(82)

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June 9, 1982

Homer Lowenberg, Chief Engineer
Office of Nuclear Material
Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Homer:

BACKUP CALCULATIONS FOR TABLE D.4, CRBR FUEL CYCLE SUPPLEMENT

Enclosed are 5 copies of my calculations for the two Fuel Fabrication Plants and the Reprocessing Plant as developed for the subject table. These may help you track my calculations from the text and other source data (e.g., WASH-1248) in preparation for the hearing(s). Please telephone if there are questions.

Sincerely,

OW

Orville F. Hill

OFH:edg

Enclosures

bcc: CA Geffen
RF McCallum
IC Nelson
PT Reardon
RJ Sorenson
DL Strenge
File/Lb

CONVERSION FACTORS USED IN DEVELOPMENT OF TABLE D.4

1 kWh = 3.6 MJ

1 MWH = 3600 MJ

1 Btu = 1.05×10^3J = 1.05×10^{-3} MJ

1 $MJ_e \equiv 1.08 \times 10^{-4}$ MT equivalent coal*

3.6×10^{-2} MT SO_x per MT equivalent coal**

$\sim 1 \times 10^{-2}$ MT NO_x per MT equivalent coal

2.3×10^{-4} MT CO per MT equivalent coal

$\sim 1 \times 10^{-4}$ MT Hydrocarbons per MT equivalent coal

$\sim 1 \times 10^{-2}$ MT Particulates per MT equivalent coal

1 ha = 2.5 acres

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* Assume 1200 Btu/lb coal

$$1\ MJ_e \equiv 3\ MJ_t$$

$$1\ MJ_e = \frac{3\ MJ_t/MJ_e}{1.05 \times 10^{-3} MJ_t/\text{Btu} \times 12000\ \text{Btu/lb coal} \times 2200\ \text{lb/MT coal}}$$

$$= 1.08 \times 10^{-4}\ \text{MT equivalent coal}$$

** Emmission factors were calculated from data presented in Atmospheric Emissions from Coal Combustion, An Inventory Guide. Published by U.S. Department of Health, Education and Welfare Service, Tables 2-2 and 2-3 (date unknown, but before 1974).

D.4 DATA CALCULATED FOR UO_2 FUEL FABRICATION (BLANKET) PLANT:

Basis: 11.1 MTU for CRBR fuel cycle.

Ratio of ~1/3 (11.1 MTU-CRBR to 35 MTU-LWR) to data presented in WASH-1248, column E, Table S-3A.

$$\frac{0.2 \text{ acres (WASH-1248)} \times 11.1/35}{2.5 \text{ acres/ha}} = 0.03$$

$$\frac{0.16 \times 11.1/35}{2.5} = 0.02$$

$$\frac{0.04 \times 11.1/35}{2.5} = 0.005$$

5.2×10^6 gallons x 11.1/35 = 1.6×10^6 gallons

~1/3 x 1.7×10^3 MWh x 3600 MJ/MWh = 2.0×10^6 MJ

~1/3x 0.62×10^3 MT equivalent coal = 200 MT

~1/3 x 23 MT SO_x = 7 MT SO_x

~1/3 x 6 MT NO_x = 2 MT NO_x

~1/3 x0.06 MT Hydrocarbons = 0.02 MT Hydrocarbons

~1/3 x0.15 MT CO = 0.05 MT CO

~1/3 x 6 MT Particulates = 2 MT Particulates

~1/3 x 0.005 MT F^- = 0.002 MT F^-

(But see calculation from Westinghouse EIA (NR-FM-013) - below)

~1/3 x 23 MT NO_3^- = 7.3 MT NO_3^-

~1/3 x 4.1 MT F^- = 1.3 MT F^-

~1/3 x 10 MT NH_3 = 3.2 MT NH_3

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11 MT CaF_2 (~1 MT CaF_2/MTU as per text. Note that Column E is incorrect. Should read 35 MT CaF_2 rather than 23 MT CaF_2.)

WASH-1248 reports 2×10^{-4} Ci Uranium released to atmosphere in support of model LWR.

CRBR uranium contains 99.8% U-238, 0.2% U-235.

For each 100 g U:

$$99.8 \text{ g U-238} \times 3.33 \times 10^{-7}\text{Ci/g} = 3.32 \times 1^{-5}\text{Ci/100 g} \ (98.8\%)$$

$$0.2 \text{ g U-235} \times 2.14 \times 10^{-6}\text{Ci/g} = \underline{4.28 \times 10^{-7}\text{Ci/100 g}} \ (1.3\%)$$

$$3.36 \times 10^{-5}\text{Ci/100 g}$$

$$\sim 1/3 \times 2 \times 10^{-4}\text{Ci U} \times .988 = 6.6 \times 10^{-5} \text{ Ci U-238}$$

$$\sim 1/3 \times 2 \times 10^{-4} \text{ Ci U} \times 0.013 = 8.5 \times 10^{-7} \text{ Ci U-235}$$

Thermal:

$\sim 1/3 \times 9 \times 10^{9}$ Btu $= 3.0 \times 10^{9}$ Btu $\times 1.05 \times 10^{-3}$ MJ/Btu $= 3.15 \times 10^{6}$ MJ

USNRC 1977b (NR-FM-013), p. 3-11

$.0286 \text{ gF}^{-}\text{/sec} \times 3600 \text{ sec/hr} \times 24 \text{ hr/da} \times 365 \text{ da/yr} \times \frac{11.1 \text{ MTU (CRBR)}}{1600 \text{ MTU (Westinghouse thruput)}}$

$= 6.3 \times 10^{3}$ grams $= 0.006$ MT/yr

$31.18 \text{ g } NH_3\text{/sec} \times 3600 \times 24 \times 365 \times \frac{11.1}{1600} = 6.7 \times 10^{6}$ g

$= 6.7$ MT/yr

p. 3-10

$1.19 \times 10^{-4}\ \mu\text{CiU/sec} \times 3600 \times 24 \times 365 \times \frac{11.1}{1600} = 26 \mu\text{Ci/yr}$

(less conservative than above)

D.4 DATA FOR MIXED OXIDE (CORE FUEL) FABRICATION:

Using DOE data from Table 5.7 - 1, Amendment XIV

750 gallons/day x 365 days/yr = 274,000 gal/yr
round to 0.3×10^6 gal/yr.

(This should be noted - discharge to ground, since according to DOE/EA-0116, nondischarged to river. Water is from wells.

9×10^3 MWh x 3600 MJ/MWh = 3.2×10^7 MJ

3.6×10^3 MT eq. coal

	SO_x:	$3.6 \times 10^3 \times 3.5 \times 10^{-2}$ =	126	(round to 130)
Particulates &	NO_x:	$\times 1 \times 10^{-2}$ =	36	(round to 35)
	HC :	$\times 1 \times 10^{-4}$ =	.36	(round to 0.4)
	CO :	$\times 2.3 \times 10^{-4}$ =	.83	(round to 0.9)

U releases (DOE/EA-0116) = 1.1×10^{-10} Ci/yr (natural U)
at thruput of 6 MT/yr

Activity of natural U is

$$0.993 \times 3.33 \times 10^{-7} = 3.31 \times 10^{-7} \text{ Ci U-238/g U}$$
$$0.0072 \times 2.14 \times 10^{-6} = 1.54 \times 10^{-8} \text{ Ci U-235/g U}$$
$$3.31 \times 10^{-7} \text{ Ci U-234/g U}$$
$$\Sigma = 6.67 \times 10^{-7}$$

Thus, for 3.2×10^{-11} Ci U-235 released (Amend. XIV, Table 5.7-1) from natural U, there should be

$$\frac{3.31 \times 10^{-7}}{1.54 \times 10^{-8}} \times 3.2 \times 10^{-11} = 6.9 \times 10^{-10} \text{ Ci U-238 released.}$$

And, for 0.2% U-235, the U-235 released would be

$$\frac{0.2}{0.72} \times 3.2 \times 10^{-11} \text{ Ci} = 8.89 \times 10^{-12} \text{ Ci}$$

Thermal: 3.6×10^3 MT coal x 2200 lb/MT x 12000 Btu/lb x 1.05×10^{-3} MJ/Btu =
1.0×10^8 MJ

D.4 DATA FOR REPROCESSING

Per Conceptual Design Report for DRP, as noted in CRBR EIS Supplement:

90 acres = 36 hectares

10 acres = 4 hectares

80 acres = 32 hectares

215,000 gpd water to effluent pond

$\times$ 300 days/yr = 6.45×10^7 gallons/yr for DRP

CRBR requirements, then are

$$6.45 \times 10^7 \text{ gallons/yr} \times \frac{11.86 \text{ MTHM (CRBR)}}{150 \text{ MTHM (DRP capacity)}} = 5.1 \times 10^6 \text{ gal/yr}$$

202,000 gpd cooling water blow-down x 2 (estimate for evaporation)

$$\times 300 \text{ days/yr} \times \frac{11.86}{150} = 9.58 \times 10^6 \text{ gal/yr}$$

Total = $(9.58 + 5.1) \times 10^6 = 14.7 \times 10^6$ gallons/yr

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$$20 \text{ MVA} \times 24 \text{ hr/da} \times 200 \text{ da/yr} \times 3600 \text{ MJ/MVA·hr} \times \frac{11.86}{150} = 4.1 \times 10^7 \text{ MJ}$$

4.1×10^7 MJ $\times 1.08 \times 10^{-4}$ MT eq. coal = 4.43×10^{-3} MT eq. coal

Plus:

2 boilers at 3.5 tons/hr =

$$7.0 \text{ tons/hr} \times 24 \text{ hr/da} \times 300 \text{ da/yr} \times \frac{11.86}{150} = 3.98 \times 10^3 \text{ tons}$$

$$= 3.62 \times 10^3 \text{ MT}$$

Total = $(4.43 + 3.62) \times 10^3 = 8.05 \times 10^3$ MT

SO_x:	8000 MT	$\times 3.5 \times 10^{-5}$	MT/MT	= 280	MT
NO_x:	"	$\times 1 \times 10^{-2}$	"	= 80	MT
H-C:	"	$\times 1 \times 10^{-4}$	"	= 0.8	MT
CO :	"	$\times 2.3 \times 10^{-4}$	"	= 2	MT
Particulate:	"	$\times 1 \times 10^{-2}$	"	= 80	MT

To calculate weight of water treatment sludge (DRP)

Assume: sludge aver. density = 1.5 g/ml
solids density = 3.0 g/ml
Then weight fraction of solids in sludge = 0.25

25,000 gpd sludge (Conceptual Design Report) x 3.785 l/gal x 300 da/yr

$\times 1.5\ kg/l \times 0.25 \times 10^{-3}\ MT/kg \times \frac{11.86}{150} = 842\ MT/yr.$

Thermal:

$8000\ MT\ coal \times 2200\ lb/MT \times 12000\ Btu/lb \times 1.05 \times 10^{-3}\ MJ/Btu =$

$2.2 \times 10^{8}\ MJ$

These Pages:

1) By page number from the June 9 draft of Appendix D indicate source of information used

2) Relates the use of the referenced information by reproduction or by further calculations, and how calculated when pertinent

3) Provides copies of the pertinent pages from the referenced source documents.

This information is supplemented by the calculations used to develop the specific information for Table D.4 relating to the blanket fuel fabrication plant, the core fuel fabrication plant, and the reprocessing plant — as transmitted letter O.F. Hill to H. Lowenberg, 6/9/82.

Numbering is by App. D page followed by period and series of pages.

Pages D-2 and D-4.

Table D.1 (p. D-2) and data at top of p. D-4 were calculated based on Figure 4.3-1 of Amendment 51 of the PSAR, as transmitted by A.G. Croff, ORNL, to H. Lowenberg, 4/5/82

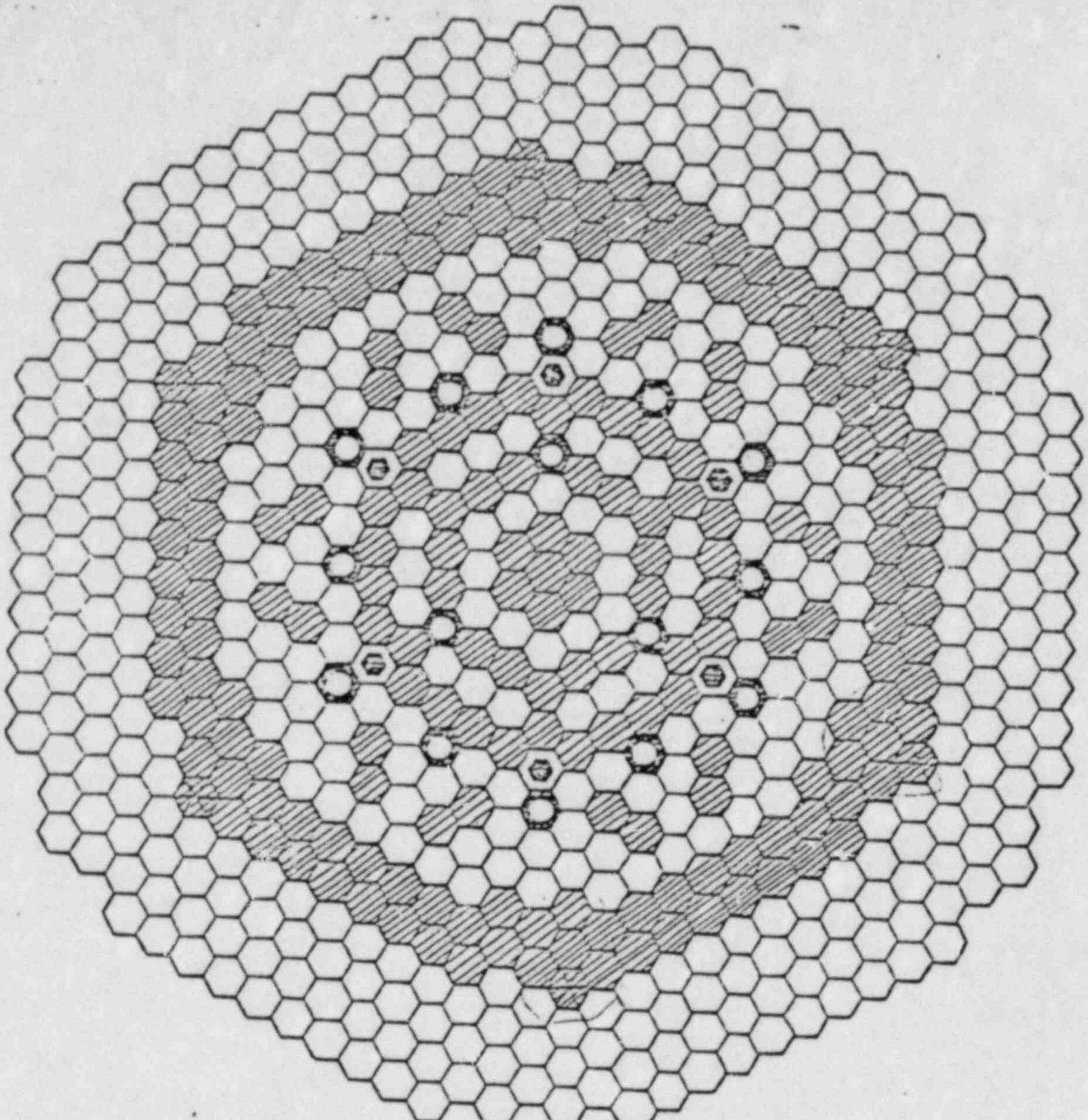


Figure 4.3-1 Clinch River Breeder Reactor Core Layout

Source: Letter A.G. Croff to H. Lowenberg, 4/20/82

Pages D-5 and D-6

Table D.2 is a direct reproduction of Table 6 as transmitted in A.G. Croff's letter to H. Lowenberg, 4/20/82

Table D.3 is a direct reproduction of Table 5, as corrected, as transmitted in A.G. Croff's letter to H. Lowenberg, 4/20/82

Table 6. Physical characteristics of CRBR fuel assemblies

	Core and axial blanket	Inner and radial blankets
Assembly component lengths, cm		
Upper end hardware	30.4	29.2
Gas plenum	124.5	124.5
Upper axial blanket	35.6	
Core or radial blanket	91.4	162.6
Lower axial blanket	35.6	
Lower end hardware	109.2	109.2
Overall total	426.7	426.7
Fuel element total	290.6	290.6
Assembly shape	hexagonal	hexagonal
Assembly flats, cm	11.62	11.62
Fuel element arrangement	triangular	triangular
Fuel elements per assembly	217	61
Fuel element OD, cm	0.584	1.285
Fuel pellet OD, cm		
Core	0.491	
Axial blanket	0.483	
Inner and radial blanket		1.194
Fuel pellet density, % of theoretical		
Core	91.3	
Axial blanket	96.0	
Inner and radial blanket		95.6
Fuel element pitch, cm	0.731	1.378
Cladding thickness, cm	0.038	0.038
Channel thickness, cm	0.305	0.305
Channel height, cm	314	314
Circumscribed volume/assembly, m^3	0.0607	0.0607
Heavy metal/assembly, kg	60.35	100.85
MO_2 assembly, kg[b]	68.45	114.39
Stainless steel/assembly, kg	135.5	122.6
Assembly total weight, kg	204	237

[a]Based on data in ref. 10.

[b]$(Pu,U)O_2$ in the core and UO_2 in the axial, inner, and radial blankets.

Source: Letter A.G. Croff to N. Lowenberg, 4/20/82
D-5/6.2

Table 5. Summary characteristics for the CRBR

Parameter	Fuel region(s)[a]					
	Fuel	AB	Fuel + AB	IB	RB[b]	Fuel + AB + IB + RB
Electric power, MW(e) net	267.4	6.1	273.5	46.9	29.6	350.0
Thermal power, MW(t)	745.0	17.0	762.0	130.5	82.5	975.0
Average specific power,[c] MW(t)/MTIHM	140.9	3.95	79.4	16.4	6.49	32.21
Average fuel burnup, MWd/MTIHM	76,031	2133	42,870	8693	7977	22,600
Effective irradiation duration, full-power days	540	540	550	530	1229	
Refueling cycle length, full-power days	275	275	275	275	275	275
Average number of assemblies charged per cycle	81	81	81	41	28.2	
Average charge, kg/refueling cycle[d]						
^{235}U	3.6	4.4	8.0	8.3	5.7	22.0
Total uranium	1805.5	21~~89.1~~ 93.5	~~3994.6~~ 3999.0	4134.9	2843.9	10,97~~[illegible]~~ 5
Fissile plutonium[e]	783.0	0	783.0	0	0	783.0
Total plutonium	889.4	0	889.4	0	0	889.4
Total (U + Pu)	2694.9	2193.5	4888.4	4134.9	2843.9	11,867
Average discharge, kg/refueling cycle[d]						
^{235}U	2.6	3.6	6.2	5.9	4.0	16.1
Total uranium	1715.8	2149.0	3864.8	3960.2	2726.9	10,552
Fissile plutonium[e]	627.2	38.5	665.7	131.6	89.1	886.4
Total plutonium	766.7	39.6	806.3	138.3	94.9	1039.5
Total (U + Pu)	2482.5	2188.6	4671.1	4098.5	2821.8	11,591

[a]Fuel = 36 in.' $(Pu,U)O_2$ region, AB = UO_2 axial blankets associated with fuel, IB = entire inner blanket, RB = entire radial blanket.

[b]Weighted average of inner radial blanket (4 cycle residence) and outer radial blanket (5 cycle residence).

[c]Based on rated power level.

[d]Averaged over 4 cycles.

[e]$^{239}Pu + ^{241}Pu + ^{239}Np$.

Source: Letter A.G. Croff to N. Lowenberg, 4/20/82

D-5/6.3

<u>Page D-8.</u>

Releases from Blanket Fuel Assembly facility based on Column E, Table S-3A of WASH-1248, except as noted in Table D.4, F^- and NH_3 releases based on NR-FM-013 (NRC 1977b), p. 3-12.

