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Waste Disposal

RADIOACTIVE WASTE DISPOSAL PRACTICES

IN THE ATOMIC ENERGY INDUSTRY

-A Survey of the Costs

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SYNOPSIS

A "house to house" survey was made on methods and related costs of disposing of radioactive wastes as practiced in 1955 by twelve atomic industry installations. The scheme for making the survey as well as detailed waste disposal practices are reported. Wherever possible, estimated unit costs of differentiated stages of waste handling are shown. These are also integrated to show the overall scope of waste disposal practices at each site. Tabular data in the concluding chapter summarize costs and operation magnitudes at the installations. Appendix 1 establishes a pattern for standardizing the reporting of fixed costs and equipment usage costs. Appendix 2 analyses the economy of solid waste volume reduction. Material costs are listed in Appendix 3. An outline for recording monthly waste disposal costs is presented in Appendix 4.

Obvious conclusions drawn from the factual data are (1) that it is more expensive per cubic foot to handle high level wastes than low level wastes and (2) that land disposal is less expensive than sea disposal.

A re-examination of baling economics shows that high compression of solid wastes is more expensive than simpler forms of compaction.

ACKNOWLEDGEMENTS

This report represents at least 300 man hours of interviewing co-operation. Wherever I went, installation personnel graciously submitted to my cross examination. Many offered helpful comments and suggestions. Almost without exception, they also offered condolences for attempting such an endeavor. This report represents the best available data from the best informed people in the industry. I wish to thank the kind and cooperative officials who made this report possible.

Much credit is due to Messrs A. E. Gorman, J. A. Lieberman and J. Newell of the Washington Office of the Atomic Energy Commission, whose concern with the large problems of waste disposal, provided the impetus for this report.

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PART I

INTRODUCTION

RADIOACTIVE WASTE DISPOSAL PRACTICES IN

THE ATOMIC ENERGY INDUSTRY

- A Survey of the Costs -

This report describes methods by which radioactive wastes are disposed, and presents statements of the costs of these operations. The method used depends upon the geographic position of the particular installation and other peculiarities. Installations in populous areas get rid of their wastes by transporting them to more remote areas; installations in sparsely settled locations dispose of their wastes on site. In general, installations on the seaboard utilize the oceans while those inland favor land disposal.

Definition of Radioactive Wastes.

Radioactive wastes are those liquid or solid materials contaminated with radioisotopes which are discarded as unwanted during or at the finish of manufacturing processes and laboratory operations. For the purposes of this report such contaminated materials become wastes when they are placed in receptacles or poured into drains for the purpose of removing them from the site of the operations.

Solid wastes are herein considered as any contaminated material that is not liquid or gaseous. These consist of paper wipes, rags or blotting paper used in "hot" working areas, some rubber gloves and other protective wearing apparel, and small

quantities of wood, glassware and miscellaneous paraphernalia from laboratories and other operations, as well as bedding material and carcasses of experimental animals, drain pipes and air ducts. In other words just about anything and everything.

Liquid waste is mostly water, contaminated with various acids, bases, salts and radioisotopes. There are some contaminated non-water solutions of solvents and oils, but these are small in volume. Slurries or concentrates from evaporation are classed as liquids. In this report sludges from chemical precipitation processes are classed as solids after they have been substantially dewatered by vacuum filtering.

High Level Wastes: Usually the term high level waste is applied to the liquid or solid process waste stream which results from the separation of gross fission products from irradiated reactor fuel. It is also applied, however, to solids which are particularly radioactive. These become radioactive from neutron irradiation or else derive from some phase of reactor operations. Materials are considered "high level" when the emitted radiation intensity is so strong as to materially reduce the time a person can be near the radiating body. Two roentgens or more per hour (2r/hr) is considered "high level" radiation.

Low level Wastes: Low level wastes can be liquid or solid in physical form. Liquids result from any of a multitude of laboratory operations or they may be cooling water from a reactor or simply waste solutions containing radioisotope tracers. Solid

wastes consist of contaminated materials as described in a previous paragraph. Materials are considered "low level" when the emitted radiation presents no particular hazard to persons nearby. They can be handled directly without undue consideration given to time of contact. Up to fifty milliroentgens per hour (0.05 r/hr) is considered "low level" radiation.

Survey Method and Reporting Technique

This survey indicates the present day costs of operating and maintaining radioactive waste handling facilities. It was deemed necessary to separately consider each of several distinct cost components, and then by adding these get total costs. Figure I represents a "flow chart" for radioactive liquid wastes. Figure II similarly represents solid wastes. One can see that the wastes may go through any one or more phases prior to land or sea disposal. The stages blocked out with solid lines represents components of the total costs reported upon in this study.

The descriptive and cost information was gathered by visiting each of the installations. Operational time of men and equipment was suggested by installation operators as was cost of expendable materials. Installation records furnished construction costs of major items such as treatment plants or buildings and these are used for computing those amortization costs. Some costs such as transportation costs were readily obtainable, but others such as construction costs of liquid waste collection systems were not. In the latter case it was necessary to estimate a cost for tanks and piping. A nominal figure of one dollar per gallon of tank capacity was

Figure 1- Schematic Representation of Liquid Wastes Handling Stages

applied in most cases, mostly to indicate that such facilities existed. Certain costs, such as fixed costs (depreciation and overhead) and equipment use costs are not kept, per se, in all installations' records. A standardized method for reporting these costs has been developed for this report and is included as Appendix 1. Costs of many of the expendable materials are listed in Appendix 3.

With few exceptions the principal item of operating cost is labor. Man hours as well as dollar expenditures are reported wherever possible to make functional comparisons possible and to alleviate doubts concerning what cost differences would be where labor rates vary.

Limitations of Cost Report

The costs reported represent the best information available at the time of the survey. In many cases they are based on estimates of man-hours, equipment-hours or numbers of containers of wastes. Costs per unit volumes are reported because volumes were the only readily obtainable measure of the wastes. Many variables influence these unit costs. Some of these are state health and safety regulations, availability of diluting waterways, geological conditions, chemical and radiochemical composition of the wastes, and, of course, the size of the operation. Costs per unit volumes should not be used to compare installation efficiencies because each installation operates under a different set of circumstances.

PART II

DETAILED FINDINGS OF
WASTE DISPOSAL SURVEY

ARGONNE NATIONAL LABORATORY

Lemont, Illinois

LIQUID WASTES

Collection and Temporary Storage Operations.

Radioactive liquid wastes fall into two categories: those which require decontamination by evaporation, ion exchange or chemical precipitation and those which require no decontamination. The Argonne National Laboratory has established standards by which a determination is made as to whether a contaminated liquid must be treated or if it can be released to the environment.

There are 51 hold-up tanks serving various operations at 15 more or less permanent locations and 8 portable hold-up tanks which are moved about as needed. These tanks vary in size from 500 gal. to 3000 gal., the average being about 1500 gallons. All are constructed of carbon steel and some have glass linings. When a tankful of the waste has accumulated a sample is taken and analysed to determine the degree of radioactivity which is the basis for decision as to the disposition of the liquid. If the radioactivity is below the established discarded tolerance level the liquid is released to a separate industrial sewer system which drains into final stage detention tanks of the laboratory waste treatment and monitoring facility near the sanitary sewage treatment plant. If measured radioactivity is higher than tolerance level, the liquid is pumped from the holding tank to a Dempster Dumpster tank and transported to the waste concentration plant.

During fiscal year 1955 a total of 5,732,000 gallons was accumulated in hold-up tanks requiring 3,781 samples to be taken and analysed. About 166,650 gallons from 152 hold-up tanks was taken to the concentration plant for decontamination. The remainder of the volume was discharged to the separate sewer system.

Wastes from certain laboratory operations known to be "hot" are accumulated at the sites of the operations in relatively small containers. Contaminated effluents are kept undiluted deliberately so that they can be handled in the small vessels. Hazardously radioactive wastes accumulate in 9-liter, 60-liter or 90-liter stainless steel containers shielded with one to four inches of lead. Some of these wastes are also accumulated in one gallon polyethylene bottles housed in half inch thick stainless steel secondary containers. The lead shielded containers were distributed and collected by the chemical engineering group with a rotorized dolly. The high level wastes in these containers were taken to the chemical engineering research building where they were accumulated in a 55 gallon stainless steel drum housed in a shielding cylinder. Neutralizing chemicals and cement were added to the wastes in the drum to solidify them. The solidified wastes were then taken to the solid wastes storage facility and stored in an underground vault.

Low level wastes from "hot" areas are accumulated in 1 gallon or 6 gallon glass or polyethylene bottles and 6 gallon, 15 gallon and 55 gallon stainless steel drums and 55 gallon carbon steel drums. As a rule glass bottles are used two or three times whereas the

plastic bottles are reused as many as 8 times after suitable decontamination. The stainless steel drums have approximately the same life as the polyethylene containers and the carbon steel drums the same as glass. The bottles are housed in and carried in stainless steel secondary containers. The low level wastes were picked up when notification was given to the waste collection group. A $2\frac{1}{2}$ ton, stake body truck is used. These wastes were taken to the concentration plant for decontamination. During Fiscal year 1955, 9,202 gallons in 451 separate containers were handled in this manner.

Collection and Temporary Storage Costs.

	<u>Wastes Over Tolerance</u> ⁽¹⁾		<u>Total Sampling and Collection Operation</u> ⁽²⁾	
	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor				
(a) Over tolerance wastes ⁽³⁾	775	\$1,890		
(b) Total operation ⁽⁴⁾			10,843	\$24,760
2. Equipment ⁽⁵⁾		2,880		2,880
3. Materials ⁽⁶⁾		<u>3,130</u>		<u>44,980</u>
Sub totals		\$7,900		\$72,620

4. Capital Investment - Depreciation

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
59 Holding tanks	\$106,200 ⁽⁷⁾	10%	10,620
Monitoring and Analytical Equipment	10,710	20%	<u>2,140</u>
		Total	\$85,380

Quantity Handled: ⁽⁸⁾ 5,732,000 gallons

Unit Cost = $\frac{\$85,380}{5,732,000}$ = \$0.015 per gallon.

-
- (1) 152 hold-up tanks and 451 smaller containers representing 175,900 gallons over tolerance.
- (2) 3781 hold-up tankfuls (5,732,000 gallons) including those over tolerance.
- (3) Sampling labor at \$2.44 per hr estimated at 15 min/sample for 152 samples.
Sample analysis at \$2.12 per hr estimated at 0.9 m hr/sample for 152 samples.
Trucking labor at \$2.53 per hr estimated at 1.5 m hrs/1000 gallons for 86,150 gallons (68 tanks).
Trucking labor at \$2.53 per hr estimated at 0.6 m hr/tank for 84 portable tanks.

Pumping labor at \$2.33 per hr estimated at 1.0 m hr/1000 gallons for 86,150 gallons (68 tanks).

Collection labor at \$2.53 per hr estimated at 0.5 m hr/container for 451 containers.

Monitoring labor at \$2.50 per hr estimated at 15 min/container for 451 containers.

Chemical Engineering labor for "hot" pots not included nor are the "hot" wastes.

- (4) All of costs for wastes over tolerance plus sampling and pumping labor at \$2.33/hr estimated at 2 hrs/tank for 3697 tanks less 17 man hrs for sampling 68 tanks and 86 m hrs for pumping included above. Sample analysis at \$2.12/hr estimated at 0.75 m hr/sample for 3628 samples and 56 m hrs for strontium determinations.
- (5) 17 hrs of pickup truck time at \$1.50/hr* collecting samples; 77 hrs of 2½ ton truck time at \$2.36/hr* handling tanks, 226 hrs hauling bottles.
- (6) 69 containers ranging from 5 gallon glass (\$2.10 each) to 55 gallon stainless steel drums (\$79 each) total - \$1500; \$10 of expendable pumping equipment for each tank pumped; \$1.50 analytical materials for each sample analysis.
- (7) Estimated at \$1800 per tank.
- (8) 152 holdup tanks (166,700 gallons) and 9,200 gallons in smaller containers over tolerances; 5,556,100 gallons under tolerance.

* See Appendix 1.

Concentration Operations.

The radioactivity of the wastes carried to the processing plant is concentrated by evaporation, chemical flocculation or ion exchange depending upon the chemical and radiochemical nature of the wastes. Separate consideration is given to each batch brought in.

During the first half of fiscal year 1955, 66,000 gallons were concentrated by evaporation, 25,000 gallons by chemical flocculation and 1900 gallons by ion exchange. The processing concentrates were poured into 55 gallon drums. These were then taken to the waste packaging yard by the waste collection crew where they were packaged along with the solid wastes in the large steel boxes.

Release to Environment.

Liquids released to the separate sewer system drain to one of two (2 more under construction) 68,000 gallon concrete detention basins. As acid wastes enter the basin they are neutralized with lime. After a tank is filled, a sample is collected and analysed for radioactivity. If radioactivity is below the established discard level, the tankful is discharged into a creek which drains into the Des Plains River. If the activity is over tolerance it is pumped into an adjacent, excavated earthen pit, with a capacity of approximately 200,000 gallons. Radioactive decay, evaporation and natural dilution tend to render the waste innocuous.

During fiscal year 1955, 46,931,000 gallons were received in the detention basins necessitating 935 samplings. Ten times the

basins were over tolerance and about 500,000 gallons were dumped to the earthen pit.

Recirculating pumps on the basins induce mixing of the caustic neutralizer. Sludge which accumulates in these basins is pumped into a holding tank where it is allowed to dry in the open air. Dried sludge is treated and handled as are other solid wastes (see section on solid wastes) if the activity level is noticeable. . otherwise it is deposited in a sanitary landfill along with ANL garbage.

Release to Environment Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	5127	\$11,750
2. Materials ⁽²⁾		34,550
3. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
(2) 68,000 gal. concrete basins	\$65,000	5%
100 x 100 excavated pit	2,000	10%
		<u>3,250</u>
		<u>200</u>
	Total	\$49,750

Wastes to pit - 500,000 gallons.

Wastes released to outfall - 46,431,000 gallons.

Total released 46,931,000 gallons.

Cost/gallon = $\frac{\$49,750}{46,931,000} = \0.001 per gallon.

-
- (1) 4192 m hrs of operating labor at \$2.33/hr covers the men who look after the settling basins, pH control, basin discharges, etc. Analytic labor at \$2.12 is estimated as one man hr per sample for 935 samples.
- (2) The caustics for neutralizing estimated to be \$50/tankful.

ARGONNE NATIONAL LABORATORY

Lemont, Illinois

SOLID WASTES

Collection, Sorting and Storage Operations.

Radioactive solid wastes are accumulated in the working areas in one cubic foot, fiber drums. These drums are set inside stainless steel cans which operate in principle similarly to household, step-on garbage cans. In areas where considerable quantities of wastes are produced, the workers are provided with cardboard cartons which hold about four and one half cubic feet. When the containers are full or when the emitted radiation from a container approaches 50 mr/hr, the container is sealed and made ready for pick up. The Radiation Safety group monitors the waste cans and boxes daily. Solid wastes are picked up daily from the working areas and taken to the storage facility for further treatment or packaging for shipment.

The collection crew also handles moderately active wastes (0.1 to 15 r/hr) along with the low level wastes. At the storage yard these intermediate and high level wastes are placed in underground storage vaults.

Strictly "high level" wastes are transferred from the working areas to the storage facility by the same collection crew with help from a rigger crew. These wastes are usually contained in aluminum cannisters and are inserted in a special "pot" having about nine

inches of peripheral lead shielding. The heavy "pot" requires a lowboy truck be used to make the transfer. At the storage yard the cannisters of wastes are hoisted from the truck to the underground storage holes with the aid of an overhead crane.

The radioactive waste storage facility is an area of about 1200 square feet fenced off with barbed wire. Within this area are three wooden sheds each about 15 feet by 30 feet. There are also five underground storage vaults. Four of the vaults are constructed of reinforced concrete in the shape of open slit trenches. Three of these are about 95 feet long by 13 feet wide by 11 feet deep. They extended about 8 feet below grade. The fourth vault was built to store "high level" wastes. It is divided into six cells with each cell 6 feet by 10 feet by 21 feet deep which will accomodate six large steel boxes, each 4 feet by 5 feet by 6 feet. The fifth storage vault is an assemblage of vertical tubes (water pipe) which terminate at the surface in a concrete pad. These tubes accomodate small cannisters of very "hot" materials.

"Intermediate level" activity wastes are placed in 4 ft. x 5 ft. x 6 ft. steel boxes previously inserted into the trench like vaults by the overhead crane. After a box is filled with wastes a concrete slab is placed over that section of the vault. The filled sections of the vault are covered by a peaked wooden tar papered roof. A record is kept of the volumes of high and intermediate level activities which are placed in the various vaults.

Collection and Storage Costs - Low Level Solid Wastes.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	3460	\$ 8,740
2. Equipment ⁽²⁾		2,360
3. Materials ⁽³⁾		6,030
4. Miscellaneous ⁽⁴⁾		170
5. Capital Investment - Depreciation		

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
Two buildings	\$3,000**	10%	300
Fencing (1400 ft) ⁽⁵⁾	700**	10%	70
Gravel (12,000sq ft.) ⁽⁵⁾	4,300	20%	<u>860</u>
		Total	\$18,530

Wastes Collected - 14,290 cu. ft.

$$\text{Unit Cost}^{(6)} = \frac{\$18,530}{14,290} = \$1.30 \text{ per cu. ft.}$$

-
- (1) Collection crew at \$2.53/hr - estimated 50 m hrs per week. Monitoring labor at \$2.50/hr - estimated 600 m hrs. Labor item does not include the collection time for some 4,500 cu. ft. of solid waste resulting from a special decontamination project - difficult to assess.
- (2) A 3½ ton truck is used only for this operation therefore it's annual use is charged here;
- (3) 12,000 (1 cu. ft.) fiber drums at \$0.40 each and 60 (4½ cu. ft.) cartons at \$0.30 each; plus some miscellaneous materials.
- (4) Laundering of protective clothing at \$100 per man year.
- (5) Cost of fencing, gravel and access roads estimated at \$5000. of this, fencing is estimated** at \$0.50 per ft.
- (6) 14,290 cu. ft. by regular collection; approximately 4,500 cu. ft. from special job hauled directly to railhead.
- * See Appendix 1.
- ** Author estimate.

Collection and Storage Costs - Intermediate and High Level Solids.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor(1)	45	\$ 100
2. Equipment(2)		40
3. Materials		40
4. Capital Investment - Depreciation		

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
(1) Underground vault	\$37,200	5%	2,400
(1) Overhead crane	9,800	10%	980
(1) Pad with tubes	46,700	5%	2,330
(3) Interm. level vaults	91,000	5%	<u>4,550</u>
		Total	\$10,440

Wastes Handled - 1.35 cu. ft. - high level
 390. cu. ft. - intermediate level

Total 391.35 cu. ft.

Unit Cost = $\frac{\$10,440}{391}$ = \$26.70 per cu. ft.

-
- (1) Labor for handling intermediate level wastes charged to low level collection. Nine high level waste transfers involved a rigger at \$2.33/hr, a rigger's helper at \$2.12/hr and a radiation safety man at \$2.50/hr, each for one hour; Two waste crew men at \$2.53 per hour at the storage yard for $\frac{1}{2}$ hour during each transfer.
- (2) A lowboy truck at \$4.77/hr* - 1 hr per transfer.
- * See Appendix 1.

Volume Reduction Operations.

About 65% to 75% of the low level, solid wastes collected are compressed by a hydraulic baling machine. The collection crew dumps the baleable materials at the temporary storage building near the baler. A week's accumulation is enough to keep another crew of two busy sorting out the baleable materials and operating the baler for an eight hour day.

A bale is made up by compressing 12 to 15 of the 1 cu. ft. fiber drums between sheets of cardboard and 4 used air filters. A bale of the compressed materials measures approximately 30 in. by 16 in. by 17 in. or about 4.7 cubic feet. Volume is thus reduced by a factor of 4 to 1. Baled wastes and the unbaleable materials are packed in steel boxes for shipment.

Concentration Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	380	\$ 960
2. Materials ⁽²⁾		130
3. Utilities ⁽³⁾		60
4. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
Building	\$1,500*	10%
Baler	2,900	20%
Baler appurtenances plus installation	3,520	20%
	Total	\$2,580

Wastes baled - 70% of 14,270 cu. ft. or 10,000 cu. ft.

Compressed volume - $10,000 \div 4.2 = 2,380$ cu. ft. approximately.

Unit Cost = $\frac{\$2,580}{2,380} = \1.08 per cu. ft.

-
- (1) Labor costs based on 0.75 man hr/bale - rate of \$2.53/hr.
 (2) Materials include banding and cardboard.
 (3) Electric power at \$5/month.
 * Author estimate.

Packaging Operations.

Sheet steel boxes, made of 16 gauge metal, 4 feet wide by 5 feet long by 6 feet deep, braced with angle irons are the containers used for packaging. When a box of this type has a sheet metal top bolted on and sealed, Argonne considers it to be safe enough to meet most exigencies of inter-state shipments on public carriers.

Two men of the waste collection crew accomplish most of the packaging of wastes for shipment. They first place the baled material and large items of unbaled waste in the large boxes. Voids remaining are filled with contaminated sawdust and smaller pieces of trash. Drums of sludge and slurry from the liquid waste treatment processes are also packaged in the large boxes.

Packaging Costs. ⁽¹⁾

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽²⁾	750	\$ 1,900
2. Materials ⁽³⁾		8,940
3. Equipment ⁽⁴⁾		<u>490</u>
	Sub Total	\$11,330

Volume of Regular wastes⁽⁵⁾ - 6,660 cu. ft.

$$\text{Unit Cost} = \frac{\$11,330}{6,660} = \$1.70 \text{ per cu. ft.}$$

Estimated Total Volume⁽⁶⁾ - 11,160 cu. ft.

Estimated Total packaging Cost - \$11,160 x 1.70 = \$19,000

-
- (1) Not all of the wastes went through the regular packaging operations; some 4,500 cu. ft. evolved in a special decontamination operation and was packaged at the decontamination site. The unit cost is calculated for the regular operations and then assumed to hold true for the other wastes.
- (2) 15 m hrs/wk at \$2.53/hr - includes placing 55 gallon drums of sludge in steel boxes.
- (3) 74 (4x5x6) boxes at \$119 each; \$1.80/box for sealing materials; does not include processed liquid packaging materials.
- (4) 2½ ton truck at \$2.36/hr* - 4 hrs per week.
- (5) Based on 90 cu. ft. per box for 74 boxes.
- (6) Based on 90 cu. ft. per box for 125 boxes.
- * See Appendix 1.

Shipping Operation.

The wastes accumulated over the fiscal year 1955 period had not been shipped as of the time of this survey. Data were available however on a shipment made during November 1954 which was about the same gross volume. The 1954 shipment consisted of 96 (4x5x6) sheet steel boxes, 10 (3x4x5) sheet steel boxes and 41 (4x4x6) wooden boxes representing a total of 12,216 cu. ft. gross.

The 137 boxes of wastes were loaded on trucks by a mobile crane, hauled by truck to the railroad siding on site and unloaded by another crane onto 7 railroad cars. There was no carrier protection or decontamination involved other than shoring the boxes on the trains.

The wastes were shipped to Oak Ridge, Tennessee for land burial. The packaging and shipments complied with ICC regulations. At Oak Ridge the wastes again had to be trucked. Oak Ridge National Laboratory personnel unloaded the railroad cars onto trucks by crane. The wastes were carried some 9 miles to the burial site. ORNL made a job charge for the men, materials and equipment involved in handling and burying these wastes.

Shipping Costs. ⁽¹⁾

	<u>Man hrs</u>	<u>1954 Costs</u>
1. Labor ⁽²⁾	628	\$1,410
2. Equipment ⁽³⁾		450
3. Materials ⁽⁴⁾		100**
4. Contract carrier charges		2,120
5. Oak Ridge charges		<u>2,360</u>
	Total	\$6,440

Wastes shipped - 12,200 cu. ft. approximately.

Shipping weight - 324,000 pounds.

Unit Cost = $\frac{\$6,440}{12,200} = \0.52 per cu. ft.

(1) For 1954 shipment.

(2) 20 hours (2½ days) were spent in loading. 4 reclamation dept. men at \$2.53/hr and a crane operator at \$2.53/hr were loading the trucks. 3 reclamation dept. men and a rigger at \$2.33/hr, a rigger's helper at \$2.12/hr, a crane operator and 2 H.P. men at \$2.50/hr were at the railroad loading site. 2 truck operators at \$2.20/hr trucked the wastes between the sites. 6 carpenters at \$2.53/hr were involved about 8 hours shoring the boxes on the railroad cars.

(3) 15 hours of each of 2 cranes at \$10.00/hr and 2 lowboy trucks at \$4.77/hr*.

(4) Shoring materials.

* See Appendix 1.

** Author estimate.

Summary of F. Y. 1955 Costs

ARGONNE NATIONAL LABORATORY

Liquid Waste Costs.

<u>Operations</u>	<u>Man hrs</u>	Fiscal Year 1955	
		<u>Labor Cost</u>	<u>Total Cost</u>
Collection and Storage	10,843	\$24,760	\$ 85,380
Concentration	†	†	†
Packaging	†	†	†
Release to Environment	<u>5,127</u>	<u>11,750</u>	<u>49,750</u>
Sub Totals	15,610†	\$36,510†	\$135,130†
Overhead			<u>36,510†</u>
	Total (liquid waste)		\$171,640†

Solid Waste Costs.

Collection, Storage (low level)	3,460	\$ 8,740	\$ 18,530
Collection, Storage (high level)	45	100	10,440
Concentration	380	960	2,580
Packaging (all wastes)	1,260	3,180	19,000
Shipping*	<u>628</u>	<u>1,410</u>	<u>6,440</u>
Sub Totals	5,773	\$14,390	\$ 56,990
Overhead			<u>14,390</u>
	Total		\$ 71,380

* For 1954 wastes which were of comparable volume.

W.A.P.D.*- BETTIS FIELD

Pittsburgh, Penn.

LIQUID WASTES

Collection Operations.

