# IN-PROCESS TECHNIQUES FOR REDUCING

# THE GENERATION OF TRANSURANIC WASTE

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## ABSTRACT

This paper contains a synopsis of a handbook prepared for the Department of Energy's Transuranic (TRU) Waste Management Program. The handbook is a compilation of techniques for reducing the generation of transuranic waste at major TRU waste sites. The techniques selected include methods which are in use, or which have been researched in laboratory or pilot scale testing. Major topics covered include administrative control, material substitution, process development and optimization, and new equipment utilization. The report also provides details on the cost to handle and dispose of TRU waste. The data will allow a site to evaluate the feasibility of the methods without extensive research.

## INTRODUCTION

In 1983, the Reduced Waste Generation Program at Rockwell International, Rocky Flats Plant, began activities to publish a handbook of methods to reduce TRU waste. The handbook has been published in a Rocky Flats report, RFP-3737, titled, "In Process Techniques for Reducing the Generation of Transuranic Waste". The work was funded by the Transuranic Waste Program of the Department of Energy (DOE). This paper contains a synopsis of that work. Further details on the methods can be found in that report.

The scope of the handbook is limited in two ways. First, methods which reduce the waste after it is generated, such as incineration, compaction, and shredding, are not included. While useful in reducing the amount of waste sent to storage, most of those methods are well documented. Second, the methods described in this report are currently in use, or have been researched in the laboratory. Unlike other reduced waste publications, this report does not include a long list of possible approaches. Instead, methods are described in detail, and cost information is included so that a site can evaluate the methods without extensive research.

A total of ten methods are described, including operating experience and test results. Much of the information can be readily applied. The ten methods are segregated into four categories. Discussions of those four categories follow a section on the economic analyses that one might use to determine the benefit of each method.

## ECONOMIC JUSTIFICATION FOR REDUCING TRU WASTE

Beginning in the early 1950's, it was recognized that radioactive waste creates unique disposal problems. Since that time, each decade has brought an increased awareness of the economic and environmental impacts that result from handling and disposing of radioactive waste. It has become increasingly obvious that, whenever possible, generators should reduce or eliminate the generation of the waste.

The costs to dispose of TRU waste can be separated into the following categories:

1. handling and packaging cost, including assaying and certifying
2. transporation costs
3. interim storage, retrieval, and processing cost
4. final emplacement and surveillance costs

A simple economic analysis compares the above costs with the cost to fund a project that reduces waste volume. Although it is easily done, this method contains two drawbacks. First, it does not consider the sunk costs. A sunk cost is a past cost that will be incurred whether or not additional amounts of waste are reduced. For instance, the Waste Isolation Pilot Plant (WIPP) storage facility will accommodate approximately 170,000 $m^3$ of waste in its baseline design. The money to build the WIPP has already been spent. Thus, as long as the total volume received does not exceed 170,000 $m^3$, which would require new construction, no savings can result in WIPP construction costs when newly generated waste is eliminated. Additional waste could, however, add to the operating costs, because additional manpower and equipment would be required to unload and handle the waste.

A second problem with this method occurs because it fails to consider the time value of money. Opinions vary as to the necessity of including this principle in federal projects. Without going into detail, it can be shown that government projects should include a small (2 to 3%) interest rate in their economic analyses. For our purposes we have not included the interest rate calculation. Including the interest charge would improve the accuracy, and is recommended when doing a more detailed site analysis. However, nearly all of the projects evaluated were cost effective without adding in the interest charge.

The average disposal costs, as estimated in 1984, will be used in the analyses which follow. The final section of the handbook contains a generic cost analysis for each of the methods presented. For this report, a typical example is shown at the end of this section.

In past years, there has been a tendency to underestimate the economic consequences of generating radioactive waste. This has been, in part, because of unknown hazards associated with shallow land burial. Because the hazards and the requirements to deal with them are better known, the estimates in this paper should more accurate than earlier analyses. Also, the Waste Isolation Project Plant is under construction and storage criteria and shipping routes are defined. Uncertainty in the costs is in the estimates themselves and not because the future handling of TRU waste is unknown. Some of the estimates are based on actual data. Others are approximations, and this accounts for the greatest doubt.