D-8.2

TABLE S-3A

Summary of Environmental Considerations for Nuclear Fuel Cycle
Normalized to Model LWR Annual Fuel Requirement

Natural Resource Use	A Mining	B Milling	C UF_6 Prod.	D Enrichment	E Fuel Fab.	F Reprocessing	G Waste Management	H Transportation	Total
Land (Acres)									
Temporarily Committed	55	0.5	2.5	0.8	0.2	3.9	-	-	63
Undisturbed Area	38	0.2	2.3	0.6	0.16	3.7	-	-	45
Disturbed Area	17	0.3	0.2	0.2	0.04	0.2	-	-	18
Permanently Committed	2	2.4	0.02	0.0	0.0	0.03	0.2	-	4.6
Overburden moved (millions of MT)	2.7	-	-	-	-	-	-	-	2.7
Water (millions of gal.)									
Discharged to air	-	65	3.3	84	-	4.0	0.13	-	156
Discharged to water bodies	-	-	23.0	11,006	5.2	6.0	0.13	-	11,040
Discharged to ground	123	-	-	-	-	-	-	-	123
Total Water	123	65	26.3	11,090	5.2	10.0	0.26	-	11,319
Fossil Fuel									
Electrical energy (thousand MW-hr.)	0.25	2.70	1.70	310	1.7	0.45	.0077	-	317
Equivalent Coal (thousand MT)	0.09	0.97	0.62	113	0.62	0.16	.003	-	115
Natural Gas (million scf)	-	68.5	20.0	-	3.6	-	-	-	92

Source: WASH-1248 (AEC 1974b)

D-8.3

TABLE S-3A (cont.)

Summary of Environmental Considerations for Nuclear Fuel Cycle
Normalized to Model LWR Annual Fuel Requirement

Natural Resource Use	A Mining	B Milling	C UF_6 Prod.	D Enrichment	E Fuel Fab.	F Reprocessing	G Waste Management	H Transportation	Total
Effluents									
Chemical (MT)									
Gases (MT)(1)									
SO_x	8.5	37.0	29.0	4,300	23	6.2	-	-	4,400
NO_x	5.0	15.9	10.0 (3)	1,130	6	7.1 (4)	-	2.6	1,177
Hydrocarbons	0.3	1.3	0.8 (2)	11	0.06	0.02	-	-	13.5
CO	0.02	0.3	0.2	28	0.15	0.04	-	-	28.7
Particulates	-	9.7	7.6	1,130	6	1.6	-	-	1,156
Other Gases									
F^-	-	-	0.11	0.5	0.005	0.11	-	-	0.72
Liquids									
$SO_4^{=}$	-	-	4.5	5.4	-	0.4	-	-	10.3
NO_3^-	-	-	0.1	2.7	23	0.9	-	-	26.7
Fluoride	-	-	8.8	-	4.1	-	-	-	12.9
Ca	-	-	-	5.4	-	-	-	-	5.4
Cl^-	-	-	0.2	8.2	-	0.2	-	-	8.6
Na^+	-	-	3.9 (5)	8.2	-	5.3	-	-	16.9
NH_3	-	-	-	-	10.0	-	-	-	11.5
Tailings Solutions (thousands)	-	240	1.5	-	-	-	-	-	240
Fe	-	-	-	0.4	-	-	-	-	0.4
Solids	-	91,000	40	-	26	-	-	-	91,000

(1) Estimated Effluents Based Upon Combustion of Equivalent Coal for Power Generation
(2) Combined Effluents from Combustion of Coal and Natural Gas and process tankage, contains 0.2 MT of Hexane
(3) 25% from natural gas use
(4) 77% from process
(5) Contains about 80% Potassium

Source: WASH-1248 (AEC 1974b)

TABLE S-3A (cont.)

Summary of Environmental Considerations for Nuclear Fuel Cycle
Normalized to Model LWR Annual Fuel Requirement

Natural Resource Use	A Mining	B Milling	C UF_6 Prod.	D Enrichment	E Fuel Fab.	F Reprocessing	G Waste Management	H Transportation	Total
Effluents (cont.)									
Radiological (curies)									
Gases (including entrainment)									
Rn-222	-	74.5	-	-	-	-	-	-	74.5
Ra-226	-	0.02	-	-	-	-	-	-	0.02
Th-230	-	0.02	-	-	-	-	-	-	0.02
Uranium	-	0.03	0.0015	0.002	0.0002	-	-	-	0.032
Tritium (thousands)	-	-	-	-	-	16.7	-	-	16.7
Kr-85 (thousands)	-	-	-	-	-	350	-	-	350
I-129	-	-	-	-	-	0.0024	-	-	0.0024
I-131	-	-	-	-	-	0.024	-	-	0.024
Fission Products	-	-	-	-	-	1.0	-	-	1.0
Transuranics	-	-	-	-	-	0.004	-	-	0.004
Liquids									
Uranium & Daughters	-	2	0.044	0.02	0.02	-	-	-	2.1
Ra-226	-	-	0.0034	-	-	-	-	-	0.0034
Th-230	-	-	0.0015	-	-	-	-	-	0.0015
Th-234	-	-	-	-	0.01	-	-	-	0.01
Tritium (thousands)	-	-	-	-	-	2.5	-	-	2.5
Ru-106	-	-	-	-	-	0.15	-	-	0.15*
Solids (buried)									
Other than high level	-	600	0.86	-	0.23	-	-	-	601
Thermal (billions of Btu)	-	69	20	3200	9	61	1.0	0.03	3,360

* Cs-137 (0-075 Ci/AFR) and Sr-90 (0.004 Ci/AFR) are also emitted.

Source: WASH-1248 (AEC 1974b)

Table 3.4. Average and maximum emission rates (g/sec) of process gases

Chemical	Average at		Maximum at	
	400 MTU	1600 MTU	400 MTU	1600 MTU
Ammonia (NH_3)	6.49	25.96	7.80	31.18
Fluorides (F^-)	0.006	0.0238	0.0072	0.0286

The DCFB process does not require the use of ammonia; therefore, should this process, which is an advanced development, be adopted to replace the ADU process, the ammonia effluent would be discontinued.

3.3.1.3 Monitoring procedures

Each release stack monitored is equipped with a device that continuously draws a sample through a low-porosity filter. The filter paper is then removed periodically and analyzed for uranium. The past analysis of air concentrations and flow rates have been utilized to give the total release rate at the present capacity (400 MTU). These calculations were then extrapolated to estimate the releases at the projected capacity of 1600 MTU. A scaling factor of 4 was used for the chemical process areas. Lower values (2.2 and 1.6 respectively) were used for the furnace exhausts and calciner combustion gases. The emissions from the air compressor room, boiler room, and UF_6 bay rest room are assumed to remain unchanged. Waste gases from chemical processing are also periodically analyzed for ammonia and fluorides. Using a scaling factor of 4, the average and maximum ammonia and fluoride gaseous effluent releases for the present operating load of 400 MTU have been utilized to estimate the values to be expected at the projected capacity of 1600 MTU.

3.3.2 Liquid effluents

Liquid wastes consist of two components: sanitary wastewater generated by plant employees and industrial wastewater generated by the manufacturing process. Both ADU and DCFB process wastes, which may contain uranium, are processed through ion-exchange columns and circulated through cartridge filters. The fluoride-containing wastes are treated with lime to form a slurry of CaF_2, which is then distilled to remove the ammonia for reuse. The slurry is then discharged to the east or west lagoon for settling of the solids.

The total annual flow rates are 47 million gallons for the 400-MTU capacity and are estimated to be 69 million gallons for the 1600-MTU-capacity plant. A schematic diagram of the waste system is shown in Fig. 3.5; the components are identified in Table 3.5.

3.3.2.1 Radioactive liquid effluents

The raw waste streams are monitored for radioactivity before leaving the plant conversion area. If the uranium concentration exceeds a specified level, the stream is diverted for additional processing. Liquid wastes from the process scrubbers, the scrap-recovery line, and the DCFB process are stored in quarantine tanks on a batch basis and then sampled before release. Only uranium concentrations in liquid-waste streams below the specified level of 30 pCi/ml (the MPC for U-234 given in 10 CFR Part 20) are permitted to leave the plant area.

In addition to the isotopes of uranium, the liquid-waste streams contain small amounts of the daughter products Th-231, Th-234, and Pa-234m. These radionuclides account for the presence of some beta-gamma activity in the liquid-waste stream.

The average discharge concentrations and the total annual release of radioactivity to the river for the present 400-MTU operation, in addition to estimated values for the projected 1600-MTU operation, are given in Table 3.6.

Source: NR-FM-013 (NRC 1977b)

D-8.5

Table 3.2. Estimated airborne uranium releases

Effluent release point	Release rate (uCi/sec) at 400 MTU	Release rate (uCi/sec) at 1600 MTU
Furnace exhausts	1.76×10^{-5}	3.87×10^{-5}
DCFB[a] emergency exhausts	5.35×10^{-6}	2.14×10^{-5}
Conversion process exhausts	1.01×10^{-5}	4.05×10^{-5}
Calciner combustion gas	2.18×10^{-6}	3.49×10^{-6}
Air compressor room	2.74×10^{-6}	2.74×10^{-6}
Boiler room exhaust	4.70×10^{-6}	4.70×10^{-6}
UF_6 bay rest room exhaust	3.30×10^{-8}	3.30×10^{-8}
Chem lab exhaust 2	2.98×10^{-7}	1.19×10^{-6}
Chem lab exhaust 6	9.58×10^{-7}	3.83×10^{-6}
HP lab exhaust	2.15×10^{-7}	8.59×10^{-7}
Incinerator exhaust	3.65×10^{-7}	1.46×10^{-6}
Totals	4.45×10^{-5}	1.19×10^{-4}

[a]Direct-conversion fluidized-bed. Source: ER, Table 3.3-3.

Source: NR-FM-013 (NRC 1977b). Used in alternate U release calculations. Not used in Appendix D since result less conservative

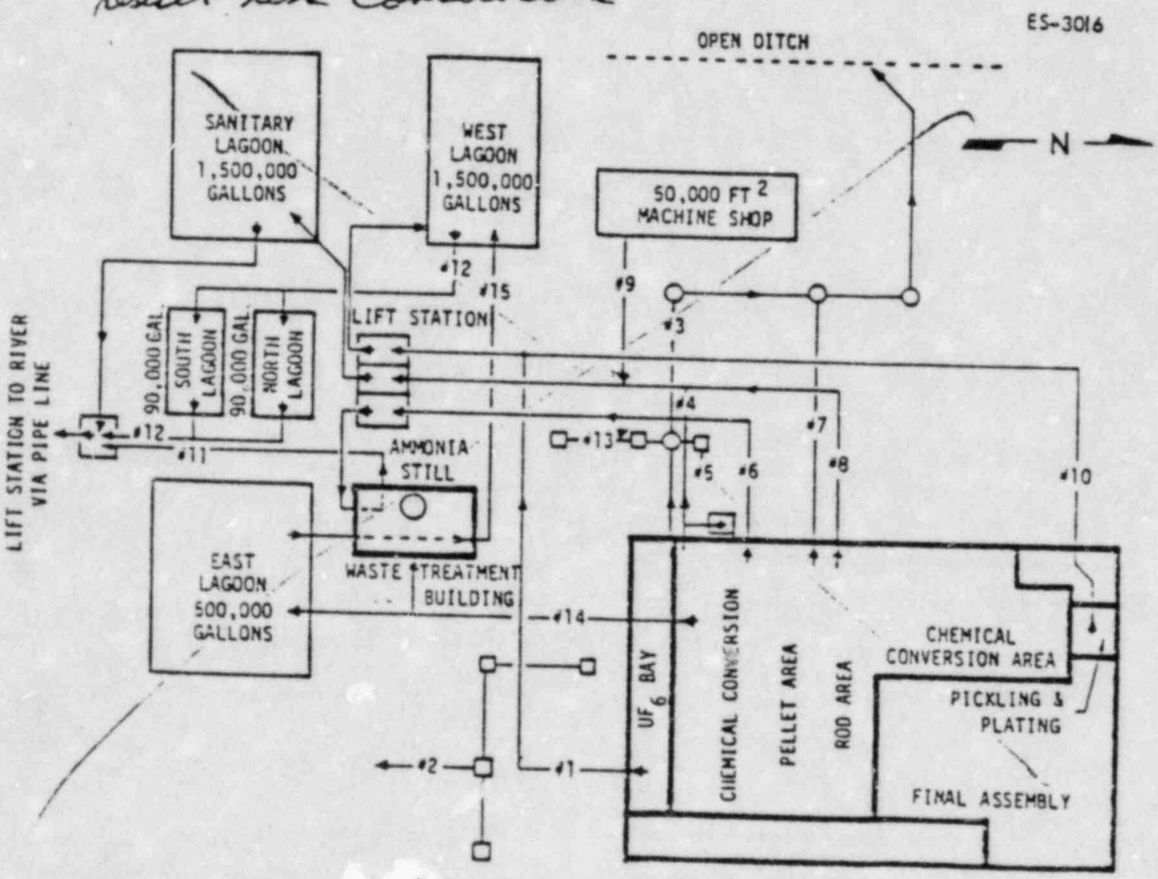


Fig. 3.5. Building and liquid-waste-treatment flow sheet. Source: ER, Fig. 3.3-2.

Page D-9.

Water use is based on DOE's Amendment XIV, Table 5.7-1, which reports 750 gallons/day.

Thermal release are based on DOE's Amendment XIV, Table 5.7-1, which reports the equivalent coal use of 3600 MT/yr:

$$3600 \text{ MT coal/yr} \times 2200 \text{ lb/MT} \times 12{,}000 \text{ Btu/lb} \times 1.05 \times 10^{-3} \text{ MJ/Btu} = 1.0 \times 10^{8} \text{ MJ/yr.}$$

HEPA filter efficiencies based on DOE/RL's requirements as noted in HPS-151-M (ERDA/RL 1976)

TABLE 5.7-1

CRBRP - SUMMARY OF ENVIRONMENTAL CONSIDERATIONS FOR FUEL CYCLE

Natural Resource Use	Fuel Fabrication: Mixed Oxide (Core Fuel)	Fuel Fabrication: Uranium Dioxide*** (Blanket)	Reprocessing****	Waste Management	Transportation	Total
Land (acres)						
Temporarily Committed	--	0.07	10.0	1.3	--	11.37
Undisturbed Area	--	0.05	9.0	--	--	9.05
Disturbed Area	--	0.01	1.0	--	--	1.01
Permanently Committed	--	--	--	2.3	--	2.3
Water (gallons/day)						
Discharged to air	--	--	4.2×10^{6}	2.7×10^{2}	--	4.2×10^{6}
Discharged to water bodies	--	1.3×10^{4}	--	--	--	1.3×10^{4}
Discharged to ground	7.5×10^{2}	--	--	2.2×10^{3}	--	2.95×10^{3}
Total Water	7.5×10^{2}	1.3×10^{4}	4.2×10^{6}	2.47×10^{3}	--	4.2×10^{6}
Fossil Fuel						
Electrical Energy (MW-hr/yr)	9.0×10^{3}**	4.2×10^{2}	--	5.3×10^{2}	--	9.9×10^{3}
Equivalent Coal (MT/yr)	3.6×10^{3}**	1.6×10^{2}	1.3×10^{3}	2.0×10^{2}	--	5.26×10^{3}
Effluents						
Chemicals						
Gases* (MT/yr)						
SO_x	133	5.8	0.4	6×10^{-2}	1.2	140
NO_x	35.2	1.5	3.9	9.1×10^{-2}	15.4	56.1
Hydrocarbons	0.36	1.5×10^{-2}	--	5.1×10^{-3}	1.6	1.98
CO	0.86	3.8×10^{-2}	0.13	2.7×10^{-2}	9.4	10.5
Particulates	35.2	--	--	6.5×10^{-2}	0.6	35.9
F^-	--	1.7×10^{-3}	--	--	--	1.7×10^{-3}

14

Amendment XIV
May 1982

Source: Amendment XIV, ER (DOE 1982)

c) Both ends of the Type "C" and "D" filter shall be fitted with a smooth continuous gasket 1/4" thick by 5/8" wide.

d) On all types, the gaskets shall be sealed to the filter frame over the entire contact area.

e) The edge of the gasket shall not project beyond the outside edge of the frame.

f) If joints in gasket material occur, they shall be located at the filter frame corners and mating surfaces shall be cemented. Joints shall be notched or rabbeted in a manner that assures no air leakage as determined by test specified in subsection 6.2 of this specification. There shall be no more than four gasket joints per gasket.

5.0 FUNCTIONAL REQUIREMENTS

5.1 FILTER EFFICIENCY (PENETRATION) AND FLOW RESISTANCE

a) All Type "A", "C" and "D" filters (in all sizes) shall have a minimum efficiency of 99.97% at rated flow; i.e., the penetration of 0.3 micron diameter, homogeneous particles of dioctyl phthalate (DOP) shall not exceed 0.03% as determined by test specified in subsection 6.1 of this specification. All Type "B" filters (in all sizes) shall have a minimum efficiency of 99.95% at rated flow; i.e., the penetration of 0.3 micron diameter, homogeneous particles of dioctyl phthalate (DOP) shall not exceed 0.05% as determined by test specified in subsection 6.1 of this specification.

b) The initial pressure drop for Type "A", "C" and "D" filters (in all sizes) shall not exceed 1.0 inches w.g. at rated flow. (See subsection 1.2 of this specification.) The initial pressure drop for Type "B" filters (in all sizes) shall not exceed 1.20 inches of w.g. at rated flow. (See subsection 1.2 of this specification.)

c) All Type "A", "C" and "D" filters, size 24" x 24" x 11-1/2" shall also have a minimum efficiency of 99.97% at 20% rated flow.

d) All Type "B" filters size 24" x 24" x 11-1/2" shall also have a minimum efficiency of 99.95% at 20% of rated flow.

5.2 FIRE RESISTANCE

Type "A", "C" and "D" filters shall meet the "Heated Air Test" and the "Spot Flame Test" re[illegible]irements of UL-586.

Source: H[illegible] (ERDA/RL 1976)

Page D-10, Table D.5

The NRC staff bases were calculated from data provided by A.G. Croff in letter to H. Lowenberg, 4/20/82, except the Am-241 content at fuel core fabrication was adjusted to an assumed age of two years at core fabrication.

Example calculation: $\frac{198 \text{ g Pu-238}}{330{,}000 \text{ g Pu total}} \times 100 = 6.0 \times 10^{-2}$ wt %

The DOE assumed bases were taken directly from the SAF Environmental Assessment (DOE 1981b)

Table 4. Initial compositions of 1000 kg of CRBR heavy metal

Nuclide	Material type: Fuel, No decay	Material type: Fuel, 4-y decay	Material type: Blankets
U-234, g	0	6	
U-235, g	1,340	1,372	2,000
U-236, g	0	16	
U-238, g	668,660	668,660	998,000
Total uranium, g	670,000	670,054	1,000,000
Np-237, g	0	4	
Pu-236, g	0.005	0.002	
Pu-238, g	198	192	
Pu-239, g	283,932	283,900	
Pu-240, g	38,610	38,594	
Pu-241, g	6,600	5,444	
Pu-242, g	660	660	
Total plutonium, g	330,000	328,790	
Am-241, g	0	1,152	
Total heavy metal, g	1,000,000	1,000,000	1,000,000

Source: Letter A.G. Croff to H. Lowenberg, 4/20/82

^{236}Pu	8×10^{-6}%
^{238}Pu	0.5%
^{239}Pu	72%
^{240}Pu	20.0%
^{241}Pu	6.0%
^{242}Pu	1.5%

FMEF + SAF ↗ 4000 kg
FMEF ↗ 430 kg

The annual amount of in-process PuO_2 used in FMEF, including SAF, will be approximately 4 MT. Maximum vault storage capacity for radioactive material including PuO_2, mixed oxides, uranium and scrap will not change from 3120 kg. In addition, SAF will add approximately 600 kg of in-process storage, principally mixed oxides.

