stated that, due to concerns about proliferation, it will not accumulate additional plutonium for military or civilian purposes. Instead, the government acknowledged in 1996 that about 50 tons of plutonium, half the national stockpile, is surplus to any conceivable military need and must be prepared for long-term disposition.

. . . but Old Habits Die Hard

Other recent DOE activities and plans contradict and undermine the stated and widely supported U.S. policies on arms control, nonproliferation, and the environment. Among the most troubling are decisions to restart some of the plants that extract plutonium and/or uranium from irradiated nuclear materials. The DOE is operating an old chemical reprocessing facility at the Savannah River Site (SRS) in South Carolina and a new "pyroprocessing" plant at the Idaho National Engineering and Environmental Laboratory (INEEL, known until recently as the Idaho National Engineering Laboratory, or INEL).

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The DOE has tried to justify reprocessing as its preferred method for dealing with environmental and safety problems.

Some of the reprocessing now under way would be justifiable if it were confined to the small quantities of materials for which few good alternatives exist and if it were subject to international monitoring. Several kinds of highly radioactive nuclear weapons production materials left over from the Cold War are not stored in a fashion that will be safe in the long run. However, for most of the "spent fuel" and other materials that the DOE is planning or considering for reprocessing, better options are available. The DOE has tried to justify reprocessing, not by a desire to add to the nation's plutonium surplus, but as its preferred method for dealing with environmental and safety problems related to these materials. Reprocessing is the wrong choice for solving most of these problems for the following reasons:

Immediate storage hazards – Some of the spent fuel now of greatest concern was designed to be reprocessed within a few months after it was removed from reactors. Since the shutdown of plutonium production reactors in 1988, the fuel has instead been stored in large pools of water that provide cooling and radiation shielding. Some of this spent fuel is corroding, which can contaminate water in the storage basins and complicate future waste management. *The DOE wants to remove this material from storage and reprocess it despite DOE's own analyses showing that reprocessing will greatly increase the safety hazards and the costs of waste management, compared to the available alternatives.*

The idea that reprocessing is the best solution is contradicted by the fact that the DOE has found ways to reduce wet storage risks and prepare for the dry storage of about 80 percent of its spent fuel inventory, which is stored at the Hanford, Washington, site. Dry storage typically uses an inert gas atmosphere that prevents corrosion and allows storage for many years.

Long-term disposal – The DOE has said that reprocessing might be necessary to makespent fuel acceptable for placement in a geologic repository. While spent fuel might require *some* kind of treatment before disposal, the reasoning that reprocessing will be needed is faulty on several counts. Whether the expected repository site at Yucca Mountain, Nevada will ever be used is uncertain. The final standards for the physical form of waste slated for disposal are even less certain and are not expected before the year 2000. There is no way to know now which forms will be deemed acceptable.

The DOE analysis in favor of reprocessing focuses on the liquid radioactive waste that will be produced and might be suitable for the disposal methods now in development, but it ignores the separated plutonium and uranium that eventually will require disposal. *Reprocessing will not solve long-term disposal dilemmas and instead is likely to aggravate them by generating wastes that are difficult and costly to stabilize and contain.* Interim dry storage, on the other hand, would provide flexibility for handling and storing spent fuel. For the long term, safer methods are available that do not carry the proliferation risks of reprocessing.

International Security – As the key ingredient for most nuclear weapons, plutonium is of great concern as a potential black market material. Most of the world's plutonium is contained in spent fuel from civilian nuclear reactors. This plutonium, however, is not viewed as an immediate proliferation threat because it is mixed with highly radioactive elements that make it very difficult to handle or use. In other words, *the plutonium in spent fuel is unlikely to be stolen or diverted for violent purposes precisely because it has not been extracted through reprocessing.*

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U.S. policy has long recognized the fact that reprocessing, regardless of its stated intent, is the crucial link between spent nuclear fuel and devastating weapons. Accordingly, the United States has sought to control and to discourage reprocessing in other countries. *Any further U.S. reprocessing will encourage the proponents of risky and unnecessary global commerce in plutonium.*

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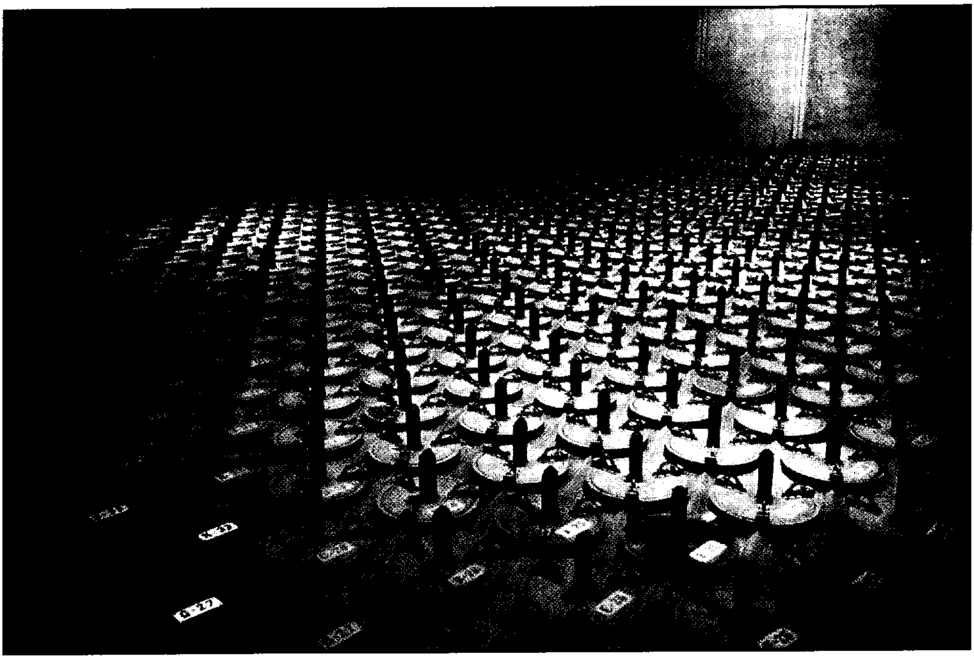
The known hazards of reprocessing are many times higher than those of other spent fuel management alternatives.

