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WASTES:
Waste System Transportation and
Economic Simulation - Version II
Technical Reference Manual

February 1988

Prepared for the U.S. Department of Energy
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Pacific Northwest Laboratory
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WASTES:
WASTE SYSTEM TRANSPORTATION
AND ECONOMIC SIMULATION - VERSION II
TECHNICAL REFERENCE MANUAL

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SUMMARY

The Waste System Transportation and Economic Simulation (WASTES) Technical Reference Manual was written to describe and document the algorithms used within the WASTES model as implemented in Version 2.23. The manual will serve as a reference for users of the WASTES system.

The intended audience for this manual are knowledgeable users of WASTES who have an interest in the underlying principles and algorithms used within the WASTES model.

Each algorithm is described in nonprogrammers terminology, and the source and uncertainties of the constants in use by these algorithms are described. The manual also describes the general philosophy and rules used to: 1) determine the allocation and priority of spent fuel generation sources to facility destinations, 2) calculate transportation costs, and 3) estimate the cost of at-reactor ex-pool storage.

An detailed description of the implementation of many of the algorithms is also included in the WASTES Programmers Reference Manual (Shay and Buxbaum 1986a).

This manual is separated into sections based on the general usage of the algorithms being discussed.

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1.0 INTRODUCTION

The WASTES model was developed for use in analyzing the effects of various policy decisions, logistics considerations, and facility operating schedules on contemplated waste management system configurations. The model provides extensive capabilities for simulating the response of the waste management system under a variety of configurations and operational philosophies. WASTES uses discrete event simulation techniques to model the generation of commercial spent nuclear fuel, the buildup of spent-fuel inventories within various components of the system, and the transportation requirements for the movement of spent fuel throughout the system.

WASTES incorporates logic for handling up to 10 different facilities of four different types [Federal Interim Storage (FIS), fuel reprocessing facilities, monitored retrievable storage (MRS), and waste repositories], two transportation modes (truck and rail), four transshipment categories (describing reactor to reactor shipments), and six different at-reactor ex-pool storage technologies.

The WASTES model uses detailed historical and projected spent-fuel discharges from the PNL spent fuel data base, along with data characterizing the present and planned commercial reactors in the U.S. as inputs to the simulation. The acceptance and discharge rate of each modeled facility is also used to drive the events simulated, as is the discharge rate of reactors being decommissioned. The combination of these factors provides the realistic and complex interrelationships required.

Year-by-year reports generated by WASTES include: annual inventories of spent fuel in each facility, annual summaries of shipments between facilities, characterization of fuel received at each facility, costs incurred by at-reactor ex-pool storage requirements, and shipping summaries giving detail on costs, number of casks required, and cask miles.

This document was developed to describe the algorithms used in the generation of the various WASTES costs reports, as well as to document the logic utilized within the transportation sections of the model. It is organized into four chapters, each describing a facet of the system. This chapter provides a

brief description of the WASTES model along with a description of the rest of the document. Chapter 2 describes the algorithms used to determine transportation distances, costs, travel time, and a levelized cask purchasing strategy. Chapter 3 discusses the algorithms used to estimate the costs associated with ex-pool storage at each reactor within the WASTES model. Chapter 4 describes the algorithms and logic used by WASTES to determine how and when spent-fuel shipments are to be made.

2.0 TRANSPORTATION ALGORITHMS

This chapter describes the algorithms used for determining transportation distances, costs, travel time, and a levelized cask purchasing strategy. The first section deals with the method used in WASTES to approximate shipping distances. The second section describes the truck and rail costing algorithms. The third and last section describes the algorithm used to determine the levelized cask purchasing strategy.

2.1 TRANSPORTATION DISTANCE CALCULATIONS

Transportation distances are calculated by utilizing the great circle distances between two points (the great circle distance represents the shortest distance between two points on the surface of a sphere). This distance is multiplied by an appropriate factor to account for the circuits of actual highway or rail routes. The great circle distance formula is:

$$\text{DISTANCE} = \text{RADIUS} * \text{ARCCOS} \left(\frac{\text{SIN}(\text{LAT}_1) * \text{SIN}(\text{LAT}_2) + \text{Cos}(\text{LAT}_1) * \text{Cos}(\text{LAT}_2) * \text{Cos}(\Delta\text{Long})}{\text{Cos}(\text{LAT}_1) * \text{Cos}(\text{LAT}_2)} \right)$$

Where: Radius = The radius of the earth (3960.0 miles)

Lat_1 = One point's latitude.

Lat_2 = The other point's latitude.

ΔLong = The difference in longitude between the points.

Note: The latitudes and longitudes entered on the input cards are in degrees and minutes. These are converted to decimal degrees, and then to radians for use in the above formula.

Once the great circle distance has been calculated, a circuitry factor is applied to account for the difference between the direct overland distance calculated by the great circle methodology and the actual highway or rail mileage. The circuitry factors were determined by calculating the difference between the calculated great circle distance and the actual highway and rail distance data obtained from Tables 1.10, 1.11, 1.14, 1.15, 1.16, 1.17, 1.18, and 1.19 in Transportation Impacts of the Commercial Radioactive Waste Management Program

published by Sandia National Laboratories (Cashwell et al. 1986). The factor for highway distances is 1.25 (Standard Error: 0.0043) resulting in an adjusted R of 0.9966 and a mean absolute error of 77.29 miles. The factor for rail distances is 1.35 (Standard Error: 0.0067) resulting in an adjusted R of 0.9919 and a mean absolute error of 133.51 miles. A comparison between route specific mileages and mileages calculated utilizing the great circle methodology is shown in Figure 2.1 for highway routings, and Figure 2.2 for rail routings.

A linear regression of both highway and rail distance data was made by regressing the calculated great circle distance versus the actual mileage. A linear fit both with and without an intercept was made, but the no intercept model was chosen on the grounds of improved statistical performance and better intuitive basis. Several data points in both data sets proved to be three or more standard deviations high, but they were retained in the model because it was not known whether they were erroneous or just anomalies. Their presence in the model did not influence the slope or intercept parameters significantly.

WASTES attempts to limit latitude and longitude entry errors by imposing boundaries on the acceptable values. These boundaries correspond roughly to a rectangle containing the United States. Latitudes must be between 25° and 49° North, and longitudes must be between 65° and 125° West.