The facility is designed to totally contain all radioactivity in the event of the design basis tornado and design basis earthquake (both 10^{-6} probability per year.) A special analysis was performed to confirm this for the SAF program. Because of the additional fuel fabrication activities incorporated into the combined facility, material safeguards have been upgraded substantially.

The estimated binder/lubricant usage for FMEF has been increased by approximately 100 gallons with the SAF addition.

Source: FMEF Environmental Assessment Supplement for Secure Automated Fabrication (SAF) (DOE 1981b)

D-10.3

Source: FMEF EA Supp. for SAF (DOE 1981b) D-10.4

TABLE 2A: ENVIRONMENTAL RELEASES FROM NORMAL FMEF SAF OPERATIONS

Isotope [1]	Ci/g	Thoughput (MT) [2]	Release Factor [3]	Cleanup [3]	Environmental Release (Ci/Yr)
Pu^{236}		$.32 \times 10^{-6}$	.001	1.25×10^{-8}	$.2 \times 10^{-8}$
Pu^{238}	17.4	.02	.001	1.25×10^{-8}	~~.04~~ .43 $\times 10^{-5}$
Pu^{239}	6.16×10^{-2}	2.8	.001	1.25×10^{-8}	$.22 \times 10^{-5}$
Pu^{240}	2.27×10^{-1}	.8	.001	1.25×10^{-8}	$.22 \times 10^{-5}$
Pu^{241}	112.4	.24	.001	1.25×10^{-8}	$.30 \times 10^{-3}$
Pu^{242}	3.9×10^{-3}	.06	.001	1.25×10^{-8}	$.30 \times 10^{-8}$
		3.92			

1) Istopic composition (typical) of plutonium dioxide (PuO_2) feed material used for fuel development and fabrication.

2) Annual amount of in process PuO_2 estimated to be used during SAF operations.

3) Exhaust gases will pass through a series of three High-Efficiency Particulate Absolute (HEPA) filters before reaching the environs. The HEPA filters will have an efficiency of at least 99.95 percent each.

$\frac{0.89}{3.92}$ → proportion of FMEF/SAF attributable to CRBRP

Factor can be applied to all releases/impacts/waste volume to determine what CRBRP accountable for

2273 → [22.73 %]

392) 8900.00

Page D-10, Table D.6

The NRC staff estimate was determined from the wt % distribution assumed by the NRC staff reported in Table D.5, for the CRBRP requirement.

Example Calculation:

6×10^{-4} (Pu-238 fraction) x 889 kg Pu (CRBR requirement) x17.4 Ci/g Pu-238 x 10^3 g/kg x 0.001 (release factor) x1.25×10^{-8} (cleanup factor) = 1.2×10^{-7} Ci Pu-238/yr.

(Note: The NRC staff assumed the same release factors and cleanup factors as those used by DOE)

The DOE assumptions were adjusted from the FMEF releases reported by DOE (DOE 1980a) for the CRBRP requirement; i.e., multiplied by the ratio of 0.889 MT Pu (CRBR) / 4.0 MT Pu (FMEF throughput), except that the Pu-238 release reported by DOE was corrected from 0.34×10^{-5} Ci/yr to 0.43×10^{-5} Ci/yr. [0.02 MT Pu-238 x17.4 Ci/g Pu-238 x10^6 g/MT x 0.001 (release factor) x1.25×10^{-8} (cleanup factor) = 4.3×10^{-6} Ci/yr.]

Example Calculation:

4.3×10^{-6} Ci/yr (FMEF release) x $\frac{0.889 \text{ MT (CRBR)}}{4.0 \text{ MT (FMEF)}}$

= 9.6×10^{-7} Ci/yr release in support the CRBRP

Pages D-11 and D-12.

The assumed bases for the DRP reported on these two pages was abstracted from the Conceptual Design Report (DOE 1981a)

The Thorex process will be used for the thorium based fuels. Both processes utilize a tributylphosphate (TBP) extractant in a normal paraffinic hydrocarbon (NPH) solvent. In the solvent extraction and product conversion steps, the fissile material is always denatured with uranium-238; the final product has a minimum U-238/Pu or U-238/U-233 ratio of 3/1. Normally, core and axial blanket fuel is processed together. However, provisions are made to segregate the axial blanket, which is then processed separately from the core in special cases. Radial blankets can also be processed separately from the core.

The uranium, plutonium, and thorium fuel products are converted to oxides in a form to be used directly in fuel fabrication. Therefore, agreements must be reached with the responsible DOE and/or commercial groups that will receive the products. Specific requirements are that the process perform decontamination of plutonium with coprocessing of the products into the following compositions: $^{238}UO_2$, ThO_2, mixed oxide consisting of up to 25 percent of PuO_2 and at least 75 percent $^{238}UO_2$, and a mixed oxide consisting of up to 25 percent of $^{233}UO_2$ and at least 75 percent $^{238}UO_2$.

Storage capacity for all oxide products is provided for 100 days of operation at the maximum production rate for any of the four oxide products stated above. Capacity to store liquid products temporarily for 30 days of operation is also provided. The design for storage and shipment of $^{238}UO_2$-PuO and $^{238}UO_2$- $^{233}UO_2$ is in accordance with the requirements of 10 CFR 70, 10 CFR 73, and applicable Department of Energy Interim Management Directives or Manual Chapters.

Reprocessing Capacity. The HEF is capable of operating at a nominal throughput of 0.5 metric ton of heavy metal (MTHM) per day when processing uranium-plutonium fuels, and 0.2 MTHM per day when processing thorium fuels. Evaluation of the design indicates that the process can operate effectively at a throughput of 0.25 MT of uranium-plutonium fuel per day.

Source: ORNL/CFRP-81/4 (DOE 1981a)

D-11/12.2

2.0 BRIEF PHYSICAL DESCRIPTION OF PROJECT

The conceptual design of the HEF, as contained in this report, describes a pilot-scale reprocessing facility that is capable of demonstrating storage and reprocessing technology for typical breeder reactor and LWR fuels, using either the uranium-plutonium or the thorium-uranium-plutonium fuel cycle. The HEF processes and equipment can be scaled up for use in production-sized plants.

This conceptual design includes the facilities, support functions, and equipment required for HEF to function as an essentially independent plant. The project has been organized as shown in the work breakdown structure (Figure 2.0-1).

The site assumed for the conceptual design is on the Oak Ridge Reservation approximately two miles east of the proposed Clinch River Breeder Reactor (CRBR) and two miles west of Oak Ridge National Laboratory (ORNL). The site occupies approximately 90 acres. A new railroad spur is provided from the Oak Ridge Gaseous Diffusion Plant (ORGDP). Water and natural gas are supplied from ORNL. Electrical power is supplied from both ORGDP and ORNL.

The dominant feature of the HEF is the Process Building, which is about 400 by 800 feet in plan and stands about 175 feet above the surrounding grade. The major portion of this structure is of reinforced concrete construction designed for seismic, tornado pressure, tornado missile, and sabotage resistance.

The demonstration of advanced reprocessing technology, remote maintenance techniques, and containment concepts will be done within the Process Building. Both inside and surrounding the Process Building is an advanced safeguards system to provide both physical protection and nuclear materials control.

SOURCE: ORNL/CFRP-81/4 (DOE 1981a)

D-11/12.3

11.11.1 Electrical (Normal and Standby) (WBS 5121)

Purpose. The electrical power system supplies power to the entire HEF during normal and abnormal conditions. The power system includes two incoming 161 kV transmission lines, standby power generation, power distribution equipment, and the 4.16 kV distribution system within the HEF. The emergency power system is described in Section 11.9.7.1.

Description. The Facility Single Line Diagram, drawing 12-P-001, shows the conceptual design of the HEF plant distribution system. The Area Plan, drawing 11-A-001, shows the routing of the 161 kV transmission lines and the Plot Plan, drawing 11-A-002, indicates the location of the outdoor substations. The HEF estimated electrical loads are summarized in Table 11.11-1.

Normal power. Normal electrical power is supplied to the facility from two dedicated 161 kV overhead transmission lines approaching the site from opposite directions. The transmission lines originate at ORGDP substation K27 and ORNL substation X10, and terminate at the primary breakers of the 161 kV — 4.16 kV distribution transformers. Each transmission line and associated primary distribution transformer is rated to supply the entire HEF load of approximately 20 MVA.

Outdoor substation No. 1 includes the 4.16 kV primary distribution switchgear which serves the entire HEF facility. The design of this switchgear is such that operation of the HEF facility is not inhibited when loss of power from one 161 kV source occurs. In this event, the normally open bus tie breaker closes and restores power to the deenergized bus section and its associated distribution circuits.

The normal power supply characteristics are:

- Capacity: 20 MVA (estimated)
- Voltage: 4.16 kV

Source: ORNL/CFRP-81/4 (DoE 1981a)
D-11/12.4

- Frequency: 60 Hz
- Phase: Three

Under normal operating conditions with off-site power available, two types of electrical loads are served from Substation No. 1: emergency loads (Class 1E) and normal loads (non-Class 1E). Electrical distribution from Substation No. 1 will be in underground duct banks.

Standby power. Standby power is that power furnished to process-related equipment which is not nuclear-safety-related but has been selected to remain operational to meet availability objectives in the event of loss of the main power source. When off-site power is lost from both 161 kV lines, power to the main switchgear at substation No. 1 is provided from the on-site standby generator G1. (The emergency switchgear at substations No. 2 and No. 3 is supplied from emergency generators G2 and G3, which are described in Section 11.9.7.1.) The standby generator starts automatically, and after reaching rated voltage and frequency, the supply breaker closes and energizes the bus. To prevent overloading of the generators, automatic load shedding and load reacceleration schemes are incorporated. In addition, the plant operator will be able to manually disconnect or energize equipment so as not to exceed the capacity limits of the generator to satisfy operational requirements of the plant. Upon return of off-site power, the generator is manually synchronized with the off-site system and the normal power supply breakers manually closed to restore normal power to the entire plant distribution system.

The standby power supply characteristics of standby generator G1 are:

- Capacity: 8,000 kW (estimated)
- Voltage: 4.16 kV
- Frequency: 60 Hz
- Phase: Three

Source: ORNL/CFRP-81/4 (DOE 1981a)
D-11/12.5

11.11.4 Diesel Oil System (WBS 5124)

Purpose. The diesel oil system provides fuel to the facility emergency and standby power sources. The diesel oil system consists of two completely independent diesel oil storage and transfer systems, one serving the emergency power generation system and the other serving the standby power generation system.

11.11.4.1 Emergency diesel oil storage and transfer system

Description. This system consists of two ind endent and redundant storage and transfer subsystems, each serving one of the two redundant emergency diesel generators. The major components of each emergency diesel oil storage and transfer subsystem are shown in Figure 11.11-1 and drawing 12-A-001. Each subsystem consists of a horizontal diesel oil storage tank, transfer pump, day tank, and interconnecting piping. The emergency diesel oil storage tanks are located on the north side of the Process Building in two separate underground concrete vaults. Each tank has a 30,000-gallon capacity — the quantity required for uninterrupted operation for a period of seven days.

The underground tank vaults are classified as Category I structures, and access to the tanks is secured to meet the facility safeguards requirements. The emergency diesel oil day tanks and transfer pumps are located inside the hardened structure (Category I) of the Process Building in separate rooms. Each day tank has a capacity of 300 gallons of diesel oil, providing a minimum of 60 minutes of uninterrupted operation at 110 percent of the rated capacity of the diesel-powered unit.

One emergency diesel oil transfer pump is used to transfer fuel from the storage tank to the day tank when the level in the day tank has dropped to a predetermined setting. Pumps are vertical, motor-driven, mounted on the storage tank, and powered from the Class 1E power source. Interconnecting piping is run underground, properly anchored and protected to

Source: ORNL/CFRP-81/4 (DOE 1981a)
D-11/12.6

Normal cooling water is circulated through the heat exchange surfaces of process closed-loop and nonprocess heat-generating equipment, using any two of the three installed 50-percent capacity pumps. Pumps are vertical deep-well type, rated at 14,500 gpm at 150 feet of head each, and driven by 700 HP electric motors. Electric power is supplied from the normal and standby power sources.

Each pump discharges into a 30-inch carbon steel header, and all three headers are manifolded into a 36-inch cold water distribution main from which different branches feed heat exchangers in the Process and Utilities Buildings.

The cooling water is returned to the cooling tower in a 36-inch diameter header at 98°F and is pumped out of the tower 85°F. A 30-inch self-cleaning strainer is provided at the discharge side of each cooling water pump.

Blowdown of the normal cooling water system is continuous in order to maintain proper water quality and is routed to the noncontaminated wastewater treatment system described in Section 11.11.13. Makeup water for blowdown, evaporation, and drift losses is provided by the primary water supply system.

During standby operation, some of the cooling water uses will be discontinued. The heat load on the cooling tower will decrease, and operation of three out of the four fans will be adequate to dissipate the corresponding heat load.

Technical uncertainties. Chemical treatment of the normal cooling water for corrosion and algae and slime control must be determined during detail design.

Source: ORNL/CFRP-81/4 (DOE-1981a)

D-11/12.7

11.11.6 Steam System (WBS 5126)

Purpose. The HEF steam system comprises a steam generation plant and condensate collection system designed to provide steam for the following users:

- Closed-loop process steam generation
- Process jet steam generation
- Process hot water system
- Process Building heating, utility stations, decontamination, and cold chemical makeup requirements
- Support Building heating
- Winterization requirements.

This system does not include steam distribution and condensate collection systems inside the Support or Process Buildings or the closed-loop process steam systems. However, parts of these systems are described here for clarity.

Description. The major components of the steam system are shown on drawing 12-U-005, Steam System. The steam generation and condensate collection system consists of two coal-fired boilers, associated feedwater and combustion control systems, a boiler blowdown tank, two full-capacity feedwater pumps, and a deaerator, all located inside the Utilities Building. Condensate collection tanks and transfer pumps are provided in miscellaneous locations; a condensate storage tank and transfer pumps are also provided and located outside the Utilities Building. Makeup to the steam system is provided from the demineralized water system.

The boilers are spreader stoker-fired type with continuous traveling grates and are capable of using natural gas as an alternate fuel to coal. Each boiler is sized to deliver 75,000 lb/hr of saturated steam at a pressure of 350 psig and is capable of meeting the maximum steam demand.

Source: ORNL/CFRP-81/4 (DOE 1981a)

D-11/12.8

At this capacity, each boiler's coal consumption rate is approximately 3.5 tons/hr. Each boiler is equipped with air pollution control devices to ensure that stack emission will meet EPA, State of Tennessee, and local code requirements.

The boiler blowdown tank is a vertical steel tank with internals designed to separate vapor and liquid. The tank is six feet in diameter and eight feet high and is equipped with a vent stack. The tank is discharged to the noncontaminated wastewater treatment system (see Section 11.11.13).

The feedwater pumps are horizontal centrifugal type with 100 HP motor driver each. The pumps are capable of pumping water at an elevated temperature of 240°F with a total discharge head of 1,000 feet.

The deaerator is a spray/tray type steel vessel with a 150,000 lb/hr capacity, equipped with a steam heater to maintain feedwater temperature at saturation.

Plant steam is furnished to supply heat for generation of process and jet steam in closed-loop systems. Plant steam condensate from these systems is collected and condensed in a process condensate flash tank located in the Process Building at 146-foot elevation. The condensate is monitored for contamination and returned to the condensate storage tank in the yard. If traces of contamination are detected, the condensate flow from the process condensate tank is then diverted to the general-purpose concentrator.

All other condensate in the Process Building is collected in a separate vertical condensate collection tank located at the 76-foot elevation.

Source: ORNL/CFRP-81/4 (DOE 1981a)

D-11/12.9

11.11.13 Noncontaminated Wastewater Treatment (WBS 5137)

Purpose. The noncontaminated wastewater treatment system provides for the treatment of nonradioactive effluents except sanitary wastewater prior to their discharge to the effluent pond and ultimately to the environment.

Description. The noncontaminated wastewater treatment system, shown schematically in Figure 11.11-10, consists of flocculation and clarification followed by media filtration. The system components are located outdoors inside the Controlled Zone in the area adjacent to the cold chemical storage tanks, as shown in drawing 11-A-002, Plot Plan.

The surge holding basin, measuring 100 feet long by 50 feet wide by 10 feet deep, receives all nonradioactive liquid effluents as shown in drawing 12-U-001, Water Use Diagram. Flows into the surge holding basin are generally gravity-fed and, with the exception of the effluent from the demineralized water system, receive no prior treatment. Liquid effluents from the demineralizer regeneration and rinse cycles are pH- adjusted in a pH adjustment tank prior to discharge to the surge holding basin.

From the surge holding basin, the waste stream enters a flocculator/clarifier, where chemicals (e.g., lime) are added to precipitate some of the dissolved inorganics such as calcium, magnesium, other metals, and alkaline substances. The removed sludge is passed through a thickener where the solids are removed and shipped off site. The liquid overflow from the flocculator/clarifier, clarifier is passed through media filters for further purification before it is discharged to the effluent pond.

Source: ORNL/CFRP-81/4 (DOE 1981a)

D-11/12.10

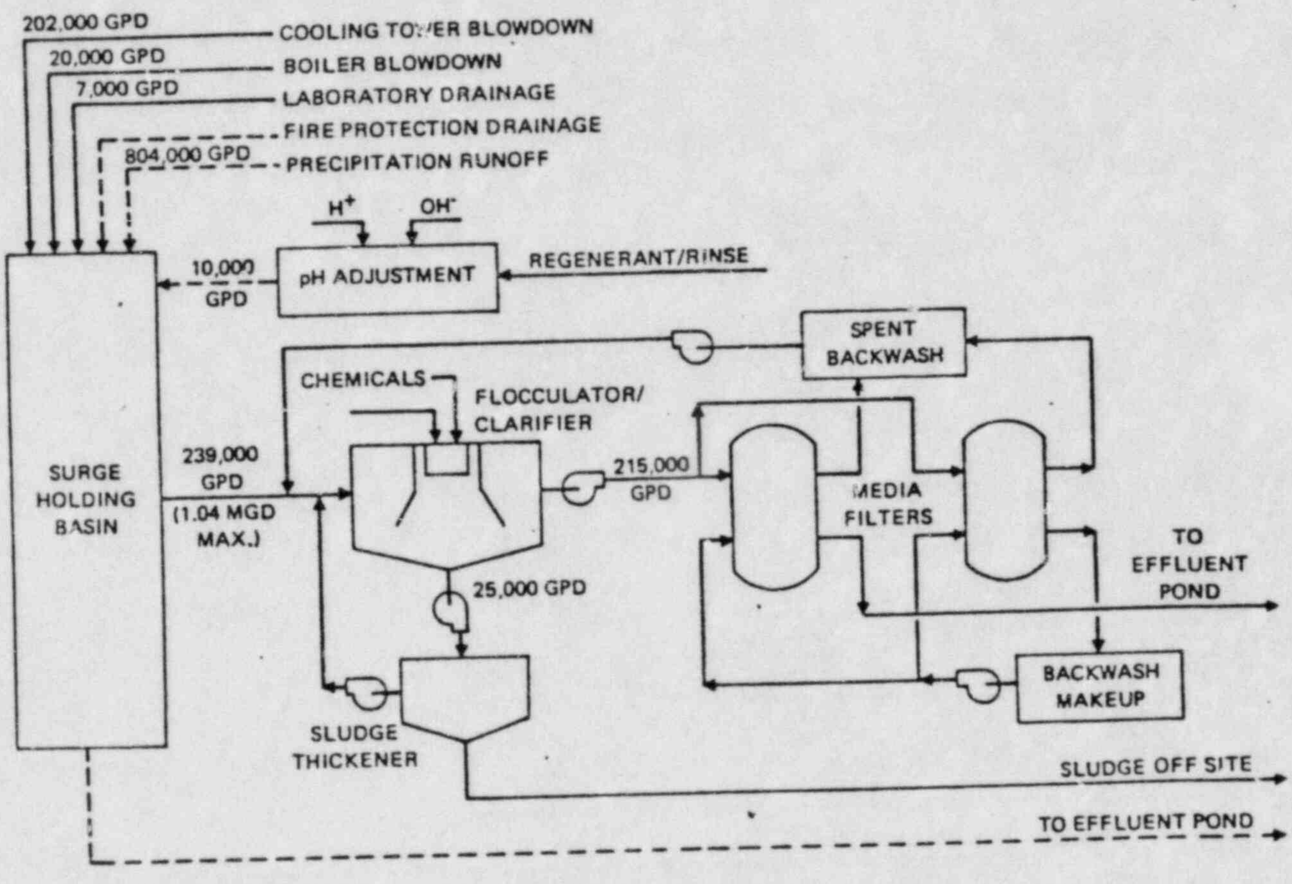


Figure 11.11-10 NONCONTAMINATED WASTEWATER TREATMENT

Source: ORNL/CFRP-81/4 (DOE 1981a)

D-11/12.11

Pages D-13 and D-14

Assumptions are as reported by A. G. Croff in letters to H. Lowenberg, dated 4/5/82 and 4/20/82.