Adding to the radioactive waste burden – The DOE's own analyses show that reprocessing will be riskier, add more to the volume of radioactive waste, and cost more than moving the fuel to dry storage. At the Savannah River Site, reprocessing will add about three million gallons of highly radioactive liquid waste to storage tanks that are already plagued with safety problems. Pyroprocessing at the Idaho National Environmental and Engineering Laboratory (INEEL) will generate new forms of waste that are poorly understood and for which no methods of long-term storage or disposal have been developed.

While no alternative is risk-free, the known hazards of reprocessing are many times greater than those of other spent fuel management alternatives. The best alternative, interim dry storage followed by immobilization and isolation from the environment, is not just a theoretical possibility; it has been under development by the nuclear industry in the United States and elsewhere for decades.

Locking out the alternatives – The DOE has displayed a chronic bias in favor of reprocessing, despite its well-documented drawbacks. This is partly because the long-established contractors who have the most to gain from running the plants also have too much influence in the selection of spent fuel management methods. For example, the Westinghouse Hanford Company argued during 1989 and 1990 that reprocessing was the best option for "stabilizing" leftover spent fuel. That argument failed to withstand independent scrutiny. The plan was dropped, and the Hanford PUREX plant was shut down, but only following intense public opposition.

Unfortunately, once even a small amount of reprocessing begins, it is likely to become entrenched for many years as the only "available" spent fuel treatment method. Meanwhile the alternatives will be neglected. A failure to improve storage conditions, for example, is likely to lead to more corroded fuel, perpetuating the safety problem. If the DOE sincerely intends to resume reprocessing for only a short time, it should place clear limits on the quantity of material to be reprocessed, and set a deadline for ending reprocessing.



Robert Del Tredici

Dry Storage of Spent Fuel *- Idaho Chemical Processing Plant. Several types of irradiated nuclear fuel are in containers, the tops of which are visible here, inside a heavily shielded building. This photograph was taken through a leaded glass window several feet thick.*

Lessons from Hanford's Spent Fuel

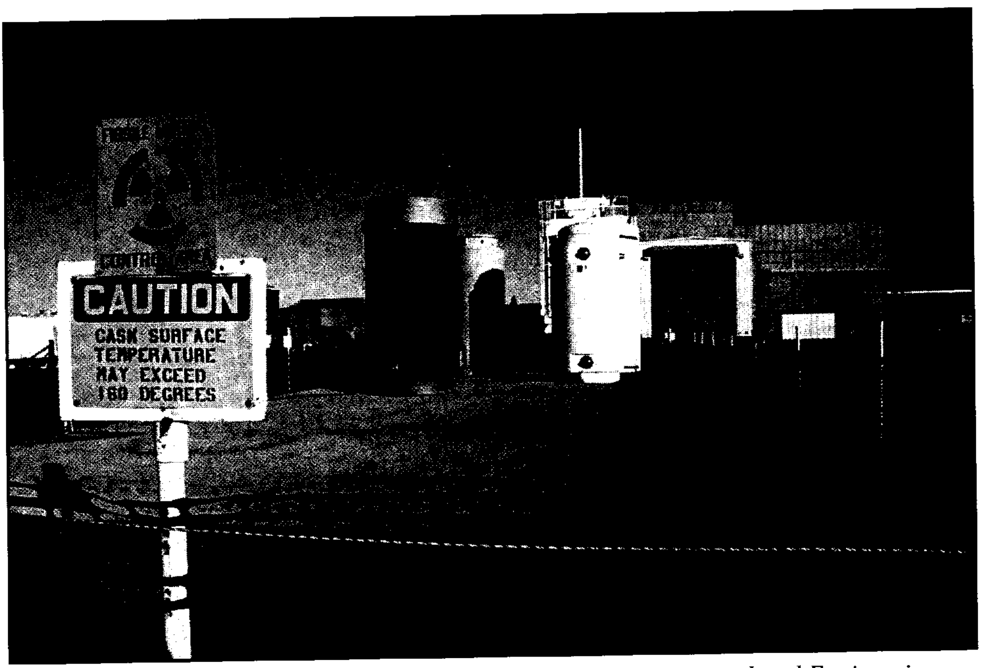
The DOE's current approach to managing spent fuel at its Idaho and South Carolina sites, with a heavy bias in favor of reprocessing, parallels the story of the Hanford, Washington, site in the late 1980s and early 1990s.[5] The Hanford N-reactor was used primarily for plutonium production. It began making plutonium at the end of 1963 and also generated electricity beginning in 1966. The N-reactor was the only plutonium production reactor at Hanford from 1971 until it was shut down in early 1988 due to safety concerns.

The N-reactor's partner in plutonium production, Hanford's PUREX reprocessing plant, was completed in 1955, operated until it was shut down in 1972, restarted in 1983, and went through an emergency shutdown in late 1988. The PUREX plant operated again for four months in 1989 and 1990 to clean out material left from the aborted 1988 operations. During that "cleanout run," operations were halted at least three times due to equipment failures.[6]

DOE's major site contractor, the Westinghouse Hanford Company, decided to restart PUREX, planning to reprocess all the remaining spent fuel between 1991 and 1995, and released the "Westinghouse Study" in late 1989 to defend that decision. This study was biased to the point of distorting the facts. For example, it assumed that, by about 1995, reprocessing could solve the spent fuel corrosion problem. Alternatives such as dry storage were depicted as inferior because they could not be fully carried out before the year 2010 when the spent fuel was expected to be in final disposal. This version of reality completely ignored the large quantities of highly radioactive reprocessing wastes that would have required decades for final disposal.[7]

The Westinghouse study of Hanford's spent fuel was biased in favor of reprocessing to the point of distorting the facts.