Table I shows the estimated costs for disposal of TRU waste. The Rocky Flats Plant currently has a system for sorting and packaging. Other sites will soon be required to do similar sorting for certification. For this reason, the disposal costs are based upon Rocky Flats experience. Transporation costs will be higher from sites such as Hanford and Savannah River, but they are not significant when compared with the total cost of disposal. The cost of transporation and final WIPP storage reflect only the increased operating costs of handling additional waste. The capital cost to build TRUPACT containers and construction of the WIPP storage site are assumed to be sunk costs. The cost/benefit calculations in this paper and the handbook use the information found in Table I, however, the cost to put waste into interim storage and retrieve it are not included. It is assumed that the methods presented will primarily affect newly generated, certified waste sent directly to the WIPP facility. Should the waste be sent to interim storage, it would make the use of a technique to reduce the waste even more attractive.

TABLE I

Potential Cost Savings from Reduced Waste Generation

| Activity | Estimated Cost | Source of Estimate |
|---|---|---|
| TRU Waste Disposal | | |
| 1. Handling and Packaging At Site; includes Labor and Materials | $ 600/$m^3$ | Rockwell International, Rocky Flats Plant Waste Operations |
| Cost to Certify | 60/$m^3$ | Estimated at 10% of Handling and Packing Cost |
| 2. Transportation to WIPP by TRUPACT, Operating Cost Only (average distance to five major sites) | 1,040/$m^3$ | DOE Memo (October 6, 1983) |
| 3. Final WIPP Storage, Operating Cost Only | 2,000/$m^3$ | Estimated WIPP Life Cycle Cost without escalation divided by average $m^3$/hr from data provided to TMSO by WIPP |
| TOTAL | $3,700/$m^3$* | |
| * Interim storage, retrieval, and processing could add $900 to $3,000 per cubic meter. The analyses at the end of each section were done for newly generated, certified waste, and thus these costs were not included. | | |
| Low-Level Waste Disposal | | |
| 1. Handling and Packaging | $ 860/$m^3$ | Rockwell International, Rocky Flats Plant Waste Operations |
| 2. Transportation (using average distance of 500 miles) | 78/$m^3$ | DOE/NE-0017/2, page 240 |
| 3. Final Storage | 90/$m^3$ | Commercial Low-Level Charge Average of three sites (DOE/NE-0017/2, page 240) |
| TOTAL | $1,028/$m^3$ | |

Many of the cost/benefit examples in the handbook use the Payback Period method. This is an economic screening technique, and a more thorough analysis would use a time value technique such as Internal Rate of Return. In the Payback Period method, the initial cost of the project is divided by the annual savings, provided that each years savings is equal. The rule of thumb that was used is, if the Payback Period is less than one-half the equipment or project lifetime, the method is acceptable.

## EXAMPLE COST/BENEFIT ANALYSIS

The following example is a typical analysis that might be done to determine whether a site should begin using a reduced waste method. In the handbook, examples are given for each of the proposed methods. For this paper, an analysis of the ferrite process at Rocky Flats is shown.

### Initial Cost

Engineering development during the past two years has cost $115,000. This does not include the earlier laboratory development, which is considered a sunk cost. Additional modifications to the existing system including engineering design, equipment, installation, and start-up costs amount to $250,000. The total initial cost is therefore $365,000.

### Annual Operating Cost

Operations using the ferrite process in the waste treatment facility at Rocky Flats are similar to the existing process. Therefore, the operating costs are considered to be the same for both processes. In this type of analysis, only the increased operating costs are considered, so the annual operating cost is $0.

### Estimated Life

The estimated lifetime of this process is 15 years.

### Benefits

The volume of TRU sludge currently generated in the waste treatment plant is about 80 cubic meters a year. It is expected that the ferrite process can cut the sludge volume by 40%. There will be a volume reduction of 32 cubic meters per year in TRU waste. In Table I it can be seen that $3,700 are saved for each cubic meter of waste. Therefore, the annual cost savings is $118,400.