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
NUCLEAR DIVISION

POST OFFICE BOX X
OAK RIDGE, TENNESSEE 37830

April 20, 1982

Mr. H. Lowenberg
Office of Nuclear Materials
Safety and Safeguards
U.S. Nuclear Regulatory Commission
7915 Eastern Avenue
Silver Springs, MD 20910

Dear Homer:

Enclosed is the revised ORIGEN2 output for the CRBR that you requested during our recent meeting in Silver Springs. I have made the following changes in the calculations per your request:

1. altered the averaging procedures so that the ORIGEN2 mass flows agree with the physical masses,

2. assumed a 4 y pre-irradiation fuel decay period,

3. eliminated the output sections for the core assembly and the reprocessing outputs from the core + core axial blanket and the inner + radial blankets, and

4. added an output section decaying the entire annual batch of discharged spent fuel.

Enclosed you should find the following items:

1. a summary ORIGEN2 output on paper for the CRBR and a table of contents for same,

2. a detailed ORIGEN2 microfiche output for the CRBR and a table of contents on paper for the same, and

3. a set of tables describing the revised CRBR model.

It will be 1 to 2 weeks before I can work on the graphs since I will not be back in town until April 26 and there are several alterations to be made to the input decks to accommodate the changes that you requested.

D-13/14.2

from A. G. Croff

ORIGEN2 Decay Calculation Parameters

The decay times employed in the calculations are self-evident by inspection of the column headings in the computer output and they will not be listed here. Major assumptions and parameters used are as follows:

a. the fresh, undecayed fuel was assumed to be decayed for 2 years before irradiation,

b. the spent fuel is assumed to be reprocessed 150 days after discharge from the reactor,

c. the parameters used during reprocessing are as follows:

 i. 0.5% of the uranium and plutonium goes to the HLW,

 ii. 0.05% of the nonvolatile fuel material is retained with the cladding,

 iii. 0.69% of the fuel assembly structural material is assumed to dissolve and go to the HLW,

 iv. 0.1% of the halogen elements and none of the noble gases, tritium, and ^{14}C is assumed to be in the HLW.

d. the compositions of the HLW, structural material waste, plutonium product, and uranium product are based on "blended" fuel which is generated by weighting each of the fuel zones in proportion to the rate at which it is charged to the reactor (see first column of Table 2).

ORIGEN2 Output Description

The ORIGEN2 output is comprised of several segments for different materials and/or decay times. The first two segments summarize the composition of the charged and discharged fuel and structural material for each of the fuel zones on a 1.0 MTHM basis. Only masses (grams) are given and no decay times are provided.

The next four segments decay core + core axial blanket, radial blanket, core, and inner blanket fuel assemblies, respectively. For these segments and all succeeding segments, only summary tables (defined below) are given. The table types provided are mass (grams), radioactivity (curies), thermal power (watts), inhalation hazard (m^3 air to dilute to 10 CFR 20 values), ingestion hazard (m^3 water to dilute to 10 CFR 20 values), and alpha radioactivity for the actinides (curies) and neutron production. Decay times range from 60 days to 10 years. All of these segments are based on one fuel assembly (not 1.0 MTHM).

D-13/14.3

from 4/5/82 letter
AG Croff to H. Lowenberg

Table D.7, Page D-13
Table D.8, Page D-15

The NRC-ORIGEN2 columns were obtained from the ORIGEN2 printout data provided by A.G. Croff in his 4/20/82 letter to H. Lowenberg with which he transmitted paper printout on the major isotopes and microfiche printout for the minor isotopes.

The DOE data were obtained directly, as indicated, from DOE's Amendment XIV, Table 5.7-3

The selected source term in Table D.8 was chosen from the higher (and therefore most conservative) of the data given in the NRC-ORIGEN2 column or the DOE-Amend XIV column.

D/13/15.1

* DECAY OF ALL SPENT FUEL DISCHARGED ANNUALLY FROM CRBR
POWER= 3.06528E+02 MW, BURNUP= 2.01260E+05 MWD, FLUX= 6.04E+15 N/CM**2-SEC

FISSION PRODUCTS

7 SUMMARY TABLE: RADIOACTIVITY, CURIES
11,867.3 KG INITIAL HEAVY METAL DISCHARGED

	ANNUAL SF	[illegible].0D	100.0D	150.0D	180.0D	240.0D	1.0YR	1.5YR	2.0YR	3.0YR	5.0YR	10.0YR
H 3	5.651E+03	5.757E+03	5.761E+03	5.717E+03	5.691E+03	5.639E+03	5.531E+03	5.376E+03	5.229E+03	4.944E+03	4.419E+03	3.339E+03
KR 85	5.231E+04	5.178E+04	5.147E+04	5.096E+04	5.069E+04	5.016E+04	4.906E+04	4.750E+04	4.599E+04	4.311E+04	3.766E+04	2.741E+04
SR 89	7.833E+06	3.438E+06	1.980E+06	9.996E+05	6.622E+05	2.906E+05	5.208E+04	4.246E+03	3.462E+02	2.302E+00	1.017E-04	1.320E-15
SR 90	3.202E+05	3.189E+05	3.181E+05	3.170E+05	3.164E+05	3.152E+05	3.126E+05	3.089E+05	3.053E+05	2.981E+05	2.642E+05	2.523E+05
Y 90	3.439E+05	3.190E+05	3.182E+05	3.171E+05	3.164E+05	3.153E+05	3.127E+05	3.090E+05	3.053E+05	2.982E+05	2.643E+05	2.524E+05
Y 91	1.008E+07	5.262E+06	3.288E+06	1.616E+06	1.275E+06	6.261E+05	1.420E+05	1.631E+04	1.875E+03	2.476E+01	4.316E-03	1.733E-12
ZR 95	1.937E+07	1.011E+07	6.556E+06	3.814E+06	2.756E+06	1.439E+06	3.704E+05	5.122E+04	7.082E+03	1.354E+02	4.951E-02	1.265E-10
NB 95	1.906E+07	1.512E+07	1.122E+07	7.223E+06	5.430E+06	2.983E+06	8.042E+05	1.132E+05	1.570E+04	3.111E+02	1.099E-01	2.810E-10
RU103	2.716E+07	9.422E+06	4.652E+06	1.925E+06	1.134E+06	3.933E+05	4.315E+04	1.720E+03	6.655E+01	1.088E-01	2.746E-07	2.778E-21
RH103M	2.447E+07	8.494E+06	4.194E+06	1.736E+06	1.022E+06	3.546E+05	3.890E+04	1.550E+03	6.179E+01	9.816E-02	2.476E-07	2.505E-21
RU106	1.056E+07	9.434E+06	8.749E+06	7.963E+06	7.526E+06	6.722E+06	5.310E+06	3.765E+06	2.670E+06	1.342E+06	3.393E+05	1.090E+04
RH106	1.057E+07	9.434E+06	8.749E+06	7.963E+06	7.526E+06	6.722E+06	5.310E+06	3.765E+06	2.670E+06	1.342E+06	3.393E+05	1.090E+04
SB125	2.683E+05	2.601E+05	2.531E+05	2.446E+05	2.396E+05	2.299E+05	2.110E+05	1.862E+05	1.643E+05	1.279E+05	7.756E+04	2.219E+04
TE125M	5.355E+04	5.727E+04	5.791E+04	5.756E+04	5.698E+04	5.538E+04	5.133E+04	4.542E+04	4.009E+04	3.121E+04	1.892E+04	5.415E+03
TE127	2.269E+06	2.091E+05	1.621E+05	1.180E+05	9.748E+04	6.656E+04	3.001E+04	9.396E+03	2.942E+03	2.884E+02	2.771E+00	2.504E-05
TE127M	3.008E+05	2.134E+05	1.655E+05	1.204E+05	9.952E+04	6.795E+04	3.064E+04	9.593E+03	3.003E+03	2.944E+02	2.875E+00	2.556E-05
TE129	5.018E+06	1.600E+05	7.009E+04	2.496E+04	1.346E+04	3.902E+03	2.946E+02	6.807E+00	1.573E-01	8.401E-05	2.396E-11	1.041E-27
TE129M	8.433E+05	2.457E+05	1.077E+05	3.838E+04	2.067E+04	5.995E+03	4.525E+02	1.046E+01	2.417E-01	1.291E-04	3.661E-11	1.660E-27
CS134	4.392E+05	4.156E+05	4.006E+05	3.826E+05	3.722E+05	3.522E+05	3.138E+05	2.653E+05	2.242E+05	1.602E+05	8.166E+04	1.573E+04
CS137	8.370E+05	8.358E+05	8.317E+05	8.291E+05	8.275E+05	8.244E+05	8.179E+05	8.085E+05	7.992E+05	7.809E+05	7.457E+05	6.643E+05
BA137M	7.957E+05	7.886E+05	7.868E+05	7.843E+05	7.828E+05	7.799E+05	7.737E+05	7.648E+05	7.560E+05	7.388E+05	7.054E+05	6.284E+05
BA140	2.161E+07	8.365E+05	9.571E+04	6.369E+03	1.253E+03	4.649E+01	5.606E-02	2.921E-06	1.469E-10	3.714E-19	2.375E-36	0.0
LA140	2.195E+07	9.626E+05	1.101E+05	7.330E+03	1.442E+03	5.581E+01	6.633E-02	3.361E-06	1.690E-10	4.274E-19	2.733E-36	0.0
CE141	2.216E+07	6.200E+06	2.643E+06	9.101E+05	4.801E+05	1.336E+05	9.248E+03	1.884E+02	3.839E+00	1.593E-03	2.745E-10	3.380E-27
PR143	1.751E+07	9.111E+05	1.180E+05	9.168E+03	1.979E+03	9.225E+01	1.544E-01	1.368E-05	1.211E-09	9.496E-18	5.831E-34	0.0
CE144	1.075E+07	9.284E+06	8.421E+06	7.455E+06	6.929E+06	5.966E+06	4.410E+06	2.825E+06	1.810E+06	7.426E+05	1.251E+05	1.458E+03
PR144	1.078E+07	9.284E+06	8.421E+06	7.455E+06	6.929E+06	5.966E+06	4.411E+06	2.825E+06	1.810E+06	7.426E+05	1.251E+05	1.458E+03
PR144M	1.292E+05	1.114E+05	1.011E+05	8.946E+04	8.315E+04	7.163E+04	5.293E+04	3.390E+04	2.172E+04	8.914E+03	1.501E+03	1.749E+01
ND147	8.756E+06	2.040E+05	1.663E+04	7.245E+02	1.105E+02	2.573E+00	1.003E-03	1.074E-08	1.149E-13	1.316E-23	1.725E-43	0.0
PM147	2.169E+06	2.192E+06	2.132E+06	2.056E+06	2.012E+06	1.927E+06	1.760E+06	1.542E+06	1.351E+06	1.037E+06	6.116E+05	1.632E+05
PM148M	1.168E+06	4.340E+05	2.218E+05	9.581E+04	5.790E+04	2.115E+04	2.564E+03	1.205E+02	5.621E+00	1.239E-02	5.862E-08	2.655E-21
SM151	3.188E+04	3.197E+04	3.194E+04	3.190E+04	3.186E+04	3.184E+04	3.176E+04	3.164E+04	3.152E+04	3.127E+04	3.080E+04	2.963E+04
EU154	2.656E+04	2.646E+04	2.623E+04	2.594E+04	2.577E+04	2.[illegible]E+04	2.474E+04	2.376E+04	2.262E+04	2.105E+04	1.742E+04	1.198E+04
EU155	1.328E+05	1.298E+05	1.278E+05	1.254E+05	1.239E+05	[illegible]E+05	1.155E+05	1.077E+05	1.004E+05	8.730E+04	6.601E+04	3.282E+04
SUMTOT	2.591E+08	1.052E+08	7.539E+07	5.500E+07	4.721E+07	[illegible]E+07	2.580E+07	1.787E+07	1.316E+07	7.840E+06	3.897E+06	2.133E+06
TOTAL	2.279E+09	1.057E+08	7.559E+07	5.512E+07	4.731E+07	3.[illegible]E+07	2.583E+07	1.789E+07	1.317E+07	7.844E+06	3.898E+06	2.134E+06

Source: Paper printout of ORIGEN2 run, transmitted with letter A.G. Croff to N. Lowenberg, 4/20/82

D-13/15.2

D-13/15.3

* DECAY OF ALL SPENT FUEL DISCHARGED ANNUALLY FROM CRBR

ACTINIDES+DAUGHTERS

POWER= 3.66526E+02 MW, BURNUP= 2.01260E+05 MWD, FLUX= 8.04E+15 N/CM**2-SEC

7 SUMMARY TABLE: RADIOACTIVITY, CURIES

11,667.3 KG INITIAL HEAVY METAL DISCHARGED

	ANNUAL SF	60.0D	100.0D	150.0D	180.0D	240.0D	1.0YR	1.5YR	2.0YR	3.0YR	5.0YR	10.0YR
U237	1.747E+06	3.745E+03	1.030E+02	4.215E+01	4.165E+01	4.130E+01	4.063E+01	3.966E+01	3.872E+01	3.690E+01	3.351E+01	2.634E+01
PU238	1.445E+04	1.526E+04	1.569E+04	1.612E+04	1.634E+04	1.670E+04	1.719E+04	1.754E+04	1.766E+04	1.765E+04	1.743E+04	1.679E+04
PU239	5.397E+04	5.406E+04	5.408E+04	5.406E+04	5.406E+04	5.406E+04	5.406E+04	5.408E+04	5.408E+04	5.407E+04	5.407E+04	5.406E+04
PU240	3.403E+04	3.403E+04	3.403E+04	3.403E+04	3.403E+04	3.403E+04	3.403E+04	3.402E+04	3.402E+04	3.402E+04	3.401E+04	3.399E+04
PU241	1.738E+06	1.724E+06	1.715E+06	1.704E+06	1.697E+06	1.684E+06	1.656E+06	1.617E+06	1.578E+06	1.504E+06	1.366E+06	1.074E+06
AM241	1.119E+04	1.164E+04	1.194E+04	1.232E+04	1.254E+04	1.296E+04	1.389E+04	1.519E+04	1.646E+04	1.890E+04	2.343E+04	3.294E+04
CM242	7.043E+05	5.460E+05	4.632E+05	3.746E+05	3.300E+05	2.560E+05	1.506E+05	6.992E+04	3.269E+04	7.650E+03	1.219E+03	8.947E+02
SUMTOT	4.303E+06	2.392E+06	2.294E+06	2.195E+06	2.144E+06	2.057E+06	1.926E+06	1.607E+06	1.733E+06	1.636E+06	1.496E+06	1.213E+06
TOTAL	7.989E+06	2.395E+06	2.297E+06	2.196E+06	2.147E+06	2.061E+06	1.929E+06	1.611E+06	1.736E+06	1.640E+06	1.499E+06	1.215E+06

* DECAY OF ALL SPENT FUEL DISCHARGED ANNUALLY FROM CRBR

ACTINIDES+DAUGHTERS

POWER= 3.66526E+02 MW, BURNUP= 2.01260E+05 MWD, FLUX= 8.04E+15 N/CM**2-SEC

23 SUMMARY TABLE: ALPHA RADIOACTIVITY CURIES

11,667.3 KG INITIAL HEAVY METAL DISCHARGED

	ANNUAL SF	60.0D	100.0D	150.0D	180.0D	240.0D	1.0YR	1.5YR	2.0YR	3.0YR	5.0YR	10.0YR
PU238	1.445E+04	1.526E+04	1.569E+04	1.612E+04	1.634E+04	1.670E+04	1.719E+04	1.754E+04	1.766E+04	1.765E+04	1.743E+04	1.679E+04
PU239	5.397E+04	5.406E+04	5.408E+04	5.408E+04	5.406E+04	5.406E+04	5.406E+04	5.408E+04	5.408E+04	5.407E+04	5.407E+04	5.406E+04
PU240	3.403E+04	3.403E+04	3.403E+04	3.403E+04	3.403E+04	3.403E+04	3.403E+04	3.402E+04	3.402E+04	3.402E+04	3.401E+04	3.399E+04
AM241	1.119E+04	1.164E+04	1.194E+04	1.232E+04	1.254E+04	1.296E+04	1.389E+04	1.519E+04	1.646E+04	1.890E+04	2.343E+04	3.294E+04
CM243	2.837E+02	2.826E+02	2.818E+02	2.809E+02	2.803E+02	2.792E+02	2.769E+02	2.735E+02	2.702E+02	2.637E+02	2.512E+02	2.224E+02
CM244	7.143E+02	7.100E+02	7.071E+02	7.034E+02	7.012E+02	6.966E+02	6.877E+02	6.748E+02	6.619E+02	6.370E+02	5.901E+02	4.873E+02
SUMTOT	1.146E+05	1.160E+05	1.167E+05	1.175E+05	1.180E+05	1.188E+05	1.201E+05	1.218E+05	1.231E+05	1.256E+05	1.298E+05	1.365E+05
TOTAL	1.147E+05	1.161E+05	1.166E+05	1.176E+05	1.181E+05	1.189E+05	1.202E+05	1.219E+05	1.232E+05	1.256E+05	1.299E+05	1.366E+05

Source: Paper printout of ORIGEN2 run, transmitted with letter A.G. Croff to H. Lowenberg, 4/20/82

Data on Actinide Isotopes from ORIGEN2 Microfiche

3863

OUTPUT UNIT = 8 PAGE 3863

DECAY OF ALL SPENT FUEL DISCHARGED ANNUALLY FROM CRBR

ACTINIDES+DAUGHTERS

11,867.3 KG INITIAL HEAVY METAL DISCHARGED

TL206	0.0	9.330E-10	9.330E-10	9.330E-10	9.330E-10	9.330E-10	9.330E-10	9.330E-10	9.330E-10	9.330E-10	9.330E-10	9.330E-10
TL208	3.791E-02	3.923E-02	4.029E-02	4.162E-02	4.212E-02	4.427E-02	4.828E-02	5.465E-02	6.137E-02	7.400E-02	9.709E-02	1.339E-01
PB206	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PB208	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PB210	2.354E-07	2.479E-07	2.494E-07	2.400E-07	2.474E-07	2.462E-07	2.437E-07	2.400E-07	2.349E-07	2.299E-07	2.165E-07	[illegible]
PB212	1.099E-01	1.072E-01	1.121E-01	1.150E-01	1.172E-01	1.232E-01	1.344E-01	1.521E-01	1.708E-01	2.089E-01	2.748E-01	3.715E-01

