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A SURVEY OF ALPHA WASTE GENERATION
AND DISPOSAL AS SOLIDS IN THE
U.S. NUCLEAR FUEL INDUSTRY
DECEMBER 1970

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PACIFIC NORTHWEST LABORATORY

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A SURVEY OF ALPHA WASTE GENERATION AND
DISPOSAL AS SOLIDS IN THE U.S. NUCLEAR FUEL INDUSTRY

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December 1970

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I. INTRODUCTION

Solid wastes containing small amounts of alpha radioactivity are routinely produced during normal commercial operations at nuclear fuel fabrication and spent fuel reprocessing plants. Although these wastes ordinarily have a very low actinide content, their heterogeneous nature combined with the very long-lived alpha content may impose a severe safety hazard for many decades. To properly assess the magnitude of the alpha waste disposal problem, it is necessary to characterize the nature and quantities of wastes produced currently and, to the extent possible, to predict future waste production rates from industrial operations.

In an attempt at providing the above assessment, a major segment of the nuclear industry involved in fuel fabrication and spent fuel reprocessing was surveyed by personal visits to each site during June, 1970. Discussions were held with representatives of nine fuel fabricators and four fuel reprocessors. The results of the survey are the subject of this report.

II. SUMMARY

Nine commercial fuel element fabrication and four spent fuel reprocessing companies were surveyed to learn their current practices regarding generation and disposal of solid alpha contaminated wastes. The information was obtained by visiting processors throughout the United States in June, 1970. Special emphasis was placed on wastes contaminated with plutonium. Current practices are reported for each of the two industries, and extrapolations are made to the year 1990.

Fuel Fabrication Industry

Most of the wastes are generated inside glove boxes, but a significant amount of waste is also generated external to the boxes in contamination control measures. In larger scale facilities, wastes contaminated with recoverable amounts of actinides are separated

from the wastes that are candidates for burial. The most common burial vessel is the standard 55-gallon steel drum. Plutonium-contaminated wastes are usually buried offsite, by a disposal contractor, in approved burial grounds located in Nevada, Kentucky, New York and Illinois. Uranium contaminated wastes are buried locally as well as at the approved sites. On the average, it is estimated that the plutonium content of the buried waste is <0.5 grams per cubic foot.

The liquid wastes, both aqueous and organic, are often neutralized and then adsorbed onto a solid such as fuller's earth or diatomaceous earth. It is estimated that almost half of the waste volume buried is this "treated" liquid stream.

Individual companies were unwilling to forecast their waste production rates beyond 1975. Therefore, the volume and plutonium content of solid waste produced in the fuel fabrication industry is extrapolated into the future by relating waste production to predictions of nuclear electrical generating capacity. An improvement in scrap recovery and recycle of plutonium beyond current practices is anticipated and incorporated in the forecast. On this basis the annual volume of solid waste from the fuel fabrication industry is predicted to increase from 26,000 ft³ in 1970 to 2,700,000 ft³ in 1990. Additional space would be required for storage because of the irregular shapes of packages. The plutonium content of the waste is predicted to increase from 5.6 kg in 1970 to 580 kg in 1990.

Spent Fuel Reprocessing Industry

Solid wastes from reprocessing plants can be classified into five categories: cladding hulls, intermediate-and low-level semi-liquid-solid (ILW/LLW), general trash, failed equipment and dry chemicals. The volume of cladding hulls, ILW/LLW and dry chemical wastes are proportional to the amount of spent fuel reprocessed, while the volumes of general trash and failed equipment are independent of plant throughput and are produced at approximately a constant annual rate per plant.

The total volume of solid waste produced in the reprocessing industry is predicted to increase from 47,000 ft³ in 1970 to 170,000 ft³ in 1975 and to 760,000 ft³ in 1990. In 1975 about 70% of the annual volume will originate from general trash, while the other 30% will be about equally divided among the other four categories. By the year 1990 the volume of cladding hulls will be about equal to the volume of the general trash, with each at about 35% of the total volume.

The Pu content of the solid waste is predicted to increase from 1 kg in 1970 to 23 kg in 1975 to 530 kg in 1990 unless further effort is made to reduce the plutonium content of the wastes. The distribution of the plutonium in the waste will remain fairly constant through the years at 32% in the cladding hulls, 42% in the ILL/LLW, 21% in the general trash, 4% in the dry chemicals and <1% in the failed equipment.

The general trend in the spent fuel reprocessing industry is to dispose of nearly all the alpha contaminated solid waste on the plant premises by licensing burial or storage locations within the perimeter of the plant. Not only is this economically attractive, but it simplifies the administrative procedures. The current principal guide line for disposal or reclamation of plutonium is economics. Therefore, the quantities of plutonium which are packaged and disposed of as solids can be expected to increase because any other option is simply more expensive than burial. However, some concern is developing in the industry as to what should be the logical threshold value for the amount of plutonium existing in solid waste.

Total Waste From Combined Industries

The amount of plutonium buried, stored or otherwise disposed of in solid wastes from both the fuel fabrication and reprocessing industries is predicted to increase from 6.6 kg in 1970 to about 1000 kg in 1990. Presently about 85% of the plutonium in solid wastes originates in the fuel fabrication industry, but by 1990 the loss will be shared about equally by each industry.

The annual volume of solid waste from the combined commercial operations is predicted to increase from 73,000 ft³ in 1970 to about 3,500,000 ft³ in 1990. The current volumes of waste originating within each industry are about equal, but by 1975 and later the fuel fabrication industry will contribute about 75% of the annual waste by volume.

By the year 1990 about 27 million cubic feet of alpha-contaminated solid waste will have been accumulated. The space required for storage will be significantly higher than this because of the irregular shape of the packages. It is estimated that about 7000 kg of plutonium will be contained in the waste by 1990.

III. PRESENT DISPOSAL PRACTICES AND CONSIDERATIONS

Disposal of alpha-containing wastes is determined by three principal considerations: (1) AEC and other regulations, (2) safety and (3) economy. Usually the processor's safety requirements are similar to those required by government regulations, but sometimes the processors add safety checks for practices which are not required to meet regulations. All of the respondents were keenly aware of the need for safe confinement of the radioactive materials, and were anxious to avoid any uncontrolled release of material. Within the imposed safety limits, all processors seek to dispose of wastes in the most economical method possible.

Burial may be accomplished either on the processor's plant site or offsite. Most waste from fuel reprocessing and from uranium fuel fabrication can be buried onsite, while waste from plutonium fuel fabrication must be buried offsite. Sometimes state regulations are more demanding than federal regulations, however. Onsite burial, when permitted, allows more latitude to the processor and is thus difficult to categorize generally. Offsite burial practices are rather uniform because of the rather specific regulations regarding

shipment. The following generalizations apply particularly to wastes which are shipped offsite. Although most of the discussion applies to fuel fabrication only, some of the considerations are also important in fuel reprocessing operations.