2.2 TRUCK AND RAIL COST ESTIMATES

Shipping cost estimates are calculated for both legal weight truck and general freight rail transportation modes. Shipping costs are computed in dollars per hundred weight. The costs for safeguards and security charges are also estimated and are computed in dollars per trip. In addition, the estimated cask transport time for each shipment is calculated. The equations listed below were obtained from an analysis of data reported by McNair et al. (1986). All costs reported by WASTES are in 1986 dollars. Truck shipping costs are adjusted from mid-1984 dollars by a 6 percent increase. Rail shipping costs are adjusted from mid-1984 dollars by a 1.1 percent increase. Updates will be made to WASTES cost factors as required to support DOE programs.

FIGURE 2.1. Truck Distance Data (Cashwell et al. 1986)

FIGURE 2.2. Rail Distance Data (Cashwell et al. 1986)

2.2.1 Truck Shipping Costs

The original data for truck shipping charges were supplied by Tri-State Motor Transit Co. (1984) for truck shipments occurring in the 48 contiguous states. These data were published in Table A.1A by McNair et al. (1986). Shipping costs are calculated assuming a round trip, where a truck will be empty on one leg of the trip, and loaded on the other leg. WASTES uses this fact to separate the costs by empty and loaded trips, combining the two to obtain the total costs.

The data for empty and loaded truck shipping costs were each analyzed, and it was determined from residual analyses that the best fit was obtained by partitioning the data into sections. Empty costs were partitioned into the following mileage ranges: 1) ≤ 350 miles, 2) 350 to 750 miles, and 3) > 750 miles. Loaded costs were also partitioned into mileage ranges: 1) ≤ 200 miles, 2) 200 to 1000 miles, and 3) > 1000 miles. The equations used for each are shown in Figures 2.3 through 2.8. The values in parentheses below each parameter indicate the standard error associated with the coefficient. The adjusted R^2 is also listed for each equation. Plots of the data used, along with the regression line and the 95 percent confidence interval, are also shown on those figures.

2.2.2 Rail Shipping Costs

Rail shipping charges were extracted from various rail tariff guides for shipments of radioactive materials between various reactors and a hypothetical national site located at Carlsbad, New Mexico. A copy of this data was included in Table A.6 by McNair et al. (1986). As with truck shipping costs, rail shipping costs are calculated assuming a round trip, where one leg of the trip will be an empty rail car and one will be loaded. WASTES uses this fact to separate the costs into empty and loaded trips and to combine the two to obtain the total costs.

Because of the large difference between shipping costs in the western tariff region and the rest of the United States, WASTES handles each separately. Western rail shipments are defined as those shipments whose source and destination longitude is greater than 100 West. However, unlike the truck

FIGURE 2.3. Truck Shipping Costs - Empty ≤ 350 Miles

FIGURE 2.4. Truck Shipping Costs - Empty 350-750 Miles

FIGURE 2.5. Truck Shipping Costs - Empty >750 Miles

FIGURE 2.6. Truck Shipping Costs - Loaded ≤ 200 Miles

FIGURE 2.7. Truck Shipping Costs - Loaded 200-1000 Miles

FIGURE 2.8. Truck Shipping Costs - Loaded >1000 Miles

shipping data, no mileage partitions were necessary. The equations determined for empty and loaded shipments, both within the western region exclusively and for the rest of the United States, are shown in Figures 2.9 through 2.12.

Because of the large variability in the data and the small number of data points for western shipments, additional data for western rail shipment costs were added from McNair et al. (1986, Table A.7). These data reflect rail shipping charges from western reactors to a hypothetical western regional storage site at Hanford, Washington. Adequate fits were obtained from linear regressions on the combined data set. The nonwestern shipment data, however, provided excellent fits. An analysis of the residuals from the linear regression displayed the requirement for a second-order term to eliminate a slight curvature in the data.

2.2.3 Truck Security and Safeguards Costs

Security and safeguards costs for truck shipments were obtained by utilizing conservative engineering judgment for casks as a function of the total distance traveled. These costs include the requirements for the number of

FIGURE 2.9. Rail Shipping Costs - Empty Excluding Western Region

FIGURE 2.10. Rail Shipping Costs - Empty Western Region Only

FIGURE 2.11. Rail Shipping Costs - Loaded Excluding Western Region

FIGURE 2.12. Rail Shipping Costs - Loaded Western Region Only

accompanying escort vehicles and the distance they accompany the shipment, armed escorts, and special equipment that would be needed as a function of the total distance traveled. The assumptions used, along with the cost components of each are included below in Table 2.1.

Escort vehicles cost \$1.48 per mile escorted, armed guards cost \$0.20 per mile (\$100.00 minimum), and special equipment costs \$0.92 per mile. The costs shown in Table 2.1 are based on the assumption that the driver is accompanied by an armed guard inside the truck, plus an armed guard in each escort vehicle.

TABLE 2.1. Truck Security and Safeguards Costs Basis

Distance	Escorts	Escort Cost	Armed Guards	Spec Equip	Total
200	1 @ 200	\$ 296	\$ 100	\$ 200	\$ 596
500	1 @ 500	\$ 740	\$ 100	\$ 460	\$1300
1000	1 @ 500	\$ 740	\$ 300	\$ 920	\$1960
1500	2 @ 500	\$1480	\$ 500	\$1380	\$3360
2000	2 @ 500	\$1480	\$ 600	\$1840	\$3920

The five data points generated by the engineering estimates described above were fit to a smooth curve by a log-log regression analysis. Although a very good fit was not obtained, the resulting curve is reasonable in light of the small number of data points and the inherent uncertainty in the engineering judgments made to generate them. The regression yielded the following formula:

$$\text{Truck S\&S Costs (\$/mile)} = 7.67 * (\text{Distance})^{-0.1795}$$

$$\text{Standard Error} = (2.8937) \quad (0.0477)$$

$$\text{Adjusted } R^2 = 0.7672$$

Figure 2.13 is a plot of truck security and safeguards costs.

FIGURE 2.13. Truck Security and Safeguards Costs

2.2.4 Rail Security and Safeguards Costs

Security and safeguards costs for rail shipments are calculated by the following formula:

$$\text{Rail S\&S Costs (\$)} = \$500.00 * (\text{Number of Days}) + \$0.16/\text{mile}$$

This assumes that two escorts would accompany each rail shipment from origin to destination at a cost of \$250.00 per day plus \$0.08 per mile per escort for the provision of a caboose. These factors were published by McNair et al. (1986). The number of days used in the above formula is rounded up to the next whole day and is computed from the travel time calculated below.

2.2.5 Truck and Rail Travel Time

The number of days that a cask will be utilized for each individual shipment is also estimated. The total costs of leased casks are calculated by multiplying the total number of days that each cask is utilized by the daily lease charge for that cask type. The daily lease rate is input by the user.