3864

OUTPUT UNIT = 8 PAGE 3864

DECAY OF ALL SPENT FUEL DISCHARGED ANNUALLY FROM CRBR

ACTINIDES+DAUGHTERS

NUCLIDE TABLE: RADIOACTIVITY, CURIES

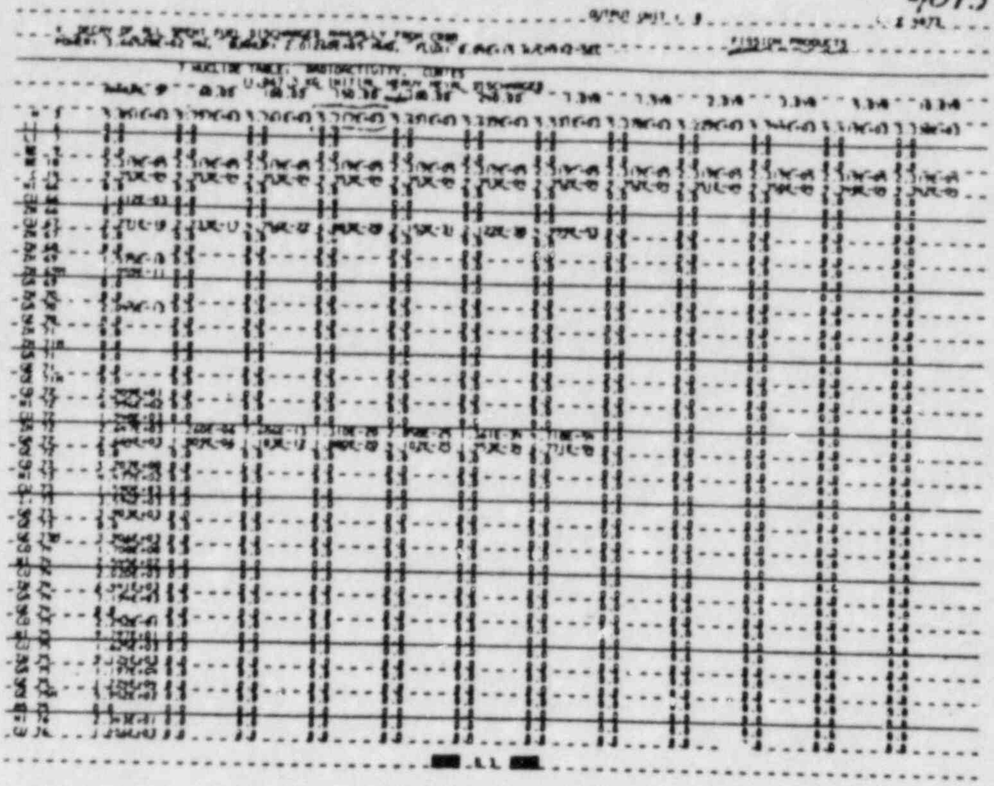
11,867.3 KG INITIAL HEAVY METAL DISCHARGED

Source: Microfiche transmitted with letter A.G. Croff to N. Lowenberg, 4/20/82

D-13/15.4

DATA on H-3 from ORIGEN2 Microfiche

4073

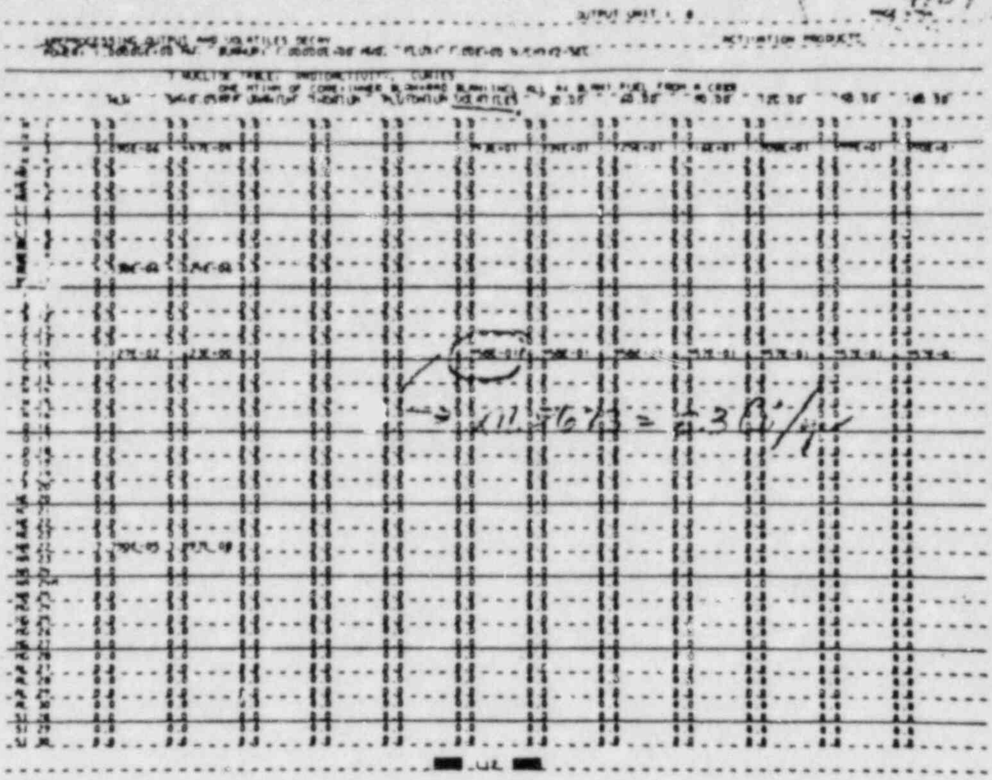


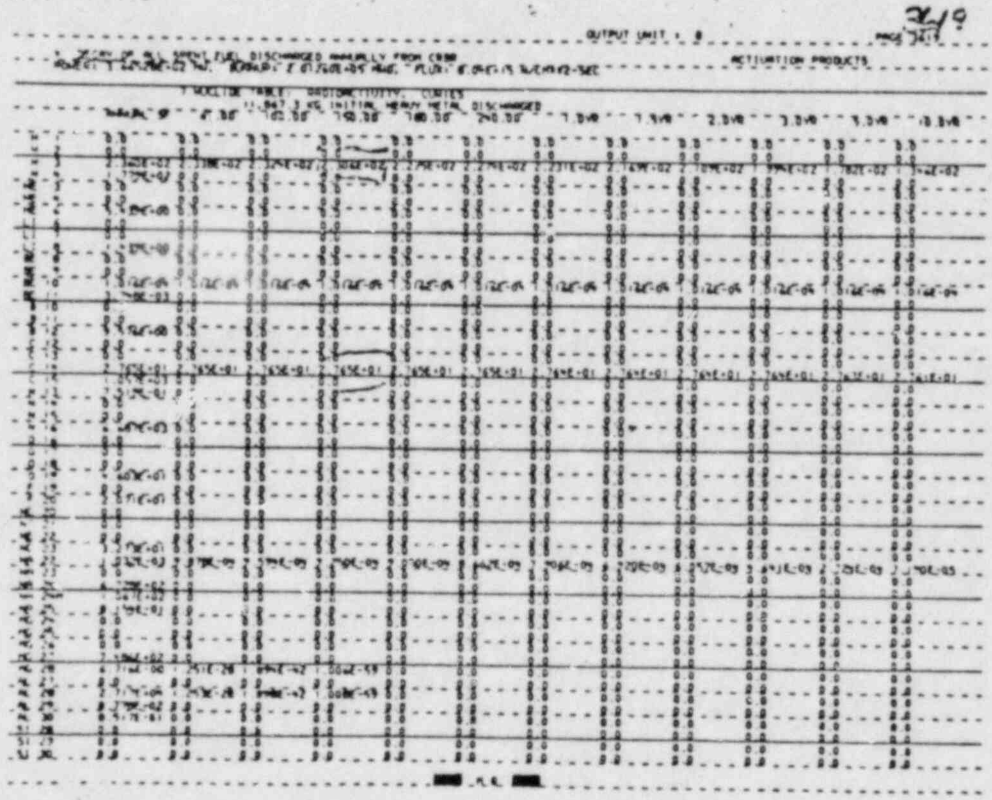
*For total H-3, need to add 2.3E+2 from Activation Products. See p. 3619, included under C-14

Source: Microfiche transmitted with letter A. G. Croff to H. Lowenberg, 4/20/82

D-13/15.5

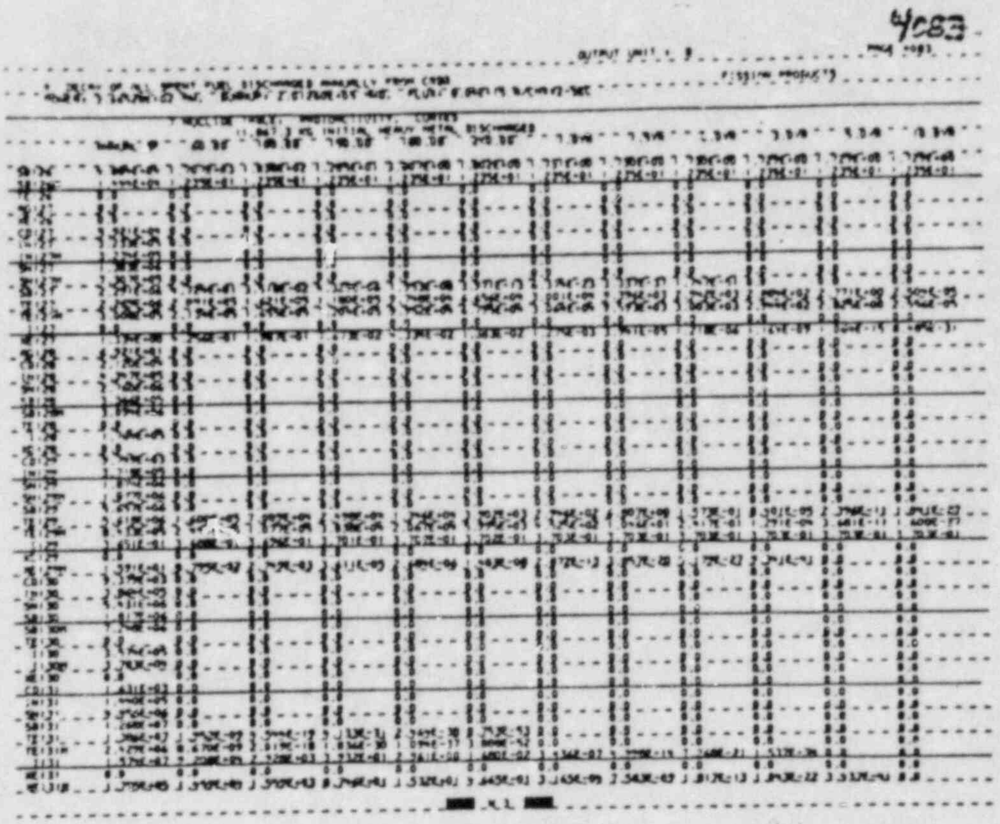
DATA FROM ORIGEN2 Microfiche on C-14





Note: C-14 in "Decay of all spent fuel = 27.7 Ci/yr
C-14 volatilized from reprocessing = 8.3 Ci/yr. (included in both Tables D.7 and D.8. The difference (according to AG(co$^{3}_{1}$)) is C-14 in the cladding that is not released.
D-13/15.6

Data on IODINE from ORIGEN2 Microfiche



Source: Microfiche transmitted with letter A. G. Croff to H. Lowenberg, 4/20/82.

D-13/15.7

(24)

Battelle
Pacific Northwest Laboratories

Project Number

Internal Distribution

KR Byers
RF McCallum
FP Roberts
RJ Sorenson
LB
File

Date 23 June 1982

To Iral Nelson

From P. T. Reardon PTR

Subject Bibliography for EIS Update

To date, the materials we made extensive use of are as follows:

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C. A. GEFFEN

NOTES FOR CALCULATIONS PERTAINING TO TRANSPORTATION IMPACTS FROM CRBR FUEL CYCLE

I. Calculations for Transportation Accidents Involving Radioactive Material

Section 7.2 CRBR EIS

From NUREG-0170 (p. 5-5):

	Truck	Train
Probability of an accident	1.06×10^{-6}/km	0.93×10^{-6}/km

Using Model II (p. 5-23, NUREG-0170)

all but category I accident severe enough to fail LSA for Type A containers; accident severity categories of 6, 7 or 8 required to fail Type B containers.

From NUREG -0170 (p. 5-11, p. 5-15):

Probability of category accident:	Truck	Train
I	0.55	N/A
6	0.0011	1.3×10^{-4}
7	8.5×10^{-5}	6.0×10^{-5}
8	1.5×10^{-5}	1.0×10^{-5}

1) Probability of accident that might fail Type A container is (Truck)

$$(1 - 0.55) = 0.45$$

accident rate: $= 1.06 \times 10^{-6} \frac{\text{acc}}{\text{km}} \times 0.45 = 4.77 \times 10^{-7} \frac{\text{acc}}{\text{km}}$

$$= \frac{\text{acc}}{\text{2 million km}}$$

$$4.77 \times 10^{-7} \frac{\text{acc}}{\text{km}} \times 4000 \frac{\text{km}}{\text{shipment}} \times 10 \text{ Type } \frac{\text{A shipments}}{\text{yr}} =$$

0.01908 accidents/yr

= 50 years per accident

2) Probability of accident that might fail Type B container is (truck)

$$[0.0011 + (8.5 \times 10^{-5}) + (1.5 \times 10^{-5})] = 1.2 \times 10^{-3}$$

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JUN 22 1982

IRAL C. NELSON

NUREG-0170

TABLE 5-1

ACCIDENT RATES

Mode	Accident Rate (per vehicle-kilometer)	Reference
Aircraft	1.44×10^{-8}	5-2*
Truck, Delivery van	1.06×10^{-6}	5-2, 5-5
ICV	$.46 \times 10^{-6}$	5-5, 5-7
Train	$.93 \times 10^{-6}$**	5-2, 5-7, 5-8
Helicopter	$.63 \times 10^{-6}$	5-9
Ship, Barge	6.06×10^{-6}	5-10

*Also see K. A. Soloman, "Estimate of the Probability that an Aircraft Will Impact the PVNGS," NUS-1416, June 1975.

**Rail accidents are given as railcar accidents per railcar-kilometer.

TABLE 5-8 (continued)

RELEASE FRACTIONS

Model II

Severity Category	LSA Drum	Type A	Type B: No Pu	Type B: 1975 Pu	Type B: 1985 Pu	Cask (exposure)	Cask (release)	ICV
I	0	0	0	0	0	0	0	0
II	.01	.01	0	0	0	0	0	0
III	.1	.1	.01	0	0	0	.01	0
IV	1.0	1.0	.1	0	0	0	.1	0
V	1.0	1.0	1.0	0	0	0	1.0	0
VI	1.0	1.0	1.0	.01	0	3.18×10^{-7}	1.0	0
VII	1.0	1.0	1.0	.05	.01	3.18×10^{-5}	1.0	0
VIII	1.0	1.0	1.0	.1	.1	3.12×10^{-3}	1.0	.1

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TACLE 5-3

FRACTIONAL OCCURRENCES* FOR TRUCK ACCIDENTS BY ACCIDENT SEVERITY CATEGORY AND POPULATION DENSITY ZONE

Accident Severity Category	Fractional Occurrences f	Fractional Occurrences According to Population Density Zones		
		Low	Medium	High
I	.55	.1	.1	.8
II	.36	.1	.1	.8
III	.07	.3	.4	.3
IV	.016	.3	.4	.3
V	.0028	.5	.3	.2
VI	.0011	.7	.2	.1
VII	8.5×10^{-5}	.8	.1	.1
VIII	1.5×10^{-5}	.9	.05	.05

*Overall Accident Rate (Ref. 5-5) = 1.06×10^{-6} accidents/kilometer (0.46×10^{-6} accidents/kilometer for ICV's)

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TABLE 5-5

FRACTIONAL OCCURRENCES* FOR TRAIN ACCIDENTS BY ACCIDENT SEVERITY CATEGORY AND POPULATION DENSITY ZONE

Accident Severity Category	Fractional Occurrences	Fractional Occurrences According to Population Density Zones		
		Low	Medium	High
I	.50	.1	.1	.8
II	.30	.1	.1	.8
III	.18	.3	.4	.3
IV	.018	.3	.4	.3
V	.0018	.5	.3	.2
VI	1.3×10^{-4}	.7	.2	.1
VII	6.0×10^{-5}	.8	.1	.1
VIII	1.0×10^{-5}	.9	.05	.05

*Overall Accident Rate = 0.93×10^{-6} railcar accidents/railcar-kilometer.

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accident rate: =

$$1.06 \times 10^{-6} \frac{acc}{km} \times (1.2 \times 10^{-3}) = 1.27 \times 10^{-9} \frac{acc}{km}$$

$$= acc/800 \text{ million km}$$

$$1.27 \times 10^{-9} \frac{acc}{km} \times 4000 \frac{km}{shipment} \times 70 \frac{\text{Type B shipments}}{yr}$$

$$= 3.56 \times 10^{-4} \text{ acc/yr}$$

$$= \underline{2800 \text{ years/accident}}$$

3) Probability of accident that might fail Type B container is (Train)

$$[(1.3 \times 10^{-4}) + (6.0 \times 10^{-5}) + (1.0 \times 10^{-5})] = 2.0 \times 10^{-4}$$

accident rate: =

$$0.93 \times 10^{-6}/km \times (2.0 \times 10^{-4}) = 1.86 \times 10^{-10} \text{ acc/km}$$

$$= 5400 \text{ million km/acc}$$

$$1.86 \times 10^{-10} \frac{acc}{km} \times 4000 \frac{km}{shipment} \times 34 \frac{shipments}{yr} = 2.53 \times 10^{-5} \text{ acc/yr}$$

$$= \underline{40{,}000 \text{ years}} \text{ per accident}$$

II. Contributions to Table D.4.

Summary of Environmental Considerations for the CRBRP Fuel Cycle Annual Requirements

Total trip miles for CRBRP fuel cycle (from Tables D.12, 13)

TRUCK		One way trips	Miles
	Fresh fuel materials	28.3	2500
		14	3000
		14	10
	Wastes	39	2500
RAIL		33.5	2500

Total round trip miles — Truck: 420,780

Rail : 167,500

From NUREG-0116: a truck averages 4.9 miles/gallon of diesel fuel (p. 4-148).

Contribution from 1 car within a train assumed negligible; thus, results are based on truck-miles.

Emissions for diesel engines are based on the following per 1000 gallons of diesel fuel.

CO	102 kg
HC	16.8 kg
NOx	168 kg
SOx	12.3 kg
Particulates	5.9 kg

- from NUREG-0116 (p.4-148)

According to DOE (ER Amendment 14), we have 450,000 miles of total transportation. This is the number used in this analysis:

$$\frac{450{,}000 \text{ miles}}{4.9 \text{ mpg}} = 91{,}836.73 \text{ gallons diesel fuel.}$$

$$= 92{,}000 \text{ gallons of diesel fuel}$$

Emission yields are 91,840 x values in NUREG-0116 or:

CO	102 kg x 91,840 =	9.4 MT
HC	16.8 kg x 91,840 =	1.5 MT
NOx	168 kg x 91,840 =	15.4 MT
SOx	12.3 kg x 91,840 =	1.1 MT
Particulates	5.9 kg x 91,840 =	0.5 MT

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Radioactivity - The average radioactivity of fuel cycle waste shipments is summarized in Table 4.34.

Accident Rates - The accident rate for trucks is taken as 2.5×10^{-6} accidents per mile; for rail, 1.5×10^{-6} accidents per railcar mile, and for barges, 9.4×10^{-6} accidents per barge mile, based on available data.[10,11] An analysis of accident rates as a function of accident severity is contained in Appendix B of WASH-1238[1] and a more recent, more detailed analysis is given in "Severities of Transportation Accidents"[10] for all modes but barge transport.