Virtually all plutonium waste is classed as Type B for shipment,⁽¹⁾ with a limit of 20 Curies per container. Depending on isotopic composition, this may range from about 3 to 10 grams of plutonium. For offsite burial, the waste is usually collected, stored and buried in standard 55 gallon steel drums (usually referred to as 17H containers). With Type B material, the drums must be shipped in reusable overpacks (usually called Paper Tigers) for transportation from the processor to the disposal site. From 10 to 30 drums with overpacks can be shipped on a single truck, and the maximum amount of plutonium on a truck is about 200 grams.

Large items which will not fit into a standard drum must also be packaged safely. If the contamination level is low enough, simple crating is enough to permit burial. For Type B material, such packaging is not enough to meet shipping requirements. Several large pieces of equipment are apparently awaiting burial because of the lack of an approved overpack with appropriate cavity dimensions. Processors are looking forward to use of a larger overpack (the Super Tiger) when it is licensed.

Maximum permissible surface contamination of the packed waste was always less than 200 d/m per 100 cm². The "normal" dose rate at the surface of the packages from plutonium operations was usually described as less than 10 mR/hr; e.g., "A couple of mR/hr," "less than one," etc. Much higher dose rates are encountered when fission products are present.

(1) Code of Federal Regulations, Title 10, Part 71.

Plutonium-contaminated wastes from fuel fabricators are buried by a burial contractor, at approved sites that are located in Nevada, Kentucky, Illinois, and New York. Uranium-contaminated wastes are buried locally as well as at the offsite approved locations.

Present disposal and shipping regulations do not offer a great incentive for reducing waste volumes since the allowable amount of plutonium per package is limited, and each package must be in an approved overpack such as a Paper Tiger. The principal cost of disposal is for an entire truckload, regardless of the actual volume of the waste. If waste volume could be reduced twofold, the truck could not necessarily carry twice as much waste since the total weight of plutonium would probably become the limiting factor. A higher allowable amount of plutonium per container and per truckload would add some incentive to reduce waste volumes.

Changes in waste disposal practices will be primarily dependent on economic considerations, unless safety regulations change. Economics are dependent on the scale of operations and availability of scrap recovery facilities. The commercial plutonium processors contacted in this survey can be divided into four principal types, differing mostly in plutonium throughput:

1. Laboratory studies only;
2. Small plant for mixed oxide fuel fabrication, but no chemical processing;
3. Plant includes conversion of plutonium nitrate to oxide, and recovery of plutonium from high-grade scrap;
4. Large scale plant with recovery of plutonium from both liquid and solid wastes.

The scrap and wastes generated in each case are similar in nature, but the amount of plutonium processed has a large effect on the economics of scrap recovery. This has a direct relationship to the amount of actinides discarded per unit throughput of plutonium. A laboratory which processes only a few kilograms of plutonium per year

can afford a high waste loss, perhaps even 10%, without reaching a level which permits economic recovery of the scrap. At the other extreme, a large-scale processor who has extensive chemical processing capabilities may find it economically attractive to recover all but 0.1% or less of his throughput. Increases in the total amount of plutonium processed per year will result in more large-scale plants, and thus a lower plutonium discard per unit throughput. Extrapolations to 1975 were made by several of the companies interviewed, but none offered longer-range extrapolations.

All of the plutonium processors contacted had similar types of waste, but differed somewhat in classification of waste and the extent of waste sorting. They generally distinguished between "scrap" which had recoverable amounts of plutonium, and "waste" which was discarded. If this distinction is used, what was waste for one processor might be scrap for another. Those who perform scrap recovery usually sort wastes more completely to provide uniform feed for subsequent processing. If scrap recovery is not performed, wastes are accumulated with little regard to source or type, except to assure that all of the materials in a single container are mutually compatible. Wastes are usually sorted by isotopic composition of the principal actinide to facilitate accountability.

Recovery efficiency also has an effect on waste volume. If the concentration of plutonium in the uncompacted waste were reduced, an economic incentive would exist for compacting. The time at which compacting will become attractive depends on regulations affecting shipment, cost of disposal, and efficiency of plutonium removal from the waste.

IV. WASTE FROM THE FUEL FABRICATION INDUSTRY

This section summarizes information concerning current practices for the disposal of solid wastes that originate from commercial

nuclear fuel element fabrication operations. The information was obtained by visiting fabricators throughout the United States. Efforts have been purposely made to delete information that would relate to the identity of any particular fabricator. This was done simply because the various contributors have not had an opportunity to review any of the information presented.

Waste Generation and Handling Practices

Most of the wastes from processing or fabrication operations and the associated analytical work are generated inside glove boxes. However, a significant amount of waste is generated outside the boxes from contamination control measures. Usually, liquid wastes are segregated from solid wastes and the solid wastes are bagged (often doubly bagged) in plastic. In addition, plutonium-contaminated wastes are often sorted by enrichment level. In plants that can be termed production rather than development facilities, wastes contaminated with what are felt to be recoverable amounts of actinides are almost always separated from the wastes that are candidates for disposal by burial. On the average, it is estimated that the plutonium content of the buried waste is less than one gram per cubic foot and probably less than 0.5 grams per cubic foot.

In general, the solid wastes are the conglomerates arising from the processing and contamination control efforts and consist primarily of paper (wipes and cartons) and plastic (bags). The radioactive constituent is often initially a fine powder. The degree of segregation of paper and plastic depends primarily on the type and extent of scrap recovery. It is estimated that the solid waste stream is about half plastic and half paper, but numerous other constituents are discarded into this stream including cloth, rubber (gloves), glassware, unusable equipment and tools, metal cans, graphite, spent ion-exchange resin, asbestos paper fiber filters, and even small amounts of treated or solidified liquid (usually organics or oil). As indicated earlier, this solid waste stream is

bagged (often doubly bagged) in plastic and then placed in the plastic lined 55-gallon drums. Larger items are crated for burial.

Each fuel fabricator has at least four types of wastes: solids from the main process line which are small enough to fit into 55-gallon drums; larger sized solid waste such as failed equipment; slightly contaminated solids generated in cleanup of small spills outside the main process line; and laboratory liquid wastes. Most fabricators also generate liquid wastes from plutonium processing, scrap recovery, or other sources.