The W.A.P.D. plant covers a relatively small area. Because of this fact, waste handling is greatly simplified. Almost all of the radioactive liquid wastes are carried by a separate sewer system directly to the receiving tanks located at the two waste concentrators. There are eleven 1500 gallon tanks and one 7500 gallon tank at one waste concentrator and two 1500 gallon tanks at the other which receive the wastes. All these tanks are made of carbon steel. The levels of radioactivity are generally low so these wastes do not constitute a serious radiation hazard. In this respect little is required in the way of radiation safety surveying. Each tankful of waste is sampled and the sample counted to determine the level of activity. The waste is below the established tolerance level or processed if over tolerance.

There are two waste concentrators, one old and semi-retired and the other newer and of larger capacity. The latter one is normally operated. However, it is sometimes necessary to shut down for repairs and then the older one is pressed into service. There is no pipe line linking the two plants so a truck tanker is used to haul liquid wastes between the two waste concentrators. The tanker also picks up contaminated liquids from locations not served by drain lines.

* Westinghouse Atomic Power Division

Bet.

A small quantity of liquid waste is hauled to the processing site in a 200 gallon tank mounted on a four wheeled trailer. These wastes originate in the air cleaner associated with the solid waste incinerator and occasionally at other places.

<u>Collection Costs.</u>	<u>Man hrs.</u>	<u>F.Y. 55 Cost</u>
1. Labor ⁽¹⁾	479	\$1,080
2. Equipment ⁽²⁾		1,550
	Total	<u>\$2,630</u>

Total quantity handled⁽³⁾ 1,600,000 gallons.

Unit Costs = $\frac{\$2,630}{1,600,000} = \0.0016 per gallon.

-
- (1) It has been estimated that 1/5 man hr is used in collecting, preparing and counting each sample for 2100 samples. Tank truck used 50 times requiring 3/4 man hr per trip. Trailer tank used 26 times requiring 0.83 man hr per trip. Labor rate = \$2.25/hr.
- (2) Total annual cost of tank truck and trailer tank charged here because this is only operation in which they are used. In addition 22 hrs of pick up truck operation @ \$1.50/hr* for hauling the trailer tank around. Total cost of tank truck estimated to be same as 2 1/2 T. truck less \$1000 for fuel or \$1365/yr.* Trailer tank estimated at \$50/yr.
- (3) 50 tank trucks of 1500 gallons each and 26 trailer tanks of 150 gallons each representing 78,900 gallons.
- * See Appendix 1.

Concentration and Packaging Operations.

There are two classes of radioactive liquid wastes handled separately yet simultaneously by the same personnel. One waste stream is concentrated and packaged for sea disposal and the other is concentrated for possible future recovery of some of the materials therein. More often than not, the latter stream also is disposed of to the sea. In the cost listing which follows the expenditures cover the handling and treating of both waste streams.

Waste liquids are concentrated in a two stage, batch evaporation process. The raw waste is boiled down to a predetermined concentration in the first stage then transferred to the second stage "slurry concentrator" for more heat treatment. Although the final concentrate is called a sludge, it has the appearance and consistency of used crankcase oil.

The concentrate which is known will go to sea is mixed with an absorbent material called "Zorbal," then packed into 30 gallon drums. In this way the waste behaves as a solid with less chance for leaks or accidental spills. The other concentrate which is sometimes reclaimed is poured into 30 gallon drums directly. All of the 30 gallon drums are the open top variety, with fitted lids and sealing rings.

Filled drums of both kinds of concentrates are taken to the storage area where solid wastes are packaged for off site shipment. Packaging for shipment consists of inserting a 30 gallon drum inside an open top, 55 gallon drum and filling the remaining void with concrete. A drum lid is tack welded in place before the sealing ring is set so there is little chance for accidentally opening the package.

Bet.

Concentration Costs.

	<u>Man hrs.</u>	<u>F.Y. 55 Costs</u>
1. Labor (1)	9000	\$18,440
2. Materials (2)		500
3. Fuel (3)		11,700
4. Misc. (4)		400
5. Maintenance (5)		6,500
6. Capital Investment - Depreciation		

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
Buildings	\$43,000	10%	4,300
Equipment	71,100	20%	14,220
			<hr/>
Total			\$56,060

Quantity Evaporated - 1,600,000 gallons.

Unit Cost = $\frac{\$56,060}{1,600,000} = \0.035 per gallon.

-
- (1) Operating labor consists of 4 men fulltime (8000 man hrs); maintenance labor consists of 100 man hrs of plant force ; both at the rate of \$365/month. In addition there was some contracted maintenance work which is accounted separately.
 - (2) Maintenance materials other than contractor jobs est. at \$500.
 - (3) 25.5×10^6 cu. ft. of gas at rate of \$0.46/1000 cu. ft.
 - (4) Laundering of protective clothing at \$100 per man per year.
 - (5) Contracted replacement of tubes in boilers (\$5400) and for evaporator shell replacement (\$1100).

Packaging Costs.

	<u>Man hrs.</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	270	\$ 600
2. Materials ⁽²⁾		2,510
		<hr/>
	Total	\$3,110

Quantity packaged - 3960 gallons of sludge.

Unit Cost = $\frac{\$3110}{3960}$ = \$0.79 per gallon.

-
- (1) 50 man hrs @ \$2.25/hr hauling the drums of slurry to storage area.
220 man hrs @ \$2.25/hr for packaging the 30 gallon drums inside
55 gallon drums. Mixing the absorbent with the slurry changed as
part of evaporation costs.
 - (2) 450 bags of absorbent @ \$1.50 per bag plus 220 - 30 gallon drums
@ \$3.00 each plus 220 - 55 gallon drums @ \$3.50 each plus 27 cu.
yds. concrete @ \$15/cu. yd.
-

Release to the Environment.

All liquids leaving the site are discharged through one common header. That is, all liquids having radioactive contamination lower than the discard limit, storm drainage and all, leave the site in one pipe. Over the F. Y. 1955, 137,000,000 gallons have been measured leaving the site. Any activity leaving the site is diluted as much as is possible.

As part of the site monitoring program samples of the effluent are taken and analysed - mostly for the records because the activity

Bet.

is rather low. A proportional sampler takes continuous samples. About 1 man hour per week is expended in gathering the samples and analysing them.

W.A.P.D. - BETTIS FIELD SITE

Pittsburg, Penn.

SOLID WASTES

Collection, Sorting and Temporary Storage Operations.

Low level solid wastes are accumulated in 55 gallon drums at about six different places on the Bettis Site. Wastes are placed in the drums by the operationg personnel or by janitors. The waste handling group takes empty drums to the accumulation points and removes filled drums to the waste processing and packaging area. Distances from points of accumulation to the waste processing area are measured in fractions of a mile which allows a fork lift to be expediently used for hauling. As many as 8 drums are carried at one time on a pallet-like skid.

Processing, packaging and storage are all accomplished in one small area consisting of a strip of windened road and part of the waste incinerator building. For the most part all of the operations, except incineration and handling high level wastes are carried on outdoors.

Low level wastes consist mostly of paper or other combustibles having rather low amounts of contamination. These wastes are loosely packed in the collection drums. Collection drums are re-used until they become contaminated. At that time they become packaging containers for offsite shipments.

High level solid wastes are accumulated in specially prepared 55 gallon drums. Sheet metal cylinders 4 inches in diameter having peripheral lead shields of varying thicknesses (1 inch to 4 inches) are set in 55 gallon drums. Concrete is poured around the shielded cylinder up to it's top which is about twelve inches below the top of the drum. The result is a small void in the center of the concrete drum.

These specially prepared drums are strategically placed in the working areas. Operating personnel insert high level wastes as they are created. After the wastes are in the drum, the waste handling people, using the fork lift, remove the loaded drum and leave an empty one in it's place. The loaded drum is taken to the processing area to complete it's packaging. All high level wastes are shipped as soon as possible. There are no long term storage facilities at Bettis.

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Collection, Sorting and Tempory Storage Costs - Low Level Wastes.

	<u>Man hrs</u>	<u>Annual Cost</u>
1. Labor ⁽¹⁾	399	\$ 900
2. Equipment ⁽²⁾		450
3. Materials ⁽³⁾		50**
4. Utilities, laundry and misc. ⁽⁴⁾		260**
5. Capital Investment - Depreciation		

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
Portion of Processing Bldg. (no fencing, no paving)	\$21,000	10%	2,100
Total			\$3,760

Wastes Collected⁽⁵⁾ ~ approx. 18,000 cu. ft.

Unit Cost = $\frac{\$3,760}{18,000}$ = \$0.21 per cu. ft.

-
- (1) Approx. 8 m hrs @ \$2.25/hr per week are expended.
(2) Fork lift for 6 hrs/wk @ \$1.50/hr.*
(3) The material cost is for the "skids" used. The cost of drums will be accounted for in the packaging section.
(4) Telephone - \$10/mo; - heat \$5/mo; light \$5/mo; laundering of protective clothing at \$100 per man year.
(5) 50 (55 gallon) drums/wk.
* See Appendix 1.
** Author estimate.

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Collection, Sorting and Temporary Storage - High Level Wastes.

	<u>Man hrs.</u>	<u>Annual Cost</u>
1. Labor ⁽¹⁾	266	\$600
2. Equipment ⁽²⁾		300
3. Materials, Depreciation and Utilities charged to Low Level Collection		
	Total	\$900

Wastes collected⁽³⁾ - 26.8** cu.ft. gross.

Unit Cost = $\frac{\$900}{26.8} = \33.60 per cu. ft.

-
- (1) 4 m hrs/wk @ \$2.25/hr.
 - (2) Fork lift - 4 hrs/wk @ \$1.50/hr*.
 - (3) 740 drums/yr - It is here assumed that 3/4 of the packages can hold 0.029 cu. ft. and 1/4 0.058 cu. ft.
- * See Appendix 1.
** Author estimate.
-

Incineration Operations.

An incinerator of limited capacity, equipped with water bath air cleaner (Rotoclone type), is used to reduce the volume of the low level solid combustible wastes. During the course of an 8 hour day, about 12 (55 gallon) drums of waste materials are manually fed to the incinerator and burned. About 3 (30 gallon) drums of ash are removed from the incinerator each week. During F.Y. 1955 it was operating experimentally and a number of modifications to the incinerator and air cleaner kept it out of operation for about 50% of the time.

Since this was the only operating incinerator of radioactive wastes in this survey, a few details about its features and operation may be pertinent. The vertical cylindrical combustion chamber is installed at one end of the wastes processing building and extends from the basement level up above the ground floor level. The air cleaner is on the ground floor level.

A one piece steel grate is tilted along it's diametrical axis for cleaning out ashes. The ashes are dumped into a 55 gallon drum containing a small amount of water. A tangential air feed arrangement, which can control the rate of burning, gives good results in degree of burn-up without the use of auxiliary fuel. The water bath air cleaner (Rotoclone) treats the hot combustion gases prior to release with results that are satisfactory to the Bettis staff. Both the Rotoclone and combustion chamber are made of stainless steel. In addition the fire box is heat shielded by an annular sheet of aluminum which keeps down the ambient temperature and the temperature within the building. It also preheats the air entering the combustion chamber.

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Incineration Costs.

	<u>Man hrs.</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	533	\$1,200
2. Materials ⁽²⁾		270
3. Fuel, utilities ⁽³⁾		40
4. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
Portion of Building	\$10,000	10%
Incinerator and Appurten- ances	10,000	20%
	Total	\$4,510

Quantity Burned⁽⁴⁾ - 13,200 cu. ft. (gross).

Ash Produced - 360 cu. ft.

Unit Cost = $\frac{\$4,510}{13,200}$ = \$0.34 per cu. ft.

-
- (1) About 16 man hrs per week (@ \$2.25/hr) when in operation.
 - (2) 90 (30 gallon) drums with tops @ \$3.00 each.
 - (3) No fuel used; laundering for 2/5 of \$100/man/yr or \$40.
 - (4) 20 (55 gallon) drums of trash form 1 (30 gallon) drum of ash - 90 drums ash produced.
-

Packaging Operations.

Bettis packages practically all of it's wastes in 55 gallon, steel drums. The preparation of drums for high level wastes has already been described, namely lead shielded cylinders surrounded by

concrete. After each drum receives it's charge of high level waste, a lead plug is inserted into the four inch cylinder prior to removal from the working areas. These drums are then moved to the processing area where they are filled to the top of the drum with concrete. Drums containing high level wastes make up the largest proportion of waste packages to be shipped from Bettis.

Ash from incineration and sludge from the liquid concentration process are first packaged in 30 gallon drums. These 30 gallon drums are placed inside 55 gallon drums and surrounded with concrete.

Non combustible wastes are placed in 55 gallon drums and surrounded with concrete. Items such as contaminated boiler tubes are first cut up into appropriate lengths and then stacked longitudinally in the drums so that when the concrete is poured over them there are few or no void spaces remaining. Completed packages are weighed and have serial numbers painted on prior to shipment. Concreted drums weigh about 1000 lbs plus or minus 200 lbs.

Second hand drums purchased locally in Pittsburgh are used. They are the regular open top type steel drum with conventional lids and sealing rings. Each finished package has the sealing ring spot welded to the lid and to the drum to prevent accidental opening of the package. Ready mix concrete purchased locally in truck load quantities is used for packaging.

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Packaging Costs - Low Level Solids(1).

	<u>Man hrs.</u>	<u>F.Y. 55 Costs</u>
1. Labor	320	\$ 720
2. Materials ⁽²⁾		1,420
3. Equipment ⁽³⁾		120
		<hr/>
	Total	\$2,260

Wastes Packaged - 360 cu. ft. incineration ash.

350** cu. ft. non combustible.

Total 710 cu. ft.

Unit Cost = $\frac{\$2260}{710}$ = \$3.19 per cu. ft.

-
- (1) Sludges are included in section on liquid wastes.
(2) The 90 drums of ash are placed in 90 (55 gal.) drums; 150 (55 gal.) drums for other non combustible solids; 55 gallon drums cost \$3.50 each. Ash drums have 3.33 cu. ft. of concrete each and the other 150 drums have 5 cu. ft. of concrete. Concrete cost \$15 per cu. yd.
(3) About 80 hours (20 min/drum) of fork lift time @ \$1.50/hr.*
* See Appendix 1.
** Author estimate.

Packaging Costs - High Level Solids.

	<u>Man hrs.</u>	<u>F.Y. 55 Costs</u>
1. Labor	984	\$ 2,210
2. Materials		
a) Drums ⁽¹⁾		2,590
b) Concrete ⁽²⁾		2,700
c) Lead "pots"		16,230
3. Equipment ⁽³⁾		150
4. Misc. ⁽⁴⁾		50
	Total	\$23,930

High level wastes packaged - 26.8** cu. ft. (gross).

Unit Cost = $\frac{\$23,930}{26.8} = \893 per cu. ft.

-
- (1) 740 (55 gallon) drums @ \$3.50 each.
 - (2) 181 cu. yds. at \$15/cu. yd.
 - (3) About 100 hrs (8 min/drum) of fork lift time @ \$1.50/hr.*
 - (4) Laundering of protective clothing at \$100/man year.
 - * See Appendix 1.
 - ** Author estimate.

Loading and Shipping Operations.

Wastes are shipped via a commercial trucking company to the Navy dock at Earle, New Jersey, 370 miles distant. Truck loads go out at about the same rate that the wastes are produced because there is not much storage space at Bettis. During 1955, 39 truck loads were shipped. Waste packages comply with ICC regulations as to the

Bet.

specified 10 mr/hr at one meter external radiation rate. Truckloads are also made up to comply with ICC standards.

The average truckload consists of about 30 drums and weighs about 30,000 lbs. The drums of wastes are loaded by 4 men at Bettis and unloaded by the Navy at Earle. The Navy charges \$10 per ton for handling the materials at Earle.

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Loading and Shipping Costs.

	<u>Man hrs.</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	506	\$ 1,140
2. Equipment ⁽²⁾		60
3. Materials ⁽³⁾		200
4. Contract Carrier charges ⁽⁴⁾		9,950
5. Navy charges ⁽⁵⁾		5,850
	Total	<u>\$17,200</u>

Wastes shipped - 1200 (55 gallon) drums = 8800 cu. ft. (gross).

Containing	-	360	cu. ft. ash
		350	" " non combustibles.
		27	" " high level
		<u>880</u>	" " sludge

1617 cu. ft. (net).

Total packaged weight of about 1,170,000 lbs.

Cost per Drum = $\frac{\$17,200}{1,200} = \14.33 per drum.

Unit Cost:

Low level = $\frac{\$14.33(240)}{710} = \4.84 per cu. ft.

High level = $\frac{\$14.33(740)}{27} = \392 per cu. ft.

Sludge = $\frac{\$14.33(220)}{880} = \3.59 per cu. ft.

-
- (1) Loading labor including shoring.
(2) Fork lift - $1\frac{1}{2}$ hrs/load at \$1.50/hr* for 40 loads.
(3) Shoring Materials - est. \$5/load.**
(4) Estimated \$0.85/100 lbs.
(5) Estimated \$10/Ton.
* See Appendix 1.
** Author estimate.

Summary of F.Y. 1955 Costs

BETTIS FIELD

Liquid Waste Costs.

<u>Operations</u>	<u>Man hrs.</u>	<u>Labor Cost</u>	<u>Total Cost</u>
Collection and Storage	479	\$ 1,080	\$ 2,630
Concentration	9000	18,440	56,060
Packaging	270	600	3,110
Release to Environment	50	110	110 +
	<hr/>	<hr/>	<hr/>
Sub totals	9799	\$20,230	\$61,910
Overhead			20,230
			<hr/>
		Total (liquid waste)	\$82,140

Solid Waste Costs.

Collection, (low level)	399	\$ 900	\$ 3,760
Collection, (high level)	266	600	900
Concentration	533	1,200	4,510
Packaging (low level)	320	720	2,260
Packaging (high level)	984	2,210	23,930
Loading and Shipping Costs	506	1,140	17,200
	<hr/>	<hr/>	<hr/>
Sub Totals	3008	\$ 6,770	\$52,560
Overhead			6,770
			<hr/>
		Total (Solid Waste)	\$59,330

BROOKHAVEN NATIONAL LABORATORY

Upton, Long Island, N. Y.

LIQUID WASTES

Collection and Temporary Storage Operations.

There are essentially three kinds of liquid wastes at Brookhaven: a) reactor fuel processing wastes, b) evaporable, low level wastes and c) normally uncontaminated or very dilute wastes.

Provision has been made to pipe the reactor fuel processing wastes to six, 8000 gallon, stainless steel, underground storage tanks which are intended for more or less permanent storage. However, very small quantities of wastes have been placed in these tanks. The cost of these tanks is amortized as part of the equipment cost in the concentration operation.

Radioactive wastes are generated in several laboratories and working areas scattered around the BNL site. These wastes accumulate in underground hold-up tanks varying in size from 1500 to 5000 gallons depending on volumes to be handled. Two of these tanks are provided at each laboratory where appreciable quantities of activity may be used. After one tank has filled, its contents are sampled and assayed for activity while the other tank is filling. If the activity levels are sufficiently low so that after dilution with other sewage it will not compromise the average concentration of 3×10^{-12} curies/ml at the

sewage treatment plant, the tank of waste is pumped into a tank truck and hauled to the tank farm for storage and decay or eventual evaporation.

In each of these labs, small containers (usually 5 gallon paint cans with polyethylene liners) are provided so that the experimenter can empty his concentrated waste. These full containers are trucked to the waste processing group at the Hot Lab by the same collection group that handles the solid waste pick up. This waste is assayed for activity. If levels are low it goes to the sewer and if they are too high the waste is added to that being stored for evaporation.

The Pile and Hot Laboratory are interconnected by drain pipe. All waste generated in either building is piped to an appropriate place for either hold-up or discharge to the sewer. If the so called low level waste that is destined for the sewer shows more activity than can be tolerated at the sewage treatment plant it is diverted to the storage tanks.

Collection and Temporary Storage Costs.

	<u>Man-hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	5234	\$10,020
2. Equipment ⁽²⁾		300
3. Materials ⁽³⁾		1,080
4. Misc. ⁽⁴⁾		260
5. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
(12) 2000 gal. c/s tanks	\$24,000**	10%
(2) 8000 gal. s/s/ tanks	32,000**	10%
(2) 2000 gal. s/s/ tanks	4,000**	10%
		<u>400</u>
	Total	\$17,660

Total Quantity Handled⁽⁵⁾ - 3,267,000 gallons.

Unit Cost = $\frac{\$17,660}{3,267,000} = \0.054 per gallon.

-
- (1) $\frac{1}{2}$ man-yr @ \$2.10/hr manipulating tanks and chemically treating; 1-2/3 man yrs @ \$2.00/hr collecting and analysing samples from holdup tanks; $\frac{1}{4}$ man yr supervision @ \$2.50/hr; 8 man hrs/wk trucking pots to evaporator; extent of health physics involvement not known.
- (2) Pick up truck operated an estimated 200 hrs/yr at \$1.50/hr* transporting samples and containers of liquid wastes.
- (3) \$15/month estimated for treatment chemicals and \$75/month for maintenance and other materials.
- (4) Laundering of protective clothing at \$100 per man yr.
- (5) 367,000 gallons of evaporable wastes; 2.9×10^6 gallons of waste was monitored as it flowed through the hot lab waste system.
- * See Appendix 1.
- ** Author estimate.

Concentration and Packaging Operations.

Those wastes which have too great a concentration of radio-activity to be released to the environment are conducted to the evaporator to be chemically treated, concentrated by evaporation and eventually packaged in drums and sent to sea. Liquid wastes are received in three 100,000 gallon steel tanks at the concentrator site. The large volume of receiving tankage is required to accept large discharges of contaminated liquids from certain facilities. On a semi-batch basis, 7000 to 10,000 gallons of waste from the receiving tanks are fed to the evaporator and are reduced to about 75 gallons, a volume reduction ratio of about 90:1 to 130:1.

Condensate from evaporation, decontaminated by a factor of 10^5 compared to feed, is discharged to the sanitary sewerage system. The concentrated, slurry like liquid is put in 55 gallon drums and stored at the evaporator until the time solid wastes are packaged for sea burial.

During the first half of fiscal year 1955 the concentrate was disposed of by mixing about 27 gallons of the slurry with 4 bags of cement in a 55 gallon drum. This drum was sealed and rotated horizontally until thoroughly mixed after which it was allowed to stand until the mixture hardened.

After the large batch mix plant was installed at the packaging area in early 1955 the hot slurry was hauled to the waste packaging area in drums and incorporated in packaging concrete. Since early 1955

all concrete for packaging of waste for sea burial has been made using this evaporator concentrate. The output of the evaporator has not exceeded the need for liquid at the concrete plant.

Concentration Costs.

	<u>Man-hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	5167	\$10,580
2. Materials ⁽²⁾		1,140
3. Utilities ⁽³⁾		510
4. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
Building	\$92,930	10%
Equipment	204,400	20%
		9,290
		<u>40,880</u>
	Total	\$62,400

Total Quantity Processed - 367,000 gallons.

Unit Cost = $\frac{\$62,400}{367,000} = \0.17 per gallon.

-
- (1) 2 men full time (4000 man hrs) @ \$2.00/hr operate the plant and do the maintenance, $\frac{1}{4}$ m yr (500 m hrs) of supervisor time @ \$2.50/hr; 1/3 man yr (667 m hr:) @ \$ 2.00/hr of analytical labor.
- (2) \$20/mo. for chemicals ; \$75/mo. for all other materials.
- (3) Steam @ \$0.70/1000 lbs. per run - 4 runs per month = \$1.40/mo; electric est. @ \$20/mo.; no process water used; laundering of protective clothing at \$100/man yr.

Packaging Costs.

	<u>Man-hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	24	\$ 50
2. Materials ⁽²⁾		<u>720</u>
	Total	\$770

Total Liquid Packaged ⁽³⁾ - 3670 gallons.

Liquid Packaged alone ⁽⁴⁾ - 3140 gallons.

Unit Cost = $\frac{\$770}{3140} = \0.25 per gallon.

-
- (1) 4 m hrs @ \$2.00/hr to transfer 10 drums from evaporator to packaging site - 60 drums transferred. The cost of mixing the slurry with sand and cement is charged to solid wastes packaging.
 - (2) 157 drums @ \$1.70 each; 378 bags cement @ \$1.20/bag; sand not charged. The materials charged are for those drums and cement used in getting rid of the surplus slurry.
 - (3) 367,000 gallons reduced by a volume reduction factor of 100.
 - (4) 157 drums with about 20 gallons slurry in each.

Release to Environment.

The normally uncontaminated or very dilute liquid waste which is released to the sanitary sewerage system goes through the sewage treatment process before it leaves the site. The sewage treatment plant is composed of an Imhoff settling tank and a system of intermittent sand filters. A small amount of radioactivity is taken out in the Imhoff tank and considerably more adsorbs to sand and soil particles in the filter beds.

The costs for operating the sewage plant are not charged to radioactive waste disposal in this study because the problem of radioactivity does not in any way effect the operational cost of the plant.

There are two monitoring points for radioactivity at the treatment plant each consisting of a flow meter and a proportional sampler. A flow gauging station is installed upstream to the point where the Lab effluent enters the stream and also at the edge of the site. The actual cost of development of these monitoring stations is not known.

Release to Environment Costs.

F.Y. 55 Costs

1. Labor

a) monitoring, sampling	1500 man hrs	\$3,000
maintenance.		

2. Materials*	100
---------------	-----

3. Capital Investment - Depreciation

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
(2) Monitoring Stations	\$10,000*	20%	<u>2,000</u>
Total			\$5,100

Total Volume Released during F. Y. 1955 - 120,000,000 gallons.

* Author estimate.

BROOKHAVEN NATIONAL LABORATORY

Long Island, N. Y.

SOLID WASTES

Collection, Sorting and Storage Activities.

Both high and low level, solid radioactive wastes are evolved in normal Brookhaven operations. The largest bulk of the low level waste comes from the Pile. Most of this waste is hauled directly to the dump for burning after it has been monitored. The pile waste that is too hot for burning is carted away in Polyethylene bags in 32 gallon galvanized iron cans. In the working areas these cans are filled by janitors or by operating personnel. The cans are collected on a routine basis by two men using a 1/2 ton pick up truck. At the processing area the plastic bag containing the wastes is removed and the empty cans taken back to where the wastes are produced. Most of these wastes are compressible.