The Westinghouse Study also suggested that alternatives such as dry storage would require more time than reprocessing because of environmental regulations (such as an EIS requirement), while reprocessing would be free of such restrictions.[8] This attitude brushed aside the intent of environmental laws, which is to limit damage caused by human activities. Reprocessing is far more polluting than storage, but Westinghouse focused on a legal technicality that had shielded reprocessing from environmental regulation. Only vigorous protest from citizens, and the threat of lawsuits, moved the DOE to abandon reprocessing at Hanford.



Robert Del Tredici

Spent Fuel Dry in Dry Storage Casks - *Idaho National Environmental and Engineering Laboratory.*

DOE's Doublespeak Industry

Since its invention in the early 1940s, reprocessing has more than earned its negative reputation. Instead of abandoning a risky and polluting technology, the DOE has adopted the practice of renaming it, apparently hoping no one will notice that it's the same old thing. An internal DOE memo even advised staff to use the search-and-replace functions of their word processors to change "reprocessing" into one or another of its euphemisms.* This reference can help citizens keep up with the repackaging game:

DOE Term	***Technical Definition***
Actinide Recycle	Reprocessing
Aqueous Processing	Reprocessing
Chemical Processing	Reprocessing
Chemical Separation	Reprocessing
Chemical Stabilization	Reprocessing
Electrometallurgical Processing	Reprocessing
Electrorefining	Reprocessing
Fuel Conditioning	Reprocessing
Materials Stabilization	Reprocessing
Partitioning	Reprocessing
Processing	Reprocessing
Process Q	Reprocessing
Pyrochemical Separation	Reprocessing
Pyroprocessing	Reprocessing
Stabilization	Reprocessing
Treatment	Reprocessing

Adapted from Science for Democratic Action, *Winter 1996, Institute for Energy and Environmental Research.*

* Memo from John Kotek, DOE Office of Nuclear Energy, to Ernie Hughes, Director, Argonne West Laboratory, INEL, June 14, 1994.

DOE's Current Activities and Plans

The DOE has begun reprocessing some types of nuclear materials and is planning to reprocess many other kinds. Although solving environmental and safety problems is the stated motive for all of these projects, each type of material entails somewhat different hazards, proliferation implications, and treatment or storage options.[9]

The DOE has made no move to submit its extracted plutonium to international inspection.

Savannah River Site (SRS)

F-Canyon Plutonium Nitrate Solutions

The material: When reprocessing ended in 1992, 80,000 gallons of plutonium nitrate solutions were left "in the pipeline" of the F-Canyon reprocessing plant at the Savannah River Site. These chemical solutions are stuck in a stage between dissolving spent fuel in nitric acid and making the final plutonium metal or plutonium oxide product.

The problem: The F-Canyon was not designed to safely store the solutions for more than six months. Plutonium in solution is susceptible to accidental nuclear chain reactions, a risk that increases with time, as plutonium particles can settle out and accumulate. Such an incident might damage the solutions' containers and lead to human radiation exposure. In addition, these materials are at some risk of accidents due to equipment failure or natural events such as earthquakes.

DOE's plan: The F-Canyon solutions posed immediate and serious risks because they were partly reprocessed materials. For this reason, the reprocessing undertaken by the DOE from early 1995 to late 1996 was arguably the best treatment option. The notable alternative, treating the solutions as waste and "vitrifying" them to a glassy form in an existing plant at the SRS, might have delayed the F-Canyon "cleanout run" by several years.

The plan's flaws: While this final operating stint for the F-Canyon appears justified, some of the DOE's actions in connection with it were not. The DOE made no move to submit the extracted plutonium to international inspection. This kind of oversight, an essential part of nonproliferation, was called for by the Clinton Administration in 1994 and by citizen groups before and since then. This recalcitrance fuels concerns about whether the DOE is abiding by the U.S. commitment not to add to its plutonium stockpile. It also undermines the effort to obtain "plutonium production cut-off" commitments from Russia and other countries.

The government has also refused to provide a timetable for F-Canyon operations or to specify limits on the kinds and quantities of materials to be reprocessed. The DOE and the site contractor, Westinghouse Savannah River Company, appear to be keeping their activities ambiguous and open-ended for as long as possible. This tactic seems designed to tilt the balance in favor of reprocessing when decisions are made about the treatment of other radioactive materials. By keeping the plant in operation and consuming funds, it is likely to be the "ready answer" to problems such as corroding spent fuel while other options are neglected.

A better way: The United States should comply with the kind of monitoring that it wants to see imposed on other countries. DOE should present a clear schedule for ending all reprocessing at SRS.

The United States should comply with the kind of monitoring that it wants to see imposed on other countries.

Other Liquid Materials

The material: In its Environmental Impact Statement (EIS) regarding the SRS, DOE lists five types of chemical solutions containing plutonium, uranium, and other radioactive elements comprising a total volume of about 80,000 gallons. Most of these liquids are stored in the other reprocessing plant at the SRS, called the H-Canyon.

The problem: As in the case of F-Canyon chemical solutions, these materials cannot be stored safely where they are.

DOE's plan: In most cases, some amount of reprocessing will be necessary to get these solutions out of the canyons and into more stable forms for storage or disposal.

The plan's flaws: As with the F-Canyon liquids, the DOE has ignored the need for international monitoring, and it has kept its plans ambiguous and open-ended by listing a variety of additional materials that it would like to reprocess and by refusing to set a schedule for ending all reprocessing.

A better way: The DOE should move quickly to arrange for international monitoring of all materials of proliferation concern that result from this work. The set of materials to be reprocessed should be clearly defined. Any stabilization should be limited to one canyon, with a clear endpoint for its operations. Meanwhile, the second canyon can be shut down.

Leaving the spent fuel as it is now stored would be environmentally irresponsible.

Spent Fuel and Targets

The material: About 200 metric tons of irradiated nuclear fuel and targets are stored at the SRS.[10] Most of this inventory came from plutonium production reactors at the site. The reactor fuel consists of highly enriched uranium (HEU, consisting mostly of U-235, see Appendix) along with fission products and some plutonium. Targets were made from nearly pure U-238 and now contain plutonium and some fission products. Smaller quantities of spent fuel stored at the site came from a research reactor in Taiwan, from an experimental breeder reactor at the INEL, and from many small foreign research reactors that were fueled with HEU from the United States. The dominant material in all these fuels is HEU combined with highly radioactive fission products. These materials are in the form of metallic rods or cylinders, and they are in underwater storage that provides cooling and radiation shielding.