Solids From Main Process Line

Most fuel fabrication operations are performed in dry glove boxes. Solid waste includes wipes, Kleenex, neoprene gloves, small failed equipment, and small air filters. Most of the waste from glove boxes results from cleanup operations. Major spills are usually recovered by using a paint brush and dust pan. Some processors use vacuum cleaners for more complete removal of dry powders which accumulate in the glove box. Occasional cleanup of the residual powders is necessary to provide proper contamination and exposure control. Cleanup is usually by wipes, Kleenex, or cheese cloth. Thus, most of the solid waste from glove boxes is initially cellulose materials. The waste is removed from the box by bagging in PVC, and a second PVC-bag is often added for additional safety as soon as the first bag is cut from the box. This introduces an appreciable amount of plastic into the waste. Neoprene gloves have to be changed regularly, and contribute additional plastic similar to the PVC. If sphincter containers are used, they also contribute either cardboard or aluminum to the wastes. Some plastic bottles or cardboard containers are often used within glove boxes. Glassware is less common, but is used by some fabricators.

Under special conditions, cleanup might be accompanied with liquids for more exhaustive cleaning. Usually these are chemically relatively mild, innocuous liquids. Many processors use cheese cloth

and nitric acid for cleaning stubborn residues of plutonium. Cloths or papers soaked with nitric acid are rinsed with water before being discarded, and often they are neutralized with caustic. Since nitric acid solutions are used only in the final stages of cleaning, these materials usually contain only small amounts of plutonium. All wet cloths or papers are allowed to air dry before being placed in solid waste.

Other small items from the glove boxes are included in this type of waste. Examples are marking pens, tools, prefilters, and small failed equipment. If the item is small enough to fit into a 55-gallon drum, or can be reduced to this size easily, it is usually treated the same as other small waste items.

Waste is usually not sorted into various types (e.g., cloth, paper, plastic, tools, and equipment) unless one or more types may contain enough plutonium to make recovery economically attractive. If recovery is contemplated, material is usually sorted into three classes: cellulose, plastic, and other. Cellulose material is oxidized or calcined (incineration is considered to be a bad word where plutonium is present), and the residue is leached to recover plutonium. Plastics may be treated similarly to cellulose materials, or may be leached for plutonium recovery. Leaching of plastics is reported to be much more efficient if shredding is done before leaching. Plutonium may be recovered from other wastes by leaching. Most of the waste reprocessing is only in the planning stages, or limited to batches of waste which have unusually large amounts of plutonium. Several fabricators are saving plutonium wastes for possible reprocessing if it should become economically favorable in the future.

The solid waste from glove boxes is usually stated to be about half plastic and half cellulose, with other components being a rather small fraction. One fabricator uses aluminum sphincter cans which constitute an appreciable fraction of the total glove box wastes.

Problem materials which may be in the waste were not identified at every site. Many fabricators use aerosol cans in at least some of the boxes. Some of them puncture the cans before placing them in the waste, while others merely assure that the can is emptied as completely as possible before discard. Those who use reactive chemicals (e.g., liquid metals, carbide fuels) react the materials to a stable form before discard. One processor who uses liquid metals (Na and NaK) for compatibility testing seals the metal in a 2R container, places Met-L-X around the container, and seals this in another container.

Perhaps the most likely source of problem materials is not the main process boxes, but the quality control boxes. The main process line is well defined, and process steps are routine, whereas quality control involves many varied operations, and may require introduction of special materials for unusual analyses. Although no specific problems associated with quality control analyses were identified, the varied nature of the work would indicate that this area should be studied further.

Wastes from glove boxes are usually collected in the box in which they are generated, and stored in the most accessible container in the box. If material is introduced in siphon cans, these are used for waste collection. Otherwise the material is usually collected in plastic bags. Sorting, if any, is accomplished at the time the waste is generated. When sufficient waste has accumulated in a box or a series of interconnected boxes, the waste is removed by normal bagout procedures. The sealed waste is stored in a 55-gallon drum with a polyethylene drum liner. When the drum is filled, the drum liner is sealed by "pigtailling", and a gasketed lid is placed on the drum.

Large Failed Equipment

Some equipment items are not easily reducible in size. Perhaps the most evident example of this type of waste is an obsolete glove

box. Such equipment is cleaned as much as practicable, enclosed in plastic for contamination control, and placed in a shipping container. Since large equipment does not fail often, each is treated as a special case at present. Disposal boxes are built to fit the particular needs for each shipment. Special pretreatment can also be used to minimize the potential for spread of contamination. One prime example is filling a glove box with rigid polyurethane foam for contamination control and mechanical support.

Large air filters are considered and handled as large equipment, even though they are replaced routinely. If they contain appreciable amounts of plutonium, some recovery may be performed. Often this only consists of tapping the filter to remove any loose powder. Leaching or oxidation is being considered by some processors for recovery of additional plutonium. Filters are typically about the size of a two-foot cube, consisting of fire resistant filter media in a wooden frame. Prefilters are often used on each individual glove box to reduce the amount of plutonium which can reach the large filters.

Slightly Contaminated Solids

Small occurrences of contamination outside the glove boxes must be cleaned thoroughly. This generates a large volume of waste with very little plutonium content. Most of the waste is cellulose and rubber gloves. Cloths or papers soaked with liquids are treated the same as those used in glove boxes. This type of waste could most easily be compacted since the plutonium content is very low and it is the least suitable for scrap recovery. (Unspent aerosol cans may be discarded into cleanup wastes.)

Waste is usually collected in plastic bags (mostly polyethylene), sealed by "pigtailling", and deposited in 55-gallon drums.

Some plutonium fabricators use extreme caution to maintain a very clean work area outside of the glove boxes so that normal materials used outside the boxes do not become contaminated.

Chemical Processing Liquids

Chemical processing liquids for waste disposal originate primarily as aqueous, often acidic, streams that include effluents such as process filtrates, pickling liquids, and decontamination liquids. Conventional water treatment steps convert the major radioactive components into a sludge which is then often solidified by incorporation into a second medium, e.g., cement or plaster of Paris.

In many instances, the liquid wastes are neutralized and then adsorbed onto a second medium, e.g., fuller's earth or diatomaceous earth, directly in the burial vessel (the standard 55-gallon drum). One common practice is to fill a 30 gallon plastic drum with additional adsorbent, and fill the 30 gallon container with an appropriate amount of liquid. The 30 gallon container is sealed with a screwed polyethylene fitting, covered with additional adsorbent, and then the 55-gallon drum is sealed in the normal manner. Smaller volumes of liquids, such as those generated in quality control operations, are usually mixed with adsorbents in one to five gallon containers. The small containers with the "fixed" liquids are then treated as solid waste. The ratio of adsorbent to liquid varies from two to ten, with three being the most commonly used amount. The liquids sometimes contain ammonium nitrate, ferrous sulfamate, or sodium nitrate, and not all processors take steps to assure destruction of these constituents. Most processors neutralize the acids prior to disposal. However, not all liquids are "treated" prior to shipping. Some are shipped as liquid to the disposal contractor for solidification.