Initial Cost = $365,000
Annual Operating Cost = $0
Estimated Life = 15 years
Benefits = $118,400 per year

Cash Flow = $-246,600 first year
= $-138,200 second year
= $- 19,800 third year
= $ 98,600 fourth year

A positive cash flow occurs in the fourth year. This is less than one-half the project lifetime, and thus, the method should be accepted.

## TECHNIQUES TO REDUCE GENERATION OF TRU WASTE

Administrative policies and procedures are a unique category. They can be easy to implement, but it is difficult to evaluate their effectiveness. Thus, it is important to keep good records and observe trends over a long period of time to see if they are, in fact, reducing the amount of waste generated. Three types of administrative controls which have been used at DOE sites are reported. The methods include administrative sorting, waste charge systems (in which generators are billed for waste storage), and waste generation awareness campaigns.

### Administrative Sorting

Administrative sorting is a procedure used to segregate waste either by its activity level; i.e., TRU waste from low-level waste (LLW), or by its composition; i.e., combustible, glass, or metal. The segregation could take place at the location where the wastes are generated, or at a central location where all the wastes are collected.

Administrative sorting has been practiced on handling of line-generated waste and room trash at Los Alamos National Laboratory (LANL) TA-55 for several years. The line-generated wastes are always treated as TRU waste, and they are also segregated into one of the following four categores: combustible, noncombustible (metal and glass), leached solid (process residue), and individual equipment with property number (for record keeping purposes).

Room trash is brought to the Multi-Energy Gamma Assay System (MEGAS) for assay. Boxes that assay less than 100 nCi/g are sent to the burial site. Boxes assaying greater than 100 nCi/g are either sorted to eliminate a small "hot" spot in the box, sent back to the area where it was packed, or disposed of as TRU waste. Before the MEGAS system was available for segregating LLW from TRU waste, all room trash was treated as TRU waste. Since using the MEGAS system, over 90 percent of the room trash has been found to be LLW.

The MEGAS system has also been proven effective at the Hanford Engineering Laboratory for sorting wastes generated while fabricating mixed oxide nuclear fuels.[1] During an eight month period, assays of combustible waste led to successful separation of as-received wastes into 82 volume % classified as non-TRU waste. It should be noted that TRU waste was originally defined as waste containing more than 10 nCi/g activity. The limit was increased to 100 nCi/g in September of 1982.

Waste Charge System

An administrative method commonly suggested for reducing radioactive waste is back charging the generator for the costs of waste disposal. In such a system, the generator becomes aware of the costs of waste disposal, and if high enough, this should provide incentive to reduce the generation rate.

The current system in place at the Idaho National Engineering Laboratory is quite simple and is not without advantages. The generators pay for handling, packaging, and shipping. These costs are part of their operating budget. The storage site cost begins when they unload the waste. They are funded programmatically for all storage, surveillance, and any future retrieval costs. In this system, bookkeeping is simplified and administrative costs are low. The responsibility for funding is clear, and a budget can be planned and executed with relative ease at both the storage and generating sites. Unfortunately, there is no incentive to reduce the amount of waste.

A second type of waste charge system exists at the Nevada Test Site. In this system, the storage site collects storage fees and tries to operate solely with the collected revenue. The advantage here is that the generators pay the entire bill for waste disposal, and therefore, storage costs are factored into the total cost of operation at the generating sites. The major drawback to this system is that unplanned waste volumes can cause funding shortages, resulting in problems trying to keep the burial site open.

In a third system used at Hanford, the offsite generators are assessed a fee, however, Hanford does not rely entirely on these funds to operate. Overhead costs are covered by program or site budgets, allowing the site to be maintained even if waste shipments are temporarily suspended. Thus, funding shortfall caused by shortages in the amount of waste sent to the site are eliminated, and a consistent, well planned fee can be assessed for the burial.

This report recommended that the third type of system be used by DOE storage sites.