The problem: Some fuel and target elements have corroded, contaminating the water, exposing workers to more radiation than usual, and increasing the risk of radioactive emissions to the environment. Leaving the spent fuel as it is now stored would be environmentally irresponsible.

DOE's plan: The DOE has stated that reprocessing is its "preferred option" for handling the SRS spent fuel.

Flaws in the plan: DOE has failed to seriously explore alternatives that are cheaper and less risky than reprocessing. The most corroded of this material has already been reprocessed, greatly reducing the justification for restarting the "H-Canyon" to reprocess the rest of it, as DOE is planning for mid 1997. This would be a waste of money at best.

A better way: Underwater storage should be improved (by "canning" or encapsulating the most corroded fuel elements, and by changing water chemistry to inhibit further corrosion, for example). The materials should then be moved into dry storage as quickly as possible. By DOE estimates, this would result in less than half as much new high-level radioactive waste, and hundreds of times lower cancer risk to the public, than would come from reprocessing. DOE is already using the dry storage option on about 80 percent of its total spent fuel inventory (stored at the Hanford, Washington site; see page 11). The decision to do that came in spite of Westinghouse's arguments that reprocessing would be necessary at Hanford. Instead of using the same rationales (and similarly incomplete and faulty logic) in pushing for reprocessing at the SRS, the government should apply the lessons learned at Hanford.

Foreign Research Reactor Spent Fuel

The material: Starting in 1994 and ending in about 2010, a total of about 19 tons of spent fuel will be returned to the SRS from small research reactors in 41 countries. These reactors are used to make radioactive isotopes for use in medicine, industry, and scientific labs, and are fueled with HEU from the United States.

The problem: The HEU in research reactor spent fuel could be used in relatively simple nuclear weapons. If HEU were disposed of without being diluted (with unenriched uranium) or adequately immobilized, it could pose risks of an accidental chain reaction, or "criticality," but only if it were reprocessed first. However, the HEU in spent fuel could only be used as a weapons material *after* being reprocessed, and reprocessing is not necessary to avoid a criticality.

DOE's plan: The return of spent fuel, along with the development of non-HEU fuel for research reactors, is a successful part of the U.S. nonproliferation effort. Reprocessing was initially DOE's "preferred alternative" for dealing with foreign spent fuel, but that option has been shelved for now.

Flaws in the plan: While in some of its documents the DOE has recognized the nonproliferation drawbacks of reprocessing this fuel, it has been ambiguous about whether the material will be stored or reprocessed. A 1995 Draft EIS noted that "the potential exists that other states (e.g., Iran), might use the restart of reprocessing in the United States as an excuse to continue [their] current [reprocessing] programs or begin new ones – activities that would run counter to U.S. nuclear weapons nonproliferation interests."[11]

A better way: Almost by definition, the returned research reactor fuel is suitable for dry storage, as it must be shipped in dry containers. The government should translate its observations about nonproliferation (noted above) into clear limits on U.S. reprocessing. Dry storage would not raise proliferation concerns, and it would keep open a better range of future options.

The government should translate its observations about non-proliferation into clear limits on U.S. reprocessing.

Politics vs. Sound Policy

The story of foreign spent fuel illustrates the fact that political expediency too often influences decisions about reprocessing. In 1994, the state of South Carolina filed suit to block spent fuel shipments on the grounds that the state did not want to become "the dumping ground for the world."[12] A leaked high-level DOE internal memo from late 1994 revealed that officials were proposing to make a bargain with South Carolina to reprocess spent fuel and perhaps even build a new reprocessing plant in exchange for the state dropping its suit. This memo pointed out that "the economic incentives associated with re-starting operations at existing facilities and possibly constructing and operating a new [re]processing facility should generate support ... from those who favor [re]processing. Such a shift in [DOE] strategy may also provide an opportunity to negotiate a settlement to the litigation associated with the acceptance of foreign fuel...".[13]

This memo inspired vigorous protest, and the DOE appears to have backed off from the "new [re]processing facility" idea. The episode indicated, however, that South Carolina politicians were expected to be more concerned about maximizing the flow of federal dollars to the SRS than about minimizing environmental and safety risks (reprocessing entails much greater risks and radioactive waste problems than spent fuel shipping or storage). Unfortunately, the DOE appeared willing to sacrifice long-term environmental, nonproliferation, and budgetary considerations for the sake of political expediency.

In a mid-1996 publication, the DOE committed itself to put aside reprocessing of foreign spent fuel at least until the year 2000 and to consider reprocessing at that time only if an alternative technology cannot be developed.[14] However, this is inconsistent with DOE's approach to the same kind of spent fuel from domestic reactors. That material is still slated for reprocessing, according to a document published at the end of 1996.[15]

In general, the DOE's proposals and decisions about spent fuel at the SRS remain heavily biased in favor of keeping reprocessing alive for as long as possible. The EIS analyses highlight the dubious advantages of reprocessed material for placement in a disposal site that has yet to be fully established while ignoring the known hazards of adding more radioactive wastes to storage tanks. The documents also attempt to dodge proliferation implications by using the term "processing" instead of "reprocessing." The EIS also fails to mention the significant technical, cost, and regulatory liabilities involved in operating reprocessing plants that are more than 40 years old.[16]

In part to satisfy South Carolina political and economic interests, Westinghouse is doing some work on alternatives, even though the contractor strongly favors reprocessing the spent fuel. It is time for politicians and officials to recognize that reprocessing should end for good.

Pyroprocessing at the Idaho National Engineering and Environmental Laboratory (INEEL)

The material: An estimated 261 tons of spent fuel are stored at the INEEL, left from operation of a plutonium breeder reactor (called the Experimental Breeder Reactor-II, or EBR-II).[17] This reactor was intended to serve as a prototype for the civilian nuclear power industry.