Miscellaneous Liquids

In addition to processing liquids, small and poorly defined quantities of plutonium-containing organic solutions and vacuum pump oils are generated. The organic solutions include solvents as well as complex chemicals associated with laboratory studies. Some solvents specifically identified are kerosene used as a lubricant in metallography, trichloroethylene, and carbon tetrachloride. In

general, current methods of treating or fixing these liquids are the same as those described above for the processing liquids. The treated miscellaneous liquids are often disposed of along with solids from the main process line, since the incorporation or adsorption step is usually conducted in small vessels inside glove boxes. Although some of the solvents may dissolve or weaken the PVC or polyethylene containers used for disposal, compatibility with the plastics is not normally verified.

Other Solids

A few types of solid waste do not fit appropriately in any of the above categories since they are not routinely generated, and they may contain significant amounts of plutonium. One such waste is spent ion exchange resins. Usually these are sulfonic acid types such as Dowex 50 or Permutit SK, which are used in scrap recovery operations. Before disposal they are washed with water or dilute caustic to remove nitric acid. They may be blended with concrete, or air dried and treated as dry solid waste. The amount of nitration of the resin is not known.

Casting compounds are used in metallographic or ceramographic examination of fuels and components. Polishing results in finely divided organic materials mixed with alpha emitters. The scale of operations determines the advisability of recovering the plutonium. Also, the mounted specimen after examination may be discarded if the plutonium content does not warrant recovery. Some of the mounting material becomes waste by spillage or deterioration before use. Although the volume is small, this type of waste introduces components not otherwise present in the waste.

Quality control processes often use special chemicals which are introduced in excess of the amount required. Virtually any chemical may be used for special analyses or for testing new analytical procedures. Usually these are introduced as solutions and eventually become laboratory liquid waste. Sometimes solids

are introduced and could enter the solid waste stream. Records or recollections about the types of chemicals introduced in this way were not complete enough to permit a listing.

Waste Monitoring

The amount of material contained in the waste is most commonly determined by accountability or material balance. Many processors use gamma or neutron counting to supplement this method or to replace it entirely. Counting may be done on an entire drum of waste, or on a smaller waste container before it is placed in a drum. Detection limits are usually about half of the maximum permissible plutonium content per container, assuming that drums are filled with similar sized containers. For example, if a drum were counted the detection limit would usually be one to three grams per drum. If a 1-1/2 gallon carton were counted, the detection limit would be 0.1 to 0.3 grams per carton, which at ten cartons per drum would correspond to 1 to 3 grams per drum. The accuracy of counting methods is uncertain since the distribution of source material and shielding can vary greatly among drums.

Surface contamination of the disposal container is always held below 200 d/m alpha in 100 cm², and sometimes processors apply even more restrictive limits. Plutonium wastes are almost always below 1 mR/hr at the surface of the container, but wastes containing fission products, ²³³U, or other materials may have appreciable surface dose rates. Some fuel fabrication wastes may approach 2R/hr at the surface of the drum, but these wastes are most unusual.

Amount of Waste

As indicated earlier, because of differences in throughput, the quantity of waste generated by individual processors varies considerably. Estimates of the volume of plutonium-contaminated waste generated that were provided by the processors are summarized in Table I. Corresponding values for current throughput and estimated amounts of plutonium in the waste are also shown in Table I. Most

It is estimated that about 100,000 grams of plutonium are generated annually in the United States.

of the waste volume is associated with standard 55-gallon drums. It is estimated that about half of the waste volume is associated with the treated liquid stream. The remaining drums are filled with solids, primarily paper and plastic. On the average, the plutonium content of the waste is less than one and probably less than 0.5 grams per cubic foot.

TABLE I

Current Quantity of Pu-Contaminated Waste
Generated by the Fuel Fabrication Industry

<u>Processor</u>	<u>Annual Throughput (kg Pu)</u>	<u>Annual Waste Volume (ft³)^(a)</u>	<u>Grams Pu in Volume</u>
A	8-12	70	100
B	8-30	1500 ^(b)	300
C	10-15	3000	1000
D	25-50	4000	300
E	60	700	200
F	350	3000	1750
G	300-400	13,500	2000
Total ^(c)	760-917	25,800	5650

(a) Volume occupied by 55-gallon drums or other containers. Storage space will be greater due to lost space between drums, etc.

(b) Includes uranium contaminated waste.

(c) Nine companies were visited but one did not have Pu-contaminated waste and one did not wish to release the information.

Anticipated Changes

The fuel fabricators feel that their current methods of handling wastes are safe and conducted in accordance with existing regulations. Any changes in waste generation and handling methods would be controlled by the cost incentive associated with scrap recovery rather

than pollution control or long-term waste disposal considerations. Changes often mentioned included the addition of leaching steps and processing steps to increase the plutonium density of scrap to facilitate recovery (e.g., evaporation, incineration, and compacting).

The processors repeatedly indicated that they were reluctant to make changes simply because they were concerned that any change would not conform with possible future revisions to shipping and/or disposal regulations. The processors expressed concern over the interactions and combinations of state and federal regulations, frequent changes in regulations, interactions between waste management and inventory control, and the dual standards they feel exist for government contractors and commercial facilities.

Several processors expressed interest in having a critically safe incinerator or thermal decomposition unit which would reduce much of the waste to a uniform solid suitable for scrap recovery operations. The ideal unit would be capable of handling plastic as well as cellulose, and would have low capital cost and low operating cost. Commercial development of such a unit is hampered by uncertainties in regulations about incinerators and uncertain costs and regulations associated with any proposed changes in waste disposal practices.

Other needed developments include improved counting systems for monitoring the amount of material in waste containers, and a plastic shredder to provide a uniform feed to a leaching system or to a thermal decomposition unit.

Finally, it should be noted that when long-term disposal is considered, both the solid and "treated" liquid wastes are in a relatively dispersible form, especially if it is assumed that dispersal by ground or surface water is the most likely mechanism.

Forecast of Future Waste Production

Most of the individual processors were willing to give their expected level of operation in the near future. Table II lists the expected throughputs for the year 1975, as indicated by the staff members interviewed.

Prediction of waste production beyond 1975 becomes more tenuous due to the numerous uncertainties involved in future waste and scrap management practices. For example, the size of a plant, the extent of scrap recovery, changes in regulations, the cost of waste disposal, and the value of plutonium are important and interrelated factors in determining the fraction of plutonium throughput which will be lost as waste.

TABLE II

Expected U.S. Fuel Fabrication Throughput for 1975^(a)

<u>Processor</u>	<u>Expected 1975 Annual Plutonium Throughput, kg</u>
A	1000
B	(b)
C	1500-2000
D	50
E	(b)
F	2500
G	1500-2000
Total	6500-7500

(a) As estimated by the various processors.

(b) An estimate was not given.