Truck travel time is obtained from the general rule that a truck will average around 840 miles per day, hence the travel time is:

$$\text{Truck Travel Time (Days)} = 0.00119 * \text{Distance}$$

The rail travel time was determined from an analysis of the median transit times published by McNair et al. (1986, Table A.6), which is the source of the rail shipping cost data. The large confidence bands of the regression line include both the uncertainty in shipment time for a given route, and the variation for different routes of the same distance. A regression of the data provided the following formula:

$$\text{Rail Travel Time (Days)} = 0.35 * (\text{Distance})^{0.4590}$$

$$\text{Standard Error} = (0.0502) \quad (0.0202)$$

$$\text{Adjusted } R^2 = 0.5074$$

Rail travel times are plotted in Figure 2.14.

2.3 LEVELIZED CASK PURCHASING

WASTES provides a levelized cask purchasing report. The algorithm used to provide levelized cask purchasing is a first-order approximation of a cask purchase/replacement methodology in which the "peak requirements" in a given year may be transferred into an earlier year. The methodology discussed in this section acts as a "levelizer" by moving cask requirements from years having peak requirements to prior years having lower requirements. The cask levelizing algorithm does not affect the WASTES simulation, but is based on simulation results. It provides a useful tool for estimating cask requirements under a levelized cask purchasing scenario.

For each shipping cask type modeled in the simulation, the algorithm allows up to 300 MTU of lag pool storage (10 percent of the annual receipt rate of a waste management facility having a 3000 MTU annual receipt rate) to be available for levelizing peak year transfer requirements.

FIGURE 2.14. Rail Travel Time

The algorithm examines the annual cask requirements previously calculated by WASTES and compares the number of casks required in a given year with the number of casks previously purchased. If the required number of casks exceeds the number of casks previously purchased, additional casks are purchased in that year. If the required number of casks are less than the number of casks available, the excess casks are use to "preship" spent fuel and thus prevent a situation in future years in which the number of required casks might exceed the amount then available.

The levelizing algorithm also ensures that a cask will be available only during its prescribed lifetime (user input). Once a cask has reached the end of its lifetime, it is either replaced (new purchase) or retired. The number of casks purchased and retired are based on the levelized cask requirements.

3.0 DRY STORAGE COSTS

This chapter discusses the algorithms used to estimate the cost of at-reactor ex-pool storage within the WASTES model. At-reactor ex-pool storage costs are calculated on a pool-by-pool basis. Ex-pool storage requirements are combined for reactors which have designated that one or more of their pools are jointly sharing their combined capacity. WASTES will place material into ex-pool storage only if 1) fuel cannot be stored in the existing pool without violating its full core reserve (FCR) and 2) all options for shipment of fuel from the pool to another facility have been exhausted.

During the simulation, WASTES maintains, for each reactor pool, an annual inventory of the number of assemblies loaded into ex-pool storage, the number of assemblies unloaded from ex-pool storage, and the total inventory (metric tons and number of assemblies) of fuel in ex-pool storage. This data is used, along with the methodologies described by Merrill and Fletcher (1983), to estimate dry storage costs.

WASTES uses separate cost coefficients for PWR fuel and BWR fuel. The user must specify which of the following six technologies will be used as the basis for estimating these at-reactor costs:

- metal storage casks
- transportable storage cask
- water basin storage
- drywell storage
- concrete cask storage
- air-cooled vault storage.

The first three technologies store bare fuel assemblies while the last three technologies require that the fuel be sealed in a canister prior to placement in storage. Cost estimates for the latter three technologies include the cost of canistering the fuel as reported by Merrill and Fletcher (1983).

The total estimated annual costs are reported by their major cost components, which include:

- capital invested in storage units
- capital invested in storage yards
- decommissioning cost for storage units
- decommissioning costs for storage yards
- operation and maintenance costs for storage units
- operation and maintenance costs for storage yards
- revenues obtained by salvaging decommissioned storage units and yard equipment.

The term storage unit represents a single cask or drywell, and the term yard is used to represent all of the equipment and/or facility modifications needed to support the storage technology.

The number of active ex-pool storage facilities, the number of storage units used (if applicable), and the total number of assemblies in ex-pool storage are also reported annually.

The costs calculated by WASTES are expressed in 1986 dollars, escalated from mid-1982 dollars by the application of a 2.0 percent increase for fixed nonresidential investments (Bureau of Economic Analysis 1982, 1986; Table 1.1 and Table 1.3, respectively). Updates will be made to WASTES cost factors as required to support DOE programs.

A description of the algorithms and unit costs used for determining ex-pool storage costs at each reactor site is contained in the following data sheets for each technology available within WASTES. The data sheets also list the major assumptions used to implement these algorithms. A more complete description of the methods used to estimate these parameters is provided by Merrill and Fletcher (1983) and a more detailed explanation of how these algorithms were implemented in the FORTRAN coding can be found in Section 8.3 of the WASTES II Programmer's Reference Manual (Shay and Buxbaum 1986a).

For each of the storage technologies mentioned above, the following data sheets give:

1. the reference for the data contained on the sheet
2. the range of capacities to which the data applies
3. the estimated capital cost associated with implementing the technology at a generic reactor site
4. the estimated cost of operating the storage facility at a generic site
5. the cost of decontaminating and decommissioning the storage facility
6. critical assumptions that were made in implementing the costing algorithms and data contained on the data sheet.

Where applicable, the capital and operating costs are broken into those costs that pertain to the storage yard and those costs that pertain to individual storage units (e.g., casks). In each of these categories the major contributors to these costs are delineated separately. Where applicable, the initial distribution of capital expenditures are estimated as the percentage that would be incurred in each year before ex-pool storage is implemented.

DATA SHEET 1

Storage Technology: Metal Storage Casks

- Reference: Merrill E.T., Fletcher J.F. Economics of At-Reactor Spent Fuel Storage Alternatives. PNL-4517, page 2.13, April 1983.