Waste Generator Awareness Training

The Oak Ridge National Laboratory (ORNL) began an awareness program to educate workers of the need to segregate and reduce solid wastes in April 1979. The effort included the coordinated use of seminars and training sessions, publication of articles in the laboratory paper, and dessemination of attractive and effective posters throughout the laboratory. Slides and viewgraphs were used by members of the waste disposal group of the Operation Division to present the problem and outline the waste volume reduction program. Also, posters were in use to continuously remind waste generators of the space problem and suggest ways to aid in volume reduction. This program could serve as a model for other sites.

MATERIAL SUBSTITUTION

The development and testing of two new materials are presented. Both have proven to be excellant replacements for existing products. In both cases, a large cost savings has resulted from the amount of waste saved, and from less frequent replacement of the product.

Kevlar[R] and Nomex[R] Fibers in HEPA Filters

The high efficient particulate air (HEPA) filters used in radioactive systems must be replaced frequently because of degradation in filtering efficiency and incrased air resistance caused by exposure to acid fumes and accumulation of radioactive particulate matter. An acid-resistant filter media consisting of 90% glass, 5% asbestos, and 5% additives had been used by the nuclear industry. The Office of Safety, Health, and Administration (OSHA) identified asbestos fiber as a possible carcinogen and filter manufacturers were discouraged from using this material. Nomex[R] and Kevlar[R] were selected as potential candidates for replacement of asbestos in HEPA filter media. Kevlar and Nomex are long-chain polyamides (nylons) in which 85% of the amide linkages are attached directly to two aromatic rings. This makes them exceptionally thermally stable and acid-resistant.

Rocky Flats Plant did acid testing on HEPA filters using Kevlar and Nomex as a substitute for asbestos. Based on the testing, it appears that the 5% Nomex-fiberglass and 15% Kevlar-fiberglass media are equivalent with regard to effects of acid on filtering efficiency. However, the 15% Kevlar exhibits less increase in air resistance than does the 5% Nomex when exposed to an acid environment. This factor can be significant, depending on the level of particulate the filter is subjected to. In systems where a large portion of particles are filtered out at the glove box level, effects of acid on air flow resistance may be of greater significance than on filtering efficiency.[2]

Inert Ceramic Coatings

Stainless steel molds coated with erbium oxide were developed at the Rocky Flats Plant to replace graphite molds in plutonium foundry work.

The erbium oxide coating process was tested in standard foundry operations. High potential exists for labor and material savings while reducing radiation exposure to personnel. In addition, a considerable amount of TRU (transuranic) waste was also eliminated. Often, the graphite molds retain enough plutonium that they are considered recoverable scrap. This further increases the generation of waste as the molds are processed to recover the plutonium. This new coating technology eliminates the use of graphite molds for ingot and figure-eight castings, saves labor in coating operations and transport time, and substantially reduces waste contaminated with a high level of plutonium. This in turn reduces the large quantities of waste that would result during reprocessing. In addition, the number of castings is increased, contamination of the castings is decreased, the amount of plutonium bound to the casting material is decreased, and radiation exposure to personnel during scarfing operations is eliminated.

Results of the production tests were very successful. One mold yielded more than 300 castings without coating failure or casting losses. This compares with two or three uses from a typical graphite mold.

## PROCESS DEVELOPMENT AND OPTIMIZATION

Improvements in plant processes that generate waste or that treat waste can be an excellent way to reduce TRU waste. They become an integral part of the operation, and waste is reduced as part of an overall change in chemical or physical phenomena. This section contains three methods that have been successfully demonstrated either on a laboratory or pilot plant scale.

### Ferrite Liquid Waste Processing

The ferrite process for removing trace amounts of transuranic nuclides from liquid waste has been developed at the Rocky Flats Plant. Preformed ferrite treatment of waste solutions, prepared using waste solutions obtained from an operating facility, lowered plutonium levels from the $10^{-4}$ g/ℓ range to around $10^{-7}$ g/ℓ or less. This was accomplished in one treatment step, whereas at least two treatment steps are required for the flocculant precipitation method. At the same time, 3.2 to 3.6 g/ℓ of solid by-product was obtained. This amounts to a reduction of approximately 50%, compared with the flocculant precipitation technique now used in plant operations.[3]

### Oil and Solvent Recycle

Used oil and solvent normally contain some radioactivity from transuranic elements and are collected in one common stream for disposal. Recycle of oil and solvent can reduce the waste disposal cost and TRU waste volume. Recycling involves bringing oil and solvent to an acceptable quality for reuse. Distillation is an appropriate method to separate solvent from oil due to their differences in boiling temperature. The boiling temperature of oil is generally above 300°C, whereas the boiling temperatures of $CCl_4$, trichloroethane, trichloroethylene are 76.8°C, 74.1°C, and 87.2°C, respectively.