As discussed in Section III, the fraction of plutonium lost during processing is expected to decrease as the throughput increases. This trend is illustrated by Figure 1, which assumes the fractional loss will decrease linearly from the current value of 0.007 to 0.0025

Figure 1. Assumed Plutonium Loss Factor

in 1990, after which it remains constant. The current value of 0.007 is obtained from the data presented in Table I by dividing the total Pu in the waste, about 5.6 kg, by the total throughput, about 800 kg. The steady-state value of 0.0025 was estimated by two companies for large-scale production.

The volume of solid alpha-containing waste which will be generated in the future is likewise uncertain and depends on such factors as changes in regulations and incentive for compaction. Under the

present regulations and charge structure for disposal minimum waste costs are usually achieved when one truckload of waste containers approaches the maximum amount of plutonium permitted per truck. Decreases in waste volume will not result in great savings since the number of truckloads is determined by the amount of plutonium in the waste. As the fractional loss of plutonium decreases, the volume of waste per kg of plutonium processed is expected to decrease also. This decreased volume can be accomplished by compaction or thermal decomposition of the waste.

For extrapolation purposes in this report, the waste volume is assumed to be proportional to the amount of plutonium discarded. From the data in Table I, the waste volume can be calculated as 4.6 ft³ per gram of plutonium discarded. The isotopic composition of the plutonium will change as higher fuel burnups are achieved, which will then change the curies per gram of plutonium. Some disposal limits are based on curies rather than grams, so the isotopic composition will have an effect on optimum waste volume. However, this effect is not expected to change disposal practices greatly, and it was not included in estimating future waste volumes.

The amount of fuel expected to be fabricated during the coming years up to 1990 is obtained from Deonigi et al.⁽²⁾ These authors present estimates of nuclear generating capacity, fuel discharge and plutonium discharge rates for each year for a variety of reactor types and fuel management schemes. High plutonium utilization seems most probable, so for the purpose of this report the case was chosen of LWR's with 50% U-236 recycle, limited plutonium recycle and maximum FBR additions beginning in 1980. It is of interest to note that predictions of fuel and Pu throughput differed by only about 10% in 1990 compared to the case of LWR's only with plutonium

(2) D. E. Deonigi, R. W. McKee, and D. R. Hoffner, Isotope Production and Availability from Power Reactors, BNWL-716. July 1968.

recycle. The fuel must be fabricated about two years prior to reactor discharge, so that fuel discharged in 1977, for example, must have been fabricated in 1975, using plutonium available from fuel discharged in 1974. A one-year delay was assumed between reactor discharge and availability of plutonium for fabrication.

The predicted quantities are listed in Table III as total installed electrical generating capacity, total Pu processed, and total fuel processed.

TABLE III

Predicted Future Fuel Fabrication Rates

<u>Year</u>	<u>Total Installed^(a) Capacity, GW(E)</u>	<u>Total Fuel^(b) Fabricated, MT/yr</u>	<u>Total Plutonium^(b) Processed, kg/yr</u>
1970	12	550	800
1975	70	2600	10,000
1980	150	6600	38,000
1985	296	14,000	100,000
1990	500	23,000	230,000

(a) Based on BNWL-716

(b) For the case of LWR's with plutonium recycle and maximum FBR additions beginning in 1980. This is within 10% of case for LWR's with plutonium recycle.

The prediction of plutonium processed in 1975 (10,000 kg) is considerably higher than the estimate supplied by the fuel fabricators as shown in Table II. However, several companies were omitted from the Table II data because they did not wish to make a prediction.

The waste volumes and associated losses of plutonium are estimated for the years 1970-1990 in Table IV. Because of the uncertainties involved, the accuracy of the predictions is considered

to be marginal, especially for the distant future. They probably are maximum amounts because incentives may arise for volume reduction and more efficient plutonium salvage.

TABLE IV
Predicted Future Solid Wastes in the
Fuel Fabrication Industry (a)

<u>Year</u>	<u>Pu in Waste ^(b)</u> <u>kg/hr</u>	<u>Waste Volume ^(c)</u> <u>10³ ft³/yr</u>
1970	5.6	26
1975	65	300
1980	175	800
1985	360	1700
1990	580	2700

(a) LWR with 50% U-236 recycle, limited Pu recycle and maximum FBR additions beginning in 1980. Estimates are within 10% of those for case of LWR only, with Pu recycle.

(b) Based on loss factor from Figure 1.

(c) Based on 4.6 ft³ per gram Pu discarded.

V. WASTE FROM THE SPENT FUEL REPROCESSING INDUSTRY

The objective of this part of the survey was to determine the current disposal practices and the plans in the nuclear spent fuel reprocessing industry, particularly as to the amount of plutonium that is or will be "fixed" in solid wastes. Four companies were surveyed by direct interviews with their staff to obtain the latest information on the quantities and characteristics of solid wastes which are or will be generated by spent fuel reprocessing plants. The information is purposely not correlated by specific companies because they have not had an opportunity to review the information as reported here.

Types of Wastes

Solid wastes from reprocessing plants can be classified functionally into the following general categories: cladding hulls, intermediate and low level waste (semi liquid-solid), general trash, equipment and dry chemicals.

Cladding Hulls - This category is simply the residual fuel element cladding and hardware from the dismantling, shearing, and dissolving operations. Although in many instances other equipment hardware is added with the hulls, the equipment hardware is included in the equipment category for the purposes of this survey.

Intermediate and Low Level Wastes (ILW/LLW) - Several of the plants generate a liquid effluent which is first highly concentrated and then placed in tanks for storage. The liquid is principally from washing of solvent, decontamination of equipment and chemical digestion (e.g., ion exchange disposal). Another solid which is added to ILW/LLW is metal fines from shearing and sawing.

General Trash - All solid material which leaves the plant for burial is termed general trash if it is not specifically included in another category. For example, offgas ventilation filters are included as general trash. Also, if plutonium scrap recovery operations are conducted, the waste is included as general trash.

Equipment - Obsolete equipment, or failed equipment which is removed from service is included in the equipment category.

Dry Chemicals - Since some of the plant operations include uranium conversion to UF_6 , the solids originating from this operation are identified as dry chemicals.

Sources of Waste in the Spent Fuel Reprocessing Industry

For the fuel reprocessing industry, the waste problem is best clarified by discussing each source of waste which potentially contains plutonium and indicate the plans for the disposal of these solids.

Fuel Receiving - The water basin for receipt and storage of fuels contains a clean-up system which from time to time requires replacement of the ion exchange resin. The plutonium content is generally unknown and is considered negligible. About four cubic feet of resin per year from small basins are buried, while up to 200 ft³ are buried each year from larger basins. Disposal concepts and practices vary. In one instance 30-gallon drums are placed within a 50-gallon drum and these are placed in a shallow dry well. Then the drums are encased by pouring concrete into the drywell. In some instances used filters from the water basin are stored in the vaults along with cladding hulls. For purposes of this survey, the waste from fuel receiving is included as general trash.