- Range of Application: 0 to 12 casks per year

- Capital Costs:

- Yard:
 - Initial construction: \$1,270,000
 - Transporter: \$1,520,000

Expenditures per year:

<u>Year</u>	<u>% of Capital</u>
-3	25%
-2	6%
-1	0%
0	69%

Concrete Storage Pads: (costs incurred in year before cask is needed) \$2,000/cask

- Cask: (cost incurred in year before cask needed) \$700,000/cask

- Operating Costs:

- Annual Maintenance supplies: 1.4% of active capital investment
- Labor and general supplies:
 - Cask Placement or removal: \$2,330/cask
 - Cask Load or Unload: \$5,000/cask
 - Annual Monitoring and security: per cask in use \$185/cask
- Annual Property Tax and Insurance: 0.93% of active capital investment

- Decontamination and Decommissioning: 10% of capital

- Salvage Value: \$0

- Assumptions:

- Fuel is not canned prior to loading into casks
- A metal cask holds 24 PWR or 52 BWR assemblies
- Costs are in mid-1982 Dollars
- All other assumptions contained in PNL-4517 (see reference identified above)

DATA SHEET 2

Storage Technology: Transportable Storage Casks

- Reference: Merrill E.T., Fletcher J.F. Economics of At-Reactor Spent Fuel Storage Alternatives. PNL-4517, page 2.13, April 1983.
- Range of Application: 0 to 12 casks per year
- Capital Costs:
 - Yard:

Initial construction:	\$1,270,000
Transporter:	\$1,520,000
Expenditures per year:	
<u>Year</u>	<u>% of Capital</u>
-3	25%
-2	6%
-1	0%
0	69%
 - Concrete Storage Pads: (costs incurred in year before cask is needed) \$2,000/cask
 - Cask: (cost incurred in year before cask needed) \$1,500,000/cask
- Operating Costs:
 - Annual Maintenance supplies: 1.4% of active capital investment
 - Labor and general supplies:

Cask Placement or removal:	\$2,330/cask
Cask Load or Unload:	\$5,000/cask
Annual Monitoring and security: per cask in use	\$185/cask
 - Annual Property Tax and Insurance: 0.93% of active capital investment
- Decontamination and Decommissioning: 10% of capital
 - Salvage Value: \$0
- Assumptions:
 - A transportable storage cask was assume to cost
 - A metal cask holds 12 PWR or 32 BWR assemblies
 - Fuel is not canned prior to loading into casks.
 - Costs are in mid-1982 Dollars
 - All other assumptions contained in PNL-4517 (see reference identified above)

DATA SHEET 3

Storage Technology: Water Basin Storage

- Reference: Merrill E.T., Fletcher J.F. Economics of At-Reactor Spent Fuel Storage Alternatives. PNL-4517, page 2.12, April 1983.
- Range of Application: 500 to 5,000 MTU per basin
- Capital Costs:
 - Initial construction:
 - Fixed costs: \$31,770,000
 - Variable costs: Fixed costs * (MTU/1000)^{0.75}
 - Transfer cask: \$1,059,000
 - Expenditures per year:

<u>Year</u>	<u>% of Capital</u>
-6	6%
-5	8%
-4	0%
-3	1%
-2	26%
-1	43%
0	16%
- Operating Costs:
 - Annual Maintenance supplies: 6.0% of active capital investment
- Decontamination and Decommissioning: 10% of capital
 - Salvage Value: \$0
- Assumptions:
 - Fuel is not canned prior to loading into the basin
 - The capacity needed at a reactor site is estimated assuming assembly weight of 0.46 MTU for PWR fuel and 0.18 MTU for BWR fuel.
 - Initial costs are in 1981 dollars escalated to mid-1982 dollars by 1.059 factor
 - All other assumptions contained in PNL-4517 (see reference identified above)

DATA SHEET 4

Storage Technology: Drywell Storage

- Reference: 1. Merrill E.T., Fletcher J.F. Economics of At-Reactor Spent Fuel Storage Alternatives. PNL-4517, page 2.14 and 2.17, April 1983.
- 2. E. R. Johnson Associates. A Preliminary Assessment of Alternative Dry Storage methods for the Storage of Commercial Spent Nuclear Fuel. DOE/ET-47929-1, November 1981.

- Range of Application: 0 to 300 canisters per year

- Capital Costs:

- Yard:

Initial construction: (holds 1000 drywells)	\$1,930,000
Transfer Equipment:	\$4,640,000
In-Pool Canning equipment:	\$642,000
Expenditures per year:	

Year	Drywell & Transfer	In-Pool Canning
-4	21%	--
-3	15%	19%
-2	--	19%
-1	26%	5%
0	38%	57%

Yard Expansion: each 1000 drywell expansion \$300,000

- Drywells: cost incurred year before needed \$18,000/drywell

- Operating Costs:

- Annual Maintenance supplies: 1.4% of active capital investment
(excluding capital associated with canistering the fuel)

- Labor and general supplies:

Canistering costs:	
Annual Fixed Canistering costs:	\$39,000
Annual Variable Canistering costs:	\$7,300/can
Drywell Placement:	\$2,750/drywell
Transfer from pool to drywell:	\$1,000/can
Transfer from drywell to pool:	\$1,000/can
Drywell Removal:	\$780/drywell
Annual Monitoring and security: per cask in use	\$185/cask

- Annual Property Tax and Insurance: 0.93% of active capital investment

- Decontamination and Decommissioning: 10% of canistering capital
2% of all other capital

- Salvage Value: \$0

- Assumptions:

- Fuel is canned in the reactor pool prior to loading into drywells
- Canisters hold 1 PWR assemblies or 3 BWR assemblies
- Drywells hold 1 canister each
- Costs are in mid-1982 Dollars
- Initial distribution for drywell capital in Table 2.4 corrected to be consistent with Table A9 of Reference 1 and related material in Reference 2 (see references identified above)
- Cost of transfer cask loading and unloading added to estimate
- All other assumptions contained in PNL-4517 (see Reference 1 identified above)

DATA SHEET 5

Storage Technology: Concrete Storage Casks

- Reference: Merrill E.T., Fletcher J.F. Economics of At-Reactor Spent Fuel Storage Alternatives. PNL-4517, page 2.15 and 2.17, April 1983.