The supposed problem: The INEEL spent fuel contains some sodium that might cause chemical instability problems in the long term. A DOE official, however, stated in 1995 that "the near-term storage of EBR-II spent fuel presents no compelling environmental, safety, or health concern."[18] Some of this material has been in storage for nearly 30 years.

DOE's plan: DOE recently decided to start a new form of reprocessing known by the euphemisms "pyroprocessing," "electrometallurgical processing," and "electrorefining." This method separates plutonium and uranium from irradiated nuclear fuel at high temperatures. The fuel is dissolved in molten salts, and plutonium, uranium, and related elements are separated from fission products by an electroplating process. The INEEL pyroprocessing plant was constructed as part of the Integral Fast Reactor (IFR), a plutonium breeder reactor intended to serve as a prototype for the civilian nuclear power industry. The plant isoperated by Argonne-West Laboratory, a contracting branch of the University of Chicago.

In 1994, DOE Secretary O'Leary asked Congress to stop funding the IFR. O'Leary wrote: "Because it is based on plutonium reprocessing and recycle, continued development of the Integral Fast Reactor would undercut our efforts to discourage other countries from plutonium reprocessing and recycle."[19] Within two years, the DOE reversed course and decided to operate the very part of the breeder reactor plant that was and is of greatest proliferation concern. This reversal appears to have been the result of political pressure to maintain the flow of federal dollars to Idaho and Illinois, and it has not been adequately explained.

Flaws in the plan: Pyroprocessing itself poses serious safety concerns, as it involves treating flammable high-level waste, including plutonium, at high temperatures. A leak of air into the facility could cause a fire that would release deadly materials into the atmosphere. Two major plutonium fires in the Rocky Flats plutonium metallurgy plant in Colorado in 1957 and 1968 rank among the costliest industrial disasters in U.S. history.

The DOE reversed course and decided to operate the very part of the breeder reactor plant that was and is of greatest proliferation concern.

The benefits of pyro-processing are uncertain at best while its nuclear proliferation consequences are serious. It should stop immediately.

The physical and chemical characteristics of waste from pyroprocessing are not adequately understood nor is its compatibility with known treatment and storage methods. The nation is already burdened with numerous complicated nuclear waste handling problems without adding new waste forms to the inventory.

Most importantly, pyroprocessing will pose serious proliferation threats due to its compact and concealable nature. The DOE has addressed this threat by asserting that pyroprocessing at the INEEL will be adjusted so that it does not produce weapons-usable plutonium. This assertion completely misses the point: the method can easily be adjusted so that it does produce weapons-usable materials.

To start this reprocessing plant, the DOE evaded environmental oversight by redefining its own terms and by claiming that the INEEL activity does not constitute reprocessing because its *intent* is not to obtain plutonium for weapons. The DOE systematically refused to address many serious questions about radioactive waste, safety and environmental hazards, and proliferation risks related to pyroprocessing.

The stated rationale for pyroprocessing, to "stabilize" about 1.6 tons of spent fuel elements from an experimental breeder reactor, is contradicted by analyses indicating that the problem of sodium instability is relatively easy to address. Dr. James C. Warf describes a simple method for extracting chemically reactive sodium and cesium from fuel rods, but DOE seems not to have considered such measures.[20]

Some observers believe that a deal between the DOE and members of Congress whose districts include Argonne Laboratory sites gave the green light to pyroprocessing. A DOE source quoted in an industry trade journal said that at Argonne-West, pyroprocessing is "just about the only thing they've got left to do. ... It's a jobs issue."[21]

A better way: The INEEL spent fuel should be kept in storage, and its storage conditions should be improved. Eventual environmental and safety benefits of reprocessing this material are uncertain at best while its nuclear proliferation consequences are serious. Pyroprocessing should stop immediately.

The MOX Option: Dangerous, Expensive, Senseless

About five times as much plutonium has accumulated in commercial spent nuclear fuel as is contained in the world's nuclear arsenals.[22] Most of this plutonium, while theoretically usable in nuclear weapons, is not considered a serious proliferation hazard because it has not been reprocessed and is therefore mixed with highly radioactive fission products. Indeed, a loose benchmark for plutonium disposition security is the *spent fuel standard*: if surplus military plutonium can be put into a form that makes it as difficult to extract as is the plutonium in spent fuel, it could be seen as a more manageable security risk.

As a way of incorporating surplus plutonium from nuclear weapons into spent fuel, the DOE is aggressively promoting a plan to use it as civilian reactor fuel, to incorporate it into spent fuel. This scheme, essentially reprocessing in reverse, is called the "MOX option" because the fuel involved would consist of "mixed oxides" of plutonium and uranium. DOE is shifting funds away from the alternatives and committing the nation to a high-risk project that could waste billions of tax dollars and will seriously weaken nonproliferation policies. Major flaws in the MOX option include:[23]

- **Easier Theft or Diversion** – Plutonium is difficult to account for as it passes through MOX fuel fabrication plants, so the theft of several bombs worth of material would be difficult and costly to detect. The commercial plutonium cycle would also require hundreds of shipments of plutonium to and from reactors and fuel plants, increasing the risks of diversion for violent purposes.
- **Riskier Reactors** – The use of MOX fuel can reduce reactor controllability unless compensating measures are taken, giving operators less time to respond to unusual events; it increases the severity of some types of accidents; and it adds to the health consequences of any "loss-of-containment" accident. The use of plutonium fuel will require increased security measures, including the possible use of deadly force, and it will complicate waste disposal.
- **Political and Regulatory Uncertainties** – The MOX option will undermine two decades of U.S. policy on commercial plutonium, and it will arouse strong opposition from a broad array of citizen organizations. The safety and environmental hazards of the plutonium fuel cycle will require an extensive and rigorous regulatory review.