Head End Treatment - The treatment for removal of iodine varies from aqueous scrubbing to silver reactors and silver zeolites. Replacement of the zeolites is anticipated to produce an overall average of 0.073 cubic feet per metric ton of uranium fuel processed. For disposal, the zeolites are placed in 55-gallon drums. However, the plutonium content in this general trash is expected to be negligible.

HEPA filters on the dissolver offgas are replaced periodically except in those plants which use permanently installed filters (e.g., sand). The volume of filter replacement varies. In one instance it is estimated to be 0.6 cubic feet of filters per metric ton. In another instance the total filter disposal including cell ventilation is 0.45 cubic feet per metric ton. In still another instance 3.7 cubic feet of filters are disposed of per metric ton.

Even though expressed as ft^3/MT , the volume of used filters is somewhat independent of throughput. No measurements or estimates of the amount of plutonium on the filters is available. The quantity of filters is included as general trash.

Cladding hulls and pieces of fuel hardware are produced from a chop leach head end in all plants and are included as a separate category. In one instance hulls are disposed of by placing them in 30-gallon drums, then inserting the drum in a 50-gallon drum and placing it in a dry well. As soon as the well is full, the void space is filled with concrete. In some plants, hulls are disposed of directly to a solid storage vault at the plant site. Both dry storage of the hulls and wet storage (hulls covered with water) are used in vaults. Also, dry cladding hulls are buried using 6'x6'x6' concrete boxes. Although there has been some stainless steel cladding and stainless steel parts as well as zirconium, it is anticipated that about 95 percent by weight of all future cladding hulls and hardware will be zirconium until fast reactor fuels are reprocessed. The amount of plutonium in the hulls is nominally 0.1 percent of the total plutonium in the fuel processed. This is expected to be somewhat lower with longer fuels (because fewer pieces exist with only one end open). Thus, in general the plutonium content is estimated to be about 0.02 percent to 0.1 percent of throughput. The volume of the hulls and hardware ranges from 12 to 20 cubic feet per metric ton to give a plutonium concentration of 0.1 to 0.8 grams per cubic foot of cladding hulls. Crushing and compressing are generally not needed and not economical with this volume and concentration. No attempt is made, at present, to measure routinely the amount of plutonium in the cladding hulls. Some of the companies are considering installing a monitor for the hulls, but the accuracy is quite uncertain.

Processing Operations - Although some companies are combining all liquid wastes within one waste tank as high-level wastes, others

are segregating the high-level liquid wastes from the intermediate and low-level liquid wastes. Since the intermediate-level liquid waste is a semisolid after appreciable evaporation, it is considered to be onsite storage of a solid or at least bulk material that is readily convertible to a solid. The quantity of this waste varies from 2 to 15 cubic feet per metric ton as stored in the tank. It contains from 0.15 to 0.6 grams plutonium per cubic foot and comes from gas scrubbing, solvent washing, decontaminating operations, decomposing of ion exchange resins and slurring of zirconium fines.

Since the trend seems to be away from ion exchange resins for actual processing, the amount of resin is not specifically identified. That which is disposed of is placed in drums as previously described and considered part of the general trash. At least one company is considering chemical decomposition of the resin.

Routine disposal of solvent is not considered for any of the plants. However, one company pointed out that it is cheaper to throw away at least a thousand gallons per year of solvent than to conduct special solvent cleanup procedures. Solvent is adsorbed on vermiculite in drums and buried. However, for purposes of the survey, no volumes were included for disposal of solvent.

Although silica gel is used, no routine disposal is planned because the material is intended to be regenerated. Any silica gel disposed to waste would be in very small amounts.

Some reprocessing companies are considering production of plutonium oxide and also associated commercial plutonium scrap operations. The amounts from these operations are included as general trash.

General Trash - Most of the material accumulated throughout a reprocessing plant is handled in the form it is collected. Some classification of the waste occurs because it is accumulated at a

specific location in the plant or because of its high beta-gamma activity. Typically, this general trash is composed of electrical cords, lights, wire cables, small equipment, glass, rags, paper and cotton wipes, clothing, floor sweepings, tape, rubbers, lead, filters, manipulator boots and sleeves and all forms of plastic. Estimates of the amount of combustible material vary from 50 to 70 percent if the plastics are considered noncombustible. In some cases the noncombustible was estimated at 10 percent with up to another 10 percent being moisture. Steel drums, plywood boxes and corrugated fiberboard boxes are used for disposal. The fiberboard (cardboard) boxes vary in volume from 4 to 8 cubic feet and are about 1.5 to 2' square and may weigh an average of about 25 lb each.

The amount of plutonium in the general trash ranges from 0.01 gram per cubic foot to 2.4 grams per cubic foot, with the majority at about 0.01 to 0.3 grams per cubic foot. The volume of general trash ranges from 30 to 300 cubic feet per metric ton of fuel processed. Where filters are routinely replaced in the plant, the volume of filters will average from 0.5 to 5 cubic feet of filters per metric ton.

Equipment Disposal - Periodic failure of equipment requires the disposal of all sizes and shapes of equipment. Most companies dispose of smaller pieces by handling them in the same manner as the cladding hulls. For example, pipe jumpers, valves, pumps, etc., can be sawed into small pieces and stored with the cladding hulls.

Larger pieces of equipment require special handling in plywood or concrete boxes. Each situation is considered special. In some instances, a vault is poured at the burial site and the equipment moved to the vault. In other situations, special mobile concrete boxes are made and the entire box is moved to the onsite burial location.

The amount of equipment disposal varies and, of course, peaks during a maintenance period and/or a process change. No equipment

may be sent to burial for one or two years, but a considerable amount another year. The assumption of one major piece per year per plant represents a reasonable expectation. The size may range from 5 to 12 feet square and up to 40 feet long. In terms of equipment volume per metric ton, about 1 to 10 ft³ per metric ton is expected.

The amount of plutonium contained on or in a piece of equipment is not measured directly. Analysis of decontaminating solutions indicate a low level of contamination. From typical surface dose readings, not more than about a gram of plutonium is expected to be on a rather large piece of equipment if plutonium is not held up in sludges or cakes.

Dry Chemicals - Some of the companies are planning for the conversion of the uranium to UF₆ at the reprocessing facility. This operation produces dry chemicals which require disposal. In one instance this waste is about 85% AlF₃, 10% Al₂O₃ and 5% NaF and MgF₂. The total volume is expected to be about 10 ft³/MT. In another approach the volume is expected to be about 3 ft³/MT and be principally Ca(OH)₂, CaF₂ and Al₂O₃.

The plutonium content is quite small since the partitioning during solvent extraction is expected to be good. Less than 0.1 percent of the plutonium throughput is lost to the uranium and eventually to dry chemical waste.