All other laboratories except pile operations wrap their contaminated materials in kraft paper and label the packages as to content and estimated amount of radioactivity. These wastes are picked up by the collection team when notification is given and taken to the processing area for final disposition. A log record is kept of each package.

The waste processing site is an area of about 400 ft. by 600 ft. and is located about a mile from most of the laboratories. It is

fenced in with barbed wire and posted for radiation safety. Within the area are two frame buildings and three old (Army) ammunition storage caves. One of the buildings is used to house the sorting and baling operation and the other building is used to house the equipment decontamination set-up. A smaller area 100 ft. x 200 ft. circumscribed by an 8 ft. anti-personnel fence is set off within the barbed wire area. Wastes are packaged in concrete and also stored within the smaller area. Two concrete block lined, trenches 22 ft. long by 2 ft. wide by 5 ft. deep have been constructed for the purpose of storing high level wastes for radioactive decay. There are also 16 sections of large size pipe (20 inch and 24 inch), each buried separately just below ground level in semi-vertical position to furnish additional underground storage for smaller objects.

After sorting low level wastes, material which is not contaminated or which has negligible contamination is trucked to the dumping area. The "dump" is an abandoned sand borrow pit now used for burning combustibles. Some radioactive wastes are buried there since BNL has established a policy whereby ten curies of radioactivity may be released to the local environment each year. Of the allowable ten curies, only one curie may have half-lives of over 100 days and of this curie only 100 millicuries may have a half-life of over 5 years. No more than 1 millicurie of plutonium and radium per year may be disposed of locally.

High level wastes at BNL receive special consideration. Most of the high level, solid wastes result from operation of BNL's reactor.

These waste materials have either been irradiated or have been grossly contaminated with material that has been irradiated. As a rule they generally come to the waste processing area in specially prepared 55 gallon drums. A drum is prepared for high level wastes by pouring concrete around a cylindrical paper form centered in the drum. The result is a hollow concrete cylinder. Varying wall thicknesses are obtained by using different sizes of forms. These hollow concrete drums are taken to the working areas where wastes are inserted. They come back in the processing area to have concrete caps poured over the wastes.

A crew of two using a Dempster Dumpster tractor equipped with a pan rig in the rear, totes the high level waste drums. At the place where the wastes originate the drums are handled by the same crew using a fork lift. At the waste processing area two health physicists, one a monitor and the other operating a hydraulic drum lifter handle the drums. The Health Physics Division staffs the waste processing group, consequently radiation monitoring is accomplished without extra assistance.

High level wastes too bulky to be handled in the drums are placed within a wooden box and hauled behind the pickup truck on a special long handled trailer. At the waste processing area these "hot" materials are either stored in one of the two underground concrete trenches or in one of the large diameter pipes sunk in the ground, until they have decayed sufficiently to be packaged.

Collection, Sorting and Storage Costs for Low Level Solids.

	<u>Man-hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	1668	\$4000
2. Equipment ^{(2)*}		1250
3. Materials ⁽³⁾		120
4. Utilities, laundry and misc. ⁽⁴⁾		<u>150</u>
	Total	\$6520

Wastes collected 16,140⁽⁵⁾ cu. ft.

$$\text{Unit Cost} = \frac{\$6520.00}{16,140.00} = \$0.40$$

-
- (1) Collection crew--2 men working part time 1618 man hours at \$2.40/hr; 50 man hrs. H.P. time (sorting at source at the Pile) at \$2.00/hr.
- (2) 1/2 ton pick up - 16 hrs/week at \$1.50/hr*.
- (3) 500 polyethylene bags/year at \$0.25 each.
- (4) Telephone \$4.00/mo; laundering \$100/man year.
- (5) All waste coming from the Pile is potentially contaminated so is monitored. Most of it is clean enough to be burned on the side of the dump along with other slightly contaminated items. (Clean waste is burned in the Lab incinerator). This waste is carted away in 2 cu. yd. containers and totals 14,040 cu. ft./year. Higher level trash is brought to packaging yard in 32 gallon garbage cans and is baled. The total for this type is 2100 cu.ft. per year.**
- * See Appendix 1
- ** Author estimate.

Collection, Sorting and Storage Costs - High Level Solids.

	<u>Man hrs.</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	729	\$1,800
2. Equipment ⁽²⁾		350
3. Miscellaneous ⁽³⁾		30
4. Capital Investment - depreciation		

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
2 ea. Reinf. concrete trenches	\$2200	5%	110
16 storage pipes in ground	1000	5%	50
Fences ⁽⁴⁾	6600**	10%	660
Roadways	3000**	10%	300
Frame Building	3000**	10%	300

Total \$3,600

Waste collected - 562 cu. ft.^{(5)**}

$$\text{Unit Cost} = \frac{3,600}{462} = \$7.80.$$

-
- (1) 329 man hours of heavy equipment operations at \$3.05/hr; 10% of the time of 2 H.P. men - 400 m hrs at \$2.00/hr. This includes the labor for loading the wastes on the trucks.
- (2) 125 hrs. of dumpster truck time at \$2.36/hr and 25 hrs. of hydraulic drum lifter time at \$2.36/hr.
- (3) Laundering of protective clothing at \$100/man year.
- (4) 2400 feet of barbed wire fence at \$.25/ft. and 600 ft. of 8 ft. cyclone fence at \$10/ft.
- (5) Calculated from waste shipment. This figure represents the void volume of the prepared drums.
- * See Appendix 1
- ** Author estimate.

Concentration Operations.

The collection crew dumps the wastes collected in G.I. cans at the building housing the baler. Baling takes place when sufficient wastes have accumulated to operate the baler for 4 hours or more.

Bales of wastes are made up by compressing the material from 3 (32 gallon) cans, including the polyethelene bags, into a rectangular, 16" x 16" x 26" shape. The baler is hand operated. Volume reduction is about 3.2 to 1. After the bale is formed baling strips are manually fastened on. The bale is then placed in a prepared drum ready for the final concreting operation.

Unbaleable solids are picked out of the bags of waste. These are accumulated in 55 gallon drums. Eventually they too are concreted in the drums.

Concentration Costs.

	<u>Man hrs.</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	400	\$ 800
2. Materials ^{(2)*}		50
3. Utilities ^{(3)*}		20
4. Capital Investment - Depreciation		

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
Building	\$2,000	10%	200
Baler and Appurtenances	600	20%	<u>120</u>

Total \$1,190

Wastes Baled - approx. 2000 cu. ft. (uncompressed)

- approx. 640 cu. ft. (compressed)

$$\text{Unit Cost} = \frac{\$1190}{640} = \$1.84/\text{cu. ft.}$$

-
- (1) 10% of the time of 2 H.P. men at \$2.00/hr.
 (2) Banding of bales; covering on floor.
 (3) Laundering of protective clothing at \$100/man yr.

* Author estimate

Packaging Operation.

The packaging of wastes for sea disposal as practiced at BNL is relatively simple in principle. Wastes are placed in 55 gallon drums and surrounded with concrete. Enough concrete is added to make the density of the drum greater than that of sea water.

The preparation of drums to receive high level wastes has already been described. viz. a hollowed out concrete cylinder within an open top 55 gallon drum. After the wastes have been placed in the drum and the drum returned to the waste processing area, additional concrete is poured over the wastes filling the drum up to the top.

Drums are prepared for low level wastes by pouring 4 to 6 inches of concrete in the bottom. Wastes are placed on top of this concrete layer and more concrete poured over them filling all the free space in the drum up to the top level. At least 4 to 6 inches of concrete caps the wastes. Two, 3/8 inch, steel reinforcing rods are set at right angles in the top slab in those drums which tend to have interior air spaces, such as those containing the baled wastes.

Solid waste materials too large to fit in drums, are cut into pieces which will fit in drums. In the cutting operation small contaminated particles can be spread around the working area. Spread is held to a minimum by working inside a sand box similar to a childs backyard type of sand box. Contaminated sand and dirt from this operation is also packaged in drums and sent to sea.

BNL had on hand a supply of used drums (enough for several years) which were obtained from the uranium processing operation at Middlesex, New Jersey. The drums cost only the price of hauling from Middlesex to BNL.

Sand is obtained from a borrow pit on the BNL site. Cement is purchased from a local supplier.

A concrete mixer of the type used on transit-mix trucks was obtained at nominal cost as surplus equipment from another AEC installation. The mixer rests on elevated concrete posts so that concrete can be poured directly into drums without rehandling. Concrete aggregates are loaded into the mixer by a mobile clam shell which incidentally, is also used in other BNL operations.

The concrete itself is unique to BNL because it is made with radioactive liquid. Concentrate from the evaporator operation is hauled to the packaging site in 55 gallon drums. A pump lifts liquid from the drums into the batch mixer where it is mixed with sand and cement. Levels of radiation emitted from this kind of concrete have run about 100 to 150 mr/hr at contact and 60 mr/hr or less at 1 ft.; levels low enough to be handled safely.

Packaging Costs - High and Low Level Solids.⁽¹⁾

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽²⁾	1945	\$4,330
2. Materials ⁽³⁾		650
3. Equipment ^{(4)*}		1,770
4. Misc. ⁽⁵⁾		<u>100</u>
	Total	\$6,850

Solid Wastes Packaged in 504 drums consisted of

462 cu. ft. high level in 309 drums and
745 cu. ft. low level in 195 drums.

$$\text{Unit cost high level} = \frac{\$6850}{462} \times \frac{309}{504} = \$9.08/\text{cu. ft.}$$

$$\text{Unit cost low level} = \frac{\$6850}{745} \times \frac{195}{504} = \$3.55/\text{cu. ft.}$$

-
- (1) It is more expedient not to separate the costs of packaging high level wastes from the costs of packaging low level wastes. The costs per drum are about the same, therefore the costs per unit volume would vary in proportion to the amount of wastes per drum.
- (2) 30% of the time of 2 H.P. men at \$2.00/hr is expended in pouring concrete, cutting up large pieces and packing materials in drums; 477 man hours of grounds crew used in pouring operation at \$2.40/hr; 205 man hours of clamshell operator time at \$3.05/hr; 47 man hours at \$2.40/hr tarring waste packages; 16 man hours at \$3.05/hr repairing concrete mixer.
- (3) 504 drums at \$.50; cement \$153; reinforcing steel \$95; cylindrical forms (sonotubes) \$150/
- (4) 200 hrs of hydraulic drum lifter time at \$1.50/hr; 200 hrs of concrete mixer time (100 horsepower) at \$2.36/hr; 200 hrs of clamshell time at \$5.00/hr.*
- (5) Laundering of protective clothing at \$100 per man yr.
- * See Appendix 1.

Loading and Shipping Activities.

Drums of wastes are shipped via commercial trucks to the U. S. Navy dock at Floyd Bennett Field, Long Island, N.Y., a distance of about 70 miles. BNL is notified by the Navy when the LST will be available; a years accumulation of packaged wastes go out at that time. It took three days and nineteen truck loads to get the 1955 wastes, 660 drums, to the L.S.T.

At Brookhaven the drums were loaded aboard trucks by a crane and a crew of eight men including Health Physics personnel. Drums are loaded aboard the trucks to make maximum use of the low activity drums as shields for the more active drums. In addition a radiation surveyor accompanied each truck load in transit. At Floyd Bennett Field the drums were transferred from the trucks to the LST by a rented crane and another BNL crew of eight men.

The entire sea disposal operation was monitored for radiation. Each worker, including the Navy crew, wore film badges and dosimeters. There were no radiation exposures over the maximum permissible weekly allowance of 300 milliroentgens.

Loading and Shipping Costs (Total Waste Output).

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	386 ⁽²⁾	\$ 910
2. Equipment ⁽³⁾		130
3. Equipment rental		150
4. Materials ⁽⁴⁾		190
5. Contract carrier charges		2,100
6. Navy charges ⁽⁵⁾		
	Total	\$3,480

Wastes shipped 660 (55 gallon) drums = 4800 cu. ft. (gross)

Containing: 462 cu. ft.** high level wastes and
745 cu. ft.** low level wastes.

Weight shipped - 550,000 lbs**

Unit Costs:

$$\text{High level} = \frac{\$3480}{462} \times \frac{309}{660} = \$3.52 \text{ per cu. ft.}$$

$$\text{Low level} = \frac{\$3480}{745} \times \frac{195}{660} = \$1.38 \text{ per cu. ft.}$$

$$\text{Surplus liquid} = \frac{3480}{3140} \times \frac{156}{660} = \$0.26 \text{ per gal.}$$

-
- (1) 240 m hrs of grounds crew time to load and unload (at \$2.40/hr);
12 m hrs of crane operator time to load and unload (at \$3.05/hr);
134 m hrs of H.P. time at \$2.25/hr.
- (2) Does not include all travel time.
- (3) 12 hrs of crane time at \$4.77/hr; 26 hrs of hydraulic drum lifter
time at \$1.50/hr; 24 hrs of fork lift time (to unload) at \$1.50/hr*.
- (4) Protection of truck beds \$114; shoring materials \$75.
- (5) The charges made by the Navy, if any, were not ascertained.
- * See Appendix 1.
- ** Author estimate.

Summary of F. Y. 1955 Costs
BROOKHAVEN NATIONAL LABORATORY

Liquid Waste Costs.

		Fiscal Year 1955	
<u>Operations</u>	<u>Man hrs</u>	<u>Labor Cost</u>	<u>Total Cost</u>
Collection and Storage	5234	\$10,020	\$ 17,660
Concentration	5167	10,580	62,400
Packaging	24	50	770
Release to Environment	<u>1500</u>	<u>3,000</u>	<u>5,100</u>
Sub Totals	11,925	\$23,650	\$ 85,930
Overhead			<u>23,650</u>
	Total (liquid wastes)		\$109,580

Solid Waste Costs.

Collection, etc. (low level)	1668	\$ 4,000	\$ 6,520
Collection, etc. (high level)	729	1,800	3,600
Concentration	400	800	1,190
Packaging	1945	4,330	6,850
Loading and shipping	<u>386</u>	<u>910</u>	<u>3,480</u>
Sub Totals	5128	\$11,840	\$ 21,640
Overhead			<u>11,840</u>
	Total (solid waste)		\$ 33,480

FEED MATERIALS PRODUCTION CENTER

Fernald, Ohio

LIQUID WASTES

Handling of Radioactive Liquid Wastes.

Prior to release to the environment all process liquid wastes flow through one central plant called the General Sump, where they are monitored. All of these wastes are effluents from various plant treatment facilities. These plant treatment facilities consist of precipitators and filters which reduce uranium and other solids content along with pH adjustment prior to discharge to the General Sump.

The radioactive contaminants of the liquid wastes are principally uranium or isotopes of the uranium series. Liquid wastes do contain other non radioactive contaminants, however, which come from the various chemical and metallurgical operations. Acids, fluorides, nitrates and oil are the most bothersome. External radiation is practically ignored because there is very little, quantitatively. Ingestion of radioactivity is the primary health concern.

Waste Concentration Operations.

A refinery plant which extracts uranium from ore evolves a liquid waste which is contaminated with the other metallic constituents of the ore as well as with the chemicals of extraction. This waste stream is evaporated to recover acid and to reduce the volume of waste to be stored. Evaporator concentrate is then spray calcined to further

reduce the storage volume required. The calcined residue is pneumatically ejected to one of two 125,000 cu. ft. concrete storage tanks. In dried state the sludge is classed as a solid waste in this analysis. The overhead or vapor from evaporation and calcining is directed to the acid recovery plant where NO_2 is recovered and the weak acid is concentrated.

Concentration Costs.⁽¹⁾

	<u>Man Hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽²⁾	60,000*	\$151,341
2. Materials ⁽³⁾		36,876
3. Utilities ⁽⁴⁾		91,275
4. Contract Maintenance ⁽⁵⁾		49,339
5. Capital Investment - Depreciation		

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
Evaporator and calciner plant	\$1,946,560	20%	<u>389,310</u>
		Total	\$718,141

Total volume handled - ? gallons.

Average concentration (evaporation) - 10:1

-
- (1) For both evaporator and calciner operation.
 (2) Operating and maintenance labor including immediate supervision. The cost is known from cost records - man hrs are estimated based on an average hourly wage of \$2.50/hr.
 (3) Operating and maintenance materials and supplies.
 (4) Fuel, electricity and steam.
 (5) Replacement of portions of the concentration equipment; this is very nearly an annual cost.
 * Author estimate.

Waste Treatment and Release to Environment Operations.

Each plant has a facility for treating their own particular wastes. The Refinery facility, as example, has a monitoring and waste treatment station. Unavoidable discharges from the Refinery which contain uranium are treated here by precipitation to recover the uranium.

Effluent from this operation is discharged to the General Sump. Unrecoverable weak acids from operations in the Refinery are also neutralized here prior to discharge to the General Sump.

The General Sump is the final monitoring station prior to discharge to the environment. All the various plant effluents are collected here in tanks and sampled to determine the type and concentration of chemical contaminants before releasing them to the river.

Close co-operation is maintained with state authorities in using the river as a receiving body for the liquid waste discharges. State established tolerance levels in the river are sustained by controlling the rates of discharge from the General Sump. Stream gauging and sampling by FMPC determines the river dilutions available and the effects of the discharges on the river.

Waste Treatment and Release to Environment Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	11,345	\$ 38,450
2. Materials ⁽²⁾		1,200**
3. Utilities and Misc. ⁽³⁾		2,010**
4. Equipment ⁽⁴⁾		1,500
5. Capital Investment - Depreciation		

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
Sump treatment plant			
building	\$ 85,780	10%	8,570
equipment	426,530	20%	<u>85,310</u>
		Total	\$137,040

Total quantity discharged - 94,200,000 gallons.

-
- (1) Operating labor is 7,845 m hrs at \$29,700, including supervision; analytical labor was estimated as 6 m hrs/day for 5 day wk at \$2.50/hr for analysing sump plant and river samples; 2000m hrs at \$2.50/hr collecting stream samples and keeping records. Maintenance labor is not known.
- (2) Chemicals for sump plant operation.
- (3) Telephone \$10/mo.; heat \$10/mo.; power \$100/mo.; laundering of protective clothing at \$100 per man year.
- (4) Pick up truck used full time collecting samples.*
- * See Appendix 1.
- ** Author estimate.

FEED MATERIALS PRODUCTION CENTER

Fernald, Ohio

SOLID WASTESSolid Waste Handling Operations.

The FMPC processes uranium ores into metallic uranium and then makes useable shapes out of the uranium ingots. All radioactive wastes associated with these operations are contaminated with uranium or the uranium daughter series. There are no fission products involved. External radiation is no hazard; ingestion forms the basis of all health and safety regulations. As a rule levels of contamination are rather low, uranium being recovered wherever possible.

Solid wastes consist of; used ore drums; contaminated, junked pieces of equipment; contaminated piping and other metals; filter cake from a scrap recovery process; and dried sludge from an evaporation calcining process. Combustible matter is either non contaminated or indistinguishably contaminated and is burned in an open clay pit or in an incinerator on the site.

Solid waste disposal is simple and **straightforward**. A truck driver and two helpers routinely collect wastes from pick up stations around the site. Contaminated drums are stacked in one pile, other contaminated metals are stacked in another. Filter cake is hauled by trailer load to an excavated clay lined earthen basin dammed off with an earthen embankment. Calcined evaporator concentrate is ejected via pipes to an above ground concrete storage resevoir.

All the wastes are kept on the site; to date none have been shipped. In several years of operation sizeable piles have been built up. Used drums stacked on their sides 5 high cover an area of 4 or 5 acres. Other contaminated metal wastes form a triangular prism pile about 400 ft. long 50 ft. wide at the base and 15 ft. high. The filter cake basin is semi-circular having a 300 ft. diameter approximately and is about 8 ft. deep; it is about 1/2 to 2/3 full.

Solid Waste Handling Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	3250	\$ 6,560
2. Equipment ⁽²⁾		2,360
3. Capital Investment - Depreciation		

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
Filter Cake Basin	\$ 3,500**	20%	700
(4) Sludge Storage Reservoirs	804,300	10%	80,430
Fence around tanks	<u>10,200</u>	10%	<u>1,020</u>
	\$818,000		\$91,070

Volume of wastes handled - 52,600 cu. ft. filter cake.

Volume of other wastes per unit time not known.

-
- (1) Truck driver and 2 helpers - 12 m hrs/day at \$2/hr on routine collection of contaminated materials; 5 m hrs/wk at \$2.25/hr bulldozer operator at filter cake disposal basin.
- (2) 2½ Ton stake truck - 4 hrs/day at \$2.36/hr* routine pickups
Time of electromagnet stacking metal pile and bulldozer for shoving filter cake not known.

* See Appendix 1.

** Author estimate.

Summary of F. Y. 1955 Costs at
FEED MATERIALS PRODUCTION CENTER

Liquid Waste Cost

<u>Operation</u>	<u>Man Hrs</u>	Fiscal Year 1955	
		<u>Labor Cost</u>	<u>Total Costs</u>
Concentration	60,000	\$151,341	\$ 718,141
Waste Treatment and Release to Environment	<u>11,345</u>	<u>38,450</u>	<u>137,040</u>
Sub totals	71,345	\$189,791	\$ 855,181
Overhead			<u>189,791</u>
	Total (liquid waste)		\$1,044,872

Solid Waste Costs

Waste Handling	3,250	\$ 6,500	\$ 91,070
Overhead			<u>6,500</u>
	Total (solid waste)		\$ 97,630

KNOLLS ATOMIC POWER LABORATORY

Schenectdady, N.Y.

LIQUID WASTES

Collection and Temporary Storage Operations.

Essentially there are two kinds of liquid wastes at KAPL: low level and high level. Low level wastes originate in the laboratories and areas working with radioactive materials. High level wastes come from laboratory chemical separations experiments. Except for small quantities of organic solvents and other such material which cannot be put through the evaporator, low level wastes are collected via laboratory sink drains in three 10,000 gallon stainless steel receiving tanks and via sump drains in one 10,000 gallon tank and one 5,000 gallon stainless steel tank at the evaporator building. High level wastes are piped to five separate 10,000 gallon stainless steel receiving tanks.

About two 55 gallon drums of contaminated oils and solvents accumulate every week. Routinely these are trucked on a low bed tractor trailer to the solid waste packaging and storage yard together with solid wastes. In addition KAPL handles about two 55 gallon drums per week of contaminated liquids for special off site users of radio-isotopes. These go into drum storage with the KAPL material.

Collection and Temporary Storage Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	300	\$ 600
2. Equipment ⁽²⁾		90
3. Materials		200*
4. Capital Investment - Depreciation		

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
(4) 10,000 gal. s/s tanks	\$40,000**	10%	4,000
(1) 5,000 gal. s/s/tank	5,000**	10%	<u>500</u>
		Total	\$5,390

Quantities handled: 1,125,000 gal. (thru drains)
 5,000 gal. (in drums)

-
- (1) 100 man hrs at \$2/hr sampling and monitoring the receiving tanks;
 200 man hrs at \$2/hr transferring solvents, etc. to 55 gallon
 drums and trucking to storage.
- (2) 16hrs of low bed tractor trailer use at \$4.77/hr; 8 hrs of fork
 lift at \$1.50/hr.*
- * See Appendix 1.
 ** Author estimate.

Concentration, Packaging and Storage Operations.

Volume reduction of low level wastes is accomplished in a single effect, forced circulation, flash type evaporator. Liquids as collected in the receiving tanks are first neutralized with caustic and then fed continuously into the evaporator. The overhead or condensate is captured and detained in either of two 5,000 gallon

tanks while samples of the contents are checked for activity level. If radioactivity is within tolerance the condensate is discharged to the storm sewer system. If above tolerance it is recirculated through the evaporator.

Evaporator concentrate, which is essentially a saturated salt solution (about 40% solids) is discharged into 55 gallon drums having polyethylene liners. Upon cooling the concentrate solidifies and forms a rather solid mass within the drum. Drums of slurry are trucked to a specially provided storage pad where they are stored until they are shipped off site.

The evaporator system effects a volume reduction of at least 500 to 1. The decontamination factor is about 10^6 . Approximately 40 curies per year are contained in all the slurry packaged. Emitted radiation intensities of about 4r/hr at the surface of any drum are common.

High level wastes may also be concentrated in the evaporator. Long term, underground tank storage space is limited to 50,000 gallons. Wastes which have previously gone into tank storage unconcentrated or not concentrated as much as was possible can be pulled out of the tanks and evaporated. This is just a matter of conserving underground storage space. The same crews and the same evaporator would accomplish this result.

Some concentrates from low level waste processing are too "hot" to put in drums. These also go into the underground storage tanks.

Concentration Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	7150	\$14,520
2. Materials ⁽²⁾		200
3. Utilities and misc. ⁽³⁾		13,780
4. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
Building	\$324,000	10%
Equipment ⁽⁴⁾		32,400
		<hr/>
	Total	\$60,900

Total quantity processed⁽⁵⁾ - 1,125,000 gallons.

Quantity of concentrate⁽⁶⁾ - 4,900 gallons.

Unit Cost = $\frac{\$60,900}{1,125,000}$ = \$0.054 per gallon.

-
- (1) Operating labor consists of 2 men for 78 hrs/wk at \$2/hr; 250 m hrs of supervisor time at \$2.50/hr; maintenance labor average 52 m hrs/~~wk~~ at \$2/hr; 400 m hrs of H.P. supervision of maintenance work at \$2.25/hr.
- (2) Maintenance materials.
- (3) Steam 48,000 lbs/day at \$1.10/100 lbs; - electric \$2,100 for the year; laundering of protective clothing at \$100 per man year.
- (4) The initial cost of the equipment was \$570,000. Because this report is using a five year amortization period for equipment and the equipment is 6 years old there is no depreciation charge recorded here.
- (5) Based on a flow of 4,500 gal./day for five day week.
- (6) 4 drums/month packed for shipment; 50 gal./wk too hot for shipment.

Packaging Costs

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	42	\$ 90
2. Materials ⁽²⁾ (slurry drums)		770
(other wastes)		<u>280</u>
Total		\$1,140

Wastes Packaged - 2,400 gallons slurry
 5,000 gallons solvents, etc.

Unit Cost = $\frac{\$1140}{7400} = \0.15 per gallon.