- **Bad Economics** – Numerous analyses have shown that as a fuel, plutonium has a negative value; in other words, the nuclear power industry must be subsidized to use it. Sound economic analyses, however, are often badly compromised by political maneuvers. If the United States justifies building MOX plants as a "treatment" method for military plutonium, the nuclear industry is likely to try to use it as the basis for a civilian plutonium fuel cycle. In Europe, Japan, and Russia, multi-billion-dollar investments in plutonium reprocessing and fuel fabrication plants have provided the momentum for energy systems that could not survive market competition.
- **Supporting Russian Irrationality** – DOE's justification for the MOX scheme hinges on the fact that Russian officials prefer to see plutonium as a resource rather than a liability, and the MOX approach reinforces the ill-conceived notion that plutonium has some value. Supposedly, Russian plutonium disposition could be better monitored if the United States were to pursue the same approach. This rationale is contradicted by a *Joint U.S.-Russian [government] Plutonium Disposition Study* that said the two nations "need not use the same plutonium disposition technology" and that "it is likely that the best approaches will be different in the two countries."[24] U.S. endorsement of MOX will lend support to the plutonium fuel cycle (including reprocessing) in Russia, Japan, and Europe, and it will delay recognition of plutonium's poor economics. Meanwhile, the Russian MOX plan is expected to require at least $3 billion in subsidies, possibly far more. Once committed to this scheme, its own security interests might compel the United States to pay much of the bill for Russia's MOX program.
- **Subsidizing Plutonium Commerce** – The MOX plan could turn into a costly back-door subsidy of the civilian plutonium fuel cycle that cannot survive in a competitive energy market even if its proliferation hazards are ignored. A program supposedly intended to solve a security problem is likely to help establish global trade in plutonium, with all of its safety and proliferation risks.
- **A Better Option Must be Developed Anyway** – DOE is neglecting and delaying a more direct and economical option that would help satisfy nonproliferation *and* environmental goals. Spent fuel and/or plutonium could be combined with some of the vast backlog of highly radioactive waste. The mixture could then be "vitrified" by blending it with molten glass. Vitrification is already being used to prepare radioactive waste for long-term storage and eventual disposal. *At least 15 percent of the current DOE plutonium surplus is not seen as usable in reactors, and according to DOE, it must be vitrified regardless of the MOX plan.*[25] This approach would also benefit taxpayers by cutting out the reactor middleman.

Robert Del Tredici

Waste Vitrification Plant *- The Defense Waste Processing Facility at Savannah River Site was constructed at a cost of about four billion dollars, including necessary auxiliary plants. The facility was built so that highly radioactive waste from reprocessing could be mixed with molten glass and poured into cannisters for long-term storage and eventual disposal.*

More Reprocessing Ahead?

If the United States pursues reprocessing and expands it by bringing spent fuel into the reprocessing buildings (in addition to the "cleanout runs" of in-plant materials), the activity will become increasingly difficult to stop for several reasons:

- The precedent of reprocessing as a waste management tool will be set, and the environmental and international security damage from doing "just a little more of it" will be subtle. The apparent legitimacy of reprocessing is also likely to inspire renewed attempts to use it in the civilian nuclear power industry. Westinghouse has already proposed using the F- and H-Canyons at the Savannah River Site to reprocess thousands of tons of civilian spent fuel.[26]
- A federal funding-dependent political constituency will become more entrenched and more impervious to rational analysis.
- DOE environmental management funds that could have supported alternatives such as dry storage facilities will instead be consumed by the reprocessing plants. This misallocation of public resources is likely to aggravate the problem of unstable spent fuel and make the supposed need for reprocessing into a self-fulfilling prophecy.

Current plans are likely to aggravate the problem of unstable spent fuel and make the supposed need for reprocessing into a self-fulfilling prophecy.

Conclusion

In recent years, the Department of Energy has taken many steps to recognize that the nuclear arms race and the Cold War are over. While this transition has been far from perfect, and while most reform has come only after intense pressure from citizens and independent critics, most of the major nuclear weapons production sites have shifted their emphasis toward environmental restoration. Unfortunately, much of this progress toward public accountability and recognition of the environmental and security implications of its work will be reversed if the DOE carries out its plans to keep alive nuclear materials reprocessing. The national interest, as well as the Energy Department's shaky public credibility, are poorly served by the DOE habit of stretching its environmental task to include its traditional nuclear production activities. The same attitude is evident in the continued nuclear weapon design work being done by the DOE National Laboratories, under a very broad interpretation of their mandate for "stockpile stewardship" of a shrinking post-Cold War arsenal.

Whether out of habit, excessive concern for its established contractors, political concerns about preserving jobs and income at plant sites, or the bureaucratic motive of institutional preservation, DOE has paid too little attention to the consequences of committing the country to an open-ended regimen of reprocessing. Current plans to reprocess an indefinite quantity of spent nuclear fuel and neglect safer and cleaner options will undermine national policy on nonproliferation. It will also pass on a larger bill for waste management and disposal to future generations.

Citizens have been saddled with the enormous cost of nuclear arms production and the environmental aftermath of the Cold War. They deserve a clear and consistent explanation for any decision that could add to that burden, particularly if it is likely to undermine efforts to control the spread of nuclear weapons.

Recommendations

Since the United States is no longer building up its nuclear arsenal, reprocessing has outlived any usefulness it once had. This activity generates large quantities of dangerous radioactive waste, weakens nuclear nonproliferation efforts, and passes its hidden costs to the future. The United States should take the following steps:

- Return to a long-standing, rational, bipartisan policy of avoiding actions that could promote or encourage the "plutonium fuel cycle" for electricity generation anywhere in the world.
- Base decisions about reprocessing on realistic analyses of its international and long-term consequences, not on its narrow benefits to a few contractors or to the nuclear industry.
- Strictly limit current reprocessing at the Savannah River Site to the radioactive solutions that were left in the reprocessing plants when plutonium production ended.
- Place all weapons-usable plutonium and uranium that are extracted from leftover materials inside the reprocessing plants under the same international monitoring and safeguards that the United States wants imposed on other countries.
- Do not bring any additional material into the reprocessing plants.
- Provide a timetable for ending all reprocessing at the Savannah River Site and closing the reprocessing canyons permanently.
- Halt pyroprocessing in Idaho and develop safer alternatives for handling spent fuel.
- Shift funding and effort from reprocessing to improvement of underwater storage of corroding spent fuel, then into interim dry storage.
- Stop using doublespeak to portray reprocessing as a benign activity. Use the internationally accepted definition of reprocessing as the separation of plutonium and uranium from irradiated nuclear materials.