General Comments

Hazards - The materials in the solid waste consist of acids, rags, vermiculite, metals, plastics, etc. Normally, no nonradioactive material is added to the waste except typical moisture adsorbing agents. Thus, the principal hazard is potential combustion.

Normally, plastic bags are used for tightness, but the containers are not considered to be vapor tight even though they are sealed. Temperature limits are not applied to handling the waste and are considered unnecessary.

Package dose rates at the surface vary. If any standard is used, it is the usual <200 mR/hr. Otherwise the packages used for onsite burial may or may not meet DOT regulations.

Packaging and Shipping - Currently, most waste is disposed of onsite. Only one company plans to ship their wastes offsite. This company will accumulate and store their waste onsite for shipments periodically. There is no standard package, although 30 and 50-gallon steel drums are used extensively. Fiberboard boxes vary in size, but normally do not exceed 2 ft by 2 ft square (to accept filters).

Actinide Content - Reliable information on the amount of plutonium in the solid waste is lacking because, in general, measurements are not made to verify the quantities. Some companies are considering monitoring at least the general trash and hope to be able to identify down to 0.1 gram of Pu per metric ton processed.

Little is known about the composition of other isotopes in the waste. Only assumptions can be made, based on the fission spectra and the source of waste in the process. For example, neptunium is expected to average about 1/20 of the plutonium content.

Since very little thorium has been processed, less than 200 grams of ^{233}U is now in solid waste.

Costs - The costs of waste disposal are difficult to assess because of the varying methods and the usual integration of the costs with other operations. Thus, a more detailed special study is required to accurately determine costs. For those companies who use a solid waste disposal contractor even though they use company-owned ground, a cost of \$0.75 to \$1.25 per cubic foot is incurred for handling charges. On the other extreme very special equipment burial with high gamma activity and special concrete boxes can cost as high as \$8/ft³ for procurement of special mobile concrete boxes. Handling costs can escalate the total costs to near \$10/ft³. Fortunately

this extreme is very infrequent and mostly disposal in concrete vaults cast in place on the company burial ground is the preferred and cheaper method.

Miscellaneous Comments - Some general opinions expressed by several companies are pertinent to solid waste disposal.

1. Most plants are located to permit solid waste burial on the plant site. This is favored because of convenience, control, economy and ease of compliance with regulatory requirements.
2. Onsite storage is considered safe and adequate by all companies.
3. Considerable reluctance was expressed concerning planning their waste disposal operations because of the lack of criteria or standards which all anticipate are forthcoming.
4. All are quite conscious of the highly competitive situation for spent fuels reprocessing. Therefore, within the limits of safety and compliance, the cheapest and quickest method for handling wastes is chosen. Before further criteria and standards are adopted, some would like to see more information on the cost vs hazards and benefits. All are of the opinion that their onsite storage practices are the best short and long range approach. Some are very emphatic about changes in approach, e.g., high level waste. They seriously question the point of diminishing returns; i.e., if you process further, you need more equipment and facilities. This generates more waste which can be processed to generate more waste, etc.
5. The hazards and problems of shipping are the foremost consideration. Some are finding that railroads will not accept radioactive shipments. All expect shipping to become more of a problem than it now is.
6. Plutonium is not recovered simply because it is uneconomical or impractical at this time. Most have briefly considered compressing or incineration operations but have not adopted them. All would need new equipment and facilities to change their waste disposal methods.

Quantity of Waste Produced

The quantity of waste produced in the spent fuel reprocessing industry can best be reported by using the classifications of waste type discussed previously. The amount of plutonium in each type of waste is shown as a function of plutonium throughput in Table V. The values given for the probable average are for the situation where the reprocessing plants are operating at near capacity levels.

Table VI lists the solid waste volume for each type of waste. The numbers in the table represent actual waste volume as a function of fuel reprocessing rate. Additional space will be required for storage due to the irregular shapes of packages and for shielding. The volume of general trash is somewhat independent of throughput and is estimated to be 40,000 cubic feet per year per plant. Likewise, the volume of waste occupied by failed equipment is estimated to be 5,000 cubic feet per year per plant.

TABLE V
Plutonium in Solid Waste From the
Spent Fuel Reprocessing Industry

<u>Waste Type</u>	<u>Pu in Solid Waste</u> <u>Percent of Pu Throughput</u>	
	<u>Range</u>	<u>Probable Average</u>
Cladding Hulls	0.02 to 0.1	0.07
ILW/LLW	0.01 to 0.2	0.1
General Trash	0.001 to 0.3	0.05
Equipment	—	<0.0002 (a)
Dry Chemicals	<0.01 to 0.1	0.01
Total	0.04 to 0.7	0.23

(a) Surfaces assumed to be decontaminated thoroughly, with no residual sludge. About one gram of Pu expected for each large piece of equipment.

TABLE VI

Estimated Volumes of Solid Alpha Wastes From
The Spent Fuel Reprocessing Industry

<u>Waste Type</u>	<u>Cubic feet per Metric Ton^(a)</u>	
	<u>Range</u>	<u>Probable Average</u>
Cladding Hulls	12 to 20	15
ILW/LLW	2 to 15	8
General Trash	30 to 300	(b)
Equipment	1 to 10	(c)
Dry Chemicals	3 to 10	5

(a) Volume of actual waste. Packaging, shielding and the irregular shape of packages may increase the space required for storage by a factor of up to 3.

(b) Volume of General Trash is independent of processing rate. Assumed to be 40,000 ft³ per year per plant.

(c) Volume of Equipment waste category is independent of processing rate. Assumed to be 5,000 ft³ per year per plant.

Forecast of Future Waste Production in The Spent
Fuel Reprocessing Industry

The solid waste produced by the spent fuel reprocessing industry can be predicted in a manner similar to that used for the fuel fabrication industry. The amount of fuel expected to be reprocessed during the period up to 1990 is obtained from Deonigi et al.⁽²⁾ and presented in Table VII. The same assumption for reactor types and fuel management scheme as was used for estimating wastes in the fuel fabrication industry was used. That is LWR's with 50% U-236 recycle, limited plutonium recycle and maximum FBR additions beginning in 1980. It should be noted that estimates of waste produced by an alternate scheme of LWR only, with plutonium recycle,

(2) D. E. Deonigi, R. W. McKee, and D. R. Hoffner, "Isotope Production and Availability from Power Reactors," BNWL-716. July 1968.

TABLE VII

Predicted Future Spent Fuel Reprocessing Rates

<u>Year</u>	<u>No. of (a) Plants</u>	<u>Spent Fuel (b) Reprocessed MT/yr</u>	<u>Plutonium (b) Throughput kg/yr</u>
1970	1	60	400
1975	3	1400	10,000
1980	4	3600	38,000
1985	6	8500	100,000
1990	7	16,000	230,000

(a) Estimated on the basis of first full year of wastes.