4.9.4 Environmental Impacts

Weight and Traffic Density - There can be as many as 18 waste shipments by truck on public highways for the annual waste requirements of facilities supporting a model LWR, but excluding waste from the LWR itself (except for spent fuel in the no-recycle case). The TRU shipments may involve return of reusable shipping packages. According to the Federal Highway Administration, the average number of trucks per day on any section of the U.S. highway system varies from about 100 to 10,000.[12] Total truck miles traveled on U.S. highways in 1974 were estimated to exceed 55 billion.[13] The truck mileage associated with waste shipments related to a model LWR is, at most, 18,000 (Table 4.34), which is less than one millionth of total truck travel in 1974, and thus is too small to have a measurable effect on the environment from the increase in traffic density. The same conclusions hold true for rail shipments.

The number of drums of waste per vehicle can be adjusted so that the truck can stay within weight restrictions imposed on highway vehicles and railcars. Therefore, there need be no excessive loads on roadbeds or bridges.

Injuries, Fuel Use, and Fuel Emissions - The nonradiological environmental effects of the shipment of materials from the nuclear fuel cycle are similar to those characteristic of the trucking industry in general, in terms of injuries, fatalities, fuel use, and emissions. Fuel cycle waste transportation adds about 18,000 miles of truck travel, including return of empty casks and protective overpacks. According to the American Trucking Association, an intercity truck averages 4.9 miles per gallon of diesel fuel, and, during 1970, trucks consumed more than 25 billion gallons of diesel fuel. The 3700 gallons of fuel that would be used to transport nuclear waste in support of a 1000-MWe nuclear reactor is less than 10^{-6} of the fuel used by the trucking industry in 1970. Based on emission yields for diesel engines of 102, 16.8, 168, 12.3, and 5.9 kg per 1000 gallons of diesel fuel respectively for CO, hydrocarbons, NO_x, SO_x, and particulates, the combustion of 3700 gallons of diesel fuel would release about 0.38, 0.062, 0.62, 0.045, and 0.022 MT respectively, which are very small annual emissions.*

Using rates of 0.03 fatality and 0.51 injury per accident[14] yields 1.3×10^{-3} fatality per reactor year (about one death per 740 reactor years), and 2.3×10^{-2} injury per reactor year (about one injury per 40 reactor years) as transportation risks from common causes.

*"Final Environmental Statement, LWBR Program," ERDA-1541, June 1976, Table IX, G(A)-3.

The value for heat generation during transportation includes contributions from the irradiated core and blanket assemblies and high level waste. These items account for most of the heat generated during transport.

From Tables D.14 and D.15,

Material	Watts per Shipment	Number of Shipments/yr	Days per Trip
Spent Core	2×10^4	14	6
Spent Blanket	5.4×10^3	12	6
HLW	2.6×10^4	3	6

Total heat generated is:

$$[(2 \times 10^4 \text{ w/ship})(14 \text{ ship/yr})(6 \text{ days})(24 \text{ hr/day})] = 4.03 \times 10^7 \text{ wh/yr}$$
$$+ [(5.4 \times 10^3 \text{ w/ship})(12 \text{ ship/yr})(6 \text{ days})(24 \text{ hr/day})] = 9.33 \times 10^6 \text{ wh/yr}$$
$$+ [(2.6 \times 10^4 \text{ w/ship})(3 \text{ ship/yr})(6 \text{ days})(24 \text{ hr/day})] = 1.12 \times 10^7 \text{ wh/yr}$$
$$= \underline{\underline{2.2 \times 10^5 \text{ MJ}}}$$

TRANSPORTATION DOSE CALCULATIONS

Population Dose Totals

III.

Shipment	Fuel
Fresh fuel	0.55597
Fresh blanket	0.00753
TRU (fuel fab)	0.31345
Spent fuel	0.73694
Spent blanket	0.63167
Radial Shield	0.00237
PuO_2	0.66698
HLW	0.1[illegible]
Tru/scrap	1.50451
LLW	0.12539
Plant Radwaste	0.50148
	5.22 rems

DOSE TO CREW MEMBERS

Dose rate is computed from the following:

$$D(d) = \frac{ke^{-ud} B(d)}{d^2}$$

p. D-1, NUREG-0170

with $d = 3$ meters (10 feet)

$k = 10^3$

$$D(d) = \frac{10^3 \left[e^{-[(.00118)(10)]}\right]\left[(.0006)(10) + 1\right]}{10^2}$$

$$= 10(0.98827)(1.00600) = 9.942$$

Thus, dose rate @ 10 feet = 9.942 mrem/hr.

BUT Computed dose rate > 2 mrem/hr.

By regulation it cannot exceed this, so it is assumed that shielding is introduced to limit dose to 2 mrem/hr as required for exclusive use vehicles.

Then: with 1) 2 crew members per truck

2 guards per rail shipment for spent fuel

2) crew exposed only during actual travel

$$\text{Duration of exposure} = \frac{\text{distance}}{\text{average speed}}$$

APPENDIX D

POPULATION DOSE FORMULAS FOR NORMAL TRANSPORT

The formulation for the assessment of population dose is based on an expression for dose rate as a function of distance from a point source of radiation. This point source approximation is acceptable for distances between the receptor and the source of more than two source characteristic lengths. At smaller distances, the point source approximation overpredicts exposure and, therefore, will provide a conservative estimate of dose. The dose rate formulation is given by:

$$D(d) = \frac{Ke^{-\mu d}\ B(d)}{d^2} \qquad \text{(D-1)}$$

where $D(d)$ = dose rate at a distance d (mrem/hr)

d = distance from source (ft)

μ = absorption coefficient for air (.00118 ft^{-1})

$B(d)$ = Berger buildup factor in air, where in this case $B(d) = .0006d + 1$ (dimensionless) (Ref. D-1)

K = dose rate factor (mrem-ft^2/hr)

D.1 DOSE TO PERSONS SURROUNDING THE TRANSPORT LINK WHILE THE SHIPMENT IS MOVING

An expression for the total integrated dose absorbed by an individual at a distance x from the path of a radioactive shipment with dose rate factor K passing at velocity V has been derived (Ref. D-1) from Equation (D-1) and is given by

$$D(x) = 2\frac{K}{V}I(x) \qquad \text{(D-2)}$$

where V = shipment speed (ft/hr)

x = perpendicular distance of individual from shipment path (ft)

$$I(x) = \int_x^{\infty} \frac{e^{-\mu r}\ B(r)dr}{r(r^2-x^2)^{\frac{1}{2}}}$$

By appropriate transformations, this integral can be expressed in terms of modified Bessel functions of the second kind of order zero, which can be evaluated. For a K of 1 mrem-ft^2/hr and a V of 1 mile/hr, the absorbed dose as a functon of x is as shown in Figure D-1.

In order to obtain integrated population dose in sectors of length L and width d on both sides of the roadway (Figure D-2), Equation (D-2) is multiplied by the average population density and L and integrated over the width of the strip

Duration of exposure for truck shipments:

$$[\frac{.90}{55} + \frac{.05}{50} + \frac{.05}{30}]\ 2500 \text{ miles} = 47.58 \text{ hr}$$

(57.09 for PuO_2)

Duration of exposure for rail shipments:

$$[\frac{.90}{25} + \frac{.05}{25} + \frac{.05}{15}]\ 2500 \text{ miles} = 103.33 \text{ hr}$$

Dose to crewmen (mrem) = 2 mrem/hr x ΔTship x Nc x SPY

Table D.16

Shipments	Spy	ΔT	Dose
Fresh fuel	14	47.58	2664.5
Fresh blanket	12	47.58	113.5
TRU (fuel fab)	5	47.58	951.6
Spent fuel	14	103.33	5784.8
Spent blanket[a]	12	103.33	17.9
Radial Shieid[a]	4.5	103.33	6.7
PuO_2	14	57.09	3197.0
HLW (a)	3	103.33	4.5
TRU/scrap	24	47.58	4567.7
LLW	2	47.58	380.6
Plant Radwaste	8	47.58	1522.6
			19211.4 mrem
			19 rem

(a)For rail shipments with no guard requirements, dose is calculated using separation distance of 152 meters (500 feet)

1) $$(d) = \frac{10^3\ [e^{-(.00118)(5000)}][.0006(500) + 1]}{500^2} = 2.88 \times 10^{-3} \text{ mrem/hr}$$

Then: $\text{Dose} = 2.88 \times 10^{-3} \frac{\text{mrem}}{\text{hr}} \times SPY \times Nc \times \Delta T_{ship}$ where Nc = 5

From NUREG-0170 (p. D-8):

Dose to persons surrounding transportation link while shipment is moving:

$$\text{Dose (person-rem/yr)} = 3.47 \times 10^{-10} (k)\ [\frac{fr^{PD}r}{Vr} + \frac{fsPDs}{Vs} + \frac{fuPDu}{Vu} (fo + 1.636f_{I})]$$

$$\times\ PPS \times SPY \times FMPS$$

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D.4 DOSE TO CREWMEN

The annual dose to crewman is obtained directly from Equation (D-1) by using an average source-to-crew characteristic distance (d) for each transport mode:

$$(\text{Dose})_{crew} = Q_3(K_o)(TI)(PPS)(SPY)(N_c)\ \frac{e^{-\mu d}\ B(d)}{d^2}\ \Delta T_{ship} \qquad \text{(D-12)}$$

where N_c = number of crewman aboard

d = average distance to crew compartment (ft)

$Q3$ = 10^{-3} (rem/mrem)

ΔT_{ship} = average time required for a shipment = $\left[\frac{f_r}{V_r} + \frac{f_s}{V_s} + \frac{f_u}{V_u}\right]$ FMPS

FMPS = average distance (miles) per shipment

The values of $\frac{e^{-\mu d}\ B(d)}{d^2}$ for the assumed values of d for the various modes are shown below:

Mode	d(feet)	$\frac{e^{-\mu d}\ B(d)}{d^2}$
Van	7	2.03×10^{-2}
Truck	10	9.94×10^{-3}
Pass. Aircraft	50	3.88×10^{-4}
Cargo Aircraft	20	2.47×10^{-3}
Rail	500	2.88×10^{-6}
Ship	200	2.21×10^{-5}
Barge	150	4.06×10^{-5}

Because of regulatory limits for dose rate in the crew compartment, 2 mrem/hr is used as an upper limit for dose rate in this assessment. If the TI carried would cause this limit to be exceeded, it is assumed that shielding would be introduced to reduce the dose rate to this level.

D.5 DOSE TO PERSONS IN VEHICLES SHARING THE TRANSPORT LINK WITH THE SHIPMENT

Figure D-3 shows a truck carrying radioactive material. The truck is traveling at a speed V along with other vehicles in the same lane. Occasionally vehicles traveling in the opposite direction pass the truck in the other lane. There are two separate doses to be computed:

1. The dose to persons traveling in the opposite direction from the shipment and

2. The dose to persons traveling in the same direction as the shipment.

Variables

Shipment	k	fr	PD_r	V_r	f_s	PD_s	V_s	fu	PD_u	V_u	fo	f_1	SPY	FMPS
Fresh Fuel	10^3	.90	15	55	.05	2000	50	.05	10000	30	.02	.98	14	2500
Fresh Blanket	10	.90	15	55	.05	2000	50	.05	10000	30	.02	.98	12	2500
TRU (fuel fab)	10^3	.90	15	55	.05	2000	50	.05	10000	30	.02	.98	5	2500
(R) Spent fuel[(a)]	10^3	.90	15	25	.05	2000	25	.05	10000	15	0[(b)]	1	14	2500
(R) Spent Blanket	10^3	.90	15	25	.05	2000	25	.05	10000	15	0[(b)]	1	12	2500
(R) Radial Shield	10	.90	15	25	.05	2000	25	.05	10000	15	0[(b)]	1	4.5	2500
PuO_2	10^3	.90	15	55	.05	2000	50	.05	10000	30	.02	.98	14	3000
(R) HLW	10^3	.90	15	25	.05	2000	25	.05	10000	15	0	1	3	2500
TRU/scrap	10^3	.90	15	55	.05	2000	50	.05	10000	30	.02	.98	24	2500
LLW	10^3	.90	15	55	.05	2000	50	.05	10000	30	.02	.98	2	2500
Plant Radwaste	10^3	.90	15	55	.05	2000	50	.05	10000	30	.02	.98	8	2500

(R)assume same method used for rail

(a)per 0170, on link dose is negligible

(b)assumed

DOSE DURING SHIPMENT STOPS

$$\text{Dose} = QK\ (SPY)\ [\Delta T_r(PD_r) + \Delta T_s(PD_s) + \Delta T_u(PD_u)]$$

$$= 2.54 \times 10^{-9}\ K\ (SPY)\ [\Delta T_r(PD_r) + \Delta T_s(PD_s) + \Delta T_u(PD_u)]$$

Shipment	Variables K	SPY	ΔT_r	PD_r	ΔT_s	PD_s	ΔT_u	PD_u
Fresh fuel	10^3	14	10	200	0	0	0	0
Fresh blanket	10	12	70	15	5	2000	0	0
TRU (fuel fab)	10^3	5	70	15	5	2000	0	0
Spent fuel	10^3	14	36	15	0	0	0	0
Spent blanket	10^3	12	36	15	0	0	0	0
Radial Shield	10	4.5	36	15	0	0	0	0
PuO_2	10^3	14	12	200	0	0	0	0
HLW	10^3	3	36	15	36	65	0	0
TRU/scrap	10^3	24	70	15	5	2000	0	0
LLW	10^3	2	70	15	5	2000	0	0
Plant Radwaste	10^3	8	70	15	5	2000	0	0

Dose to Persons in Opposite Direction from Shipment

Dose = 1.89×10^{-7} (K)(SPY)(FMPS)(P) x

$$\left\{ f_r \frac{N^1_r I_{fwy}}{V^2_{Tr}} + f_s\left(\frac{f_{rh}\, 2N^1_s I_{fwy}}{(V_{Ts}/2)^2} + \frac{f_n N^1_s I_{fwy}}{(V_{ts})^2}\right) + f_u\left[f_{fwy}\left(\frac{f_{rh}\, 2N^1_u I_{fwy}}{(V_{ts}/2)^2} + \frac{f_n N^1_u I_{fwy}}{(V_{Tr})^2}\right) + f_{4\ell}\left(\frac{f_{rh}\, 2N^1_u I_{4\ell}}{(V_{ts}/2)^2} + \frac{f_n N^1_u I_{4\ell}}{(V_{Ts})^2}\right) + f_{cs}\left(\frac{f_{rh}\, 2N^1_u I_{cs}}{(V_{Tu}/2)^2} + \frac{f_n N^1_u I_{cs}}{(V_{Tu})^2}\right)\right]\right\}$$

To simplify: assume all $f_{rh} = 0$, $f_n = 1$, $f_{cs} = 0$

Then we have:

Dose = 1.89×10^{-7} (K)(SPY)(FMPS)(P) x

$$\left[\frac{f_r N^1_r (2.9 \times 10^{-2}/ft)}{V^2_{Tr}} + \frac{f_s N^1_s (2.9 \times 10^{-2}/ft)}{V^2_{Ts}} + f_u\left(\frac{f_{fwy} N^1_u (2.9 \times 10^{-2}/ft)}{V^2_{Tr}} + \frac{f_{4\ell} N^1_u (4.8 \times 10^{-2}/ft)}{V_{Ts}^2}\right)\right]$$

Assume P = 2 (see PNL-3308)

PNL-3308

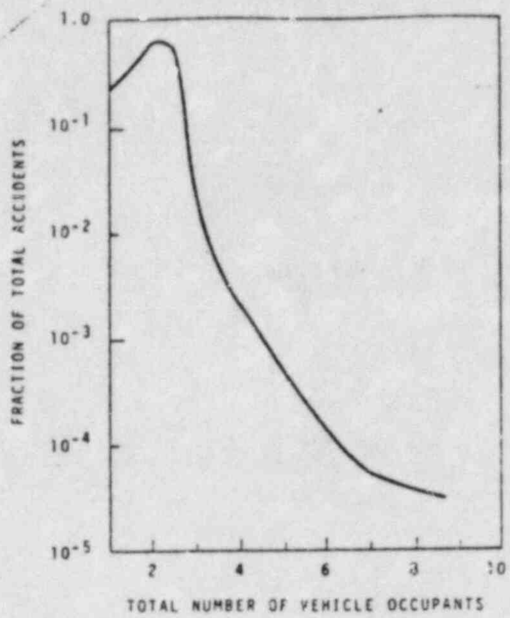

FIGURE 10.2. Estimated Total Number of Vehicle Occupants Involved in Heavy Truck Accidents Plotted as a Function of Accident Frequency

TABLE 10.5. Estimated Fatalities of Vehicle Occupants in an Accident with a Significant Release

Average Number of People	Fraction of Total Accidents	Accidents per Year with Significant Release	Average Fatality Rate in Fire Accidents	Expected Fatalities per Year
1	0.20	14	0.4	1.12
2	0.65	14	0.4	3.64
3	0.04	14	0.4	0.22
4	0.003	14	0.4	0.02
5	0.007	14	0.4	0.0039
6	0.0002	14	0.4	0.0011
7	0.00008	14	0.4	0.0004
8	0.00006	14	0.4	0.0003

response teams. Assuming that a group of from ten to fifteen firefighters will respond to an accident, and that, as in the highway environment, a fatality rate in a fire accident is forty percent, an estimate of the number of firefighters killed per year in propane train accidents may be derived. For the significant release event every 2 years from propane train transport, an expected 1 to 2 firefighters may be killed in addition to members of the general public.

Dose to Persons Traveling in Opposite Direction from Shipment (see p. D-11 NUREG-0170)

Shipment	K	SPY	FMPS	f_r	N^1_r	V_{Tr}	f_s	N^1_s	V_{Ts}	f_u	f_{fwy}	N^1_u	$f_{4\ell}$
Fresh fuel	10^3	14	2500	.90	500	55	.05	800	50	.05	.98	3000	.02
Fresh blanket	10	12	2500	.90	500	55	.05	800	50	.05	.98	3000	.02
TRU (fuel fab)	10^3	5	2500	.90	500	55	.05	800	50	.05	.98	3000	.02
Spent fuel (R)	10^3	14	2500	.90	negligible								
Spent blanket (R)	10^3	12	2500	.90	negligible								
Radial shield (R)	10	4.5	2500	.90	negligible								
PuO_2	10^3	14	3000	.90	500	55	.05	800	50	.05	.98	3000	.02
HLW	10^3	3	2500	.90	negligible								
TRU/scrap	10^3	24	2500	.90	500	55	.05	800	50	.05	.98	3000	.02
LLW	10^3	2	2500	.90	500	55	.05	800	50	.05	.98	3000	.02
Plant Radwaste	10^3	8	2500	.90	500	55	.05	800	50	.05	.98	3000	.02

Variables: K through $f_{4\ell}$

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2. The traffic count doubles during the commuter rush periods (applicable in urban and suburban population zones).

3. The average speeds decrease by a factor of 2 during commuter rush periods (applicable in urban and suburban population zones).

4. Urban travel may be on freeways, four-lane roads, or city streets. Suburban and rural travel is all on freeways.

5. Urban travel on freeways and four-lane roads during rush hour is at half the average suburban velocity.

6. Urban travel on freeways during non-rush hours is at the average rural velocity. Urban travel on four-lane roads during non-rush hours is at the average suburban velocity.