- Range of Application: 0 to 100 casks per year

- Capital Costs:

- Yard:

Initial yard const.: (holds 1000 casks)	\$1,930,000
Loading facility:	\$1,510,000
Reactor to Cask transfer equipment:	\$4,640,000
Cask Transporter:	\$2,280,000
In-Pool Canning equipment:	\$642,000
Expenditures per year:	

Year	Facilities & Transfer	In-Pool Canning
-4	18%	--
-3	11%	19%
-2	--	19%
-1	25%	5%
0	46%	57%

Yard preparation: (incurred in previous year)	\$2,000/cask
Yard Expansion: each 1000 cask expansion	\$300,000

- Concrete Cask: (cost incurred in year before cask needed)

Concrete cask:	\$61,000/cask
Cask Liner:	\$17,000/cask

- Operating Costs:

- Annual Maintenance supplies: 1.4% of active capital investment
(excluding capital associated with canistering the fuel)

- Labor and general supplies:

Canistering costs:	
Annual Fixed Canistering costs:	\$9,000
Annual Variable Canistering costs:	\$7,300/can
Cask Placement:	\$7,600/cask
Transfer cask handling: (each transfer)	\$1,000/can
Canister loaded into cask:	\$2,430/can
Canister unloading from cask:	\$1,070/can
Cask Removal:	\$1,880/cask
Annual Monitoring and security: per cask in use	\$185/cask

- Annual Property Tax and Insurance: 0.93% of active capital investment

- Decontamination and Decommissioning: 10% of canistering capital
2% of all other capital

- Salvage Value: \$0

- Assumptions:

- Fuel is canned in the reactor pool prior to loading into concrete casks
 - Canisters hold 1 PWR assemblies or 3 BWR assemblies
 - Concrete casks hold 4 canisters each
 - Costs are in mid-1982 dollars
 - Cost of transfer cask loading and unloading were explicitly included
 - All other assumptions contained in PNL-4517 (see reference identified above)

DATA SHEET 6

Storage Technology: Air-Cooled Vault Storage

- Reference: Merrill E.T., Fletcher J.F. Economics of At-Reactor Spent Fuel Storage Alternatives. PNL-4517, page 2.16 and 2.17, April 1985.

- Range of Application: 0 to 300 assemblies per year

- Capital Costs:

- Initial yard construction:
 - Fixed: \$19,900,000
 - Variable: \$30,200/can
- In-Pool Canning equipment: \$642,000
- Expenditures per year:

<u>Year</u>	<u>Vault Facility</u>	<u>In-Pool Canning</u>
-6	7%	--
-5	8%	--
-4	--	--
-3	1%	19%
-2	25%	19%
-1	38%	5%
0	21%	57%

- Operating Costs:

- Annual Maintenance supplies: 1.4% of active capital investment (excluding capital associated with canistering the fuel)
- Labor and general supplies:
 - Canistering costs:
 - Annual Fixed Canistering costs: \$39,000
 - Annual Variable Canistering costs: \$7,300/can
 - Cask Placement: \$7,600/cask
 - Transfer cask handling: (each transfer) \$1,000/can
 - Canister Placement: \$4,760/can
 - Canister Removal: \$1,270/can
 - Annual Monitoring and security:
 - per cask in use \$185/cask
- Annual Property Tax and Insurance: 0.93% of active capital investment

- Decontamination and Decommissioning: 10% of canistering capital
2% of all other capital

- Salvage Value: \$0

- Assumptions:

- Fuel is canned in the reactor pool prior to loading into the vault
- Canisters hold 1 PWR assemblies or 3 BWR assemblies
- Costs are in mid-1982 dollars
- Cost of transfer cask loading and unloading were explicitly included
- All other assumptions contained in PNL-4517 (see reference identified above)

4.0 SHIPPING ALGORITHMS

This chapter describes the algorithms and logic used by WASTES to determine how and when spent fuel is shipped in the waste management system. Three types of events may initiate the movement of spent fuel: 1) the discharge of fuel into a full reactor pool, 2) the prioritization of a shut-down reactor with acceptable fuel remaining in the reactor pool, and 3) a facility soliciting a fuel shipment from another facility or reactor within the system to fully utilize its receipt capacity. The need to move fuel will result in an intrareactor shipment (the placement of fuel in ex-pool storage), an inter-reactor shipment (transshipment of fuel to another reactor site), or a shipment to a facility. In all cases the oldest acceptable fuel is shipped and it will always occur in integer cask quantities except for the last cask that is transferred out of a facility or reactor. There are many factors that will determine the priorities for selection of source/destination pairs, the acceptability of fuel, or the availability of a shipping link. These are discussed in the following sections.

4.1 PRIORITY

The selection of a site to complete a shipping link is determined by the priority cards and shipping method. If capacity is being sought, the priorities set by the FILLORDER card are used. If fuel is being sought, the priorities set by the PRIOR and ALTPRI cards are used.

The order in which facility types are searched for receipt of the fuel in reactor discharge and decommissioning events is determined by the priorities set by the FILLORDER card. Selection of the facility within the facility type is determined by the shipping method (optimal/proximal). The oldest fuel in the reactor pool with the forced discharge or at the decommissioned reactor (pool or dry) is selected for shipment.

For facility solicitation events, the order in which facility types are filled is determined by the priorities set by the FILLORDER card. Facilities within a facility type are filled sequentially with the lowest minor identifier coming first (e.g., 3.1 then 3.2 etc.). The location of sites to supply fuel

to the facility is determined by the priorities set by the PRIOR and ALTPRI cards. Facilities are searched for fuel in the order they are listed on the PRIOR card and the first facility encountered with fuel is taken. If a zero facility is encountered in the PRIOR list before fuel is located, priorities are shifted to the ALTPRI list. Facilities on the ALTPRI list are searched simultaneously for fuel, and if only one facility has fuel, that facility is selected. Multiple sites with fuel are handled by the optimal/proximal shipping algorithms.

4.2 ACCEPTANCE

After the shipping link has been found and the batch of fuel to be shipped has been identified, constraints placed on the run are checked to determine if the transfer is acceptable. The primary constraints on the system are the age acceptance criteria (set by the AGEAT, AGETO, DECOMAGE, and FCAGE data input cards), facility and reactor capacities (set by CAPACITY data input card and the RXINFO data file, respectively), fuel type, and available cask links.

Age acceptance criteria set the amount of time that a batch of fuel must have aged to be moved to a new location. Both total age and time elapsed since entering its current physical location are used to determine the eligibility of the batch for movement to the new site. The action caused by each of the input cards is discussed in the WASTES Users Guide (Shay and Buxbaum 1986b, Appendix A, Section A.2).

Capacity at the receiving site must be sufficient to accept the batch without violating ultimate and annual receipt capacities if it is a facility or the FCR margin if it is a reactor. Exceeding annual receipt capacities of facilities by less than one cask is allowed. Violating the FCR margin of a reactor pool is only allowed when a fractional dry cask load has been left in the pool after a shipment has been completed.

Fuel types used by the WASTES model can be from either PWRs or BWRs. Reactors with other types of fuel declared in the reactor information file are ignored. If a reactor is transshipping spent fuel, then both the shipping and

receiving reactors must use the same fuel type. If a partial cask is being filled, the fuel type must be the same as the previous fuel used to fill the cask.

Truck and rail casks can be used by the WASTES model, and at least one of each type must be supplied. A common cask link must exist between the shipping site and the receiving site in order for the shipping link to be accepted. When more than one cask can be used to form a shipping link, the cask with the highest priority for the destination facility is used.