-
- (1) 12 man hrs/yr at \$2/hr supplying drums at the evaporator. -
 Evaporator operators fill drums and move them to storage.
 30 m hrs/vr at \$2.25/hr of Health Physics time monitoring drum storage.
- (2) 48 polyethylene lined 55 gallon drums at \$16 each; solvents and oils are put in used drums available on the site, however, some 40 (55 gallon) drums at \$7.00 each were bought for this purpose.

Long Term Storage Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	36	\$ 90
2. Materials ⁽²⁾		<u> </u>
3. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
(5) 10,000 gallon s/s tanks	\$50,000**	10%
		<u>5,000</u>
	Total	\$5,090

Total Quantity Stored - 42,000 gallons.

F.Y. 1955 Accumulation - 2,500 gallons.

-
- (1) There is labor involved, but it is the evaporator operators who look after the tank storage and maintain the facilities. These operators have been charged to concentration costs. Sampling and analytic labor amounts to 36 m hrs at \$2.50 per hr.
- (2) None indicated at the time of this survey.
- ** Author estimate.

Release to Environment Operations.

The only liquids released to the environment which contained radioactivity were the distillate from evaporation and waste water from the protective clothing laundry. These liquids are discharged to the storm drain system which merges with the effluent from the sewage treatment plant at an outfall on the bank of the Mohawk River. The total quantity of radioactivity released is relatively small, less than 1 curie per year.

There is a detention basin above the outfall in which evaporator distillate and laundry wash water is collected for sampling prior to release. A flume at the outfall measures the quantity which is discharged. There is also a proportional sampler on the outfall which continuously collects samples of the discharge for analysis. A monitoring and environmental effects program is also carried out on the effects to the Mohawk River. No data was obtained on the latter.

Release to Environment Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	603	\$1,430
2. Materials ⁽¹⁾		
3. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
Detention Basin	\$29,539	10%
Flume	4,550	10%
Instruments	4,450	20%
		<u>890</u>
	Total	\$5,720

Total quantity released - 126,000,000 gallons.

-
- (1) The cost of a water sample analysis is estimated at \$1.00 when performed in groups of 10 samples. There are 260 such samples analysed each year. In addition one weekly sample is analysed isotopically at a cost of \$9.00 when performed in groups of four. Based on a labor rate of \$2.50 per hour, there would be 291 man hrs for analytical labor. Material costs are negligible. Obtaining samples involves 312 man hrs per year at \$2.25 per hr. Labor involved in releasing wastes is performed by evaporator operators and has been charged to concentration costs.

KNOLLS ATOMIC POWER LABORATORY

Schenectady, N.Y.

SOLID WASTES

Collection, Sorting and Storage Operations.

Low level, radioactive contaminated solid wastes are accumulated in the laboratories and working areas in paper bag lined garbage cans. As much as possible combustible and compressible materials such as paper, rags, rubber and items of clothing are accumulated in separate cans from non-combustible, non compressible materials like glass, lab equipment, wood, and air filters. Janitors transfer these cans of materials to waste pickup stations. The cans of compressible matter are dumped into Dempster Dumpster Pans and the non-compressible into 4 ft. by 4 ft. by 4 ft. wooden boxes. The waste collection crew equipped with Dempster tractor, low bed truck and fork lift collect the boxes and pans and transfer them to the waste processing area on a routine basis.

Volumetrically small items of high level waste materials are kept in small paint can containers whereas bulky material like scrap metal turnings, floor sweepings and contaminated equipment are accumulated in 55 gallon drums. The radiation levels of the former range from 3 r/hr to 200 r/hr. The latter ranges from 1/2 r/hr to 24r/hr, averaging 3 r/hr or less. The paint cans, 1/2 pint and 1/2 gallon in size, are transferred to a fenced off, concretepaved storage pad

having underground storage tubes consisting of 4" and 8" cast iron pipe placed vertically in the ground. The smaller paint cans are placed in a 4" dia x 42" long cylindrical, aluminum can which is lowered into one of the underground tubes. The 8" holes receive larger sized cans of wastes. After the containers of wastes are set in the holes a 3 ft. plug of concrete is set in the top section of the pipe and shields the wastes in the hole. To date, all wastes which have been placed in this high level storage pad are still there, none have been taken out. All the containers which go into tubes are serial numbered. Contents and location are recorded so they can be recovered at any future date.

The 55 gallon drums of high level wastes are sealed with a regular drum lid and sealing ring and transferred to the storage area in the solid waste processing yard to await shipment off site for disposal.

The waste processing area is a gravelled and paved area of about two acres surrounding the building housing the hydraulic baler. It is posted but not fenced off. All packaged solid wastes are stored outdoors near the waste processing building.

Low Level Collection, Sorting and Storage Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	1846	\$3,710
2. Equipment ⁽²⁾		1,840
3. Materials ⁽³⁾		100**
4. Utilities ⁽⁴⁾		330**
5. Capital Investment - Depreciation		

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
1/2 of waste handlin bldg.	\$19,300	10%	<u>1,930</u>
		Total	\$7,910

Gross Volume handled⁽⁶⁾ - 20,000 cu. ft. - baleable
 16,000 cu. ft. - unbaleable
880 cu. ft. - int. level

Total 36,880 cu. ft.

Unit Cost = $\frac{\$7,910}{36,880} = \0.21 per cu. ft.

-
- (1) 1650 m hrs at \$2/hr collecting, sorting and stacking boxes of wastes, including Dumpster operator and low bed truck operator; 2 m hrs/wk at \$2.25/hr for monitoring collection stations; 8 m hrs/month at \$2.00/hr handling 55 gallon drums of intermediate level wastes.
 - (2) Dumpster truck operation - 5 hrs/wk at \$2.36/hr; low bed operation 4 hrs/wk at \$4.77/hr; fork lift - 4 hrs/wk at \$1.50/hr.*
 - (3) Paper bag can liners, trash cans.
 - (4) Telephones \$10/mo.; heat \$5/mo.; electric \$5/mo.; laundry service \$100/man year.
 - (6) Volumes of containers handled i.e., 200 dumpster pans of 100 cu. ft. each and 250 - 4 x 4 x 4 (64 cu. ft.) boxes; Ten 55 gallon drums per month of intermediate level wastes.

* See Appendix 1.

** Author estimate.

High Level Collection, Sorting and Storage Costs.

	<u>Man hrs.</u>	<u>F.Y. 55 Costs</u>
1. Labor(1)	150	\$ 300
2. Equipment(2)		150
3. Materials(3)		500**
4. Capital Investment - Depreciation		

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
250 hole storage pad	\$39,000	5%	<u>1,950</u>
		Total	\$2,900

Gross volume handled(4) - 5.6 cu. ft. in cans
100 cu. ft. in drums

Unit Cost = $\frac{\$2900}{105.6} = \27.50 per cu. ft.

-
- (1) 8 m hrs/month at \$2.00/hr handling 55 gallon drums of wastes; 2 m hrs/wk at \$2/hour transferring small "hot" items to underground storage; 1 m hr/wk of H.P. monitoring of transfers of "hot" items at \$2.25/hr.
- (2) Fork lift used in all transfers - 4 hrs/mo. handling drums and 1 hr/wk transferring cans. Total 98 hrs at \$1.50/hr.*
- (3) Paint cans, aluminum cans, 3 ft. lead plug shields.
- (4) Approx. 28 cu. ft. have been put in holes in the ground since 1951 (5 yrs). The 100 cu. ft. was collected in thirteen 55 gallon drums and is stored in a pipe tunnel.

* See Appendix 1.

** Author estimate.

Concentration Operations.

Dumpster pans of compressible wastes are emptied on the floor in the waste processing building. Several times a week the workers sort

out the incompressible items and compress the remainder in a hydraulic baler. Baling reduces the volume about 6 times. The baler is hooded and vented to the atmosphere when operated.

The incompressible items are accumulated in a 4 ft. x 4 ft. x 4 ft. wooden box which when filled is capped and stored until shipped offsite.

Concentration Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	1,056	\$2,110
2. Materials ⁽²⁾		100*
3. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
1/2 of waste handling bldg.	\$19,300	10%
Hydraulic baler and auxiliary equipment	5,130	20%
		<u>1,030</u>
	Total	\$5,170

Volume Materials Baled - 20,000 cu. ft. gross.

Volume bales (6:1 reduction) - 3,300 cu. ft. gross.

Unit costs = $\frac{\$5170}{3300} = \1.57 per cu. ft.

-
- (1) 16 m hrs at \$2.00/hr to bale 3 dumpster loads of material.
 (2) Banding strips and baler maintenance materials.
 * Author estimate.

Packaging Operations.

KAPL packages all wastes shipped off site to comply with ICC regulations. All packages are sealed tight and are built to be strong enough to withstand any foreseeable hard knocks. Except for some trash in 55 gal.drums, everything is "wrapped" in wooden boxes.

The wooden boxes are pre-fabricated in the carpenter shop, filled by the waste collection crews and sealed with wooden tops by the carpenters. Those boxes which are stored outdoors have a layer of waterproofing, sisal kraft paper tacked on the top surface.

There are several sizes of boxes use. Boxes 4 ft. x 3 ft. x 2 ft. nicely hold two bales of compressed trash. 4 x 4 x 4 boxes are standard size for uncompressible matter. Large items are first inserted then the remaining voids filled with smaller junk and trash. Contaminated items of equipment too large for the regular boxes have special boxes built around them; some as large as 4 ft. x 6 ft x 8 ft. Loose, bulky matter like contaminated sawdust and dirt are packaged in 55 gallon drums.

Packaging Costs - Low and Int. Level Wastes.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	2542	\$ 6,130
2. Materials ⁽²⁾		10,700
3. Equipment ⁽³⁾		<u>1,010</u>
	Total	\$17,840

Quantity packaged - 20,275 cu. ft. boxes
675 cu. ft. drums

Total 20,950 cu. ft.

Unit Cost = $\frac{\$17,840}{20,950} = \0.85 per cu. ft.

-
- (1) 1150 m hrs at \$2/hr - packing the materials in boxes and water proofing them; 348 boxes between April 1954 and May 1955 - labor 4 m hrs/box at \$2.75/hr.
 - (2) 82 - (4 x 4 x 2) and smaller boxes \$25 each; 257 - 4 x 4 x 4 boxes at \$29 each; 8 - 4 x 4 x 8 and larger boxes at \$50 each; 92 - 55 gallon drums at \$7.50 each; 23 drum pallets at \$4.75 each.
 - (3) Fork lift which is used in all operations - the charge here is for full time minus the time it is used in the other operations.

Loading and Shipping Operation.

In April and in September of 1954, KAPL shipped wastes to the Lake Ontario Storage area at Tonowanda, N. Y. After September the wastes were sent to the Oak Ridge Tennessee burial grounds. The combined April and September shipments to LOSA consisted of four railroad carloads containing eighty-two 4 x 4 x 4, or larger, boxes, eighty (55 gal.) drums and thirty-seven boxes of assorted sizes.

In March, 1955, six railroad carloads consisting of 231 boxes and 152 (55 gallon) drums went to ORNL.

Six men, two fork lifts and a lowboy truck load a railroad car in one day. The wastes are loaded on the truck, taken a hundred yards or so to the railhead and transferred to the railroad car.

The unloading and stacking of the wastes at LOSA was accomplished by a trucking contractor obtained on a competitive bid basis. At Oak Ridge the wastes had to be unloaded onto trucks and hauled some nine miles from the railhead to the burial site. Charges are listed for the services performed at both terminals.

Loading and Shipping Costs - (To LOSA).

	<u>Man hrs</u>	<u>6 mos. cost</u>
1. Labor ⁽¹⁾	284	\$ 660
2. Equipment ⁽²⁾		240
3. Materials ⁽³⁾		80
4. Contract carrier charges		960
5. Contract unloading charges		<u>1,540</u>
	Total	\$3,480

Wastes shipped - 6,980 cu. ft. solids - 138,000 lbs.
 (in 4 RR cars) 586 cu. ft. liquids - 37,600 lbs.

Total 7,566 cu. ft. (gross) 175,600 lbs.

Shipping Unit Costs = $\frac{\$3,480}{175,600} = \0.01983 per lb.

Shipping cost (solids) = $\$0.01983 (138,000) = \$2,735.$

Shipping cost (liquids) = $\$0.1983 (37,600) = \745

-
- (1) 192 man hrs at \$2.25/hr to load 4 cars; 12 m hrs at \$2.75/hr lining cars with paper and shoring; 80 m hr at \$2.50/hr H.P. monitoring at LOSA.
 (2) 64 hrs of fork lift time at \$1.50/hr; 32 hrs of truck time at \$4.77/hr*.
 (3) Paper for lining and lumber for shoring.
 * See Appendix 1.

Loading and Shipping Costs - To ORNL.

	<u>Man hrs.</u>	<u>6 mos. Cost</u>
1. Labor ⁽¹⁾	306	\$ 700
2. Equipment ^{(2)*}		370
3. Materials ⁽³⁾		120
4. Contract carrier charges		2,959
5. ORNL charges		<u>2,067</u>
	Total	\$6,216

Wastes shipped - 13,970 cu. ft. solids = 194,060 lbs.
 in 6 RR cars 440 cu. ft. liquids = 26,400 lbs.

Total 14,410 cu. ft. (gross) 220,460 lbs.

Shipping Unit Costs = $\frac{\$6,216}{220,460} = \0.02815 per lb.

Shipping cost solids = $\$0.02815 (194,060) = \$5,470$.

Shipping cost liquids = $\$0.02815 (26,400) = \$ 746$.

-
- (1) 288 m hrs at \$2.25/hr to load 6 cars ; 18 m hrs at \$2.75/hr lining cars with paper and shoring.
 (2) 96 hrs of fork lift time at \$1.50/hr*; 48 hrs of truck time at \$4.77/hr*.
 (3) Paper for lining and lumber for shoring.
 .* See Appendix 1.

Summary of F. Y. 1955 Cost at
KNCLLS ATOMIC POWER LABORATORY

Liquid Waste Costs.

		Fiscal Year 1955	
	<u>Man hrs.</u>	<u>Labor Costs</u>	<u>Total Costs</u>
Collection, etc.	300	\$ 600	\$ 5,390
Concentration	7,150	14,520	60,900
Packaging	42	90	1,140
Long term storage	36	90	5,090
Release to environment	<u>603</u>	<u>5,500</u>	<u>13,270</u>
Sub totals	8,131	\$16,730	\$78,240
Overhead			<u>16,730</u>
Total (liquid waste)			\$94,970

Solid Waste Costs.

Collection, etc. (low level)	1,846	\$ 3,710	\$ 7,910
Collection, etc. (high level)	150	300	2,900
Concentration	1,056	2,110	5,170
Packaging	2,542	6,130	17,840
Loading and Shipping (LOSA)	284	660	3,480
Loading and Shipping (ORNL)	<u>306</u>	<u>700</u>	<u>6,216</u>
Sub totals	6,184	\$13,620	\$43,516
Overhead			<u>13,620</u>
Total (solid wastes)			\$57,136

LOS ALAMOS SCIENTIFIC LABORATORY

Los Alamos, New Mexico

LIQUID WASTES

Collection and Temporary Storage Operations.

The Los Alamos installation, comprised of an assortment of research laboratories, is spread out over a large area of a gully marked plateau. As a result of the great spaces between research units there are three waste treatment plants serving four separate areas. Almost all of the liquid wastes are piped to the treatment plants herein referred to as plants A, B and C.

The principal contaminant in the liquid wastes is plutonium, (an alpha emitter) consequently external radiation is not much of a hazard. The wastes which go to plant A, the largest of the three plants, are accumulated in ten 5,000 gallon reinforced concrete holding tanks at the area producing the wastes. Monitoring in these 5,000 gallon holdup tanks is the responsibility of the waste producers. Tankfuls are sampled and analysed for activity (fissionable material content). If the liquids are within the established discard levels, they are discharged to the plant A drain system. Liquids over tolerance are returned to the waste producer for recovery of the fissionable material.

A neutralizing station in the outfall line which has two 20,000 gallon basins, automatically neutralizes and volumetrically measures wastes going to plant A. Waste treatment plant personnel maintain this neutralizing station.

Wastes which go to plant B are first caught in a hold-up system consisting of one 1,000 gallon tank, one 500 gallon stainless steel tank and four brick sumps equipped with automatic samplers. Wastes are analysed prior to release from the tanks. The sumps with samplers provide a record of the volume and characteristics of the wastes pumped. Here too, monitoring and measuring in the hold-up system is the responsibility of the waste producers and not the wastes processors.

Plant C is a limited capacity, special purpose, ion exchange unit which is situated at a remote facility. Four, 50,000 gallon tanks provide considerable time for radioactive decay. Monitoring for radioactivity is also performed here.

Collection and Temporary Storage Costs.

No data was furnished relative to the operational and maintenance labor involved in the hold-up and monitoring systems. At Los Alamos it is felt that these are costs which are applicable to lab operations and not to waste disposal operations because they measure the amount of plutonium primarily, waste volume secondarily.

All that can be listed here is the capital investment costs of the hold-up systems. The neutralizing station is properly a part of the treatment facilities.

Jan-Dec.
1954 Costs

1. Labor Not furn.
2. Capital Investment - Depreciation

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
Plant A - (10) 5000 gal. rein- system forced concrete tanks	\$37,500	10%	\$3,750
Plant B - (1) 1000 gal s/s tank system (1) 500 gal s/s tank (4) sumps with samplers	\$21,250	10%	<u>2,120</u>
	Sub total		\$5,870

Total quantity handled - see Concentration Section.

Concentration Operations.

The waste treatment processes at both plants A and B are similar to methods used in a conventional water treatment plant, i.e., chemical coagulation, sedimentation and sand filtration. They differ from conventional plants, however, in that the settled floc

or sludge is radioactive and is not discharged directly to the environment, nor is the filter back wash liquid discharged.

Wastes which come to plant A are neutralized en route and are received in quaternary 10,000 gallon reinforced concrete tanks at the plant. These tanks serve to level out flow fluctuations as well as provide storage space for overnight and weekend flows when the plant is not being operated. The wastes flow in turn through flocculators, where chemicals are added, to the settling tanks and then to the rapid sand filters. Effluent from the filters is collected in two 15,000 gallon concrete tanks from where samples are taken. Analysis of the samples determines the radioisotopic concentration. If within tolerance, the treated liquid is discharged into an adjacent gully. Back wash water from the filters is collected in a 4,000 gallon concrete tank and then pumped back to the influent holding tanks. Settled floc or sludge from the sedimentation basins is piped to a sludge tank where further sedimentation and concentration is effected. Sludge is dewatered on vacuum filters employing a diatomaceous earth filter aid cover over the drum. The dewatered sludge is packaged in used oil drums and taken to the solid waste burial facility.

At plant B the pH of the influent is measured by an automatic device as the liquid flows to two 13,000 gallon, steel accumulating standpipes. Caustic neutralization is applied to acid wastes when necessary. B plant's equipment is of a smaller scale and different style than A plant's, but the resulting treatment is the same. The filter effluent is caught in two other 13,000 gallon standpipes where

it is sampled and analysed. If within tolerance it is released to a dry gully; if over tolerance it is rerun through the treatment process. In addition to the conventional treatment equipped there is a 1,200 gallon, stainless steel, hopper bottomed tank for processing wastes which would upset the regular treatment process. Sludge from plant B's processes is hauled to plant A in a 250 gallon tank mounted on a two wheeled trailer.

Plant C is a small special purpose ion exchange treatment unit for water contaminated with strontium 90 and other short-lived materials. Before passing through the ion exchangers the liquids are accumulated and detained in four 50,000 gallon concrete basins operated in series. Their purpose is to provide time for decay of the radioisotopes in the waste. The treated effluent is discharged to an adjacent gully after appropriate monitoring. The ion exchange unit had not been operated long enough to get cost data to report upon.

Unit costs of waste treatment at Los Alamos are low because laboratory research is combined with the operation of the waste treatment plants. Treatment plant personnel have a dual function; they work in the treatment plant and in the lab research program. Since the waste treatment plants are not operated full time, only that time of the operators spent in plant operation is charged to plant operations; the remainder is charged to research.

Concentration Costs. Plant A (WD-2)

	<u>Man hrs</u>	<u>1954 Costs</u>
1. Labor		
a. operation		\$10,900 ⁽¹⁾
b. maintenance ⁽²⁾		17,750
c. analytic		4,500
2. Materials ⁽³⁾		20,000
3. Utilities ⁽⁴⁾		4,850
4. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
Neutralizing station	\$ 50,000	10%
Treatment plant bldg. ⁽⁵⁾	35,000	10%
Treatment equipment	165,000	20%
		<u>33,000</u>
	Total	\$99,500

Total flow to the plant in 1954 - 10,700,000 gallons.

Total filter cake produced - 33,200 gallons approx.

Unit Cost = $\frac{\$99,500}{10,700,000}$ = \$0.0093 per gallon.

-
- (1) Only that portion of operators time actually spent in plant operation - includes supervision.
 - (2) The recorded costs are \$35,500 - here equally divided between labor and mat.
 - (3) Operating chemicals \$2,250 plus \$17,750 maint. matls. from (2).
 - (4) Reported as \$6,050 approx.; which includes telephone, water, electric and rent (L.A. method of charging property). Herein \$100/mo. or \$1200 is subtracted for the latter charge.
 - (5) The total cost of the building and equipment was about \$350,000. The figure of 35,000 represents an estimate for the cost of that portion of the building housing the treatment equipment.

Concentration Costs -- Plant B - (D P W).

	<u>Man hrs</u>	<u>1954 Costs</u>
1. Labor ⁽¹⁾		
a. operating		\$ 8,100
b. maintenance ⁽²⁾		1,050
c. analytic		3,960
2. Materials ⁽³⁾		1,870
3. Utilities		2,400
4. Equipment ^{(4)*}		150
5. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
Treatment Plant Bldg.	\$14,300	10%
Treatment Equipment	91,900	20%
		<u>18,380</u>
		Total \$37,340

Total flow to plant during 1954 - 3,200,000 gallons - approx.

Wet Sludge hauled to plant A - 30,200 gallons

$$\text{Unit Cost} = \frac{37,340}{3,200,000} = \$0.012 \text{ per gallon}$$

-
- (1) Only that portion of operators time actually spent in plant operations; includes supervision.
- (2) The recorded costs are \$2,100 approx.; here equally divided between lab. and mat.
- (3) Operation chemicals - \$820 plus \$1,050 for maintenance materials (from⁽³⁾).
- (4) Truck to haul trailer tank of sludge to plant A - 100 hrs at \$1.50/hr.* based on 2 m hrs/trip - 2 trips per week.
- * See Appendix 1.
- ** Author estimate.

Release to Environment.

Wastes from a protective clothing laundry are discharged untreated to a seepage bed adjoining the laundry site. The seepage bed is an excavated hole in the ground filled with boulders and gravel and topped with sand. Approximately 2,000,000 gallons per year are sent to this fenced off pit to either evaporate or percolate into the soil.

Treated effluents of plants A, B, and C are discharged to adjacent canyons or gullies which drain surface runoff away from the Los Alamos site. Wastes streams disappear into coarse stream bed sand within several miles of their points of discharge. A regular monitoring program has been established to determine effects of waste disposal on the environment. Soil samples of the stream bed as well as water samples from six test wells and eleven producing wells are collected and analysed periodically.

The six test wells, ranging in depths from 120 ft. to 1200 ft. were drilled for the purpose of detecting radioactive contamination of the ground water by wastes. The cost of these wells has not been reported, consequently no data can be presented in this regard. The only information given was that \$15,000 was budgeted for the environmental program.

LOS ALAMOS SCIENTIFIC LABORATORY

Los Alamos, New Mexico

SOLID WASTES

Collection Operations.

The waste handling and burial operations at Los Alamos may be likened to a regular municipal trash collection and disposal operation. The wastes are picked up by a regular collection crew on a routine basis and taken to one central location where they are buried by a method similar to a municipality's sanitary landfill.

In the working areas wastes are accumulated in polyethylene bags inside garbage cans. When full, the ends of these bags are tied and the bags are packed in 2 cu. ft. cardboard cartons by operating personnel or by the janitorial staff. On the average two bags of wastes make up a boxful. The box is then sealed with 2 inch masking tape and taken to a designated collection station. Items which are too large for the bag and box treatment are wrapped or packaged individually. Sometimes these large items are wrapped with tape or if they are considered hazardous they may be packed in wooden boxes built to fit.

As with liquid wastes, the principal contaminant is plutonium. External radiation is not much of a hazard, consequently heavy shielding is not involved. The major concern is one of preventing ingestion, which is the reason for the double packaging. Workmen handling wastes wear protective clothing and gas masks.

No sorting of wastes is attempted; combustible and non combustible materials are packaged and handled together. Small quantities of liquids from bench type operations are packaged in vials, bottles and cans of various sizes and are handled along with solid wastes and sludges.

A truck driver and helper using a $2\frac{1}{2}$ Ton stake truck collect wastes from the producing areas. A health physics man together with his monitoring equipment and vehicle, accompanies and supervises the collection crew.

Collection Costs.

	<u>Man hrs</u>	<u>Cal. Year 1954 Costs</u>
1. Labor		
a. Collection crew ⁽¹⁾	4000	\$ 8,130
b. health physics	2000	4,680
2. Equipment ⁽²⁾		4,620
3. Materials ⁽³⁾		13,300
4. Misc. ⁽⁴⁾		<u>1,300</u>
	Total	\$32,030

Waste Volume handles - 58,000 cu. ft. solids
4,400 cu. ft. sludge

Total 62,400 cu. ft. (gross)

Unit Cost = $\frac{\$32,030}{62,400} = \0.51 per cu. ft.

-
- (1) Based on \$948/mo. including 40% O.H. or \$677/mo. less O.H.
 (2) Charges for truck and sedan \$385/mo. - includes oil, gas, maintenance.
 (3) 29,000 boxes at \$0.21 each; 58,000 polyethylene bags at \$83/1000; 87,000 yds tape at \$.0276/yd.
 (4) Laundry service - estimated* at \$2/man/wk (2 uniforms/day); construction of large wood boxes - estimated* to be \$1000.
 * Author estimate.

Land Disposal.

Five distinct areas have been used for radioactive waste burial at Los Alamos; only one is currently in use. Each area is fenced off with 8 feet high cyclone type fencing. In all about 12,000 ft. of fence have been used. The current burial area measures about 10 acres.