(b) Based on Reference (1), BNWL-716, for LWR with 50% U-236 recycle, limited Pu recycle and maximum FBR additions beginning in 1980.

differ by only about 10% in 1990 from the reference case. A one-year delay is assumed between fuel discharge from the reactor and fuel reprocessing.

The rate at which some types of waste are produced depends more on the number of plants than the combined throughput. Table VII presents estimates of the number of active reprocessing plants predicted to be in operation during the period up to 1990. It is anticipated that the design capacity of later plants will be greater than that of the initial ones, and that the capacity of the early plants will be expanded as the industry matures.

The annual amount of plutonium estimated to be lost in the solid waste ranges from 1 kg/yr in 1970 to 530 kg/yr in 1990, as shown in Table VIII. The predicted waste volumes range from about 50,000 ft³/yr in 1970 to 760,000 ft³/yr in 1990, as shown in Table IX.

TABLE VIIIPredicted Plutonium Content of Solid Waste in The
Spent Fuel Reprocessing Industry (a)

	Plutonium in Solid Waste, kg/yr ^(b)				
	<u>1970</u>	<u>1975</u>	<u>1980</u>	<u>1985</u>	<u>1990</u>
Cladding Hulls	0.3	7	27	70	160
ILW/LLW	0.4	10	38	100	230
General Trash	0.2	5	19	50	115
Equipment	<0.01	<0.2	<0.8	<2	<5
Dry Chemicals	0.04	1	3.8	10	23
Total Waste	0.95	23	90	230	530

(a) Assuming LWR's with 50% U-236 recycle, limited Pu recycle and maximum FBR additions beginning in 1980.

(b) Based on loss factors from Table V and processing rates from Table VII.

TABLE IXPredicted Volumes of Solid Waste in The
Spent Fuel Reprocessing Industry (a)

	Volume of Waste, 10 ³ ft ³ /yr ^{(b) (c)}				
	<u>1970</u>	<u>1975</u>	<u>1980</u>	<u>1985</u>	<u>1990</u>
Cladding Hulls	0.9	20	55	130	240
ILW/LLW	0.5	11	29	68	128
General Trash	40	120	160	240	280
Equipment	5	15	20	30	35
Dry Chemicals	0.3	7	18	43	80
Total Waste	47	170	280	510	760

(a) Assuming LWR's with 50% U-236 recycle, limited Pu recycle and maximum FBR additions beginning in 1980.

(b) Based on volume factors of Table VI and processing rates of Table VII.

(c) Volume of actual uncompacted waste. Packaging and shielding will increase space required for storage by a factor up to 3.

The relative proportion of each type of waste is shown in Tables X and XI for plutonium content and volume, respectively. The distribution of plutonium is expected to remain fairly constant through the years, with about 75% of the plutonium being associated with the cladding hulls and the ILL/LLW categories. The distribution by volume shifts considerably with time. About 85% of the volume in 1970 is due to general trash, but it reduces to about 36% in 1990. The percentage of total waste volume due to cladding hulls, ILW/LLW and dry chemicals increases from about 4% in 1970 to 60% in 1990. The average concentration of plutonium in the waste increases from <0.1 gram Pu per cubic foot in 1970 to about 0.7 in 1990.

TABLE X

Percentage Distribution of Plutonium in Solid Waste
in The Spent Fuel Reprocessing Industry

	<u>Percent of Total Pu^(a)</u> <u>In All Wastes</u>
Cladding Hulls	32
ILL/LLW	42
General Trash	21
Failed Equipment	<1
Dry Chemicals	4
Total	<u>100</u>

(a) The distribution is expected to remain fairly constant at these average values through 1990.

TABLE XIPercentage Distribution of Waste Volume
in The Spent Fuel Reprocessing Industry

	<u>Percent of Total Volume</u>				
	<u>1970</u>	<u>1975</u>	<u>1980</u>	<u>1985</u>	<u>1990</u>
Cladding Hulls	2	12	20	25	32
ILW/LLW	1	7	10	13	17
General Trash	85	68	57	48	36
Equipment	11	9	7	6	4
Dry Chemicals	<1	4	6	8	11
Total	<u>100</u>	<u>100</u>	<u>100</u>	<u>100</u>	<u>100</u>

VI. COMBINED FUEL FABRICATION AND REPROCESSING INDUSTRIES

An estimate of the total amount of alpha-contaminated solid waste which will be produced in the United States by the combined commercial operations of the nuclear fuel fabrication and spent fuel reprocessing industries can be made by adding the wastes produced by each industry. Table XII shows the total amount of plutonium predicted to be lost in solid wastes from the combined industries. Plutonium loss is initially much greater in the fuel fabrication industry, but by 1990 the loss is about equal in each industry.

Table XIII gives the predicted volume of solid waste from each industry and the total through the year 1990. About 75% of the total waste volume will originate in the fuel fabrication industry.

TABLE XII

Plutonium Loss in Solid Wastes From The
U.S. Nuclear Fuel Handling Industry (a)

	Plutonium in Waste, kg/yr		
	<u>Fabrication</u>	<u>Reprocessing</u>	<u>Total</u>
1970	5.6	0.95	6.6
1975	65	23	88
1980	175	90	265
1985	360	230	590
1990	580	530	1010

- (a) Assuming LWR's with 50% U-236 recycle, limited Pu recycle and maximum FBR additions beginning in 1980.

TABLE XIII

Volume of Solid Wastes From The U.S.
Nuclear Fuel Handling Industry (a)

	Waste Volume, 10 ³ ft ³ /yr (b)		
	<u>Fabrication</u>	<u>Reprocessing</u>	<u>Total</u>
1970	26	47	73
1975	300	170	470
1980	800	280	1080
1985	1700	510	2200
1990	2700	760	3460

- (a) Assuming LWR's with 50% U-236 recycle, limited Pu recycle and maximum FBR additions beginning in 1980.
- (b) Actual volume of waste. Irregular shape of packaging will increase storage space required.

The data contained in Tables XII and XIII are presented graphically in Figures 2 and 3. These figures show clearly the predicted annual volumes of solid wastes and their plutonium content up to the year 1990. The curves of Figures 2 and 3 can be integrated to provide estimates of accumulated waste at any future date. For example, by the year 1990 it is estimated that about 27 million cubic feet of waste will have accumulated and this volume will contain 7000 kg of plutonium. These data should provide a reasonable basis for planning solid waste storage and disposal facilities for the next 20 years.

FIGURE 2. ANNUAL PLUTONIUM LOSS IN SOLID WASTES FROM THE U.S. NUCLEAR FUEL HANDLING INDUSTRY

FIGURE 3. ANNUAL VOLUME OF SOLID WASTES FROM THE
U.S. NUCLEAR FUEL HANDLING INDUSTRY

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