4.3 INTRAREACTOR SHIPMENTS

Intrareactor shipments involve movements of fuel between a reactor's storage pool and dry storage.

Transfer of fuel to dry storage occurs only when a reactor has a forced discharge to the pool that exceeds the FRC margin and not enough fuel can be shipped to facilities or other pools to restore the FCR margin. When fuel is transferred to the dry storage site, the oldest fuel in the reactor pool is removed in integer dry storage cask increments until the FCR margin is restored. Cask accounting is not maintained so the oldest cask in dry storage contains the oldest batches in dry storage.

Transfer of fuel from dry storage to a storage pool occurs when fuel has been shipped from dry storage to a facility and a fractional dry storage cask remains in dry storage. The fractional dry cask, consisting of the oldest batches in dry storage at that reactor, is placed in the pool so that an integer number of dry casks is maintained.

4.4 INTERREACTOR SHIPMENTS

Interreactor shipments (also known as transshipment) involves movement of fuel from one reactor pool to another reactor pool. Transshipment occurs when a reactor has a forced discharge that violates the FCR margin and the facilities cannot accept enough fuel to restore the FCR and transshipment is allowed. When transshipment occurs, the oldest batches in the pool are moved to the reactors that are within the same utility group and that have the largest

remaining capacity as of the end of the previous year. The destination reactor will not accept fuel that will violate its FCR margin, and transshipment to dry storage is not allowed.

Three types of transshipment are allowed by the WASTES code: intra-utility, intrastate, and user defined. Each of these transshipment types utilize data provided by reactor information file to determine the proper transshipment group. The transshipment queue from which the destination reactor is selected contains a list of all reactors that can receive transshipped fuel. The queue is ordered by the transshipment group and remaining reactor capacity $[(10,000 \times \text{group}) + \text{remaining capacity}]$. Reactors are removed from the transshipment queue only after they have been decommissioned.

4.5 SHIPMENTS TO FACILITIES

The WASTES model contains two shipping algorithms from which the user may choose. These algorithms represent optimal or proximal selection of source/destination pairs. Each type of facility may be specified to be filled in a different manner. All three of the subroutines/events that move spent fuel will accomplish the movement according to the same shipping algorithm.

The optimal routing allows a true minimization of shipping distance or shipping costs to be done where proximal routing provides a suboptimal minimization. The implementation and functions of these algorithms are described in the following sections.

4.5.1 Optimal Algorithm

This algorithm is used only when there are exactly two facilities of the destination facility type open for receipt of fuel. If more than two facilities of the destination facility type are defined, they will be filled optimally in the years in which only two can accept fuel. Otherwise they will be filled proximally even though optimal processing was specified. As additional constraints, the destination facilities and the source facility must share a compatible shipping cask so that shipments can go to either destination. In instances where the source and one destination share a compatible shipping cask, the shipment will occur directly to the facility for which compatibility

exists. If the destination facilities do not have the same age acceptance criteria and a shipment is acceptable to one facility and not the other, the shipment will occur directly to the facility that can accept the waste.

If the user has included a PRIOR WASTES input for a facility or facilities that the user specified to be filled optimally, the way in which the optimized facilities will solicit fuel is affected. The loading priorities for the first facility (lowest minor ID) are processed first and no optimization of shipments results. The loading priorities for the second facility are then processed and again this results in non-optimal shipping. Any remaining unused annual receipt capacity is then filled optimally, thereby minimizing either distance travelled or unit shipping cost.

The optimization algorithm examines all material to be shipped to the specified facility type within a calendar year and maintains a file of batch pointers that are sorted according to the difference in distances or the difference in costs for shipping to the two facilities from the source facility. The optimized queue is emptied and the resulting material transfers occur at the end of the year. If insufficient material is available (in a given year) to meet the annual receipt rates of both facilities, the facility with the smallest minor facility ID will be filled first.

4.5.2 Proximal Algorithm

This algorithm determines the closest destination facility to the source of the shipment from shipping distances that have previously been calculated for each material transfer which may occur. The closest facility that also has the capacity to accept the material is chosen, and the final source/destination pair is determined immediately. The source/destination pairs are subject to the availability of a common shipping cask and acceptable fuel.

If the user has included a PRIOR WASTES input for a facility or facilities that are being filled proximally (default value) and there is more than one facility in the class of facilities, the way in which the facilities solicit fuel is affected. The loading priorities for each facility are processed in the order of the minor facility ID's (shipments are not necessarily routed to

the closest destination facility). Any remaining unused annual receipt capacity for the facilities in the class is then filled proximally.

5.0 REFERENCES

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APPENDIX A

GREAT CIRCLE CIRCUITY FACTOR DATA

<u>REPOSITORY</u>	<u>LATITUDE</u>	<u>LONGITUDE</u>
Deaf Smith, TX	35.07	102.45
Hanford, WA	46.30	119.40
Oak Ridge, TN	36.04	84.12
Yucca Mountain, NV	36.50	116.27