In this mountainous region, tuff is the predominant surface cover and in places extends down to about 1500 ft. to 2000 ft. (Tuff is a porous rock, usually stratified, formed by consolidation of volcanic ashes and dust.) Burial sites are selected in consultation with geologists of the U.S.G.S. stationed at Los Alamos. Ground waters travel through the most permeable portion of the sub strata at a rate of about 300 ft. per year. Offsite downstream users are many miles away. Experimental evidence indicates that the tuff is effective in absorbing and retaining plutonium, the most hazardous isotope.

Burial of wastes is not complicated. A very large hole is scooped out of the earth surface by bulldozers. Trucks are driven into the hole, their wastes unloaded and then driven out. There is a certain degree of classification in placing wastes in the hole in that large items are kept separate from small items. When a half acre or so of the bottom area of the hole is covered with a layer of wastes, a bulldozer covers the wastes with a layer of dirt about 2 to 3 feet thick.

The hole being filled at the time of this survey was dug in a hillside. It was a large hole, amounting to about 1,160,000 cu. ft. of excavation. Rectangular in shape, it measured approximately 500 ft. long by 100 ft. wide and had an average depth of 20 ft. The ends of the hole were sloped so that trucks could be driven in and out. It was made large especially to accomodate a rather large (25,000 sq. ft.) contaminated frame building which was razed. Several boxes, 6 ft. x 6 ft. x 10 ft., each and an old two ton truck are among other large items buried in this hole.

Cost accounting for the operation is more complex than the actual operation. The hole itself was dug under a sub contract for about \$22,000. The equipment, i.e., the collection truck, sedan and bulldozer are rented from the Zia corporation, which in charging includes it's overhead in the rental charges. The waste collection crew and bulldozer operator are also supplied by Zia. The University of California, the contractor operator of Los Alamos, supplies engineering and health physics supervision. Overhead charges made by Zia are not included in the costs listed in this report.

The 25,000 square foot building was razed and trucked to burial also under a sub contract for about \$5 per square foot. Obviously this effects the average unit cost of burying waste as practised at Los Alamos.

Land Disposal Costs.

	<u>Man hrs</u>	<u>Cal. Year 1954 Costs</u>
1. Labor		
a. recurring ⁽¹⁾	270	\$ 810
b. excavation ⁽²⁾	447	1,340
2. Equipment		
a. recurring ⁽³⁾		3,600
b. excavation ⁽⁴⁾		800
3. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
4400 ft. fence	\$24,200	10%
		<u>2,420</u>
	Total	\$8,970

Volume of wastes buried = 58,000 cu. ft. - trash
during cal. year 1954. 4,400 cu. ft. - sludge

62,400 cu. ft. recurring
250,000 cu. ft. special job

312,400 cu. ft.

Unit Costs = $\frac{\$8,970}{62,400} = \0.14 per cu. ft.

-
- (1) Monthly charge (without overhead) for bulldozer operator is \$76 (rate of \$3/hr.)
- (2) Charge for digging large hole was \$21,775 which includes 8% G and A overhead. Without G and A the charge was \$20,160. Of this, \$6,000 charged for equipment leaving \$14,160 for labor which includes 40% overhead. Labor costs without overhead were \$10,120. The proportionate costs for 1954, assuming the hole to be 2/3 full are $\frac{2}{3} (10,120) = \$6,740$. This amounts to a cost/cu. ft. of $\$6,740 \div 312,400$ or \$0.0215 per cu. ft. of waste. Excavation costs are then \$0.0215 (62,400) or \$1340.
- (3) Monthly charge for bulldozer = \$300.
- (4) \$6,000 equipment charge for digging hole. Following same reasoning as (2) above the excavation costs are - $\frac{2}{3} (6000) \times \frac{62,400}{312,400}$ or \$800.

Summary of F. Y. 1955 Costs at
LOS ALAMOS SCIENTIFIC LABORATORY

Liquid Waste Costs.

	<u>Man hrs</u>	<u>Labor Costs</u>	<u>Total Costs</u>
Collection (depreciation only)			\$ 5,870
Concentration (plant A)		\$33,150	99,500
Concentration (plant B)		<u>13,110</u>	<u>37,340</u>
Sub totals		\$46,260	\$142,710
Overhead			<u>46,260</u>
Total (liquid waste)			\$188,970

Solid Waste Costs.

Collection	6000	\$12,810	\$ 32,030
Land Burial	<u>717</u>	<u>2,150</u>	<u>8,970</u>
Sub totals	6717	\$14,960	\$ 41,000
Overhead			<u>14,960</u>
Total (solid waste)			\$ 55,960

NATIONAL REACTOR TESTING STATION

Arco, Idaho

LIQUID WASTES

Handling of Radioactive Liquid Wastes.

Radioactive wastes originate at several different places on the 650 square mile NRTS site. The Chemical Processing Plant, whose primary function is to process reactor fuel elements, by far produces the bulk of the waste radioactivity. Other facilities producing wastes with a lesser degree of activity are the several experimental reactors in operation at NRTS. Each facility is separated from the others by a distance of several miles. Each facility is surrounded by a fence within which the contractor assumes responsibility for radioactive materials and wastes except for those amounts of activity which can be released to the environment. AEC establishes tolerances for radioisotope releases. Outside perimeter fences the AEC has responsibility for the wastes. In this report on costs attention will be centered on the Chemical Processing Plant Operations.

Essentially there are two kinds of liquid wastes at the Chemical Processing Plant: high level wastes and low level wastes. Both are associated with the separation of fission products from irradiated reactor fuel elements. Fission product separations are accomplished in several cycles of chemical processing. These separations result in high level wastes. Low level wastes result from processing high level wastes and from associated analytical and clean up operations.

High level wastes: The first cycle raffinate from fission product separation is not considered a waste at C.P.P. until after it is concentrated to about 150 curies per gallon and pumped to an 18,250 gallon, stainless steel temporary storage tank. Prior to this stage, the waste is considered a part of the materials processing operation. When the liquid in the tank approaches the full level, the actual volume of liquid and its radioactivity are measured. The liquid is then jetted to one of several 318,000 gallon underground storage tanks for more permanent storage. These underground tanks are equipped with cooling coils to dissipate thermal heat.

Second and third cycle raffinates are also considered wastes only after they are concentrated to about 1.5 and 0.002 curies per gallon respectively. These concentrated liquids are pumped to another 18,250 gallon temporary storage tank where they are accumulated along with evaporator concentrates from evaporation of a low level waste stream. When this tank is nearly full the radioactivity and liquid volume are measured and the wastes are then jetted to another 318,000 gallon underground storage tank for long term storage. Wastes in this tank average less than a curie per gallon initially.

Low level wastes: There are two, low level liquid waste streams associated with the chemical separations processes. At C.P.P. they are called the Process Equipment Wastes (PEW) and the Cell Floor Drain Wastes (CFD). The PEW stream includes; condensates from evaporation of first, second and third cycle wastes from fission product separation processes; wastes from the "hot" lab sinks and from floor drains

in the separations area. These wastes are collected in two, 4000 gallon stainless steel tanks. Samples are taken from the collection tanks when about full and analysed for radioactivity and pH. The wastes are then pumped to an 18,250 gallon evaporator feed tank from where they are fed to the PEW evaporator. Volume reduction achieved by evaporation is about 70 to 1. Condensate goes to two, 4,000 gallon, stainless steel, condensate receiving tanks where it is sampled to ascertain activity level. If within tolerance it is discharged to a monitoring station and subsequently to an underground disposal well. If over tolerance it is recycled through the evaporator. Evaporator concentrate is mixed with second and third cycle separation wastes.

Cell Floor Drain wastes are liquids from "cold" lab sinks and condensate from the final product evaporator. These wastes are collected in two, 4000 gallon stainless steel tanks. Samples are taken for analysis when a tank is nearly full. If the sample analysis shows the tankful of waste to contain more than 100 millicuries of activity the waste is pumped to the PEW evaporator feed tank. If the activity is less than 100 millicuries the wastes go to a monitoring station and then to the deep well where they are released underground.

No cost data was furnished relative to the operations with the high level wastes except for capital investment in long term, underground storage tanks.

Some data pertaining to the overall costs of handling low level liquid wastes was furnished. These costs were not broken down as to labor and materials. All the direct costs of the low level wastes

processing system, collection, sampling, evaporation, monitoring and deep well disposal are included.

Overall Costs of Low Level Waste System.

	<u>6 Month Costs</u>	<u>12 Month Costs</u>
1. Labor and Materials		
a. analytical	\$ 7,770	\$15,540
b. maintenance	9,430	18,860
c. operating.	20,000	40,000
2. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
a. Pipe lines, pumps, holding tanks and appurtenances	\$ 435,400	10%
b. Waste processing building	1,028,200	10%
c. Evaporators and Appurtenances	1,230,300	10%
d. Piping and Monitoring station	164,400	10%
e. Disposal Well	13,245	5%
		<u>660</u>
	Total	\$360,890

Total volume low level wastes handled during the 6 month period are:

483,500 gallons (CFD)
187,200 gallons (PEW)

Total 670,700 gallons

Volume to evaporator - 252,400 gallons.

Concentrate from evaporator 3,565 gallons.

Condensate from evaporator 312,000 gallons.

Long Term Storage Costs.

No data was furnished regarding the labor and materials involved in operating and maintaining the tank form, consequently all that can be given is the construction costs of the five 318,000 gallon underground storage tanks.

Cost of (5) 318,000 gallon tanks = \$3,701,000.

Cost per gallon capacity = \$2.30/gallon.

NATIONAL REACTOR TESTING STATION

Arco, Idaho

SOLID WASTES

Collection Operations.

Radioactive solid wastes evolve from operations of reactors and from chemical processing of reactor fuel elements. Radioactivity is due to fission products and for the most part is beta-gamma activity. The bulk of the wastes is low level, but there are some high level wastes which receive special consideration in handling.

In some of the working areas wastes are accumulated in cardboard cartons held in place by specially built steel frames having hinged lids. When a carton is full it is removed from the steel frame, sealed with masking tape and taken to a pickup station. In other areas wastes accumulate in 32 gallon galvanized iron garbage cans lined with polyethylene bags. When full the can and bag liner are taken to a pickup station. Wastes are routinely collected from the pickup stations by a crew of three using a government owned, contractor operated, closed van. At certain times when operating or processing equipment is being overhauled or modified a sizeable quantity of low level and "suspect" wastes are taken to the burial site in dump trucks. Over fiscal year 1955 ninety such loads were hauled.

High level solid wastes receive special consideration in handling. High level wastes to be disposed of at any one time are generally small

in volume and weight. They are usually carried to the burial site on a special two wheeled trailer. This trailer has a 20 ft. long tongue which affords air shielding for the driver. The trailer is normally pulled by a pickup truck. Each load of high level wastes is conveyed by a health physics representative in another vehicle. He evaluates personnel hazards and supervises the transfer to burial.

Collection Cost - Low Level Wastes.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	1146	\$2,580
2. Equipment ⁽²⁾		2,600
3. Materials ⁽³⁾		<u>1,100</u>
	Total	\$6,280

Total Volumes Trucked⁽⁴⁾ - 27,000 cu. ft. gross

Unit Cost = $\frac{6,280}{27,000}$ = \$0.23 per cu. ft.

-
- (1) \$90/mo. - labor for trucking C.P.P. wastes; \$90/mo. for trucking labor for other packaged wastes; plus 93 dumptruck loads at 2 m hrs/load and \$2.25/m hr.
- (2) \$90/mo. truck for C.P.P. wastes; \$90/mo. truck for other packaged wastes; plus 93 dump truck loads x 2 hrs/load x \$2.36/hr.*
- (3) 1320 boxes at \$0.23 each; 1392 polyethylene bags at \$0.27 each; plus 100** G.I. cans at \$3.50 each; masking tape 2 yds/box at \$.75/25 yds.
- (4) $1318 \times 12 = 15816$; $1392 \times \frac{32}{7.5} = 5940$; $93 \times 2 \times 27 = 5020$

* See Appendix 1.

** Author estimate.

Collection Costs - High Level Wastes.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	150	\$375
2. Equipment ⁽²⁾		<u>225</u>
	Total	\$600

Total volume wastes collected 230 cu. ft. gross.

Unit Cost = $\frac{\$600}{230} = \2.60 per cu. ft.

-
- (1) The average labor rate is \$2.50/hr.
 (2) 75 hrs of pickup truck time and 75 hrs of sedan time - both at \$1.50/hr*.
 * See Appendix 1.

Land Disposal Operations.

The burial area is a fenced off plot of ground approximately 13 acres in size. It is centrally located with respect to the several operating facilities. Soil in the region is predominately lava and is quite thick, going down hundreds of feet in some areas. The water table is down at about the 300 ft. level.

Burial trenches are dug within the enclosure by an excavation subcontractor. A backhoe excavated trench is about 1000 ft. long by 6 ft. wide by 15 ft. deep. These trenches are filled to the top with wastes. A dirt cover is bulldozed over the wastes and compacted by NRTS personnel. Hazardous high level wastes are covered with a layer of dirt at the time they are placed in the trench.

Land Disposal Costs.

Actual costs of digging the trenches used for burial was not available. However, it is known that these costs were about average for the area, i.e., about \$1.10 per cubic yard. All or parts of several trenches were used, hence the devious method of calculating the excavation costs. The volume of one trench and the amount of waste which went into it is known. These quantities were $970 \times 16 \times 15$ or 87,000 cubic feet of hole and 26,000 cubic feet of wastes respectively. This gives a ratio of 3.35 cu. ft. of hole per cu. ft. of waste. During fiscal year 1955, 27,230 cu. ft. of NRTS wastes and 44,000 cu. ft. of Rocky Flats wastes were buried. This total volume of waste required $3.35 (27,230 + 44,000)$ or 239,000 cu. ft. of trench hole.

NRTS

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor		
a. recurring ⁽¹⁾	200	\$ 500
b. excavation ⁽²⁾	1940	4,850
2. Equipment		
a. recurring ⁽³⁾		1,200
b. excavation ⁽²⁾		4,850
3. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
13,000 ft. roadway	\$17,700	10%
3,300 ft. fencing	2,500	10%
		<u>1,770</u>
		<u>250</u>
	Total	\$13,420
Charges to Rocky Flats		<u>3,520 cr.</u>
	NRTS Cost	\$ 9,900

Total Volume (NRTS) wastes buried - 27,230 cu. ft.

Unit Cost = $\frac{\$9,900}{27,230}$ = \$0.36 per cu. ft.

-
- (1) Bulldozer operator in backfill operation - 4 m hrs/wk at \$2.50/hr.
 (2) 239,000 cu. ft. of excavation at \$1.10/cu. yd. = \$9,700. Assuming this is divided equally between labor and equipment.
 (3) Bulldozer - 4 hrs/wk at \$6/hr*.

* See Appendix 1.

Summary of F. Y. 1955 Costs at
NATIONAL REACTOR TESTING STATION

Liquid Waste Costs.

	<u>Man hrs</u>	<u>Labor Costs</u>	Fiscal Year 1955 <u>Total Costs</u>
Low Level System	?	?	\$360,890
Overhead			<u>?</u>
		Tptal	\$

Solid Waste Costs.

Collection (low level)	1146	\$2,580	\$ 6,280
Collection (high level)	150	375	600
Burial	<u>2140</u>	<u>5,350</u>	<u>13,420</u>
Sub totals	3436	\$8,305	\$ 20,300
Overhead			+ 8,305
Credit - Charge to Rocky Flats.			<u>- 3,520</u>
		Total	\$ 25,085

OAK RIDGE NATIONAL LABORATORY

Oak Ridge, Tenn.

LIQUID WASTES

Collection and Disposal Operations.

There are essentially three liquid waste systems in use at ORNL, a) for reactor fuel processing wastes, b) for relatively high level lab wastes and c) for low level wastes.

Reactor fuel processing wastes, when they are produced, are ejected to underground storage tanks. During fiscal year 1955 little, if any, of this kind of waste was produced. Storage tanks that were used for this purpose in the past still contain the wastes that were put in them. These wastes are being held for possible recovery of the fissionable materials they contain.

High level lab wastes (10^{-4} curies/liter) follow a less direct route to their ultimate repository. In the working areas these wastes are dumped into "hot" sinks which drain into holding tanks. There are about 14 of these temporary storage tanks scattered around the area. They are made of stainless steel and vary in size from 500 to 2000 gallons. Although these tanks are equipped with automatic sampling devices, samples are not ordinarily taken from them. The tanks are used mostly for temporary storage to allow radioactive decay. From these tanks the wastes are pumped to three 17,000 gallon reinforced concrete tanks at a central location. Samples

are taken from the large tanks primarily to check the pH. Caustic is added when necessary to neutralize acid wastes.

About every two weeks wastes are pumped from the large tanks to a scooped out earthen pit located about a mile away. This trial pit, or lagoon as it is called at Oak Ridge, is situated in a formation of Conosauga Shale and is remote from lab activities. Construction of the lagoon consisted simply of scooping out a hole in the ground with a bulldozer. The basin is ringed with a series of bored wells which are intended to detect seepage from the basin.

After a lagoon is filled with waste liquid, it is fenced off and a new pit initiated. Two lagoons have been filled in several years of operation and a third is being filled. The first lagoon had a capacity of 200,000 gallons and all of the latter ones had capacities of 1,000,000 gallons.

Collection and Disposal Costs - Relatively High Level Wastes ⁽¹⁾

	<u>Man hours</u>	<u>F.Y. 55 Costs</u>
1. Labor		
a. operating ⁽²⁾	6250	\$15,550
b. analytical ⁽³⁾	5000	11,250
c. health physics	2600	6,500*
d. maintenance	7200	18,000
2. Materials ⁽⁴⁾		8,000
3. Utilities ⁽⁵⁾		4,000**
4. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
(14) 1500 gal.(av) s/s tanks	\$21,000**	10%
(3) 170,000 gal. concrete tanks	60,000	10%
(1) Million gal. earthen basin	14,000	100%
		<u>14,000*</u>
	Total	\$85,400

Total quantity handled - approximately - 1,000,000 gallons

Unit Cost = $\frac{\$85,400}{1,000,000}$ = \$0.085 per gallon.

-
- (1) Labor and material costs, which were available, were arbitrarily divided all down the line, two-thirds to high level, and one-third to low level. Any individual item may be considerably incorrect.
- (2) 4250 m hrs at \$2.25/hr direct labor taking samples, pumping etc.;
2000 m hrs at \$3.00/hr supervision
- (3) 5000 m hrs at 2.25/hr analysing samples.
- (4) Operating materials - \$2,200 plus maintenance materials \$5,800.
- (5) Electricity for pumping, etc.
- * A considerable amount of time and effort was expended for hydrologic and geologic exploration and follow-up. This is done as research and the annual costs which are not included here were approximately \$3700 for wells and cores, and \$15,000 for radiologging, sampling the wells, and analysis of the samples.
- ** Author's estimate.

Low level radioactive liquid wastes from laboratories and areas working with radioisotopes are dumped into sewers which eventually drain to the low point of the ORNL. Non-radioactive lab wastes and storm water also flow in this sewer system. Seven monitoring stations equipped with proportional samplers are strategically located on the sewer network. At the sewer outfall the waste flows through a diversion box into a million gallon detention basin. Samples are taken every 4 hours at the diversion box and analysed for beta activity. If a sample count increases greatly over the previous count then samples are collected back along the system of 7 monitoring stations to try to find and alter the reason for the high count.

From the detention basin the liquids flow into White Oak Creek which incidentally is impounded at a downstream point. White Oak Creek drains into the Clinch River which drains into the Tennessee River. By an ambitious area monitoring program periodic checks are made of the radioactivity accumulations and effects on the creek and river system. ORNL has established a tolerable discharge level of an average of 5 curies per day. There are certain restrictions pertaining to build up which could reduce this quantity should the situation become undesirable.

Collection and Disposal Costs - Low Level Liquids.⁽¹⁾

	<u>Man Hours</u>	<u>F.Y. 55 Costs</u>
1. Labor		
a. operating ⁽²⁾	2117	\$ 5,260
b. analytical	1700	3,800
c. health physics	900	2,250
d. maintenance	2500	6,250
2. Materials ⁽³⁾		2,750
3. Utilities ⁽⁴⁾		1,550*
4. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
(7) monitoring stations	\$8,400	20%
		<u>1,680</u>
	Total	\$23,540

Total quantity handled - approximately - 158,500,000 gallons

Unit Cost is meaningless because the divisor includes non-radioactive wastes.

-
- (1) Labor and material costs, which were available, were arbitrarily divided, all down the line, two-thirds to high level and one-third to low level. Any individual item may be considerably incorrect.
- (2) 1450 m hrs at \$2.25/hr direct labor taking samples, pumping, etc.;
667 m hrs at \$3.00/hr supervision;
- (3) Operating materials - \$750; maintenance materials - \$2,000.
- (4) Electricity for pumping, etc.
- * Author estimate.

OAK RIDGE NATIONAL LABORATORY

Oak Ridge, Tennessee

SOLID WASTESCollection and Handling Operations.

There are three separate waste producers at the Oak Ridge installation, namely, the Oak Ridge National Laboratory (ORNL), the Gaseous Diffusion Plant (K-25) and the Electromagnetic Plant (Y-12). Each collects and handles it's own radioactive wastes. ORNL operates a waste burial ground and charges the others for burying their wastes. ORNL also handles and buries radioactive wastes from other installations around the country.

ORNL Collection Operations. The wastes of the ORNL are varied; they evolve from all kinds of laboratory research and from isotopes production. In the working areas wastes accumulate in cardboard boxes, cylindrical ice cream cartons and polyethylene bag lined, 32 gallon garbage cans. The latter are most prevalent. Wastes below 7 mr/hr are transferred at about 20 pickup stations to Dempster Dumpster pans. Wastes with higher radiation levels are taken to any of 7 pickup stations each having 15 to 20 (32 gallon) G.I. cans. Health Physics personnel survey the dumpster pans and the G.I. cans and if any are found to be over 7 mr/hr they are tagged. In picking up, the collectors must limit their contact time with the tagged containers.

ORNL has 6 dump trucks and 2 Dumpster tractors for handling radioactive materials. However, only one dump truck and one Dumpster tractor are used in radioactive waste collections. The other Dumpster is used for non radioactive trash collection. One of the dump trucks is used in carrying contaminated, surplus process equipment to a salvage yard for possible future recovery. The other dump trucks are used for transferring various radioactive materials within the ORNL area.

A truck driver and two helpers on a routine daily basis spend about 4 hrs per day picking up G.I. cans of wastes with a dump truck. One Dumpster operator works full time hauling dumpster pans of wastes to the burial ground.

K-25 and Y-12 Collection Operations. The K-25 and Y-12 operations maintain their own collection crews. The only information made available regarding these operations was the number of truck loads of wastes hauled to ORNL burial and in the case of Y-12 the average cost of collecting and hauling per truckload.

Collection and Handling Costs.

	<u>Man hrs</u>	<u>6 Mo. Costs</u>
1. Labor ⁽¹⁾	5338	\$10,800
2. Equipment ⁽²⁾		6,700
3. Materials ⁽³⁾		1,000**
4. Utilities ⁽⁴⁾		<u>720**</u>
Total		\$19,220

Gross Volumes of wastes collected: in the 6 months

ORNL	22,650 cu. ft.
Y-12	32,000 cu. ft.
K-25	<u>3,550</u> cu. ft.
Total	58,200 cu. ft.

Unit Cost = $\frac{\$19,220}{58,200} = \0.33 per cu. ft.

-
- (1) ORNL dumpster driver - 2000 m hrs/yr at \$2.25/hr and truck driver at \$2.25/hr and 2 helpers at \$2.00/hr 8 hrs/day picking up GI cans; Y-12 reports approximately 295 truck loads in 6 months at \$9.57 per load for labor (estimated** 4 m hrs/load). K-25 sent 79 truck loads in the 6 months period. Estimated** 2 m hrs/load at \$2.40/m hr.
- (2) ORNL Dumpster - 1000 hrs; Truck 500 hrs; Y-12 truck - 4 hrs/load* = 1180 hrs. K-25 truck - 2 hrs/load* = 158 hrs. Total 2838 hrs at \$2.36/hr.
- (3) Polyethylene bags, ice cream cartons, G.I. cans, and cardboard boxes.
- (4) 3 telephones at \$10/month each; heat \$5.00 each of 3 places ORNL, K-25, Y-12; electric \$5/month for same places.
- * See Appendix 1.
- ** Author estimate.

Land Disposal Operations.

The Oak Ridge National Laboratory operates and maintains a land burial service for radioactive wastes. Radioactive solid wastes from the Oak Ridge operations as well as wastes from other installations are buried. Prior to 1953, three separate burial sites comprising about 25 acres have been dedicated to hold radioactive materials. The fourth burial site, started about 1953 has been extended 3 or 4 times; it now covers or will cover about 24 acres.

Parts of the hilly country of East Tennessee are fairly adaptable to land burial operations. The upper stratum of earth consists of clays and loose shale underlain by more consolidated shales and rock sections. The burial sites are selected by a geologist. Limestone formations are avoided as much as possible as are areas over or near geologic faults. Because the land is hilly (marked with valleys) it is not difficult to check for radioactivity leached out into overland runoff. The clays of the burial stratum are rather impervious causing a retarded subsurface water movement. The clays also have an affinity for adsorbing certain radioisotopes.

Burial is accomplished by excavating trenches and pits, inserting the wastes and covering them with dirt. The procedure is straight forward. One man operates the burial ground, excavating holes, routing truck loads of wastes and backfilling the waste filled holes. A $1\frac{1}{2}$ cubic yard back hoe is used to excavate both long trenches and square pits. Trenches which measure about 200 ft. long x 8 ft. wide x 16 ft. deep receive beta and gamma contaminated wastes. Square pits which

measure about 15 ft. x 10 ft. x 14 ft. deep receive alpha contaminated wastes. Truck loads of wastes are backed up to the excavations and the wastes dumped right into the holes. When a hole is full the back hoe is used to tamp the material down about 3 ft. The trenches are then backfilled with dirt by a bulldozer and graded over about 2 ft. higher than original grade. The alpha wastes alternately receive covers of dirt, concrete and another finish layer of dirt.