Under these assumptions the following expression is obtained for the annual population dose in person-rem/year to persons traveling in a direction opposite to the shipment for a given shipment type:

$$(\text{Dose})_{\text{opp}} = Q(K_0)(TI)(PPS)(SPY)(FMPS)(P)(F) \qquad \text{(D-17)}$$

where

$$F = f_r \frac{N_r' I_{fwy}}{V_{Tr}^2} + f_s\left(\frac{f_{rh} 2N_s' I_{fwy}}{(V_{Ts}/2)^2} + \frac{f_n N_s' I_{fwy}}{(V_{Ts})^2}\right)$$

$$+ f_u \left[f_{fwy}\left(\frac{f_{rh} 2N_u' I_{fwy}}{(V_{Ts}/2)^2} + \frac{f_n N_u' I_{fwy}}{(V_{Tr})^2}\right) + f_{4\ell}\left(\frac{f_{rh} 2N_u' I_{4\ell}}{(V_{Ts}/2)^2} + \frac{f_n N_u' I_{4\ell}}{(V_{Ts})^2}\right) + f_{cs}\left(\frac{f_{rh} 2N_u' I_{cs}}{(V_{Tu}/2)^2} + \frac{f_n N_u' I_{cs}}{(V_{Tu})^2}\right)\right]$$

In deriving this expression, the substitution $K = K_0 \times TI \times PPS$ has been made, where TI = TI/package, and PPS = number of packages/shipment. Other symbols in this equation are as follows:

f_r, f_s, f_u = fractions of distance traveled in rural, suburban, and urban zones, respectively

f_{rh} = fraction of distance traveled in rush hour traffic

f_n = fraction of distance traveled in normal traffic

f_{fwy} = fraction of travel on freeways or interstates

$f_{4\ell}$ = fraction of travel on four-lane roads

Dose to Persons Traveling in Same Direction as Shipment.

Dose: 3.79×10^{-7} (K)(SPY)(FMPS)(P) x

$$\left[\frac{f_r N^1{}_r (0.008)}{V^2{}_{Tr}} + \frac{f_s N^1{}_s (0.008)}{V^2{}_{Ts}} + fu\left(\frac{f_{fwy} N^1{}_u (0.008)}{V^2{}_{Tr}} + \frac{f_{4\ell} N^1{}_u (0.031)}{V^2{}_{Ts}}\right)\right]$$

Variables required are same as those for opposite direction travel.

GENERAL POPULATION

Doses	Persons Surrounding Link (Mov.)	To Pop During Shipment Stops	On-Link: Opposite Direction	On-Link: Same Direction
Fresh fuel	0.356	0.07112	0.08269	0.04616
Fresh blanket	0.00305	0.00337	0.00071	0.00040
TRU (fuel fab)	0.12709	0.14034	0.02953	0.01649
Spent fuel	0.71774	0.01920	--	--
Spent blanket	0.61521	0.01646	--	--
Radial Shield	0.00231	0.00006	--	--
PuO_2	0.42702	0.08534	0.09923	0.05539
HLW	0.15374	0.02195	--	--
TRU/scrap	0.61002	0.67361	0.14175	0.07913
LLW	0.05084	0.05613	0.01181	0.00659
Plant Radwaste	0.20336	0.22452	0.04724	0.02636

IV. Sources of numbers for Tables D.14 and D.15

UF_6: CRBR reqmts of 11.1 MTU/year

Total needs over plant life = 492.6 $MTUF_6$

One 14-ton cylinder contains 12,500 kg product (PNL-2211).

[Depleted UF_6 is stored in 14-ton cylinders (Breeder Briefs 3/82)].

UF_6 shipments are made mostly by truck, one 14-ton cylinder per shipment (PNL-2211).

11.08 MT U_d required.

238 + 114 = 352 g/mole UF_6

$$11.08 \times 10^6 \text{g U} \times \frac{\text{mole U}}{238 \text{ g}} = 46{,}640 \text{ moles U}$$

$$46{,}640 \times 6 = 279{,}330 \text{ moles F} \times \frac{19\text{g}}{\text{mole}} = 5.3 \text{ MT F}$$

Total = 11.08 + 5.3 = 16.38 MT UF_6

Therefore, one cylinder contains:

$$\frac{11.1 \text{ MTUd}}{16.42 \text{ MTUF}_6} = \frac{X}{12.5 \text{ MTUF}_6}$$

$$= 8.45 \text{ MTU per cylinder}$$

$$\frac{333 \text{ MTUd over plant life}}{8.45 \text{ MTU/cyldiner}} = 39.41 \text{ cylinder over life of plant.}$$

$$\frac{39.41 \text{ cylinders}}{30 \text{ years}} = 1.31 \text{ shipments/year}$$

Heat generation: negligible

Estimated activity : negligible

Average shipping distance: from DOE Amendment 14 = 2500 miles.

UO_2:

Required: 4.02 MTU_d as UO_2 to fuel fab plant/year

UO_2 can be transported in a double-stacked 55 gallon drum.

110 kg UO_2 per package

64 packages per truck

WASH-1535

one shipment thus carries 7,040 kg UO_2

4.02 MTU_d = ? UO_2

238 + 2(16) = 270 g/mole UO_2

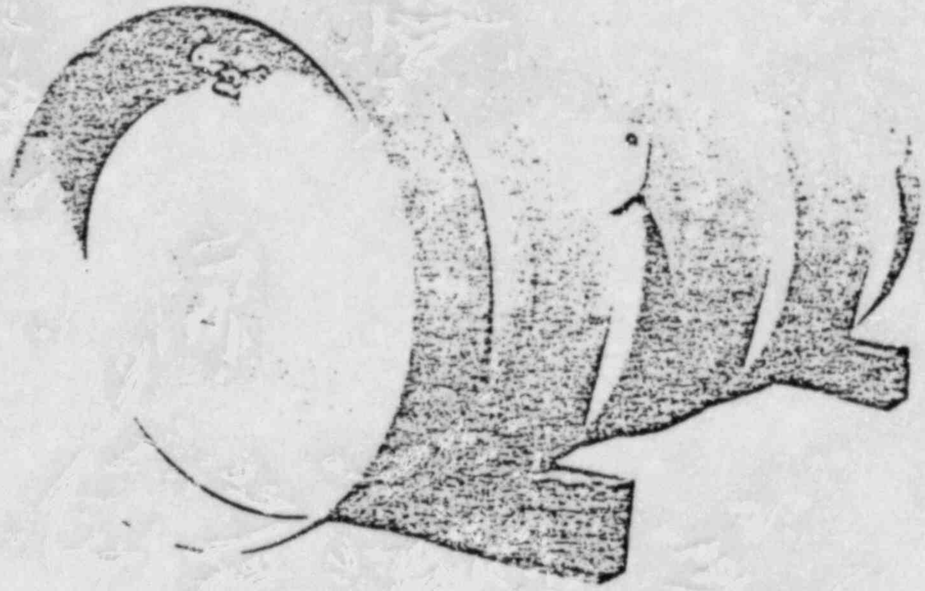


FIGURE A.4. UF_6 Cylinder Model 48Y

TABLE A.4. General Data for UF_6 Cylinder Model 48Y Other Descriptive Terminology Used - 14-ton

Nominal Diameter	122cm (48 in.)
Nominal Length	381cm (150 in.)
Wall Thickness	1.59cm (5/8 in.)
Nominal Tare Weight	2359kg (5,200 lb)
Maximum Net Weight	12,501kg (27,560 lb)
Nominal Gross Weight	14,860kg (32,760 lb)
Minimum Volume	$4.04m^3$ (142.7 cu ft)
Basic Material of Construction	Steel
Service Pressure	$1.38 \times 10^6 \frac{N}{m^2}$ (200 psig)
Hydrostatic Test Pressure	$2.76 \times 10^6 \frac{N}{m^2}$ (400 psig)
Isotopic Content Limit	4.5% ^{235}U Max With Moderation Control

Breeder Briefs 3-82

breeder briefs

MARCH 1982

Extensive Sodium Fire Tests Underway

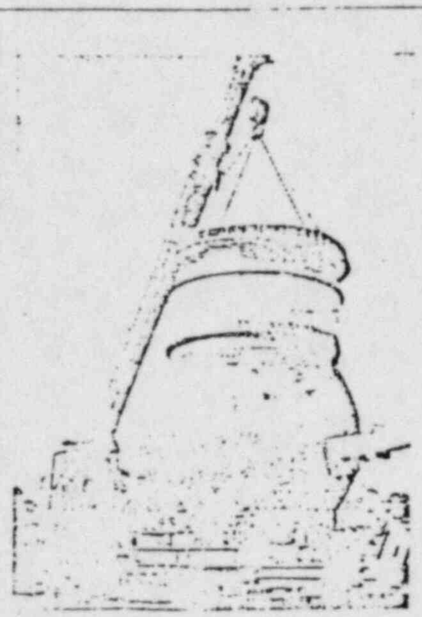
Engineers at Atomics International (AI) in Canoga Park, California, have been carefully studying the properties of liquid sodium which is used as the coolant and heat transfer agent in the Clinch River Breeder Reactor Plant (CRBRP).

The basic properties of sodium are well known: at atmospheric pressure it melts at 207°F and boils at 1616°F; it reacts with water or oxygen to form products such as hydrogen, sodium hydroxide, and sodium oxide. In CRBRP, it will enter the reactor core at 730°F and leave at 995°F. At this temperature, however, liquid sodium will burn when exposed to the air (oxygen).

The CRBRP design includes extensive features to mitigate consequences incurred by an extremely unlikely situation such as a sodium spill. Some plant cells that have sodium-containing equipment are lined with steel, and the atmosphere in these cells contains an inert gas so that in the case of a spill, there would be no oxygen to support a sodium fire.

Where sodium-containing equipment is located in an area that cannot be inerted, the CRBRP design includes a unique fire suppression system, consisting of a catch-pan and a fire suppression deck.

Continued on page 3



A 6,600-gallon sodium holding tank is lifted off the truck to be installed in the Large-Scale Sodium Fire Test Facility at Atomic International's test facility in Santa Susana, California. Sodium is to be transferred from 110 55-gallon drums to the holding tank. Each 55-gallon drum is heated to melt the sodium so that it can be transferred into the tank. Sodium from the holding tank will be emptied into a fire-suppression system which simulates CRBRP systems.

Oak Ridge Now Has Over 4,500 U-238 Canisters

About 4,500 canisters now lie in storage at the Oak Ridge Gaseous Diffusion Plant — canisters containing uranium tails (uranium 238), the material that will breed new fuel in the LMFBR plants. More canisters are stored at uranium enrichment plants at Paducah, Kentucky, and Portsmouth, Ohio.

A by-product of the uranium enrichment process, the combined inventory of uranium tails now in storage, if used in breeders, represents the energy equivalent of $66 trillion of oil. Henry Piper, chief, CRBRP Project Office's Licensing Branch, and David Hambright, chief of

Continued on page 2

13 Contractors Attend Pre-Proposal Conference

Thirteen potential proposers attended a pre-proposal conference in Oak Ridge, Tennessee, February 2-3, conducted by Stone & Webster Engineering Corporation (SWEC). The firms were studying a request for proposals for preliminary site preparation for the Clinch River Project.

The U.S. Department of Energy has filed a request under Section 50.12, Code of Federal Regulations, Title 10, with the Nuclear Regulatory Commission (NRC) to begin clearing, grubbing, and excavation for the CRBRP site. The NRC's decision on whether to grant permission to begin site preparation is scheduled to be announced early in March.

The Conference apprised potential proposers of licensing procedures, the scope of work for site preparation, and safety requirements, and enabled them to gather additional information from the Project Office.

The Conference included a demonstration of excavation sequencing by use of Stone & Webster's excavation model. Participants also visited the site and examined core borings previously made.

Presiding at the Conference for Stone & Webster were J. G. Webster, procurement manager; J. E. McGee, senior contract administrator; J. A. Capazzoli, resident engineer; and J. E. Karr, quality assurance manager.

Richard Chidlaw, assistant director for CRBRP Construction, said, "The Conference went very well. Our prospective bidders asked penetrating questions and received responses. We anticipate that SWEC will receive highly competitive bids on March 2 from highly competent contractors."

Legislative Update The Reagan Administration's budget proposal for Fiscal Year 1983 was announced February 8. Proposed nuclear fission funding is down seven percent, from $1.089 billion in FY 1982 to $1.016 billion in FY 1983. Proposed funding for the Clinch River Project is $252 million.

[illegible]essional Engineers Support CRBRP [illegible]ly Site Prep Request

[I]n response to the opportunity to comment on the request by the Department of [En]ergy (DOE) to begin early site preparation for the Clinch River Plant, the National Society of Professional Engineers wrote the following letter to the Nuclear Regulatory Commission:

"... The National Society of Professional Engineers (NSPE) wishes to state its support for NRC approval of the subject request. The engineering experience, education, and certification of NSPE's members places NSPE in a unique position from which to provide substantive and pertinent comments regarding the Clinch River Breeder Reactor Plant (CRBRP) and the Department of Energy's request.

The Liquid Metal Fast Breeder Reactor (LMFBR) is this country's best prospect for generating electricity after the year 2000. To maintain a strong breeder reactor research and development program, the Clinch River Project should be completed as soon as practicable. The construction and operation of this essential step in demonstrating breeder technology is also crucial to the nation's ability to keep pace with foreign developments in this technology.

Because the previous administration had allowed the CRBRP completion date to be delayed to the point where unavailability of LMFBR experience might jeopardize the use of nuclear fission as a long-term energy option, timely and vigorous action by the Federal Government is necessary to complete the Clinch River Project and preserve this option. Fortunately, the Department of Energy has developed a plan to start site preparation activities, pursuant to appropriate NRC environmental review and authorization, more than a year earlier than would otherwise be possible. NSPE agrees with this action and considers that NRC approval is warranted by (1) the national priority assigned to the Clinch River Project, (2) NRC's own determination that these site preparation activities would not result in significant environmental impacts, (3) DOE's commitment to redress the site if required by further licensing activities, and (4) recognition of the clear cost advantage to the taxpayers of earlier start and completion of construction activities. NSPE wholeheartedly endorses the legitimate use of the 10 CFR 50.12 procedure in this case.

NSPE notes that the nation has already expended about $1 billion on the Clinch River Project. Further delays in this Project would defer returns from this substantial investment in breeder technology. A monetary cost of about $100 million could be assigned to one year's deferral of these returns (assuming a 10 percent annual interest rate). This would be in addition to DOE's estimated savings of $120-$240 million of increased costs. However, NSPE believes that such an approach to determine the cost of delaying the benefits of this Project greatly understates the actual benefits that would accrue, in terms of reestablishing the United States as a leader in the international nuclear community and insuring that the potential for stretching our increasingly short supplies of uranium is developed in time to avoid severe economic consequences. The benefits of accelerating the CRBRP schedule by one year as proposed by DOE would thus be far greater than the hundreds of millions of dollars estimated above. For these reasons, we consider the granting of an exemption for the CRBRP to be in the public interest.

Approval of DOE's request would not detract from the CRBRP purpose of demonstrating licensability of breeder reactors because (1) the 10 CFR 50.12 provisions are an integral part of NRC's regulations, (2) as noted in the Commission's memorandum and order, five such requests for LWRs have been considered over the years, and (3) the CRBRP Project will still be required to comply with the rest of NRC's environmental and safety review regulations, including public hearings. Future LMFBRs would neither be precluded from nor required to utilize the 10 CFR 50.12 procedure. NSPE believes that consideration of DOE's request must also acknowledge the unusual circumstances of the Clinch River Project that have evolved from the delays dictated by the last administration and the undue hardship to the Project and national objectives of further delays.

In closing, NSPE strongly recommends the immediate authorization for DOE to commence site preparation activities for the Clinch River Project. We discern no legal requirement to deny this request and are persuaded by the overwhelming benefits to the nation of proceeding expeditiously with these activities and breeder reactor development.

Thank you for allowing us to submit these comments in this matter.

Herbert C. Koogle, P.E., Chairman
Legislative and Government Affairs Committee

U-238 Canisters in Storage

Continued from page 1

Technical Information for Project Management Corporation, put it this way in a recent article for the January issue of *Electric Perspectives*: "A stack of one thousand $1,000 bills — a total of one million dollars — tightly pressed together is approximately 5 inches high. Therefore, one trillion dollars would make a stack of $1,000 bills 79 miles high. The stack representing the equivalent dollar value of the tails based on the conservative price of $31.25 per barrel for oil would be 5,272 miles high."

By converting once useless uranium tails to valuable fuel, a breeder can produce from the contents of one 14-ton canister the same amount of energy produced by 60 oil tankers. The canisters now in storage at Oak Ridge, Paducah, and Portsmouth hold energy equivalent to 600 years of foreign oil, if imported at the present rate.

The term "endless energy" is no misnomer, for production of uranium tails is expected to increase by 500 metric tons in Oak Ridge by the year 2000. That means that by the end of the century as many as 60,000 canisters will be ready for use in Oak Ridge alone.

·dium Fire Tests Underway Continued from page 1

The catch-pan accommodates the maximum possible volume of sodium that can be spilled within the cell. The fire suppression deck allows the sodium to drain into the catch-pan while limiting the sodium surface area available to react with the oxygen in the air.

...the largest such tests ever undertaken in the U. S.

The CRBRP design for such sodium fire mitigation is based on extensive analysis and supporting experimental data. To verify that sodium fire suppression measures taken in the CRBRP design will perform as expected on a large scale, tests are being conducted at AI. These tests are the largest such tests ever undertaken in the U.S. and possibly the world.

AI is simulating the CRBRP design for sodium spill conditions, complete with fire suppression decks, aerosol detectors, catch-pans, and insulation, in an environment that is not inerted. Both small-scale and large-scale configurations and their accompanying conditions have been tested. In the final large-scale test, approximately 6,600 gallons of sodium will be released on a specially constructed fire protection system prototype.

Such a system has been designed for CRBRP to provide sufficient precautions to accept the conditions of the unlikely sodium fire: heat load, gases, impingement of sodium on concrete, and pressurization.

To perform this function, the test facility directs spilled sodium down onto a fire suppression deck and into a catch-pan at extreme flow rates and temperatures. The system is designed to suppress the fire by limiting the oxygen supply to the sodium.

...in the case of a spill, there would be no oxygen to support a sodium fire.

The design configuration used to conduct the small-scale tests employed a channeled fire suppression deck containing 1½ inch drain pipes and vent pipes. Subjected to a series of sodium spills and sprays, the suppression deck and catch-pan beneath it withstood two fast spills of 15 gallons per minute (gpm) of 1000°F sodium. A slow spill at 1.5 gpm was also conducted, in addition to three tests in which 1000°F sodium was sprayed onto the fire suppression deck. In two of the sprayings, water was used in lieu of sodium to determine liquid dispersion characteristics directed through a walk grating simulating those to be used in CRBRP. Because of its position, the walk grating played an important part during the small-scale tests in determining how a sodium spray would be dispersed.

In defining parameters for the large-scale tests which will be completed in March, engineers introduced a number of other important tests, including tests studying the distribution of sodium droplets upon concrete, tests analyzing the effectiveness of magnesium oxide insulation, and a "spray maximization" test.

Before studying the way sodium behaves when it is sprayed on concrete, "spray maximization" tests again used water to determine the size of droplets coming from a spray of liquid sodium. Water was sprayed onto a drum, and through photography techniques, engineers determined the size of the droplets under the most severe spray conditions. Specially designed and fabricated nozzles will be used in the large-scale tests to actually provide these most severe sodium spray conditions.

...hands-on experience with sodium fires.

To ensure that the concrete to be subjected to these sprayings would be adequately insulated during large-scale tests as it will be in CRBRP, tests were performed with magnesium oxide, which is to provide an insulation barrier between the concrete floor and the catch-pan containing spilled sodium. These tests confirmed that magnesium oxide insulation, when exposed to catch-pan sodium temperatures ranging from 400°F to 1650°F, would effectively prevent excessive heating of the concrete.

All the data from the small-scale tests, the spray maximization tests, and the magnesium oxide insulation tests were collected so that realistic calculations for the large-scale sodium fire tests could be made.

To perform large-scale tests, AI had to assemble large-scale components. As part of these tests, 6,600 gallons of liquid sodium, contained in a large holding tank, will be spilled into the test cell containing a catch-pan measuring 20' X 30'. The cell where the 94-minute spill will take place has three-foot-thick walls prototypic of the plant's cell walls. Those same walls are insulated with a fibrous material, called "cerrablanket," for concrete protection. The cell has 24 spray nozzles above and a fire suppression deck, or "Q deck," below. Below the Q deck is the catch-pan, with magnesium oxide insulation underneath.