Recycle technology on the spent lathe coolant containing mostly oil and $CCl_4$ was studied at Rocky Flats Plant in 1983. Samples of separated oil and solvent were submitted for analysis. The oil samples were found to be unfit for use as a lathe coolant due to oxidation. Carbon tetrachloride samples were found to contain other process solvents including trichloroethane, Freon, and dioxane. Therefore, carbon tetrachloride was also not suitable for reuse as solvent. No further development work was done at Rocky Flats. However, it was felt that if the different solvents had their own collection systems, then the recycled solvent could be fit for use over and over again.

### Improved Cementation Medium for Organic Wastes

Development work at the Rocky Flats Plant showed Envirostone® gypsum cement, which is a polymer-modified gypsum cement, to be the best medium for solidifying organic wastes. Due to different proportions of oil and solvent in the organic waste stream, the amount of Envirostone® used in mixing also varies. Under normal conditions, it has been found that the loading of the organic waste should be kept at about 50 vol %. Use of the Envirostone® resulted in a significant waste reduction over use of cement in the same process.

## NEW EQUIPMENT UTILIZATION

### Instrumentation for Sorting TRU Waste

The Advanced Nuclear Technology Group of LANL has developed improved instrumentation for assaying TRU content in waste. The Multi-Energy Gamma Assay System (MEGAS) was designed to assay low density, combustible type wastes in a 2 ft. cardboard carton. The MEGAS has been significantly upgraded to operate in a segmented mode; which allows the determination of hot spots within waste packages.[4]

Much of the plutonium and uranium waste generated in the nuclear industry is ultimately packaged in 208 L barrels or large crates having typical dimensions of 1.0-m or more on a side. An active-passive 4 neutron counting system has been developed to assay/screen these large containers for their TRU and uranium content. Active assay refers, in general, to interrogating the sample with an external source of neutrons, photon, etc., then measuring the resulting induced radioactivity as an indication of TRU content. Passive assay refers to monitoring the radioactivity already occurring naturally in the sample (e.g., spontaneous fission, neutrons, gamma ray emissions, etc.). This crate counter is made from discrete moderated He neutron detector modules which are easily arranged into a variety of assay chamber geometries. Large objects and debris from decommissioning programs can be easily accommodated in the counter.[5]

The crate counter is being field tested at Rocky Flats. The drum counter is installed at ORNL for test and evaluation purposes under field conditions.[6]

### Replacement of Raschig® Rings

Raschig® rings made of borosilicate glass and are used to fill large diameter tanks which store fissile solution. Raschig® rings serve as a fixed neutron absorber for criticality control. Some of the fissile solutions are very corrosive and routine checkings of the quality of the Raschig® rings in the tank are required to ensure their service as a neutron absorber. However, due to high maintenance cost and radiation exposure to the surveillance workers, the poison tube tank is being studied as an alternative to the Raschig®-ring-filled tank.

A poison tube tank is a vertical shell-and-tube type vessel with tubes welded to a horizontal top plate and inclined bottom plates. The tank has hundreds of uniformly spaced tubes which are filled with neutron-absorbing materials. The tank is isolated from the corrosive effect of the fissile solution by the tube material, normally stainless steel or other appropriate metal. To assure that this isolation is not negated by a leak, a collector plate is mounted immediately below the bottom plate. Any liquid leakage drains to a trap, where a detector and alarm system alert operating personnel to the situation. Tests on a nuclear critical-safe designed poison tube tank are currently being carried out at the Rocky Flats Critical Laboratory.

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