Unloading wastes collected in G.I. cans entails emptying the cans into the hole. Some producers send their waste in 55 gallon drums. These are dumped, in toto, into the trench. When railroad carloads come in from Argonne or Knolls, the wastes are hauled about 9 miles from the railhead to the burial area in ORNL dump trucks.

For this service of hauling and burying wastes of others, including K-25 and Y-12, ORNL charges for the labor, equipment and materials involved in handling these particular wastes. Because of this the cost picture of the ORNL burial operation is rather complex and difficult to present. An indication is had of what ORNL charges the outsiders for the burial service but this includes costs for an unknown* quantity of labor, equipment, time and material involved in hauling to the burial site as well as the actual burying. Therefore, in the cost presentation certain of the charges to outsiders will be listed as part of the costs. For the most part these charges represent additional labor and equipment not shown in the other items listed.

* unknown to the author.

Table 1. Quantity of Radioactive Wastes Buried - ORNL - Jan. -June 1955

Source	Dumpster Pans 100 ft ³	Other G.I. cans 32 gal.	Loads 55 gal. drums	6 Mos. Volume ft. ³	6 Mos. charges	F.Y. 55 Volume ft. ³	Approximate charges
ORNL	1250	5000		22,650		45,300	
Y-12	295 loads - av. 4 yds/load			32,000	3540	64,000	\$ 7,080
K-25	25		54 loads	3,550	1180	7,100	2,360
Mound				7,750	1900	15,500	3,800
ORINS				700	270	1,400	540
U.T.				1,150	580	2,300	1,160
KAPL				14,050*	2067	28,100	4,134
ANL				15,000**		15,000	2,357
Other	125 pkges (say 8 ft ³ each) -			1,000	1250	2,000	2,500
Total						180,700	\$23,931

* March 55 shipment (6 months accumulation)

** November 1954 shipment (12 months accumulation)

Land Disposal Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	2700	\$ 7,300
2. Equipment ^{(2)*}		14,850
3. Materials ⁽³⁾		1,340
4. Utilities ⁽⁴⁾		240
5. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
Burial yard shack	\$ 500	20%
Fences, signs, roads ⁽⁵⁾	20,000**	10%
6. Charges to others ⁽⁶⁾		<u>10,290</u>
	Gross Total	\$36,120
	Net Total	25,830

Total wastes buried - 180,000 cu. ft. gross (F.Y. 1955)

Unit Cost = $\frac{\$25,830}{116,400} = \0.22 per cu. ft.

-
- (1) 2000m hrs at \$2.60/hr for burial yard operator; 700 m hrs at \$3.00/hr for supervision.
- (2) 3 hrs/day for 250 days for: backhoe at \$13.80/hr, bulldozer at \$6.00/hr (equipment used on more than one operation)
- (3) 25 cu. yds. concrete (at \$14/cu. yd.) per month; gravel for roads \$500**.
- (4) Telephone \$10/month, heat \$5/month, light \$5/month.
- (5) For all burial yards, old and new.
- (6) Charges to ANL (\$2357), KAPL (\$4134*), Mound (\$3800*).
- * See Appendix 1.
- ** Author estimate.

Summary of F. Y. 1955 Costs at
OAK RIDGE NATIONAL LABORATORY

Liquid Waste Costs

	<u>Man hrs</u>	<u>Labor Costs</u>	Fiscal Year 1955 <u>Total Costs</u>
High level lab wastes	21,050	\$51,300	\$ 85,400
Low level waste	<u>7,217</u>	<u>17,560</u>	<u>23,540</u>
Sub totals	28,267	\$68,860	108,940
Overhead			<u>68,860</u>
	Total (liquid wastes)		\$177,800

Solid Waste Costs

Collection	5,338	\$21,600	\$ 38,440
Burial operation	<u>2,700</u>	<u>7,300</u>	<u>25,830</u>
Sub totals	8,038	\$28,900	64,270
Overhead			<u>28,900</u>
	Total (solid wastes)		\$ 93,170

ROCKY FLATS
Denver, Colorado

LIQUID WASTES

Collection and Temporary Storage Operations.

There are two types of liquid wastes at Rocky Flats: a) those which require treatment of one kind or another and b) those which require no treatment. Levels and types of radioactive contamination are such that external radiation presents no particular hazard. Wastes which require treatment contain certain toxic chemicals, as well as the radioisotopes which determine the treatment and degree of treatment given to any particular waste stream.

As the wastes leave the working areas they are collected in holdup tanks. Samples are taken and analysed to determine the disposition of the individual tankfuls collected. If contamination is within the R.F. established tolerance, the liquid is discharged to the sanitary sewerage system or as in the case of some relatively uncontaminated laundry wastes, discharged directly to the environment via a surface waterway. Waste liquids over tolerance are directed to the chemical waste processing plant. There are some 8 hold-up tanks ranging in size from 1000 gallons to 6000 gallons and constructed of stainless steel, asphalt lined carbon steel or of reinforced concrete. In addition there are two 25,000 gallon reinforced concrete holding tanks at the laundry.

About 2500 gallons per year of contaminated oils and the like are evolved in the R.F. operations. These are put in 55 gallon drums and stored indefinitely on the plant site.

Collection and Temporary Storage Costs.

	<u>Man hrs.</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	3562	\$10,100
2. Materials ⁽²⁾		500*
3. Misc ⁽³⁾		180
4. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
(2) 3000 gallon s/s tanks	\$ 6,000*	10%
(3) 6000 gallon c/s tanks	18,000*	10%
(2) 1000 gallon s/s tanks	2,000*	10%
(1) 6000 gallon r-concr.	3,000*	10%
(2) 25,000 gallon r-concr.	<u>25,000*</u>	<u>10%</u>
	\$ 54,000	10%
		<u>5,400</u>
	Total	\$16,180

Total quantity handled - 4,812,000 gallons.

Unit Cost = $\frac{\$16,180}{4,812,000}$ = \$0.0034 per gallon.

-
- (1) Sampling and analytic labor for the various areas consists of:
 Bldg 81 - 413 samples at $4\frac{1}{2}$ m hrs/sample; Bldg 44 - 71 samples x
 6 m hrs/sample; Bldg 71 - 990 m hr/yr; Bldg 41 - 56 samples x
 6 m hr/sample; all at \$475/mo.
- (2) Sampling materials, i.e., bottles, etc. and analytic lab materials.
- (3) Laundering of protective clothing at \$100/man yr.
- * Author's estimate.

Concentration Operations.

Liquid wastes from the holding tanks are received at the chemical treatment plant in two 2000 gallon stainless steel receiving tanks or in four 7,500 gallon concrete tanks depending on the waste and the treatment to be given. Essentially the treatment consists of adding chemical coagulating agents to the receiving tankfuls of waste, agitating then settling the precipitate out in flocculators. The settled floc or sludge is bled off and dewatered on vacuum filters, then packaged in drums.

Reconditioned 55 gallon drums are purchased locally in Denver. They are fitted with polyethylene bag liners prior to receiving the dewatered sludge. When a truckload of drummed sludge is accumulated the drums of wastes are directly loaded on tractor-trailers for shipment off site.

The treated liquids, decontaminated by a factor of 1000, are discharged either to a holding pond or to a series of detention basins, depending on the chemical nature of the wastes.

Some low level liquids, too low in activity for effective chemical precipitation, are discharged to the sanitary sewage system. Sewage is treated by the activated sludge process. In this treatment about 90% of the activity is removed from the liquid and concentrated in the sewage sludge. The latter is air dried on sand drying beds. Sludges below or near the AEC recommendations for use as fertilizer are buried on the plant site.

Concentration Costs.

	<u>Man hrs.</u>	<u>F.Y. 55 Costs</u>
1. Labor		
a. operating ⁽¹⁾	10,000	\$ 25,200
b. maintenance ⁽²⁾	3,500	8,700
c. analytical ⁽³⁾	2,000	5,900
d. Health physics	960	2,400
2. Materials ⁽⁴⁾		21,850
3. Utilities and misc. ⁽⁵⁾		2,820
4. Capital Investment - Depreciation		

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
Building	\$100,000	10%	10,000
Equipment	467,500	10%	46,750
200,000 gallon storage tank for emergencies	25,000	10%	<u>2,500</u>

Total \$126,120

Total quantity treated during F. Y. 1955 - 1,572,000 gallons.

$$\text{Unit Cost} = \frac{\$126,120}{1,572,000} = \$0.08 \text{ per gallon.}$$

-
- (1) 4 men full time at \$4800/yr and 1 full time supervisor at \$6000/yr
 (2) The total cost which includes shop overhead is \$17,300; actual labor is assumed to be about $\frac{1}{2}$ of this.
 (3) The analytical charges were \$10,900; Labor is assumed to be $\frac{1}{2}$ of this
 (4) Operating materials were charged at \$15,250 of which \$7000 is for drums and drum liners to be charged off in packaging. Other materials include the balance of the analytical charges of \$5000 plus maintenance materials worth \$8,600.
 (5) Electric power cost about \$2000; laundering of protective clothing at \$100/man year.

Packaging Costs.

	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	\$ _____
2. Materials ⁽²⁾	<u>4,370</u>
Total	\$4,370

Quantity packaged - 43,000 gallons sludge

2,500 gallons oil

Total 45,500 gallons

Unit Cost = $\frac{\$4,370}{45,500} = \0.096 per gallon

-
- (1) The actual labor involved in inserting the wastes in drums is charged under concentration costs. There are no transfer costs.
- (2) 780 drums and 780 polyethylene bags at \$4.60 each and \$1.00 each respectively for sludge. 50 drums at \$4.60 each for contaminated oils, etc.

Release to Environment.

About half of the decontaminated liquids discharged from the chemical treatment process go to a holding pond because of their toxic chemical nature. The holding basin is simply a dry gully with an earthen dam. There is sufficient capacity so that there is no over-land runoff; the liquids either are evaporated or seep into the earth. To prevent this seepage, a water-tight, asphalt-lined evaporation pond is being constructed. The pond will have a surface area of three acres and a capacity of seventeen acre feet.

The other half of the decontaminated liquids are mixed and diluted with the sewage treatment plant effluent at the sewage treatment plant and then goes to a series of dammed basins. These basins, three in number, are similar in construction to the holding basin described above. However these are in series on the same slope so that the liquid flows through each one in turn. The basins afford a detention period during which algae and sunlight affect further purification so that wastes leaving the last basin are relatively clean. Here too, there is some seepage into the ground and also evaporation. Evaporation rates are rather high in the mountainous country around Denver.

Rocky Flats has an area monitoring program in which samples of the effluents are collected and analysed to determine just what is being discharged and also to measure effects, if any, on the environment.

Release To Environment Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor		
a. sampling	2860	\$ 7,150
b. analytical(1)	4300	10,750
2. Materials(1)		10,750
3. Equipment(2)*		1,500
4. Misc.(3)		360
5. Capital Investment - Depreciation		

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
(1) Holding basin	\$4,000	5%	200
(3) Holding basins	6,000	5%	<u>300</u>
		Total	\$31,010

Total quantity released - 40,000,000 gallons.

$$\text{Unit Cost} = \frac{\$31,010}{40,000,000} = \$0.0008 \text{ per gallon}$$

-
- (1) \$21,500 charged for sample analysis - it is assumed that $\frac{1}{2}$ or \$10,750 is labor and $\frac{1}{2}$ for materials.
 (2) $\frac{1}{2}$ ton pickup used 4 hrs/day at \$1.50/hr* (1000 hrs total)
 (3) Laundering of protective clothing at \$100/man year.
 * See Appendix 1.

ROCKY FLATS

Denver, Colorado

SOLID WASTES

Handling of Radioactive Solid Wastes.

There is no routine trash collecting and packaging set-up at Rocky Flats as there is at other installations even though all of the solid wastes are shipped off site. Operating personnel and janitors place wastes in drums which are the shipping containers. Most of the loaded drums are stored at the building where wastes originate. Some of the drums are transferred to a central loading dock where they remain until shipped.

Contaminated air filters are the only waste items not packaged in drums. They are placed in polyethylene bags and then packaged in the original shipping cartons of the replacement filters. Second hand, 55 gallon and 30 gallon drums, purchased locally in Denver are used for waste packaging. Heavy items of waste are put in the smaller drums to keep individual package weights more uniform.

Loading and Shipping Operations.

Rocky Flats ships all of its solid wastes to the National Reactor Test Station near Idaho Falls, Idaho, a distance of about 700 miles. The wastes are transported by common carrier truck. Private trucking outfits around Denver competitively bid for the freight job of carrying the wastes.

Mechanics of the operation are simple. At Rocky Flats the truck or trailer bed is covered with a layer of paper for protection against contamination. The truck is then driven around to the various waste accumulation points where packages of wastes are loaded aboard the truck. A crew of Rocky Flats personnel using a fork lift accomplish the loading. At NRTS the truck pulls up adjacent to the burial trench and the wastes are simply pushed into the excavation. NRTS buries these wastes with its own wastes and charges Rocky Flats proportionally for the amount of labor and equipment use expended.

Some 35 shipments of wastes have been made over an eleven month period, not quite one per week. All of the shipments have complied with the ICC regulations. No couriers or guards accompany the truckloads. By agreement, in case of any emergency, wastes en route are the responsibility of Rocky Flats up to the half way point - after which NRTS assumes responsibility.

Packaging, Loading and Shipping Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	1086	\$ 2,700
2. Equipment ⁽²⁾		300
3. Materials ⁽³⁾		
a. packaging		15,380
b. loading and shipping		1,350
4. Contract carrier charges		27,520
5. Burial charges		<u>3,520</u>
	Total	\$50,770

Wastes shipped	No of drums		gross cu.ft.
	<u>55 gal.</u>	<u>30 gal.</u>	
Solid wastes -	2837	675	23,500
Sludge -	760	20	5,600
Filters -			<u>4,800</u>
	<u>Total</u>		33,900 cu. ft.

$$\text{Unit Costs} = \frac{\$50,770}{33,900} = \$1.50 \text{ per cu. ft.}$$

-
- (1) 2 m hrs at \$2.50/hr to move 50 drums to dock - 1400 drums moved; 1030 man hrs preparing and loading the carrier (\$2,575);
- (2) Forklift 3 hrs/load at \$1.50/hr* - 36 loads; 56 hrs of stake truck time at \$2.36/hr* hauling drums to dock.
- (3) 2837 (55 gallon) drums at \$4.60 each. 675 (30 gallon drums at \$3.50 each.
- * See Appendix 1.

Summary of F.Y. 55 Costs at

ROCKY FLATS

Denver, Colorado

Liquid Wastes Costs.

		Fiscal Year 1955	
	<u>Man hrs</u>	<u>Labor Costs</u>	<u>Total Costs</u>
Collection, etc.	3,562	\$10,100	\$ 16,180
Concentration	16,460	42,200	126,120
Packaging	—	—	4,370
Release to environment	<u>7,160</u>	<u>17,900</u>	<u>31,010</u>
Sub totals	27,182	\$70,200	\$177,680
Overhead			<u>70,200</u>
	Total (liquid waste)		\$247,880

Solid Waste Costs.

Packaging, loading and shipping	1,086	\$ 2,700	\$ 50,770
Overhead			<u>2,700</u>
	Total (solid wastes)		\$ 53,470

UNIVERSITY OF CALIFORNIA RADIATION LABORATORY

Berkeley, California

LIQUID WASTES

Handling of Radioactive Liquid Wastes.

Radioactive liquid wastes evolve from bench scale radio-isotope experiments, however, these are relatively small in total volume, of the order of magnitude of 1000 gallons per year. At the place of origin, they are collected in containers instead of being discharged to the sewer. Containers are the kind normally found in any chemistry laboratory. Five gallon carboys are used most. This separate collection of liquid radioactive wastes in the laboratory removes the radioactive contaminant from an estimated 300,000 gallons per year of general chemical and acid wastes that also emanate from the radio chemical laboratories.

These containers of liquids are picked up by the collection crew at the same time solid wastes are picked up. They are stored at the waste processing area in the containers of collection until they are packaged in concrete for sea disposal. Prior to F.Y. 1955, liquids were packaged by inserting a 5 gallon container of the wastes into a prepared 55 gallon drum and surrounding it with concrete. The concreted drums were then stored outdoors until they were shipped offsite. The method was considered unsatisfactory because loading of the barge involved placement of the drums on their sides. During the winter season liquids would run out of the space between the concrete and drums.

These liquids in all cases proved to be innocuous and were considered to be rainwater. However, because of the concern of everyone until tests were made on this effluent and because of the testing and checking required, the packaging of liquids as such has been discontinued.

For several years experiments have been conducted on means for solidifying liquid wastes before incorporation into concreted drums. During Fiscal Year 1955 liquid wastes were processed with Amigel, a chemical agent, which when added to neutralized liquid wastes caused the liquids to coalesce into a gelatin like mass. The gel is packed in 30 gallon drums which are set in and surrounded by concrete in 55 gallon drums.

Packaged liquid wastes are handled and shipped together with the solid wastes. Costs for liquid wastes have been included in the section on loading and shipping costs for solid wastes.

The radiation lab also discharges a sizeable volume of liquid wastes to the Berkeley City sanitary sewer system. These wastes are normally uncontaminated. If contaminated with radioisotopes the level of contamination is well within the tolerances established in Handbook 52 of the Bureau of Standards. However, to be absolutely certain, the radiation lab is installing an automatic sampling and monitoring station on the outfall. This was not completed in August 1955, consequently there was no operating or investment data available for this report.

Packaging Costs.⁽¹⁾

	<u>Man hrs</u>	<u>Annual Costs</u>
1. Labor ⁽²⁾	192	\$ 380
2. Materials ⁽³⁾		440
3. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
Treatment Building	\$5,000*	10% 500
Treatment Equipment	3,000*	20% 600
		<u> </u>
		\$1,920

Total quantity packaged - 1000 gallons.

Unit Cost = $\frac{\$1920}{1000} = \1.92 per gallon.

-
- (1) Based on experimental evidence.
 (2) 16 m hrs/month at \$2/hr.
 (3) 40 (30 gallon) drums at \$2.25 each; 40 (55 gallon) drums at \$0.50 each; 1000 lbs of amigel at \$100; 100 lbs. of caustic at \$180; \$50 for concrete.
 * Author estimate.

UNIVERSITY OF CALIFORNIA RADIATION LABORATORY

Berkeley, California

SOLID WASTES

Collection, Sorting and Storage Operations.

The university's radiation research wastes are mostly by-products of particle accelerator and radioisotope experimentation. Heavy element isotopes and long lived alpha emitters are the predominant contaminants of such things as paper, rags, animal carcasses and laboratory paraphernalia.

Radioactive contaminated solids are accumulated in the laboratories in trash cans lined with chemically treated paper bags. After precautionary monitoring the filled bags are sealed by stapling and then set aside. Waste items too large for the trash can treatment are considered separately. For the most part these are carried in toto to the packaging site. A regular waste collection crew of two men using a pick-up truck routinely collects wastes twice a week. The wastes are taken to the waste packaging site, a small area set aside for the purpose, situated in amongst the radiation laboratory buildings. The packaging area is paved with cement and enclosed by a chain-link fence. Wastes are stored here until a sufficient amount has accumulated to keep the waste packaging crew busy for a day or more.

Collection and Storage Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	1275	\$2,550
2. Equipment ⁽²⁾		600
3. Materials ⁽³⁾		340
4. Misc. ⁽⁴⁾		<u>120</u>
	Total	\$3,610

Total wastes collected - 6,200 cu. ft. (gross)

Unit Cost = $\frac{\$3610}{6200} = \0.58 per cu. ft.

(1) Based on 1.5 m hrs/drum for 850 drums at a rate of \$2.00/hr.

(2) Pick-up truck - 8 hrs/wk at \$1.50/hr.*

(3) Can liners - \$0.20 each average 2/drum - 850 drums.

(4) Laundering of protective clothing - \$100/man year; telephone at \$5/mo.

* See Appendix 1.

Packaging Operations.

All the wastes of the radiation lab are packaged for sea burial. Small items are packaged in 55 gallon drums; large items receive special consideration. Drums are prepared to receive wastes by first placing about six inches of concrete in the bottom of each. A piece of wire cable of such length that when it is bent in half and has the ends set in the 6 inch layer of concrete, forms a loop above the top of the finished package by which it can be handled. Several bags of trash, about 4 cubic feet uncompacted, are placed on top of the initial concrete

layer. Wet concrete is added and stirred up with the wastes. Enough concrete is added to make the drum package weigh at least 550 pounds. The drums are weighed at the time of shipment to ensure compliance with the weight requirement. After the concrete mixture hardens it is ready for shipment.

Large items of waste are figuratively "wrapped" in concrete. Prefabricated wooden sheets, which when assembled together shape a rectangular box whose outside dimensions are 5 ft. x 7 ft. x 7 ft. Laboratory isolation (glove) boxes and other bulky waste items are placed within the wooden form work. Space is left between the item and the outer walls for at least six inches of concrete. When all the waste items are in place concrete is poured over and around the items up to the top of the form work. A breather tube consisting of a section of $1\frac{1}{2}$ or 2 inch pipe extends from large voids within the package to the outside of the package. This is a precautionary measure designed to relieve pressure differences when the package is dumped into the sea. The finished package weighs about 7 tons.

The used 55 gallon drums are generally supplied gratis by various Army and Navy installations located in the Bay area. However, UCRL must pick up these drums at the source, haul them to Berkeley and cut out the tops in order to use them for packaging solid wastes.

Packaging Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor	3484	\$ 6,970
2. Materials		3,980
3. Misc.		180
4. Capital Investment - Depreciation		

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
Concrete mixer and assoc. tools	\$1,000*	20%	<u>200</u>
		Total	\$11,330

Total volume packaged⁽⁴⁾ - 3180 cu. ft. (drums)
3000 cu. ft. (boxes)
 6180 cu. ft. gross

$$\text{Unit Cost} = \frac{\$11,330}{6,180} = \$1.83 \text{ per cu. ft.}$$

-
- (1) 15 men at \$2/hr rate consume 171.5 m hrs per 54 drums - 850 drums packaged; labor for 28 (5 x 7 x 7) packages is 28 m hrs per packager at same labor rate.
- (2) 850 (55 gallon) drums at \$0.50 each; 850 bags cement at \$1.20 per bag; 850 x 500 lbs gravel at \$0.75/500 lbs; materials for 28 (5 x 7 x 7) packages, i.e., 28 x \$68 for wood and concrete.
- (3) Laundering of protective clothing at \$100/man year; fuel for mixer at \$6.
- (4) Based on 3.75 ft³/drum and 108 cu. ft. per 5 x 7 x 7 box.
- * Author estimate.

Loading and Shipping Operations.

The U. S. Navy group at Hunters Point which handles the sea going phase of the disposal operations notifies UCRL when the barge is

to make a trip to sea. Upon such notification the prepared packages are loaded onto a UCRL truck-trailer and delivered to the Hunters Point Navy dock. A Navy crane rig and crew unloads the truck and loads the barge. For its part, the Navy does make a nominal charge to cover the cost of the dockside handling (men and equipment).

All of the concreted packages are monitored to insure safety from radiation hazards. A radiation surveyor accompanies each truck shipment. A marking is painted on each package to identify UCRL items and a record is kept of each drum and its weight and each large concrete package and its weight or dimensions. The location of the sea dumping is also recorded.

Loading and Shipping Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	725	\$1,760
2. Equipment ⁽²⁾		890
3. Tolls ⁽³⁾		200
4. Navy charges		<u>2,000</u>
	Total	\$4,850

Wastes shipped - 877 (55 gallon) drums = 3180 cu. ft.
 28 (5 x 7 x 7) boxes = 3000 cu. ft.

Unit Cost = $\frac{\$4850}{6180}$ = \$0.78 per cu. ft.

-
- (1) Loading - 4 m hrs at \$2.00/hr and 1 m hr at \$2.50/hr for each truckload of 30 drums. Transport and unloading 10 m hrs at \$2.50/hr for each truckload of 30 drums. Loading - \$13/box for 28 (5 x 7 x 7) boxes. Transport and unloading - \$13/box for 28 boxes.
 (2) Fork lift - 2 hrs/truckload at \$1.50/hr (33 truckloads - incl. boxes)
 (3) Tolls - \$6/trip.

Summary of F. Y. 1955 Costs at
UNIVERSITY OF CALIFORNIA RADIATION LABORATORY
Berkeley, California

Liquid Waste Costs.

	<u>Man hrs</u>	<u>Fiscal Year 1955 Labor Costs</u>	<u>Total Costs</u>
Packaging	192	\$ 380	\$ 1,920
Collection, loading and shipping included in solid wastes			
Overhead			<u>380</u>
Total (liquid waste)			\$ 2,300

Solid Waste Costs.

Collection and Storage	1275	\$ 2,550	\$ 3,610
Packaging	3484	6,970	11,330
Loading and Shipping	<u>725</u>	<u>1,760</u>	<u>4,850</u>
Sub totals	5484	\$11,280	\$19,790
Overhead			<u>11,280</u>
Total (solid waste)			\$31,070

UNIVERSITY OF CALIFORNIA, LIVERMORE LABORATORY

Livermore, California

LIQUID WASTES

Handling of Radioactive Liquid Wastes.

The liquid waste system at Livermore is similar to that described for the Berkeley Laboratory. Known or suspected radioactive solutions are placed in lab containers, such as five gallon carboys, in each individual laboratory. These containers of liquids are picked up by the regular waste collection crew along with the solid wastes. About 500 gallons per year are handled this way. This separate collection of liquid radioactive wastes removes the radioactive contaminant from about 250,000 gallons per year of general chemical and acid wastes that also emanate from the radiochemical laboratories.

The general chemical and acid wastes are handled through a piping system replete with ten 1000 gallon, plastic lined tanks. The purpose of the holding tanks is to permit checking for chemicals and acidity that might be toxic to the Livermore (City of) sewage treatment plant operation which receives the wastes. In addition, each 1000 gallon tankful is checked for radioactivity. The few batches found to be radioactive are decontaminated, batch wise, by a coagulation-coprecipitation method.

None of the lab containers of radioactive wastes were packaged during Fiscal Year 1955. These wastes were stored pending the outcome of the gelling agent experiments at Berkeley.