<u>REACTOR NAME</u>	<u>LAT.</u>	<u>LONG.</u>	--- TRUCK MILEAGES ---				--- RAIL MILEAGES ---			
			<u>DS</u>	<u>HF</u>	<u>OR</u>	<u>YM</u>	<u>DS</u>	<u>HF</u>	<u>OR</u>	<u>YM</u>
FARLEY	31.13	85.06	1398	2721	414	2323	1884	2952	501	2945
CARROLL COUNTY	41.50	89.22	--	--	742	--	--	--	778	--
PALO VERDE	33.23	112.52	788	1533	1909	605	933	1689	2285	652
ARKANSAS	35.19	93.13	572	2069	579	1598	769	2199	626	2053
CALVERT CLIFFS	38.26	76.26	1712	2877	575	2634	1919	2885	702	2953
PILGRIM	41.57	70.35	2040	3004	1014	2934	2139	3112	1305	3189
ROBINSON	34.24	80.10	1507	2842	369	2432	1790	3065	404	2851
HARRIS	35.35	78.55	1557	2894	420	2483	1887	3027	459	2948
ZIMMER	38.52	84.14	--	--	306	--	--	--	334	--
PERRY	41.48	81.09	1415	2381	593	2312	1374	2384	679	2435
DRESDEN	41.24	88.17	1064	2013	605	1886	1031	2008	676	2237
QUAD CITIES	41.44	90.19	1039	1909	713	1774	937	1981	860	1998
ZION	42.27	87.48	1160	1937	640	1978	1177	1981	675	2009
LA SALLE	41.15	88.40	1059	2016	624	1880	971	2066	707	2263
BYRON	42.05	89.17	1107	1913	678	1841	1020	1961	729	2081
BRAIDWOOD	41.15	88.13	1050	2015	607	1907	986	2058	681	2096
CT. YANKEE	41.39	72.30	1918	2883	925	2813	2047	3013	1211	3090
BIG ROCK POINT	45.19	85.15	1574	2464	833	2393	1439	2411	869	2601
PALISADES	42.24	86.16	1199	2089	621	2019	1166	2134	597	2324
MIDLAND	43.36	84.14	1413	2302	673	2232	1431	2399	555	2589
LA CROSSE	43.41	91.14	1139	1748	854	1872	1115	1745	917	2080
FERMI	41.58	83.16	1353	2254	545	2184	1398	2371	594	2543
OCONEE	34.48	82.54	1364	2686	280	2289	1696	2903	295	2757
MCGUIRE	35.26	80.57	1423	2758	285	2348	1908	2876	308	2783
CATAWBA	35.03	81.04	1420	2757	283	2346	1747	2954	345	2808
BEAVER VALLEY	40.37	80.26	1455	2421	615	2352	1482	2469	789	2544
CRYSTAL RIVER	28.57	82.42	1671	2992	639	2596	1699	3212	697	2998
TURKEY POINT	25.26	80.20	1967	3288	934	2893	2059	3400	975	3254
ST LUCIE	27.21	80.15	1824	3146	791	2750	1900	3241	817	3095
HATCH	31.56	82.21	1446	2768	414	2372	1827	3000	443	2888
VOGTLE	33.09	81.46	1433	2756	402	2360	1862	3035	479	2923
RIVER BEND	30.45	91.20	1059	2562	674	1984	933	2838	719	2692
CLINTON	40.10	88.50	982	2065	555	1930	914	2160	603	1975
COOK	41.57	86.32	1169	2059	592	1990	1117	2085	548	2275
ARNOLD	42.02	91.48	991	1861	803	1725	948	1942	908	1780
OYSTER CREEK	39.49	74.12	1857	2847	774	2777	1988	2954	933	3021
WOLF CREEK	38.14	95.41	589	1774	827	1495	506	1898	951	1752
SHOREHAM	40.58	72.52	1951	2916	924	2845	2075	3048	1241	3125
WATERFORD	30.00	90.28	1141	2645	628	2067	959	2743	648	2597
MAINE YANKEE	43.57	69.42	1747	3113	1121	3042	2179	3152	1479	3270
3 MILE ISLAND	40.10	76.44	1693	2681	594	2612	1767	2733	868	2801
GRAND GULF	32.00	91.03	1058	2542	561	1984	846	2670	551	2524
COOPER	40.20	95.38	782	1628	860	1525	896	1730	1199	1569

REACTOR NAME	LAT.	LONG.	--- TRUCK MILEAGES ---				--- RAIL MILEAGES ---			
			DS	HF	OR	YM	DS	HF	OR	YM
NINE MILE POINT	43.27	76.26	1750	2715	873	2645	1747	2713	912	2790
MILLSTONE	41.19	72.10	1963	2927	937	2858	2062	3034	1228	3111
MONTICELLO	45.20	93.50	1133	1525	1030	1867	1235	1642	1112	1919
PRAIRIE ISLAND	44.37	92.38	1095	1614	987	1830	1216	1640	1029	2277
FORT CALHOUN	41.31	96.05	864	1609	942	1468	989	1663	1147	1517
HUMBOLDT	40.43	124.14	1761	674	2834	1077	1816	1342	3345	1117
DIABLO CANYON	35.12	120.48	1311	1121	2433	626	1460	1226	2867	637
SUSQUEHANNA	41.06	76.09	1675	2640	686	2569	1832	2798	933	2866
PEACH BOTTOM	39.45	76.16	1729	2729	628	2659	1805	2778	779	2846
LIMERICK	40.15	75.39	1763	2754	664	2684	1833	2799	933	2867
TROJAN	46.02	122.52	1843	301	2628	1327	2211	301	2895	1462
FITZPATRICK	43.27	76.26	1749	1714	872	2644	1748	2714	912	2791
INDIAN POINT	41.16	73.57	1833	2799	808	2728	1965	2930	1129	3008
MARBLE HILL	38.26	85.27	--	--	315	--	--	--	320	--
SEABROOK	42.54	70.51	2041	3007	1016	2936	2082	3055	1382	3173
SALEM	39.28	75.32	1770	2827	676	2674	1887	2853	832	2920
HOPE CREEK	39.43	75.28	1770	2827	656	2673	1880	2846	826	2914
GINNA	43.17	77.19	1659	2625	835	2555	1688	2660	859	2738
RANCHO SECO	38.20	121.10	1441	875	2550	757	1482	938	3007	777
SUMMER	34.18	81.19	1425	2761	289	2352	1727	2934	325	2788
SAN ONOFRE	33.22	117.33	1092	1299	2215	409	1235	1432	2540	411
SOUTH TEXAS	28.48	96.03	866	2370	1155	1695	856	2745	1129	2599
BROWNS FERRY	34.35	87.35	1107	2431	265	2033	1290	2565	212	2351
SEQUOYAH	35.14	85.05	1146	2468	120	2071	1465	2672	82	2526
WATTS BAR	35.41	84.52	1150	2473	56	2077	1430	2637	47	2491
BELLEFONTE	34.43	85.56	1130	2452	165	2055	1530	2609	148	2591
COMANCHE PEAK	32.14	97.45	574	2077	920	1500	462	2285	970	1650
DAVIS-BESSE	41.36	83.05	1348	2251	540	2182	1312	2322	618	2373
CALLAWAY	38.46	91.47	823	1908	585	1646	764	1991	672	1845
VERMONT YANKEE	42.47	72.31	2974	2940	959	2869	2025	2998	1190	3075
SURRY	37.10	76.42	1678	2898	540	2603	1814	2944	555	2875
NORTH ANNA	38.03	77.47	1659	2814	472	2536	1840	2808	590	2775
WNP 1;2;4	46.40	119.34	1677	29	2462	1161	1734	10	2651	1296
POINT BEACH	44.17	87.33	1288	1914	767	2107	1298	2029	795	2130
KEWAUNEE	44.21	87.32	1291	1918	772	2111	1255	1961	867	2198
YANKEE-ROWE	42.44	72.56	1914	2880	997	2810	1904	2876	1203	2995
BRUNSWICK	33.58	78.01	1653	2988	516	2580	1791	3098	527	3019
GE REPRO PLANT	41.30	88.50	1066	2015	0	1889	1029	2006	0	2235
WEST VALLEY	42.50	78.60	1577	2544	755	2473	1687	2659	895	2864
WEST VALLEY	42.50	78.60	1579	2546	--	2744	1687	2659	--	2864
HANFORD	46.30	119.40	1663	26	--	1148	1726	18	--	1288
IDAHO	43.30	112.30	1214	610	--	740	1200	696	--	763
SAVANNAH RIVER	33.25	81.63	1421	2743	--	2360	1521	2895	--	2749