The Q deck is designed so that sodium is directed through drains, or "downcomers." Essentially, the Q deck is arranged to reduce the surface area available for combustion, thereby smothering the fire. Within 94 minutes the entire 6,600 gallons of 1000°F sodium from the tank will be discharged into the cell.

Such procedures are expected to yield a great deal of valuable information. Primarily, the effectiveness of a generic catch-pan fire suppression deck should be borne out, and that is the major objective of the tests for CRBRP.

In general, the tests will give CRBRP engineers hands-on experience with sodium fires. That means a chance to test sodium aerosol detection equipment, to test prototypic vent closure devices and louvers in the ventilation system, and to study sodium cleanup and disposal techniques.

According to PMC's Anthony Grande, who worked on the tests, "The tests will also give us valuable data on sodium aerosols and composition and data to enhance our confidence in the computer codes used in the CRBRP design."

Clinch River Facts

- Plant design: about 85 percent complete.
- Project research and development: about 96 percent complete.
- Equipment completed and on-order totals: about $610.8 million.
- Total Project expenditures: $1.2 billion.
- Licensing activities suspended in 1977 but resumed in September 1981.
- Value of major components completed and in storage or undergoing testing: approximately $248 million.
- Current estimate of completion: dependent on action by the Administration and Congress. The start of plant operation will be about seven years after receiving regulatory consent to begin construction.
- Current total plant cost estimate: about $3.2 billion.

Table 4.5-3

SHIPPING INFORMATION FOR URANIUM DIOXIDE

Depleted UO_2 Package Specifications	
Type	Double-stacked 55-gal drum
Height	74 in.
Outer Diameter	24 in.
Inner Container Diameter	11.5 in.
Inner Container Height	63.5 in.
Inner Drum Diameter	9.5 in.
Inner Drum Height	9.75 in.
Number of Drums per Package	6
Tare Weight of Package	135 kg
Net Weight UO_2 per Package	110 kg
Shipping Requirements[a]	
Annual Production, uranium	16,048 kg
Net Weight U per Package	97 kg
Powder Density, g U/cm^3	2.0
Packages per Year	165.44
Packages per Vehicle	64
Shipments per Year	2.58
Radioactivity per Package	1.60 Ci
Thermal Power per Package	0.0026 W
Shipping Distance, one way	750 miles
Shipping Time, one way	3 days

[a]For a single 1000-MWe LMFBR.

Table 4.5-4

SHIPPING INFORMATION FOR PLUTONIUM DIOXIDE

PuO_2 Package Specifications	
Type	55-gal drum
Height	35 in.
Diameter	22.5 in.
Inner Container	4.81 in.
Inner Container Height	18 in.
Usable Volume	0.16 ft^3
Tare Weight of Package	90.9 kg
Net Weight PuO_2	10.24 kg
Shipping Requirements[a]	
Annual Production, plutonium	1679 kg
Pu Shipped per Package	9 kg
Packages per Year	186.55
Packages per Vehicle	64
Shipments per Year	2.91
Radioactivity per Package	1.04×10^5 Ci
Thermal Power per Package	81 W
Shipping Distance, one way	750 miles
Shipping Time, one way	1.5 days

[a]For a single 1000-MWe LMFBR.

4.02×10^6 g Ud x $\frac{\text{mole U}}{\text{238 g}}$ = 16890.76 moles U

16890.76 x 2 = 33781.51 moles O x $\frac{\text{16 g}}{\text{mole}}$ = 540,504.2 g O

4.02 MTUd = 4.02 MTU + 0.54 MTO
= 4.56 $MTUO_2$

Since one shipment holds $7MTUO_2$. it can all go on one.

$\underline{PUO_2}$:

CRBR requirements: 0.894 MTPu (as PuO_2) per year.

How much PuO_2? 0.894×10^6 g Pu x $\frac{\text{mole Pu}}{\text{242 g}}$ = 3694.21 moles Pu

3694.21 x 2 = 7388.41 moles O x $\frac{\text{16 g}}{\text{mole}}$ = 118,214.88 g O

Total PuO_2 = 0.894 MTPu + 0.12 MTO_2
= 1.01 MT PuO_2

Given: DOE shipments of 14/year

Reasonable because: if using packaging in WASH-1535, contains 9 kg Pu/container, 64 packages/truck. This would be 99 packages, or 2 shipments.

If using AGNS container (TTC-0027A, by Exxon) carries 0.028 MT Pu per container, 8 containers per truck. This would be 31.7 packages, or 4 shipments.

If using canister with overpack, holding 32 kg PuO_2 per package, we'd need 31.56 packages. At 7 packages per shipment, this would require 4.51 shipments.

Quantity/shipment derived by calculation; shipping distance from DOE=ER Amendment 14.

TABLE 2.1 - (Continued)

LWR FUEL CYCLE TRANSPORTATION SYSTEM EQUIPMENT PARAMETERS

EQUIPMENT PARAMETERS	LEG 5-2[5]			LEG 6	LEG 7-1&2	LEG 8	LEG 9-1&2	LEG 10-1[2]	
CAPITAL COST									
Container Designation	Truck Cask	Rail Cask[3]		48Y	AGNS Design	17H Drum	51032	Rail Cask[3]	
Cost ($)	750,000	2,500,000		3840	7500	20	8500	3,000,000	
Design Life (Yrs.)	10	10		20	10	1	20	10	
% of Total U/Pu Carried	25	75		100	100	100	100	100	
Usage Potential	80%	80%		3 Cycles/Yr.	80%	12 Cycles/Yr.	4 Cycles/Yr.	80%	
Procurement Lead Time (Months)	9	18		6	6	1	6	18	
OPERATING COST									
Capacity (MTHM)	0.892/0.708[4]	5.352/5.664[4]		8.4	0.028	0.38	0.73	3.122/3.186[4]	
# Containers/Truck									
Loaded	1	NA		NA	8	40	4	NA	
Empty	1	NA		NA	8	100	6	NA	
# Containers/Rail Car									
Loaded	NA	1		4	NA	NA	NA	1	
Empty	NA	1		4	NA	NA	NA	1	
Turnaround Time (Hrs.)		1 Car	2 Car					1 Car	2 Car
Originating Facility	20	48	72	NA	24/36[6]	NA	NA	48	72
Destination Facility	13	28	28	NA	48/72	NA	NA	28	28
One-Way Distance (Miles)	600	320	890	800	1400[7]	1400	1500[7]	320	890
Travel Distance (Mi./Day)									
Loaded	850	360	360	NA	850	450	NA	360	360
Empty	850	360	360	NA	850	450	NA	360	360
Tariff ($/Mi.)									
Loaded	1.72	46.25	24.65	3.00	5.15/7.42[6]	1.09	5.43/7.22[6]	46.25	24.65
Empty	1.72	43.50	23.15	No Charge	5.15/7.42	1.09	5.43/7.22	43.50	23.15
Decommissioning Cost ($/Container)	35,000	60,000		NA	200	NA	NA	60,000	
Maintenance Cost ($/yr.) Per Container	10,000	70,000		200	50	NA	100	70,000	
Disposable Container Cost	NA	NA		NA	NA	NA	NA	NA	

TTC-0027A

Fresh Core Assembly

CRBR requirements: 81 core fuel assemblies per year, 4.889 MT HM/year

DOE says 6 assemblies per shipment, 14 shipments/yr; looks reasonable (see below). Should be no criticality problem. Should be no thermal problem (maybe 0.2 w/g).

Pu enrichment of 33.2 weight percent.

Quantity shipped/year → 4890 MTHM/year. Fourteen shipments (given by DOE) translates to 350 kg HM per shipment.

But: At 60.35 kg HM per assembly, 6 assemblies = 360 kg HM per shipment (full shipments).

Fresh Fuel

Two LMFBR core or blanket fuel assemblies can be carried in an M-51032-1 container.

"MOX fuel assemblies contain a "formula quantity" of strategic special nuclear material. Truck shipments must therefore meet the safeguards results of 49 CFR 73.26. A legal weight transporter designed to meet these safeguards requirements can carry four loaded M-51032-1 containers."

TTC-0026A

81 assemblies → 2/container
4 container/shipment (also from WASH-1535)
= 11 shipments

443#/assembly → 24.35 # Pu
108.22 # U
= 132.57 # HM per assembly (as MOX and axial blanket)
= 60.13 kg HM
= 0.06013 MTHM

Total: .89 MT Pu
3.95 MT U] → 16.3 MT of assembly per year

TTC-0026A

U-235, it can be shipped in DOT Spec. 17-H 55 gallon drums or equivalent in a manner similar to U_3O_8 (E-11). The requirements for these drums are contained in Paragraph 178.118 of Reference E-33.

Each 55 gallon drum will hold approximately 950 lbs.* of UO_2 or 0.38 MTU (E-11). Approximately 40 loaded drums comprise a legal weight truck shipment and approximately 100 empties are carried in a shipment. Each drum can be cycled approximately 12 times during its one year life, after which it would be used to package low-level waste (E-11). Since the drums are replaced annually, the cost of $20.00 per drum (E-11) is handled as an operating expense rather than a capital expense.

Natural UO_2 will probably be shipped by private carrier. The tariff is $1.09 per mile for loaded or empty shipments (E-34).

2.9 Segment 9 - MOX Fuel Assemblies From Fabrication Facility to Reactors

2.9.1 Shipment of MOX Fuel Assemblies

Two (2) PWR or BWR MOX fuel assemblies can be packaged in an M-51032-1 type container (See Paragraph 2.4.1) and transported in an exclusive use vehicle in order to meet the requirements of Paragraph 173.393 (J) of Reference E-33. Mox fuel assemblies contain a "formula quantity" of strategic special nuclear material as defined in Paragraph 73.2(Y) of Reference E-35. Truck shipments must therefore meet the safeguards requirements of Paragraph 73.26(I) of Reference E-33. A legal

*The study assumes that natural UO_2 will be shipped as Low Specific Activity material in exclusive use vehicles so that each drum can be filled beyond the 800 pounds specification limit.

weight transporter designed to meet these safeguards requirements can carry four loaded or six empty M-51032-1 containers(E-21).

MOX fuel assemblies will probably be transported by private carrier. It is estimated(E-21) that the additional safeguards requirements of Reference E-35 will add approximately 20% to the cost of the published tariff(E-32). This will result in a tariff of $5.43 per round trip mile (a 200 mile deadhead must be added to the actual mileage). Since a substantial portion of this cost is due to the two escort vehicles and guards required by the regulations, a unit cost saving can be realized if two cargo vehicles are convoyed together. The tariff in this case would be $3.61 per round trip mile, for each cargo vehicle.

Economic parameters for the M-51032-1 container are given in Paragraph 2.4.1.

2.10 Segment 10 - Spent MOX Assemblies From Reactor to Reprocessing Plant

2.10.1 Shipment of Spent MOX Fuel

MOX spent fuel has considerably higher thermal and radiation sources than UO_2 spent fuel. An evaluation was made for transporting MOX spent fuel in similar casks as discussed in Paragraph 2.5.1.

Fresh Blanket Assembly

CRBR requirements of 69.2 assemblies per year (6.98 MTU)

Distance and number of shipments given by DOE (6 assemblies per shipment reasonable).

$$\frac{6980 \text{ kg/hr}}{12 \text{ shipments}} = \frac{582 \text{ kg HM}}{\text{shipment}}$$

But: at 100 .g HM per assembly 6 assemblies = 600 kg HM (assume full shipments).

Spent Core Assembly

CRBR information from DOE amendment 14. Fourteen shipments/year; shipping distance; by rail. From ORIGIN 2 runs: (4/27/82).

100 days after discharge: heat output is 3.291 KW per assembly.

Thus, heat output per shipment is 19.75 KW. A cask is available to handle this level of heat; DOE specifies cask design limit of 26 KW.

From Table 5, Oak Ridge Origen 2 output of April 20, 1982, discharge fuel has 4671 kg U + Pu (also has fission products, which are not counted here as heavy metals). Since heavy metal content has changed,

HM per shipment = $\frac{4671 \text{ kg}}{14}$ = 334 kg

Spent Blanket Assembly

CRBR information from DOE Amendment 14.

12 shipments/yr; shipping distance; by rail.

From Table 5, Oak Ridge Origin 2 output of 4/20/82.

Discharge blankets have 6920 kg HM (total average per year). This translates to 580 kg/shipment.

From ORIGEN 2 runs (4/27/82) and Attachment B.

100 days after discharge, heat output of blanket assembly (inner + radial) = 5440 W.

Table 5. Summary characteristics for the CRBR

Parameter	Fuel region(s)[a]					
	Fuel	AB	Fuel + AB	IB	RB[b]	Fuel + AB + IB + RB
Electric power, MW(e) net	267.4	6.1	273.5	46.9	29.6	350.0
Thermal power, MW(t)	745.0	17.0	762.0	130.5	82.5	975.0
Average specific power,[c] MW(t)/MTIHM	140.9	3.95	79.4	16.4	6.49	32.21
Average fuel burnup, MWd/MTIHM	76,031	2133	42,870	8693	7977	22,600
Effective irradiation duration, full-power days	540	540	550	530	1229	
Refueling cycle length, full-power days	275	275	275	275	275	275
Average number of assemblies charged per cycle	81	81	81	41	28.2	
Average charge, kg/refueling cycle[d]						
^{235}U	3.6	4.4	8.0	8.3	5.7	22.0
Total uranium	1805.5	2189.1	3994.6	4134.9	2843.9	10,973
Fissile plutonium[e]	783.0	0	783.0	0	0	783.0
Total plutonium	889.4	0	889.4	0	0	889.4
Total (U + Pu)	2694.9	2193.5	4888.4	4134.9	2843.9	11,867
Average discharge, kg/refueling cycle[d]						
^{235}U	2.6	3.6	6.2	5.9	4.0	16.1
Total uranium	1715.8	2149.0	3864.8	3960.2	2726.9	10,552
Fissile plutonium[e]	627.2	38.5	665.7	131.6	89.1	886.4
Total plutonium	766.7	39.6	806.3	138.3	94.9	1039.5
Total (U + Pu)	2482.5	2188.6	4671.1	4098.5	2821.8	11,591

[a]Fuel = 36 in. $(Pu,U)O_2$ region, AB = UO_2 axial blankets associated with fuel, IB = entire inner blanket, RB = entire radial blanket.

[b]Weighted average of inner radial blanket (4 cycle residence) and outer radial blanket (5 cycle residence).

[c]Based on rated power level.

[d]Averaged over 4 cycles.

[e]$^{239}Pu + ^{241}Pu + ^{239}Np$.

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ATTACHMENT 3

Watts for RB:

p.162 @ 100 days:	5.877×10^{2} watts/assembly	× 28.2 assemblies/yr	=	1.657 E+04 watts/yr (1.~~523~~ corrected to 657)
p.198	: 1.188×10^{3}	× 41.0	=	4.871 E+04
		Total		6.528 E+04
		× 1/12	=	5.440 E+03

Curies:

p.180	: 2.982 E+05 curies/assy (~~watts~~)	× 41.0 assemblies/yr	=	1.223 E+07 curies/yr
p.160	1.425 E+05	× 28.2	=	4.019 E+06
				1.624 E+07
		$\times \frac{1}{12}$	=	1.354 E+06

TRU Waste: fuel fab from DOE-ER Amendment # 14 130 m^3 is compacted to fit into 145 containers. The containers are 55-gallon drums (.21 m^3 each). This translates to a shipped waste volume of 30 m^3. DOE specifies shipment by truck, about 30 containers per shipment, five shipments a year, and shipping distance. These values appear reasonable (and conservative).

TRU wastes must go in overpack (Type B) as "large quantity" shipments. A TRUPACT provides Type B protection, and can hold 36-55 gallon drums in one container (one TRUPACT per truck trailer).

From Table 5.7-4, DOE-ER #14. TRU has estimated activity of 64 ci/m^3. This is applied to the volume before compaction (130 m^3). The estimated activity of the TRU waste is thus 8.3×10^3 ci. Divided among 5 shipments, this translates to = 1660 ci/shipment.

LLW from CRBR Plant

DOE-ER Amendment 14 specifies transport by truck, 67 m^3, 320 containers (55-gallon drums), shipping distance, number of shipments per year, and destination. This is reasonable (and conservative). LLW is usually transported in 55-gallon drums. 40 drums per truck shipment is within truck loading limits.

According to DOE-ER #14, the estimated activity of LLW is < 10^2 ci/m^3.

If 67m^3 is shipped in 8 shipments, then 8.4 m^3 is shipped per shipment (also corresponds to 40 drums and 0.21 m^3 each). So, estimated activity per shipment is 8.4 (10^2) = 840 ci/shipment.

LLW from Reprocessing Plant

DOE-ER Amendment 13 specifies transport of 25 m^3 LLW by truck in 2 shipments over a distance of 2500 miles (4020 km). This appears reasonable, since this is 120 containers, 60 drums per truckload, which is within feasible limits.

According to DOE-ER #14, the LLW from reprocessing has an estimated activity of 10 ci/m^3; transporting 25m^3 in 2 shipments translates to 12.6 m^3 per shipment (also 60 drums of .21 m^3 ea).

Thus, estimated activity per shipment is: $12.6 \frac{m^3}{ship} \times \frac{10\ ci}{m^3} = 126$ ci/shipment rounded up to 130.

TRU Waste from Reprocessing Plant (and Metal Scrap)

DOE-ER Amendment 14 specifies transport of 10 m^3/year by truck in 7.1 shipments.

[TRU waste + metal scrap = 21.5 shipment/year]

7 containers/shipment for TRU

6 containers/shipment for metal scrap.

TRU: 10 m^3, 50 containers (55 gallon drums). 50 containers and 7/ship = 7.1 shipments. At 0.21 m^3 per container, 50 containers can hold 10 m^3. Shipping system seems reasonable and within current standards (see previous discussion of TRU).

7 containers/shipment = 7(.21) = 1.4 m^3/shipment. Estimated activity of TRU = 10^3 - 10^6 Ci/m^3, average of 5 x 10^5 ci/m^3. This translates to 7 x 10^5 ci/shipment.

METAL SCRAP: 14 m^3, 102 containers (cylinders) = 0.14 m^3/container. 102 containers at 6/ship = 17 shipments. At 0.14 m^3 per container, this is about 0.84 m^3 per shipment. Estimated activity of metal scrap = 4 x 10^5 ci/m^3. This translates to 3.36 x 10^5 Ci/shipment.

High-Level Waste for Reprocessing Plant

From DOE-ER Amendment #14, HLW (1 m^3/year) is transported by rail in 3 shipments/year over 2500 miles. This translates to about 0.3 m^3/shipment and appears reasonable (and conservative) since it will be shipped in a cask similar to the spent fuel cask (2 containers per cask).

From DOE-ER #14, estimated activity of HLW is 1.5 x 10^7 ci/m^3. Thus, at 0.33 m^3/shipment, we get 5 x 10^6 ci/shipment.

The heat load for HLW may be obtained from the ORIGEN 2 code run by Oak Ridge. Output of 4-27-82 (received from Orv Hill).

HLW will be shipped at 1 year (from DOE-ER #14). The heat load of HLW at 1 year is

$$\frac{6.605 \text{ KW}}{\text{one MTIHM of core/blanket fuel}} \times 11.87 \text{ MTIHM}$$

$$= 78.40 \text{ KW total HLW/year}$$

This translates to about 13 KW per container, or 26 KW per shipment (limit of the cask design).

Noble Gases (Kr-85) and Iodine (I-129) from Reprocessing Plant

From DOE-ER Amendment #14:

Kr-85: 0.01 m^3/year, 0.035 containers/year (1 container every 28 years).
= 0.3 m^3/lifetime of plant

Estimated Activity of Kr-85 is 3.4×10^6 ci/m^3 at 0.3 m^3/shipment, this translates to 1.02×10^6 ci/ship

I-129: 0.01 m^3/year, 0.05 container/year

1.5 container probably means 1 shipment/plant life (0.03 shipments/year)

Estimated activity of I-129 is 1.4×10^2 ci/m^3 at 0.3 m^3/shipment, this translates to 42 ci/shipment.