Appendix: What are "Fissile Materials"? (Plutonium-239 and Uranium-235)

All nuclear power plants and all nuclear weapons depend on the splitting or "fission" of the nuclei of unstable heavy elements. The more powerful thermonuclear or "hydrogen" bombs derive part of their energy from the joining or "fusion" of lighter elements, but they still must be initiated with a fission-driven explosion. A fission chain reaction can occur when particles called neutrons from the splitting of one atom strike other atoms and cause at least one additional fission.

Every natural and man-made element is identified by an atomic number, which is the number of protons in its nucleus. The sum of protons and neutrons in each atom identifies the "isotope" of the element.

An isotope that can sustain a fission chain reaction is called a "fissile material." Because nuclear bombs cannot be made without them, the monitoring and control of fissile materials and of the means of producing them are fundamental tools for inhibiting the spread of nuclear weapons.[27] The two fissile isotopes used in nuclear weapons are plutonium-239 and uranium-235.[28]

Uranium: Uranium-235 (U-235) is the only fissile isotope found naturally on earth. Natural uranium can be used as reactor fuel, but it is not sufficient for making nuclear weapons because it contains less than one percent U-235 while more than 99 percent is the non-fissile U-238 isotope.

To serve as the core of a nuclear bomb, uranium must be *enriched* to increase its proportion of U-235. The higher the enrichment, the smaller the quantity of fuel or bomb material required to sustain a chain reaction. Because U-235 and U-238 are virtually identical except for their small difference in atomic mass, enrichment typically requires huge, complicated factories and large amounts of energy. Only half a dozen countries, including the United States, have built production-scale enrichment plants.

Highly enriched uranium is roughly defined as any uranium with a U-235 content higher than 20%, and it is considered a proliferation hazard because of its potential use as a nuclear explosive. Uranium used as a fissile material for weapons is usually at least 90 percent U-235.[29] Highly enriched uranium (HEU) can be used as the core of a relatively primitive nuclear bomb such as the one that exploded over Hiroshima. With higher enrichment, a reactor is more compact and requires less frequent refueling, so naval propulsion reactors typically run on HEU. This fuel has also been used in numerous small research reactors. Some of the DOE's planned reprocessing will separate HEU from research reactor spent fuel, raising concerns about how the material will be managed and whether it will be subject to international oversight.

Plutonium: Plutonium is not found in nature, and nuclear reactors provide the only known practical means for obtaining significant quantities of it.[30] When U-238 atoms absorb neutrons, they are "transmuted" into Plutonium-239 (Pu-239), the most desirable isotope for nuclear weapons use.[31] All uranium-fueled reactors create at least some plutonium.[32] The United States operated 14 plutonium production reactors during the Cold War. Plutonium was created in the uranium fuel and/or in "targets" made of nearly pure U-238, depending on the reactor design.

As Pu-239 is irradiated, some of it absorbs neutrons and becomes Pu-240; some of that Pu-240 then becomes Pu-241, and so on. To avoid the buildup of heavier isotopes, fuel and targets were subjected to relatively little irradiation in military reactors, and the material was reprocessed frequently. Although the U.S. stockpile consists of "weapons-grade" plutonium (defined by the DOE as containing less than seven percent Pu-240), any grade of plutonium, including the material embedded in spent fuel from commercial reactors, can be made into a nuclear bomb. The use of lower-grade plutonium poses some disadvantages, such as a somewhat lower and less predictable explosive yield and higher radiation exposure to workers, but the fact that it can be made into a bomb has been known since the early decades of the Cold War.

Disposal: Plutonium and enriched uranium are difficult to store or dispose of because they are susceptible to accidental nuclear chain reactions and because they are potentially usable in nuclear weapons. Plutonium "decays" more rapidly than does uranium, but the dominant isotope, Pu-239, nonetheless has a half-life of 24,000 years.[33] Both elements must be stored or disposed of with the very distant future in mind.

Plutonium is more radioactive, and it is dangerous in smaller amounts. Another key difference is that HEU can be "blended down" by mixing it with unenriched uranium. This process greatly reduces the risk of a chain reaction, and it can make the uranium just as difficult to use in nuclear weapons as is the commercial reactor fuel now widely available. Plutonium cannot be blended down, so other procedures are required to keep it from contaminating the environment or falling into human hands. For a period of one to several centuries, plutonium can be made difficult to transport or use by leaving it in spent fuel or by mixing it with radioactive waste to produce the equivalent of spent fuel. For the longer term, plutonium can be isolated using physical barriers such as emplacement deep underground, and it can be made more difficult to recover by diluting it in a medium such as glass.

For More Information . . .

The following organizations are active in the debate over reprocessing and can provide documents, references, and news about recent developments.