APPENDIX B

TRUCK SHIPPING COST DATA

(All Costs in \$/cwt)

<u>Dist</u>	<u>Empty</u>	<u>Loaded</u>	<u>Dist</u>	<u>Empty</u>	<u>Loaded</u>	<u>Dist</u>	<u>Empty</u>	<u>Loaded</u>
100	1.06	1.58	1125	4.77	5.68	2400	10.17	12.12
110	1.07	1.66	1150	4.84	5.78	2450	10.39	12.39
120	1.11	1.67	1175	4.92	5.95	2500	10.62	12.58
130	1.14	1.72	1200	5.05	6.03	2550	10.80	12.84
140	1.17	1.78	1225	5.14	6.18	2600	11.03	13.10
150	1.19	1.84	1250	5.26	6.31	2650	11.22	13.36
160	1.20	1.91	1275	5.36	6.44	2700	11.46	13.61
170	1.23	1.98	1300	5.47	6.56	2750	11.63	13.87
180	1.26	2.10	1325	5.56	6.67	2800	11.88	14.11
190	1.31	2.15	1350	5.67	6.83	2850	12.07	14.38
200	1.34	2.25	1375	5.79	6.93	2900	12.30	14.61
225	1.41	2.32	1400	5.89	7.06	2950	12.45	14.89
250	1.50	2.44	1425	5.98	7.19	3000	12.72	15.10
275	1.51	2.52	1450	6.08	7.29	3050	12.92	15.38
300	1.57	2.59	1475	6.21	7.46	3100	13.09	15.63
325	1.68	2.69	1500	6.29	7.56	3150	13.31	15.88
350	1.73	2.79	1525	6.43	7.68	3200	13.55	16.15
375	1.74	2.84	1550	6.53	7.83	3250	13.80	16.40
400	1.78	2.94	1575	6.61	7.94	3300	13.95	16.66
425	1.91	3.06	1600	6.71	8.08	3350	14.19	16.87
450	1.97	3.141	1625	6.84	8.22	3400	14.42	17.15
475	2.05	3.2	1650	6.92	8.30	3450	14.61	17.41
500	2.13	3.32	1675	7.04	8.46	3500	14.82	17.66
525	2.29	3.37	1700	7.14	8.57	3550	15.02	17.89
550	2.38	3.45	1725	7.33	8.68	3600	15.25	18.15
575	2.47	3.58	1750	7.42	8.83	3650	15.48	18.40
600	2.58	3.65	1775	7.54	8.93	3700	15.64	18.67
625	2.70	3.74	1800	7.68	9.08	3750	15.92	18.91
650	2.83	3.82	1825	7.74	9.19	3800	16.11	19.16
675	2.87	3.91	1850	7.83	9.32	3850	16.32	19.39
700	2.94	3.99	1875	7.96	9.44	3900	16.51	19.68
725	3.12	4.09	1900	8.10	9.60	3950	16.74	19.93
750	3.22	4.17	1925	8.18	9.71	4000	16.95	20.19
775	3.27	4.24	1950	8.25	9.81	4050	17.19	20.42
800	3.36	4.33	1975	8.38	9.98	4100	17.38	20.66
825	3.48	4.33	2000	8.47	10.07	4150	17.59	20.90
850	3.56	4.48	2025	8.56	10.22	4200	17.80	21.20
875	3.66	4.62	2050	8.69	10.34	4250	17.98	21.43
900	3.78	4.67	2075	8.81	10.47	4300	18.22	21.67
925	3.92	4.75	2100	8.90	10.60			
950	4.01	4.87	2125	8.99	10.71			
975	4.11	4.91	2150	9.12	10.82			
1000	4.20	5.03	2175	9.21	10.93			
1025	4.33	5.13	2200	9.34	11.10			
1050	4.43	5.30	2250	9.53	11.36			
1075	4.50	5.41	2300	9.76	11.61			
1100	4.61	5.56	2350	9.97	11.86			

APPENDIX C

RAIL SHIPPING COST DATA

(All costs in \$/cwt)

Without Western Shipments

<u>Dist</u>	<u>Empty</u>	<u>Loaded</u>
421	5.18	5.52
674	6.56	7.00
733	6.94	7.40
749	7.04	7.51
838	7.53	8.03
892	7.79	8.30
913	7.88	8.40
936	7.99	8.52
949	7.99	8.52
976	8.25	8.80
1012	8.37	8.92
1107	8.86	9.45
1125	8.86	9.45
1149	8.97	9.57
1171	9.06	9.67
1206	9.31	9.93
1206	9.31	9.93
1206	9.31	9.93
1210	9.31	9.93
1221	9.31	9.93
1248	9.43	10.06
1249	9.43	10.06
1259	9.58	10.22
1267	9.58	10.22
1283	9.68	10.32
1315	9.81	10.46
1333	9.92	10.58
1371	10.02	10.68
1399	10.15	10.82
1425	10.29	10.98
1471	10.50	11.20
1476	10.62	11.33
1478	10.62	11.33
1481	10.62	11.33
1503	10.75	11.47
1503	10.75	11.47
1507	10.75	11.47
1541	10.84	11.56
1571	10.96	11.69
1588	11.07	11.81
1639	11.31	12.06
1687	11.58	12.35
1786	12.07	12.87
1880	12.51	13.34

Without Western Shipments

<u>Dist</u>	<u>Empty</u>	<u>Loaded</u>
1904	12.68	13.53
1926	12.77	13.62
1977	13.01	13.88
2106	13.62	14.53
2195	13.97	14.90
2239	14.19	15.14
2349	14.66	15.64

Western Shipments

<u>Dist</u>	<u>Empty</u>	<u>Loaded</u>
333	4.77	5.09
289	4.96	5.29
926	8.54	9.10
602	9.01	9.61
1207	10.31	11.00
1185	11.30	12.05
941	12.61	13.45
1591	12.61	13.45
1295	12.83	13.69
1346	13.02	13.88
1960	13.89	14.82
1680	15.75	16.80
2203	15.75	16.80

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