Liquid Waste Handling Costs.⁽¹⁾

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽²⁾	1100	\$2,750
2. Materials ⁽³⁾		500
3. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
(10) 1000 gallon c/s tanks	\$18,000	10%
Chemical Treatment equipment	13,000	10%
		<u>800</u>
		<u>1,300</u>
	Total	\$6,350

Total acid wastes handled - 250,000 gallons.

Total acid wastes decontaminated - 10,000 gallons.

Unit Cost = $\frac{\$6,350}{250,000} = \0.025 per gallon

-
- (1) For general chemical and acid wastes only.
 (2) 1000 man hrs at \$2.50/hr for monitoring and sampling 250 gallon to 1000 gallon batches; 100 man hrs at \$2.50/hr for treating 10 gallon to 1000 gallon batches.
 (3) For treating the 10 gallon to 1000 gallon batches.

UNIVERSITY OF CALIFORNIA, LIVERMORE LABORATORY

Livermore, California

SOLID WASTES

Solid Radioactive Waste Operations.

The waste handling operations at Livermore parallel those at Berkeley because both facilities are operated by the same contractor. Cost differences are slight and are due to differences in plant and in shipping distances. Livermore packages all of its wastes for sea disposal and trucks the wastes to Hunters Point in the same way as does Berkeley.

Collection and Storage Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	1145	\$2,290
2. Equipment ⁽²⁾		600
3. Materials ⁽³⁾		300
4. Misc. ⁽⁴⁾		60
5. Capital Investment - Depreciation		

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
Storage yard facilities ⁽⁵⁾	\$2,750**	10%	<u>270</u>
		Total	\$3,520

Total wastes collected - 4,260 cu. ft. (gross)

Unit cost = $\frac{\$3520}{4260} = \0.83 per cu. ft.

-
- (1) Based on 1.5 m hrs/drum at \$2.00/hr for 764 drums shipped.
 (2) Pickup truck 8 hrs/wk at \$1.50/hr*.
 (3) Can liners - \$0.20 each - average 2/drum - 764 drums.
 (4) Laundering of protective clothing at \$100/man year.
 (5) Fence - \$750; Paving \$2000.

* See Appendix 1.

** Author estimate.

Packaging Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	2776	\$5,550
2. Materials ⁽²⁾		2,750
3. Misc. ⁽³⁾		140
4. Capital Investment - Depreciation		

<u>Item</u>	<u>Cost</u>	<u>Rate</u>	
Concrete mixer and assoc. tools	\$1,000*	20%	<u>200</u>
		Total	\$8,640

Total volume packated⁽⁴⁾ - 2860 cu. ft. (drums)
 1300 cu. ft. (boxes)
 Total 4160 cu. ft. gross

Unit Cost = $\frac{\$8640}{4160} = \2.08 per cu. ft.

-
- (1) Same rate as Berkeley - thus $2700 \times \frac{764}{850} = 2430$ m hrs - (\$2/hr rate) plus labor for 12 (5 x 7 x 7) packages, i.e., 28 x 12 m hrs at \$2/hr.
- (2) 764 drums at \$0.60 each; plus 764 bags cement at \$1.20/bag; plus 764 x 500 lbs gravel at \$0.75/500 lbs; plus materials for 12 (5 x 7 x 7) boxes i.e., 12 x \$68 for wood and cement.
- (3) Laundering of protective clothing at \$100/man year.
- (4) Based on 3.75 cu.ft/drum and 108 cu.ft.per 5 x 7 x 7 box.
- * Author estimate.

Loading and Shipping Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	481	\$1,070
2. Equipment ⁽²⁾		600
3. Toll charges ⁽³⁾		80
4. Navy charges		<u>1,800</u>
	Total	\$3,550

Wastes Shipped - 764 (55 gallon) drums = 2860 cu. ft.
 12 (5 x 7 x 7) boxes = 1300 cu. ft.
 4160 cu. ft.

Unit Cost = $\frac{\$3,550}{4,160} = \0.86 per cu. ft.

-
- (1) Loading - 4 m hrs at \$2.00/hr and 1 m hr at \$2.50/hr for each 30 drums. Transport and unloading - 16 m hrs at \$2.50/hr for every 60 drums. Loading - \$13.00/box for 12 (5 x 7 x 7) boxes. Transport and unloading - \$13.00/box for 12 boxes.
- (2) Fork lift - 2 hrs/30 drums at \$1.50/hr*; plus 1 hr at \$1.50 for 12 boxes. Tractor trailer and trailer - 8 hrs/trip - \$5.00/hr- and 13 trips.
- (3) Tolls - \$6.00/trip.
- * See Appendix 1.

Summary of F. Y. 1955 Costs at
UNIVERSITY OF CALIFORNIA, LIVERMORE LABORATORY
Livermore, California

Liquid Waste Costs.

	<u>Man hrs</u>	<u>Fiscal Year 1955 Labor Costs</u>	<u>Total Costs</u>
Liquid Waste System	1,100	\$3,750	\$ 6,350
		Total	<u>\$ 6,350</u>

Solid Waste Costs.

Collection and Storage	1,145	\$2,290	\$ 3,520
Packaging	2,776	5,550	8,640
Loading and Shipping	<u>481</u>	<u>1,070</u>	<u>3,550</u>
Sub totals	4,402	\$8,910	\$15,710
Overhead			<u>8,910</u>
Total (solid waste)			\$24,620

NAVAL RADIOLOGICAL DEFENSE LABORATORY

San Francisco, California

LIQUID AND SOLID WASTES

Waste Collection and Storage Operation.

Except for one or two minor deviations, low level, radioactive, liquid and solid wastes are collected, packaged and shipped together. There are no high level wastes of any consequence at NRDL; most lab operations are with isotopes. Low level solid wastes are accumulated in working areas in 20 gallon and 55 gallon steel drums. Liquid wastes from experimentation are caught in plastic lined five gallon buckets. Some liquid wastes evolve from a decontamination unit. These are accumulated in either a 5,000 gallon stainless steel tank or in two 750 gallon carbon steel tanks for special handling at a later time.

Routinely, a waste collection team picks up the full containers and leaves empty ones. Filled drums and buckets are taken to the waste packaging site which is an area of about an acre fenced in with an 8 ft. chain link fence. Contaminated items of solids larger than will fit in drums are handled individually.

Collection and Storage Costs.(1)

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor(2)	388	\$ 970
2. Equipment(3)		220
3. Materials(4)		100
4. Utilities(5)		140
5. Capital Investment - Depreciation		
<u>Item</u>	<u>Cost</u>	<u>Rate</u>
Storage yard	\$1,500**	10%
		<u>150</u>
	Total	\$1,580

Total wastes collected - 7000 gallons liquids

3000 cu. ft. solids

-
- (1) Liquids and solids.
 (2) 288 m hrs picking up in truck; 100 m hrs analytical labor for liquids collected in tanks. Labor rate \$2.50/hr.
 (3) 144 hrs of pick-up truck time in collection at \$1.50/hr.*
 (4) 84 liquid containers at \$1.25 each.
 (5) Telephone \$10/month; laundering protective clothing at \$100/man yr.
 * See Appendix 1.
 ** Author estimate.

Packaging and Shipment Operations.

When a sufficient amount of waste material has accumulated to keep a crew of men busy for a day or more, the wastes are packaged for sea disposal. Liquids are packaged in used 55 gallon oil drums. About 110 pounds of sand are inserted in the drums and approximately

45 gallons of liquids added. When the bung hole is plugged, the drum is ready to go. Drums with sand in them are carried to the tankfuls of decontamination liquids where they are filled. The small containers of liquids are poured in at the waste packaging yard.

Solid trash is packaged sandwich like in open top 55 gallon drums by alternating layers of concrete with layers of trash until the drum is filled. Enough concrete is added to make each drum weigh at least 550 lbs. A scale is used. Each drum holds about four cubic feet (loose) when packaged in this manner. The drums are surplus oil drums obtained from the salvage yard. Drum tops are removed for the packaging of solid wastes. Ready-mix concrete purchased locally is used in the packaging operation.

Large items such as contaminated isolation (glove) boxes are packaged in a prefabricated, concrete box which measures approximately 4 ft. x 4 ft. x 8 ft. The walls of the box are 6 inches thick and reinforced with steel bars and wire mesh. After large items of waste have been inserted, smaller waste items are put in to fill up the void spaces. Pouring the six inch top slab is the last step in completing the package.

Each package of radioactive wastes has a serial number painted on. A log is kept of the containers and their contents and also the location of their ultimate repository in the ocean.

The Naval Radiological Laboratory co-ordinates the sea disposal operation. It integrates wastes of the University of California and several other waste producers in the San Francisco area with those of

it's own to make up barge loads to go to sea. A Navy shipyard crew of a crane and several riggers transfers the wastes to the barge using a portable shipyard crane.

Packaging Costs. (1)

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽²⁾	444	\$1,110
2. Materials ⁽³⁾		150
3. Equipment ⁽⁴⁾		150
4. Misc. ⁽⁵⁾		<u>20**</u>
	Total	\$1,430

Resultant packages - Volumes - same as collected.

156 (55 gallon) drums liquids

533 (55 gallon) drums solids

8 (4 x 4 x 8) concrete boxes.

-
- (1) Liquids and solids.
 (2) 30 m hrs filling drums with liquids; 122 m hrs handling drums, i.e., picking up used drums and moving filled drums around; 36 m hrs preparing drums for liquids; 256 m hrs packaging solids, i.e., pouring boxes and filling drums; all at \$2.50/hr.
 (3) 8.5 tons sand at \$3/ton; 6 cu. yd. concrete for drums and 3.5 cu. yd. concrete for boxes at \$11/cu. yd.
 (4) 100 hrs of fork lift time at \$1.50/hr* handling filled drums.
 (5) Laundering of protective clothes at \$100/man year.
 * See Appendix 1.
 ** Author estimate.

Transfer Costs.

	<u>Man hrs</u>	<u>F.Y. 55 Costs</u>
1. Labor ⁽¹⁾	200	\$500
2. Equipment ⁽²⁾		<u>490</u>
	Total	\$990

Wastes shipped - same as packaged.

-
- (1) 50 m hrs to move 689 drums and 8 boxes to dockside at \$2.50/hr; plus 150 m hrs of riggers time to load 689 drums and 8 boxes aboard barge; all at \$2.50/hr.
- (2) 30 hrs of truck time at \$4.77/hr* to move 689 drums to dockside; plus 25 hrs of crane time at \$13.80/hr.*
- * See Appendix 1.
-

Summary of F.Y. 55 Costs at

NAVAL RADIOLOGICAL DEFENSE LABORATORY

Liquid and Solid Waste Costs.

	<u>Man hrs</u>	<u>Labor Costs</u>	<u>Total Costs</u>
Collection and Storage	388	\$ 970	\$1,580
Packaging	444	1,110	1,430
Transfer	<u>200</u>	<u>500</u>	<u>990</u>
Sub totals	1032	\$2,580	\$4,000
Overhead			<u>2,580</u>
Total (liquid and solid)			\$6,580

PART III

SUMMARY OF

WASTE DISPOSAL PRACTICES

There is no established nationwide AEC policy concerning the disposal of radioactive wastes other than having those wastes which are returned to nature be below certain allowable limits of activity.* The practice of releasing waste to the environment varies among all the installations. Some installations release curies of activity at their sites every year. Others release little or no activity at their sites, transferring their waste materials elsewhere for release instead. In general, those installations which have large areas of land release low level liquids and bury radioactive solids within their site boundaries. Necessarily they keep a continuous check to determine if any activity escapes and to measure effects of the released activity on the environment. Those installations which are relatively small in size package and transport the bulk of their waste radioactivity to the larger sites for disposition or to the sea coast for dumping in the oceans.

Waste Collection.

The objective of waste collection is to gather the wastes into one or more places so that they may be: a) treated, b) packaged or c) policed and released in a safe and economical manner. Collection practices are rather uniform throughout the country. All of the installations take extra precautions with hazardous wastes, whether they be alpha emitters or beta-gamma emitters. Low level wastes which are relatively non-hazardous are

* These allowable limits of activity are specified in the National Bureau of Standards Handbooks on radioactivity, especially Handbook 52.

handled with less restraint. Low level liquids are collected in regular sewer systems and solids are collected by crews using motorized carriers.

Liquid Wastes: Most liquid wastes are collected on site in sewers; some are handled in integral containers. Sewer systems vary in size, extent and method of construction. Wastes flowing in them are under more or less continual scrutiny as they pass through monitoring points. Usually monitoring points are located at the point of origin of the wastes, the point of treatment and the point of discharge to the environment. Collection in sewers is not a fool-proof method. Sewers have been known to leak causing a great deal of consternation about uncontrolled release of radioactivity to the environment. Sewers which carry high level wastes have built-in safeguards, such as a sewer within a sewer, which gives more positive control over the wastes. Monitoring points, built-in safeguards and other special facilities and controls make the collection of liquid wastes more expensive than the municipality counterpart of sewer collection.

Solid Wastes: Almost all solid wastes are accumulated in laboratories and working areas in regular G.I. (galvanized iron) cans, cardboard cartons, kitchen style garbage cans and 30 gallon and 55 gallon steel drums. The cans usually have paper or polyethylene liners. There is no reason, as far as could be ascertained, for the wide variation in accumulation methods other than differences in opinions. The simplest procedure is that of collecting the wastes

in the containers which are shipped. The next simplest appears to be the can method using 32 gallon G.I. cans lined with polyethylene bags. This method is low in cost, especially at those places purchasing the bags at a low unit cost.

Another problem of collection is that of transportation, i.e., physically moving the wastes from the point of origin to a central or convenient location for further treatment. This handling cost varies with the level of activity of the waste, the type of container used, the distance between point of origin and point of treatment and the kind of equipment used to make the transfer. The more spread out the installation, the more time spent on the vehicle and vice versa.

Refinements of the central storage area also directly affect the cost of collection (as considered in this report). Provisions for decay storage, usually underground, again follow different philosophies. Safety at low cost is desirable, but safety nevertheless. In this phase, philosophies of safety are measurable in relative dollars and cents because they are directly reflected in construction costs.

Waste Treatment.

The primary reason for treating radioactive wastes is to reduce the volume in which the radioactivity is contained. It is less difficult to monitor and package small volumes than large volumes. The cost of reducing the volume must offset the cost of disposing the untreated volume minus the treated volume,

otherwise, there is no economic basis for treatment. Each installation has made a study of its problems. The methods in use reflect the results of those studies.

Liquid Wastes: Liquid wastes in the atomic industry are treated by any of three methods: evaporation, co-precipitation with chemical coagulants and ion exchange. Each method has its special merits and special applications. Large volumes of more or less homogeneous liquids are effectively handled by co-precipitation. Heterogeneous wastes are more easily concentrated by evaporation processes. Ion exchange is used mostly for selective removal of certain isotopes.

Solid Wastes: Solid wastes are reduced in volume by one of two methods, namely, combustion or compression. Combustion gives the greater volume reduction but it also introduces the further problem of treating combustion gases which carry off some of the contaminating isotopes. Presently only one installation, WAPD at Bettis Field, uses incineration. There, the level of contamination of the wastes is rather low and does not present a very difficult gas problem. Actual results with the Bettis Field incinerator have not yet been made known.

Several installations compress their trash materials in baling machines to reduce the volume of wastes they must transport. Since common carrier charges are based on weight, the principal reason for baling is to reduce the packaging costs. An analysis of the economy of solid waste volume reduction is presented in Appendix 2.

Packaging for Disposal.

Packaging for on-site burial is minimal. The wastes are just sufficiently restrained for expeditions and safe handling in collection and transfer to burial. Considerable preparation and packaging are involved in shipments off site. The ultimate repository, i.e., on land or in the sea, determines the characteristics of the packages. Those packages of waste which are disposed of into the sea are made heavy with concrete to ensure sinking. Waste packages which are to be buried on land do not have the added concrete and consequently involve less shipment weight per volume of waste. Packages shipped off-site for both land and sea disposal are made tight so there will be no spillage in transit.

There are no regulations, per se, which specify packaging materials or methods of constructing packages. Interstate Commerce Commission regulations state that a package containing radioactive materials should be "tight" allowing no leakage from a package. ICC regulations do specify a limit of tolerable emitted radiation. These are based on the possible fogging of X-ray film which may be in transit. AEC shipments of radioactive materials are exempted from ICC regulations if a courier accompanies the shipments. All those installations utilizing common carriers have reported that their shipments do comply with the ICC regulations.

Two kinds of packages predominate in waste shipments: steel drums and wooden boxes. Other packaging materials include fiber drums, fabricated steel boxes and poured concrete boxes. Steel

drums and the concrete boxes contain most of the wastes that go to sea. All the other packaging materials together with steel drums contain shipments destined for land burial. Drums usually contain slurries and loose bulky materials and the other kind of packages contain trash and miscellaneous items of waste.

A study should be made of the problem of packaging for waste shipments and should cover both methods and materials. Each installation now uses a method which it believes to be best suited to it's own purposes. The methods used are in large part dictated by circumstances and the availability of materials on site and secondarily by conformity with past practices. Even though results are satisfactory, that fact should not preclude practices which are equally effective and less expensive. The study which is recommended should consider all the factors involved including: type of waste, destination, ultimate responsibility, ICC regulations and economy.

Waste Transportation.

The mode of transportation to any disposal site is determined by convenience and economy. AEC contractor owned trucks are used in some cases but mostly the shipments are by the common carriers, both railroad and truck. Most of the wastes are packaged according to ICC specifications and these are transported without the accompaniment of a courier. A radiation surveyor does accompany those shipments whose radiation levels are above ICC tolerances; a few such shipments are made from Brookhaven,

Berkeley and Livermore. To limit possible contamination and to facilitate decontamination most of the installations cover the floor and walls of the conveying vehicle with a protective layer of paper.

The wastes are loaded aboard the conveying vehicle by AEC contractor personnel and with one or two exceptions they are also unloaded by AEC contractor personnel. The exceptions are those cases in which the Navy unloads the wastes at dockside. The routes traveled by the waste carriers are most direct; public highways by the trucks and regular freight routes by the railroads. So far as is known all shipments have been made without any loss of life, limb or time for all individuals involved.

Disposition of Wastes on Land.

Most of the waste materials that are shipped to land destinations are buried in the earth. (Some of the wastes sent to the Lake Ontario Storage Area are still stored above ground). These wastes include low and intermediate level solids and liquids. The intermediate level liquid wastes are the residues of evaporation or concentration processes in the form of sludges and are more or less solid in physical form. Usually wastes that are buried are buried in their shipping containers. Radioactive wastes are buried by a method similar to a sanitary landfill operation. A trench or hole is first excavated in a geologically suitable area. The packages of wastes, those shipped cross-country and those collected locally, are dumped into the excavated hole and covered with dirt. Some in-

installations backfill by alternating layers of dirt and wastes and others use only one cover layer of dirt on top. The excavations range from 10 to 20 feet in depth. Dirt cover is proportional to radioactivity, ranging from a minimum of 3 ft. for low level wastes to 6 or 8 ft. for high level wastes.

Decontaminated liquids and low level radioactive liquids are released to the environment at the installations. Some places release to nearby surface watercourses and others to underground strata by seepage from surface lagoons, pits, cribs or by discharge to reverse wells. All the installations have established certain tolerance levels for the release of radioactive material to the environment. Area monitoring programs at all of the installations releasing materials are pursued to determine the effects, if any, on the environment.

None of the installations release high level liquid wastes to the environment. These particularly hazardous wastes are confined within specially constructed, underground storage tanks.

Sea Disposal.

On the West Coast, the San Francisco Navy Shipyard (Hunters Point) is the home port of the YGN-73, a modified dump scow whose mission is to carry out and dump radioactive wastes at sea. The Naval Radiological Defense Laboratory at Hunters Point co-ordinates truck shipments from the Berkeley and Livermore sites of the University of California Radiation Laboratory. Wastes from these sites and from the USNRDL constitute the bulk of the matter taken out to

sea and dumped in a designated area about 20 miles off San Francisco where the water is at least 500 fathoms (3,000 ft.) deep.

On the East Coast the Navy operates a disposal service for defective ammunition. An LST puts in at selected ports along the Atlantic Coast to pick up unwanted ammunition and haul it out to sea. Co-operating with the AEC the Navy also accepts packaged radioactive wastes and disposes of it along with the defunct ammunition. The designated dumping areas in the Atlantic are at the edge of the continental shelf about 100 miles from the mainland where the water is at least 1000 fathoms deep.

Both in the East and in the West, most of the waste material is packaged in 55 gallon drums. Unique to the West Coast operation are some large (6' x 6' x 12' max) concrete disposal units which contain contaminated isolation (glove) boxes and other bulky items.

Conclusions Regarding Liquid Wastes Disposal Costs.

On the basis of available data it is difficult to make equitable comparisons of the costs of radioactive liquid waste disposal among the installations surveyed. Table 1 summarizes the principal items which make up these costs. To make a comparison one has to calculate a unit cost -in the case of liquids say, cost per gallon. The column headed "Collected after Monitoring" includes all of the wastes in some cases and only part of the wastes in others. As a divisor in determining unit costs it is not equitable because it varies with the different kinds of wastes. The largest item of collection cost, namely the amortization cost

of the collection systems is lacking. In most cases it was not available. In others many years of installation records would have had to be scrutinized and summarized. The other possible index of "total volume," the column "Effluent Discharged" also has an element of unreliability. Unit costs computed from either one of these indices could be made lower by diluting the waste stream with water, possibly storm water, and thus increasing volume.

The costs of liquid waste treatment and waste concentrate disposition operations are summarized in Table 2. The reader is cautioned against comparing these costs. The basis for each item is not the same.

Conclusions Regarding Solid Waste Disposal Costs.

Tables 3 and 4 summarize, by installations, the costs of the various phases of handling low level and high level wastes. For preparing these tables an attempt was made to ascertain the total cost of disposal per cubic foot of waste. In some cases this was not possible because all the costs are not known. Cost data for those installations disposing of wastes to the oceans lack one important item, namely the true charges for the ship and crew which took the material out to sea. This service was rendered as any inter-governmental agency service. Another unknown cost item is that cost for removing high level wastes from storage or for maintaining and guarding the high level waste storage facilities in the years of storage. Even without these realistic cost items one can draw some conclusions regarding the costs of disposing of solid radioactive wastes.

Installation	Collected after Monitoring	Transferred in Containers	Radioisotope Concentration Treatment				Effluent Discharged		Stored in Underground Tanks
			Evaporated	Chemically Precipitated	Ion Exchanged	Concentrate Produced	To Surface	To Subsurface ⁽¹⁾	
Argonne Nat. Lab.	5,732 ⁽²⁾	176	66	25	1.9		46,400	500	none
Bettis Field (WAPD)	1,679 ⁽³⁾	79	1,600	none	none	3.96	137,000	none	none
Brookhaven Nat. L.	3,267 ⁽⁴⁾	12	367	none	none	3.67	120,000	none	none
Fernald (FMPC)				none	none		94,000	none	none
Knolls At. Pow. Lab.	1,130	5	1,125	none	none	4.9	126,000	none	42
Los Alamos	13,900	none	none	13,900	none	33.2	13,900	none	none
NRTS (CPP) ⁽⁵⁾	671	none	252	none	none	3.56	none	671	3.56
Oak Ridge (ORNL)	1,000	none	none	none	none	none	158,000	1,000	none
Rocky Flats	4,800	none	none	1,570	none	45.5	40,000	786	none

(1) Discharged either to a surface holding pond or directly to subsurface.

(2) Does not include high level wastes collected in "pots".

(3) Does not include wastes dumped to sewer system.

(4) The quantity monitored was between 367,000 and 120,000,000 gallons.

(5) The quantities listed are for a 6 month period. They would not be true for a 12 month period if doubled because waste production varied.

Table I Volumes of Liquid Wastes Handled (by stages) During Fiscal Year 1955
(Units in 1000's gallons)

Installation	Wastes Treated (1000 gal)	Gross Cost of Concentration	Concentration Cost Per Gallon	Operating Cost ⁽¹⁾	Operating Cost Per Gallon	Concentrate Produced (gallons)	Concentrate Packaging Cost	Concentrate Packaging Cost Per Gallon	Concentrate Shipping ⁽²⁾ Cost	Cost of Underground Storage ⁽³⁾ Facilities	Summary Cost = Concentrating Packaging Shipping &/or Storing Costs	Unit Summary Cost (per gal.)
NO TREATMENT GIVEN												
Oak Ridge (ORNL)	1,000	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	\$ 85,400	\$0.085
BY EVAPORATION												
Argonne Nat. Lab.	66	\$	\$	\$	\$		\$	\$	\$	\$	\$	\$
Beths Field (WAPD)	1,600	56,060	0.04	37,510	0.023	3,960	3,110	0.79	3,150	N.A.	62,320	0.039
Brookhaven Nat. L.	367	62,400	0.17	12,230	0.033	3,670	770	0.21	830	N.A.	64,000	0.174
Knolls At. Pow. Lab.	1,125	60,900	0.05	8,500	0.025	4,900	860	0.36 ⁽⁴⁾	610 ⁽⁵⁾	2,400	64,770	0.057
NRTS (CPP) ⁽⁶⁾	252					3,565	N.A.	N.A.	N.A.	8,200		
BY EVAPORATION AND CALCINING												
Fernald (FMPC)		718,141		328,831			N.A.	N.A.	N.A.	⁽⁷⁾		
BY CHEMICAL PRECIPITATION AND VACUUM FILTRATION OF SLUDGE												
Argonne Nat. Lab.	25											
Los Alamos	13,900	136,840	0.01	75,630	0.005	33,200	nil ⁽⁸⁾	nil ⁽⁸⁾	1,870 ⁽⁹⁾	N.A.	138,710	0.010
Rocky Flats	1,570	126,120	0.08	66,870	0.043	43,000	4,140	0.10	5,940	N.A.	136,200	0.087

N.A. signifies "not applicable".

(1) Total treatment cost minus fixed cost

(2) Estimated as a proportion of the gross weight or volume shipped.

(3) Construction unit cost of storage facilities multiplied by annual input. Does not include operational and maintenance costs.

(4) Only 2,400 gallons packaged

(5) Theoretical cost of shipping 2,400 gallons to ORNL. (21,800 lbs at \$2.81/cwt.)