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ENDNOTES

1. For information on plutonium, see *Plutonium: Deadly Gold of the Nuclear Age* by a special commission of International Physicians for the Prevention of Nuclear War and the Institute for Energy and Environmental Research, International Physicians Press, 1992.
2. Declaration of Professor James C. Warf, March 20, 1996 in a lawsuit regarding "pyroprocessing" at the Idaho National Engineering Laboratory. This and related documents available from Committee to Bridge the Gap (see p. 28).
3. See *Risky Relapse into Reprocessing* by Noah Sachs, IEER, January 1996, and its predecessor, *To Reprocess or not to Reprocess: The PUREX Question*, by Scott Saleska and Arjun Makhijani, Ph.D., July 1990. Information about these reports can be obtained from IEER at 301-270-5500, or email: ieer@igc.apc.org.
4. *Nuclear Notes from France*, Oct.-Nov., 1996. The item referred to a controversial plan to build a "mixed-oxide" (or MOX, a blend of plutonium and uranium oxides) fuel plant in Russia.
5. The Hanford spent fuel is slightly different from that of the SRS in that it is coated with zirconium rather than aluminum. This difference does not pose serious technical obstacles to the interim dry storage of either fuel type.
6. Westinghouse Hanford Co., Chemical Processing Program Monthly Status Report, Dec. 1989, Jan., Feb., March 1990.
7. *To Reprocess or not to Reprocess: The PUREX Question*, p. 4.
8. *Ibid*, p. 3.
9. See *Risky Relapse into Reprocessing* for an analysis of the materials and of the DOE's plans.
10. The metric ton, used throughout this report, is 1,000 kilograms or about 2,205 pounds. In the context of spent fuel and targets, the data provided by the DOE refer to "metric tons of heavy metal," mainly plutonium and uranium. The total mass of spent fuel is higher than that of the heavy metal.
11. *Draft Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel*, Washington, DC: DOE Office of Environmental Management, March, 1995.
12. *Nuclear Fuel*, Oct. 10, 1994.
13. Memo prepared for, but not signed by, Assistant Secretary of Energy for Environmental Management Thomas P. Grumbly, late 1994.
14. *Record of Decision on a Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel*, U.S. Department of Energy, Washington, DC, May 13, 1996, p. 17.
15. *Federal Register*, Dec. 31, 1996 (61 *Fed. Reg.* 25092), cited in a letter from Paul L. Leventhal, president of the Nuclear Control Institute, to Energy Secretary Hazel O'Leary, Jan. 10, 1997.
16. Comments on the EIS by Brian Costner of the Energy Research Foundation, Columbia, SC, July 20, 1995.
17. The term refers to the fact that such a reactor can "breed" relatively large quantities of plutonium in the uranium placed in its core.
18. Letter from Ray Hunter, DOE Office of Nuclear Energy, Science, and Technology, to Dan Horner, Nuclear Control Institute, June 28, 1995.
19. Letter from Energy Secretary Hazel O'Leary to Senator John Kerry, 1994, cited in *Risky Relapse into Reprocessing*.
20. See endnote 2.
21. *Nucleonics Week*, June 8, 1995.
22. Albright, Berkhout, and Walker, *World Inventory of Plutonium and Highly Enriched Uranium 1992*, Oxford University Press, 1993, pp. 78-80. Estimate based on projections for the year 2000.
23. See *MOX Disposal of Surplus Weapons Plutonium: Politically Expedient, But Does it Make Sense?*, by Paul Leventhal, Nuclear Control Institute, Feb. 12, 1997 for detailed arguments.
24. *Joint United States/Russian Plutonium Disposition Study*, Sept. 1996, Executive Summary, p. Ex-Sum-2.
25. Briefing of the Nuclear Regulatory Commission, by Howard Canter, Acting Director, Office of Fissile Materials Disposition, DOE, et al., Rockville, MD, Jan. 27, 1997.
26. *Chemical Stabilization of Defense Related and Commercial Spent Fuel at the Savannah River Site (U)*, Westinghouse Savannah River Company, Doc. No. NMP-PLS-950239, Aug. 16, 1995.
27. See *World Inventory of Plutonium and Highly Enriched Uranium 1992* for more information on fissile materials.
28. U-233, which can be made in a reactor from thorium-232, is also fissile and weapons-usable, but it is not easily produced in sufficient quantities, and it is not generally seen as a serious proliferation concern.
29. The term "weapons usable," refers to material that can form the fissile core of a nuclear explosive. Unenriched uranium is also used in multi-stage thermonuclear warheads, but it is not sufficient for any known bomb design.
30. An extremely small amount of plutonium is created in water and soil by cosmic radiation that strikes natural uranium, and by uranium decay. Human activities such as nuclear weapons testing have added much larger quantities of plutonium to the environment.
31. The heavier plutonium isotopes are more radioactive, give off more heat, and can, unless special design measures are taken, cause a nuclear weapon to pre-detonate, reducing its explosive power.
32. Reactors fueled with HEU contain less U-238 and produce correspondingly less plutonium.
33. In about one quarter-million years, 99.9% of plutonium-239 will decay into uranium-235. U-235's half-life is about 700 million years; that of U-238 is about 4.5 billion years.

Presidental opposition to reprocessing:

"The goal is to prevent [nuclear] proliferation, not simply deplore it. We must be sure that all nations recognize that the U.S. believes that nonproliferation objectives must take precedence over economic and energy benefits if a choice must be made. I have concluded that the reprocessing and recycling of plutonium should not proceed unless there is sound reason to conclude that the world community can effectively overcome the associated risks of proliferation."*

– President Gerald Ford, November 1976

"We will defer indefinitely the commercial reprocessing and recycling of the plutonium produced in the U.S. nuclear power programs. … The plant [a proposed new facility at] Barnwell, South Carolina, would receive neither federal encouragement nor funding from us for its completion as a reprocessing facility."†

– President Jimmy Carter, April 1977

"Therefore, I have set forth today a set of principles to guide our nonproliferation efforts… These steps include a decision not to produce plutonium and highly-enriched uranium for nuclear explosive purposes and a number of proposals to strengthen international actions against those who contribute to the spread of weapons of mass destruction and the missiles that deliver them."‡

– President George Bush, July 1992

"The United States does not encourage the civil use of plutonium and, accordingly, does not itself engage in plutonium reprocessing for either nuclear power or nuclear explosive purposes."§

– President Bill Clinton, September 1993

* *Public Papers of the Presidents of the United States, Gerald R. Ford*, 1976-77, Book III – July 10, 1976 to Jan. 20, 1977, pp. 2764-2768.

† *Public Papers of the Presidents of the United States, Jimmy Carter*, 1977, Book I – Jan. 20 to June 24, 1977, pp. 587-588.

‡ *Statement by President George Bush*, The White House, July 13, 1992.

§ *Fact Sheet—Nonproliferation and Export Control Policy*, The White House, Sept. 27, 1993.

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