(6) The quantities listed are for a 6 month period. They would not be true for a 12 month period if doubled because waste production varied.

(7) Construction unit cost is \$1.61 per cu. ft.

(8) Used drums are obtained from other operations on the site.

(9) The cost of hauling and burying the sludge.

Table 2 Costs of Liquid Waste Treatment and Waste Concentrate Disposition Operations
Fiscal Year 1955

Installation	Waste Collection			Method	Waste Concentration				Waste Packaging			Shipping and Terminal Handling Data					Overhead	Total Known Cost	Total Cost per cu. ft. Collected
	Volume (cu. ft.)	Cost	Unit Cost		Volume m Before	cu. ft. After	Cost	Unit Cost ⁽¹⁾	Volume (cu. ft.)	Cost	Unit Cost	Destination	Overland Distance (miles)	Volume (cu. ft.)	Cost	Unit Cost			
Argonne Nat. Lab.	14,290	\$ 18,530	\$ 1.30	baling	10,000	2,380	\$2,580	\$.614	6,660	\$11,330	\$1.70	Oak Ridge	530	6,660	\$3,460	\$0.52	\$12,230	\$46,270	\$ 3.38
Bettis Field (WAPD)	18,000	3,760	0.21	inciner	13,200	360	4,510	.123	710	2,530	3.56	Earle, N. J.	370	710	3,440	4.84	3,320	17,560	0.97
Brookhaven Nat. L.	16,140	6,520	0.40	baling	2,000	640	1,190	.380	745	2,650	3.55	Floyd Bennett Field	70	745	1,030	1.38	6,740	18,130	1.12
Knolls At Pow. Lab.	36,880	7,910	0.21	baling	20,000	3,300	5,170	.861	20,950	17,840	0.85	Lake Ontario St. Area Oak Ridge	300 850	6,980 13,970	2,735 5,470	0.39 0.39	13,320	53,445	1.45
Los Alamos	62,400	32,030	0.51	none	N. A.	N. A.	N. A.	N. A.	N. A.	N. A.	N. A.	Site burial	-	62,400	8,970	0.14	14,960	55,960	0.90
NRTS, Idaho	27,000	6,280	0.23	none	N. A.	N. A.	N. A.	N. A.	N. A.	N. A.	N. A.	Site burial	-	27,230	9,900	0.36	4,620	20,800	0.77
Oak Ridge	116,400 ⁽²⁾	38,440	0.33	none	N. A.	N. A.	N. A.	N. A.	N. A.	N. A.	N. A.	Site burial	-	116,400	25,830	0.22	26,900	93,170	0.80
Rocky Flats	N. A.	N. A.	N. A.	none	N. A.	N. A.	N. A.	N. A.	33,900	15,380 ⁽³⁾	0.45	NRTS, Idaho	700	33,900	35,390	1.04	2,700	53,470	1.58
U. of Cal. Rad. Lab. Berkeley	6,200	3,610	0.58	none	N. A.	N. A.	N. A.	N. A.	6,180	11,330	1.83	San Francisco	20	6,180	4,850	0.77	11,290	31,070	5.01
Livermore	4,260	3,520	0.83	none	N. A.	N. A.	N. A.	N. A.	4,160	8,640	2.08	San Francisco	50	4,160	3,550	0.86	8,910	24,620	5.78

N.A. signifies "not applicable"

(1) Concentration unit cost measured in dollars per unit of concentration

(2) For 12 months based on 6 months of record

(3) Materials only

Table 3 Costs of Low Level Solid Wastes Disposal Practices
Fiscal Year 1955

Installation	Collection (and Storage)			Packaging			Shipping and Terminal Handling Data				Capital Investment Depreciat'n Charged (1)	Overhead	Total Known Cost (3)	Total Cost per cu. ft. Collected
	Volume (cu. ft.)	Cost	Unit Cost	Volume (cu. ft.)	Cost	Unit Cost	Destination	Volume (cu. ft.)	Cost	Unit Cost				
Argonne Nat. Lab.	391	\$10,440 ⁽²⁾	\$ 26.70	N.A.	N.A.	N.A.	Site storage	N.A.	N.A.	N.A.	\$ 10,260	\$ 100	\$10,540	\$ 27
Bettis Field (WAPD)	26.8	900	33.60	26.8	\$23,930	\$ 893	Earle, N.J.	26.8	\$10,600	\$ 392	none ⁽⁴⁾	3,510	38,940	1,450
Brookhaven Nat. L.	462	3,600 ⁽²⁾	7.80	462	4,200	9	Floyd Bennett Field	462	1,620	3.52	1,420	4,870	14,290	30
Knolls At. Pow. Lab.	5.6	2,900 ⁽²⁾	518.00	N.A.	N.A.	N.A.	Site storage	N.A.	N.A.	N.A.	1,950	300	3,200	572
NRTS, Idaho	230	600	2.61	N.A.	N.A.	N.A.	Site burial	230	80	0.36	none ⁽⁴⁾	375	1,055	4.58

N.A. signifies "not applicable".

(1) Cost of maintaining and guarding high level wastes in storage represents an additional cost not included.

(2) Includes amortization of construction cost of storage facilities.

(3) Sum of collection, packaging, shipping and overhead costs.

(4) Some of the depreciation charged to low level wastes practices could be charged here.

Table 4 Costs of High Level Solid Wastes Practices
Fiscal Year 1955

One fact is immediately obvious. It is more expensive per cubic foot to handle high level wastes than low level wastes. This is true even if the wastes are merely stored. Another is that land disposal is less expensive per cubic foot than is sea disposal even without the additional cost of water transportation added to the latter. The least expensive method of disposal is burial on site as practiced by the large remote installations.

Some Pertinent Suggestions.

It is recommended that a study be made of methods and materials of packaging radioactive wastes for shipment. This study should consider the multiple factors affecting waste shipments such as: type of waste, destination, ultimate repository, ICC regulations and economy.

It is suggested that each installation keep a serial record of the amounts of wastes handled. Volumes can be determined with 90%, or better, certainty. At the same time associated weights of the waste volumes should be recorded. Weights can be ascertained either by direct weighing or by estimates based on weighing samples of the waste.

Records such as these would be useful in making up annual budgets, and perhaps in determining better ways to do the waste disposal job.

An outline of a form which can be used for the serial record is provided in Appendix 4. Although the form is for a monthly summary, the time unit can be varied to suit the operation as can daily, weekly or monthly work sheets for each stage of the operation.

APPENDICES

• APPENDIX 1 -

STANDARDIZATION OF FIXED COSTS AND MOTORIZED
EQUIPMENT USEAGE COSTS

Fixed Costs: Fixed costs considered in this report are depreciation and overhead and are deemed inalienable components of the cost structure. The first of these is based on capital investments; overhead is based on operational labor. Capital investments were obtained first hand from the operating installations either directly from cost reports or indirectly as estimates based on mensuration and experience. Fixed costs were calculated as follows:

1. Depreciation: Depreciation is computed on a straight line basis, that is, uniform costing over a spread of years. It is known that buildings and equipment of one installation will not necessarily depreciate at the same rate as different buildings and equipment of another installation. However, to simplify costing and to indicate relative investments, depreciation rates are assumed to be uniform and have been arbitrarily set as follows:

buildings	-	10% per year
equipment*	-	20% per year

2. Overhead: Overhead represents cost items such as salaries of management, clerical and office staffs, security police force and so forth. Book-keeping methods varied among the different

* Exceptions are certain vehicles which are noted on following pages and "permanent" storage facilities. For the latter, cost per unit capacity or investment costs per filling rate per year may be used. However, the least argumentative is believed to be a straight line write off as with other equipment but over a longer period. Say 20 years.

installations, consequently overhead charges also varied. To smooth out the variations due to methods of keeping records, this report uses 100% of direct labor costs as the overhead charge. It is listed as a separate item and is not included in any of the labor costs.

Labor Costs: For the most part, the labor involved in the various waste disposal operations was estimated. The estimates are based on the judgement of the installation staffs and represent "average" or "normal" operation for the past fiscal year. Some of the cost accounting sections had records of the total man hours expended which was a good check on the estimates, but did not have cost break-downs as were desired for this analysis.

Health physics labor is included in certain operations such as the loading of shipment vehicles or monitoring of effluents, i.e., in situations where trained waste disposal personnel could be equally effective. The cost of policing of plant operations, other than waste handling, is not intended to be in this report.

In calculating labor costs actual salaries were used as much as possible even though these varied across the nation. The variance was from \$2/hr. to about \$2.60/hr. for non-skilled workers. Man hours are also listed wherever possible. Annual costs are built up from daily, weekly or monthly averages using a figure of 2000 man hours as a working year.

Motorized Equipment Costs: Cost of operating motorized equipment (exclusive of labor) include depreciation of the capital investment, interest, taxes, insurance, storage, repairs, maintenance, fuel and lubricating costs. Unless otherwise noted the costs of operating the vehicles will be based on the following:

Use	-	10,000 mi or 1000 hrs/yr.
Depreciation (straight line)	-	100% ÷ life in years.
Interest, taxes, insurance and storage	-	6%/year.
Repairs and maintenance (100% spread over life)	-	100% ÷ life/yr.
Fuel and Lubricating	-	\$0.30/gal. gasoline and \$0.20/gal. fuel oil plus 25% of fuel as allowance for lubrication and oil.
Fuel consumption	-	0.06 gal/H.P. hr. - gasoline 0.04 gal/H.P. hr. - fuel oil
Fuel and lubricating	=	0.06(.30) x 1.25 = \$0.0225/H.P. hr. (gasoline)
cost	=	0.04(.20) x 1.25 = \$0.010/H.P. hr. (oil)

1. Operating Costs - $\frac{1}{2}$ Ton Truck (same for fork lift):

1st Cost - \$1,800.

30 H.P. - life = 5 yrs.

	<u>Rate</u>	<u>Annual Cost</u>
a. Depreciation	20%	\$ 360.00
b. Interest, taxes, insurance, storage	6%	108.00
c. Repairs and maintenance	20%	360.00
d. Fuel and lub. (0.0225 x 30 x 1000)	=	<u>675.00</u>
Total	=	\$1,503.00

$$\text{Cost/hr} = \frac{1,503}{1,000} = \$1.50/\text{hr.}$$

$$\text{Cost/mi} = \frac{1,503}{10,000} = \$0.15/\text{mi.}$$

2. Operating Cost - $2\frac{1}{2}$ Ton Truck:

1st Cost - \$4,000.

50 H.P. - Life = 8 yrs.

	<u>Rate</u>	<u>Annual Cost</u>
a. Depreciation	12.5%	\$ 500.00
b. Interest, taxes insurance storage	6%	240.00
c. Repairs and maintenance	12%	500.00
d. Fuel and lub. (0.0226 x 50 x 1000)	=	<u>1,125.00</u>
Total	=	\$2,365.00

$$\text{Cost/hr} = \frac{2,365}{1,000} = \$2.36/\text{hr.}$$

$$\text{Cost/mi} = \frac{2,365}{10,000} = \$0.24/\text{mi.}$$

3. Operating Cost - Semi Tractor Trailer (Low boy):

1st Cost - \$12,000

75 H.P. - life = 10 years

	<u>Rate</u>	<u>Annual Cost</u>
a. Depreciation	10%	\$1,200.00
b. Interest, taxes, insurance storage	6%	720.00
c. Repairs and maintenance	10%	1,200.00
d. Fuel and lub. (0.0225 x 75 x 1000)	=	<u>657.00</u>
Total	=	\$4,777.00

$$\text{cost/hr} = \frac{4,777}{1,000} = \$4.77/\text{hr.}$$

$$\text{cost/mi} = \frac{4,777}{10,000} = \$0.48/\text{mi.}$$

4. Operating Cost $1\frac{1}{2}$ cu. yd. Back hoe:

1st cost - \$50,000 est.

80 H.P. - life - 10 years.

	<u>Rate</u>	<u>Annual Cost</u>
a. Depreciation	10%	\$ 5,000
b. Interest, taxes, insurance, storage	6%	3,000
c. Repairs and maintenance	10%	5,000
d. Fuel and lub. (0.010 x 80 x 1000)	=	<u>800</u>
Total		\$13,800

$$\text{Cost/hr} = \frac{13,800}{1,000} = \$13.80$$

5. Operating Cost - Bulldozer:

1st cost - \$20,000

80 H.P. - life 10 years

	<u>Rate</u>	<u>Annual Cost</u>
a. Depreciation	10%	\$2,000
b. Interest, taxes, insurance, storage	6%	1,200
c. Repairs and maintenance	10%	2,000
d. Fuel and lub. (0.10 x 80 x 1000)	=	<u>800</u>
Total		\$6,000

$$\text{cost/hr} = \frac{6,000}{1,000} = \$6/\text{hr.}$$

- APPENDIX 2 -

ANALYSIS OF THE ECONOMY OF SOLID WASTE VOLUME REDUCTION

In order to save money by reducing the volume of wastes to be packaged and shipped, the cost of reducing the waste volume and the cost of packaging the reduced volume should be less than the cost of packaging the unreduced volume.

Let:

A = the unconcentrated volume

B = the concentrated volume

F = concentration factor = $\frac{A}{B}$

k = unit cost of packaging, a constant (\$/cu.ft.).

C = cost of concentrating = L A + I

L = cost of labor per cu. ft. of waste.

I = capital investment in concentrating equipment and building.

The savings, S, realized by concentration may then be calculated as follows:

$$S = kA - kB - C$$

$$\text{but } B = \frac{A}{F}, \text{ and } C = L A + I$$

$$\text{therefore, } S = kA\left(1 - \frac{1}{F} - \frac{L}{k}\right) - I$$

In the following analysis k, A, L and I are more or less constant for any, given volume. Consider only the concentration factor F, as varying. It is an actuality that savings, if any result only from reduced packaging requirements. The amount saved is a function of the concentration factor.

If F, the concentration factor takes on different values, i.e., 1,2,3,..., one can calculate the increment of savings for succeeding degrees of concentration. For example, the savings for concentrating by a factor of 2 over not concentrating at all is

$$S_2 = k A (1 - \frac{1}{F_2} - \frac{L}{K}) - I$$

while the savings for concentrating by a factor of 3 is

$$S_3 = k A (1 - \frac{1}{F_3} - \frac{L}{K}) - I$$

Subtracting S_2 from S_3 , the value of concentrating to 3 times over 2 times is

$$\begin{aligned} S_3 - S_2 &= \left[k A (1 - \frac{1}{F_3} - \frac{L}{K}) - I \right] - \left[k A (1 - \frac{1}{F_2} - \frac{L}{K}) - I \right] \\ &= k A \left(\frac{F_3 - F_2}{F_2 \cdot F_3} \right) \end{aligned}$$

If one does this for all the possible concentration factors, you get the series formula.

$$S = (S_2 - S_1) + (S_3 - S_2) + (S_4 - S_3) + \dots$$

In this form, it is readily evident that the most you can save is cost of packaging the unconcentrated volume. Substituting in the incremental values for the increasing concentration factors, letting F take on the values 1, 2, 3 we find the increments saved for each higher concentration factor. viz.

$$S = k A \left[\frac{2-1}{2 \cdot 1} + \frac{3-2}{2 \cdot 3} + \frac{4-3}{3 \cdot 4} + \dots + \frac{(n+1)-n}{(n+1)(n)} + \dots \right]$$

The value of the bracketed term approaches unity as n approaches infinity. The values of the first few terms are:

$$S = k A \left[\frac{1}{2} + \frac{1}{6} + \frac{1}{12} + \frac{1}{20} + \frac{1}{30} + \dots \right]$$

Applying this method of analysis to the 3 installations which practice baling we get estimated savings for theoretical concentration factors based on actual packaging costs.

Table 2-1 Effects of Different Concentration Factors on Reducing Costs of Packaging Solid Wastes.

Site	Uncon- cen- trated Vol. (cu.ft)	Pack- aging cost/ cu.ft.	Cost of Packaging of unconcen- trated volume	Estimated Savings in Packaging if Volume of Wastes is reduced by factor of				
				2	3	4	5	6
ANL	9,000	\$1.52	\$13,680	\$6,840	\$9,120	\$10,260	\$10,944	\$11,400
BNL	2,000	4.46	8,920	4,460	5,950	6,690	7,136	7,434
KAPL	20,000	0.85	17,000	8,500	11,300	12,748	13,598	14,164

Figure 2-1 is a graphic presentation of the same data. It is readily evident that the largest increment of saving is that achieved by halving the original volume. All other increments are progressively smaller.

So far, the cost of concentrating the wastes has been neglected. If this cost is subtracted from the packaging savings, the net savings are somewhat less. Table 2-2 below analyses the economy of concentrating wastes as practiced in 1955.

Figure 2-1 Effects of Concentration Factors on Reducing Costs of Packaging Solid Wastes

Table 2-2 Effects of Concentrating on Cost of Solid Waste Disposal.

Site	Vol. of Wastes Before conc.	Wastes After conc.	Pack-aging Cost/ cu.ft.	Est. Cost of Packaging Unconc. Volume	Cost of Packaging Conc. Volume	Cost of Concentrating	Theoretical Saving by Concentrating
<u>Concentration by Baling</u>							
	(cu. ft.)						
ANL	9,000	2,600	\$1.52	\$13,680	\$3,950	\$4,710	\$5,020
BNL	2,000	640	4.46	8,920	2,850	1,930	5,740
KAPL	20,000	3,300	0.85	17,000	2,800	5,170	9,030
<u>Concentration by Incineration</u>							
Bet.	13,200	360	3.56	47,000	1,280	4,510	41,210

The Bettis saving appears to be substantial. It is felt that this is a real saving. On the other hand the savings by baling are thought to be more ethereal than real. When overhead is included, a higher proportion of overhead is chargeable to concentration than to packaging because more labor per cubic foot of waste is involved in the former. Another cost factor not considered is that all of the baling apparatuses are rather new and maintenance has not yet become a cost item. The building housing the baler will also require maintenance as time goes on.

If one compares Table 2-2 with Table 2-1, it is readily evident that the cost of concentrating plus the cost of packaging the concentrated volume is nearly equal to the cost of packaging the original volume reduced by a factor of two. One interpretation of this set of circumstances is that if the original volume can be reduced by a

factor of 2 or more by stomping on the wastes in their shipping container or by some other inexpensive compaction method, there is little or no money saved by mechanically compressing the wastes.

- APPENDIX 3 -

MATERIEL COSTS USED IN THIS REPORT

Collection Materials

<u>Item</u>	<u>Cost</u>	<u>Where</u>
Cardboard Cartons		
4½ cu. ft.	\$0.30 ea	ANL
2 cu. ft.	0.21 ea	LASL
12 cu. ft.	0.23 ea	NRTS

Container lining materials

double kraft paper	1/cu.ft.	0.20ea	UCRL
polyethylene bag	32 gal.	0.29 ea	BNL
" "	1 cu.ft.	0.083 ea	LASL
" "	32 gal.	0.27 ea	NRTS
" "	55 gal.	1.00 ea	R.F.
Fiber drums	1 cu. ft.	0.49 ea	ANL
Polyethylene bottles	6 gal.	10.00 ea	ANL

Packaging Materials

Liquid Solidification Agents:

Amigel	0.10/lb	UCRL
Zorbal	0.30/lb	Bet.

Steel drums

30 gal used	3.00 ea	Bet.
30 gal reconditioned	3.50 ea	R.F.

<u>Item</u>	<u>Cost</u>	<u>Where</u>
Steel drums (cont.)		
30 gal new	2.25 ea	UCRL
55 gal used	3.50 ea	Bet.
55 gal new	7.00 ea	KAPL
55 gal polyethylene lined	16.00 ea	KAPL
55 gal reconditioned	4.60 ea	R.F.
Cement	1.20/bag	UCRL
Ready Mix Concrete	15.00/yd	Bet.
	13.00/yd	USNRDL
Sand	3.00/ton	NRDL
<u>Estimated Costs</u>		
Fencing (in place)		
4 strands barbed wire	0.25/ft.	
Farm fence 4 ft.	0.50/ft	
8 ft. cyclone fence(chain link, etc.)	10.00/ft	
Gravel	2.50/cu. yd.	
Utilities		
Electric (for field office)	5.00/mo.	
Heat (for field office)	5.00/mo.	
Telephone (for field office)	10.00/mo	
Laundrying of protective clothing	100.00/man year	

- APPENDIX 4 -

OUTLINE OF FORM FOR RECORDING MONTHLY WASTE DISPOSAL COSTS

LIQUID WASTES

I. Collection and Storage

A. Collection through piping system.

1. Total quantity handled _____ gal.
2. Labor and Supervision _____ mhrs.
3. Radiation Monitoring _____ mhrs.
4. Materials - Type and cost
 a) Treatment _____
 b) Maintenance _____
5. Utilities _____

B. Manual Collection in Containers

1. Total quantity handled _____ gal.
2. Labor and Supervision _____ mhrs.
3. Radiation Monitoring _____ mhrs.
4. Materials (containers, etc.) _____
5. Transport equipment and useage
 Example: 5000 gal tanker 50 mi. or 20 hrs.

6. Utilities _____
7. Remarks _____

LIQUID WASTES

II. Release to Environment (water courses, well, surface, pit or pond).

1. Total Quantity released _____ gal.
2. Labor and Supervision _____ mhrs.
3. Radiation Monitoring _____ mhrs.
4. Materials _____
5. Utilities _____
6. Remarks _____

III. Concentration by Evaporation, Ion Exchange or Co-Precipitation.

1. Labor and Supervision
 - a) Operating _____ mhrs.
 - b) Analytical _____ mhrs.
 - c) Monitoring _____ mhrs.
 - d) Maintenance _____ mhrs.
2. Materials
 - a) Operating _____
 - b) Maintenance _____
 - c) Analytical _____
3. Utilities _____
4. Operating Data
 - a) Volume Concentrated _____ gal.
 - b) Volume of Concentrate _____ gal.
 - c) Average initial activity _____ curies/cc
 - d) Average final activity _____ curies/cc
5. Remarks _____

LIQUID WASTES

IV. Packaging.

A. Concentrate from Concentration Process.

1. Labor and Supervision _____ mhrs.
2. Packaging Materials
 - a) container type _____ no. used _____

 - b) raw materials (cement, etc.) _____
3. Equipment and useage _____

B. Liquids Other Than Concentrate.

1. Quantity _____ gal.
2. Labor and Supervision _____ m hrs.
3. Packaging Materials
 - a) type _____ b) no. used _____

 - c) raw materials (caustic, etc.) _____
4. Equipment and useage _____

V. Long Term Tank Storage

1. Labor and Supervision _____ m hrs.
2. Radiation Monitroing _____ m hrs.
3. Materials (maintenance) _____
4. Quantity to tank _____ gal.
5. Remarks _____

LOW LEVEL SOLID WASTES

I. Collection, Preparation, Monitoring, Sorting and Storage.

1. Combustible Wastes: _____ lbs; _____ cu.ft.

2. Non-combustible Wastes: _____ lbs; _____ cu.ft.

3. Labor and Supervision _____ m hrs.

4. Radiation Monitoring _____ m hrs.

5. Materials

a) expendable containers _____

b) maintenance of storage facilities _____

6. Equipment and useage

Example: $2\frac{1}{2}$ T. Truck _____ 80 mi. or 120 hrs.

7. Utilities _____

8. Remarks _____

II. Concentration by Baling or Incineration.

1. Quantity Concentrated: _____ lbs; _____ cu. ft.

2. Concentrated Volume: _____ cu. ft.

3. Labor and Supervision

a) operating _____ m hrs.

b) maintenance _____ m hrs.

c) radiation monitoring _____ m hrs.

4. Materials

a) operating _____

b) maintenance _____

LOW LEVEL SOLID WASTES

5. Equipment and useage _____
6. Utilities _____
7. Remarks _____

III. Packaging.

1. Quantity packaged _____ cu.ft.; _____ lbs.
2. Labor and Supervision
- a) operating _____ m hrs.
- b) radiation monitoring _____ m hrs.
3. Packaging Materials
- a) container type _____ no. used _____
- _____
- b) raw materials _____ quantity _____
- _____
4. Equipment and useage _____
5. Utilities _____
6. Remarks _____

HIGH LEVEL SOLID WASTES

I. Collection, Sorting, Monitoring and Storage.

1. Wastes Collected _____ lbs. _____ cu.ft.
2. Labor and Supervision _____ m hrs.
3. Radiation Monitoring _____ m hrs.
4. Materials
 - a) expendable containers _____
 - b) maintenance of storage facilities _____
5. Equipment and useage
Example: 10 T. Lowboy _____ 10 hrs. _____

6. Remarks _____

II. Packaging.

1. Quantity Packaged _____ cu.ft. _____ lbs.
2. Labor and Supervision
 - a) operating _____ m hrs.
 - b) radiation monitoring _____ m hrs.
3. Packaging Materials
 - a) container type _____ no. used _____

 - b) raw materials _____ quantity _____

4. Equipment and useage _____
5. Utilities _____
6. Remarks _____

ALL WASTES

I. Shipment-Including Loading and Unloading.

1. Quantity Shipped

a) Liquids _____ cu.ft. _____ lbs.
b) Low level solids _____ cu.ft. _____ lbs.
c) High level solids _____ cu.ft. _____ lbs.

2. Labor and Supervision

a) Carrier preparation _____ m hrs.
b) Loading, unloading _____ m hrs.
c) Radiation monitoring _____ m hrs.
d) Carrier decontamination _____ m hrs.

3. Materials _____

4. Transportation

charges \$ _____ wastes shipped _____ cu.ft. _____ lbs.

5. Loading, unloading and handling equipment and useage.

Example: 10 T. crane(mobile) 10 hrs.

6. Charges by destination authority \$ _____

7. Remarks _____

ALL WASTES

II. Disposal on Land.

1. Quantity Disposed

- a) Liquids _____ cu.ft. _____ lbs.
b) Low level solids _____ cu.ft. _____ lbs.
c) High level solids _____ cu.ft. _____ lbs.

2. Labor and Supervision

- a) Excavation and backfill _____ m hrs.
b) Maintenance _____ m hrs.
c) Radiation monitoring _____ m hrs.
d) Other _____ m hrs.

3. Equipment and useage

Example: 1½ yd. backhoe 20 hrs.

4. Materials _____

5. Remarks _____