DPSTD-79-34

TECHNICAL DATA SUMMARY

BETA-GAMMA CONTAMINATED SOLID WASTE INCINERATOR FACILITY

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1. INTRODUCTION

1.1 Objectives

This technical data summary outlines a reference process to provide an incinerator to reduce the storage volume of combustible process waste contaminated with low-level beta-gamma emitters in response to DOE Manual 0511. Low-level beta-gamma waste is defined at SRP to be waste measuring less than 50 mR/hr at 3 inches from the unshielded package. This waste, amounting to more than 200,000 ft^3 per year, is presently buried in trenches in the burial ground. The anticipated storage volume reduction from incineration will be a factor of 20.

The incinerator will also dispose of 150,000 gallons of degraded solvent from the chemical separations areas. This solvent is presently stored in underground tanks in the burial ground and increased by ∿5000 gallons per year.

The Savannah River Plant also generates ∿5000 gallons per year of miscellaneous nonradioactive solvents which are presently being drummed for storage. These solvents, some of which are classified as hazardous chemical substances by the EPA, may be conveniently and safety disposed of in the proposed incineration facility. The operating characteristics of the incinerator for radioactive wastes are well within the recommended values for the disposal of hazardous substances by the EPA (i.e., 2 seconds residence time at 1000°C).

Processing steps in this incineration facility would be waste receiving, determination of suitability for incineration, incineration, solid packaging with radiometric assay, and off-gas cleanup. Special attention has been taken to simplify processing operations and minimize radiation exposure of operating personnel.

In brief, the process involves a 2-stage, ∿400 lb/hr controlled-air incinerator. The waste solvent and solids are charged to separate and dedicated primary combustion chambers which are connected to a common secondary combustion chamber. These primary combustion chambers will not operate simultaneously but are campaigned individually as solid or solvent waste is scheduled to be incinerated. Space is provided outside the building for non-campaign storage of incoming solid waste combustible materials in portable metal containers. Solvent is stored in a small tank.

The common secondary combustion chamber (afterburner) provides complete combustion of the primary combustion chamber off-gases. Equipment is provided for cooling, neutralizing, and filtering the incinerator off-gas to meet all Federal and South Carolina air emission standards. Facilities are provided for loading the radioactive incinerator ash and off-gas filtered solids into steel drums for storage. No structural shielding will be required for the facility and process in general; however, local supplementary shielding may be required for collection of the incinerator ash and for the residual buildup of radioactivity in the incinerator primary combustion chambers.

1.2 Background

This technical data summary is an updated revision of a low-level beta-gamma incinerator project description[1] issued July 1977. The Engineering Department made a high spot estimate of 20 million dollars for this previous design[2] on the basis of a reduced scope.

The present data summary includes the elements of the reduced scope, updates waste feed information and incorporates a dry off-gas cleanup system which is simpler and more economical than the previously proposed wet off-gas system.

The dry off-gas system was chosen in preference to the wet off-gas system because:

- In the wet system, evaporation of large quantities of liquid chloride-laden scrubber solution is required ($\sim$100,000 gal/yr). This evaporation process is known to be a probable source of operational problems and significant evolution of airborne radioactivity.

- The dry off-gas system has a higher particulate removal efficiency than the wet system in the anticipated particle size range, resulting in less HEPA filter use.

- The sintered metal filters used in the dry system provide greater overpressure protection of the HEPA filters than the venturi scrubber in the wet system.

In the proposed dry off-gas system, a spray drier cools the incinerator off-gas and neutralizes HCl and SO_2 by the addition of Na_2CO_3. The exit temperature of the gases from the spray drier is kept at 149°C to ensure that hygroscopic salts trapped by the following sintered metal filters do not absorb moisture and reduce gas flow. Also by maintaining this temperature, deposition of volatiles can be controlled to occur ahead of the

sintered metal filters and be removed by them. Following the sintered metal filters, the gas is cooled by air dilution to 88°C to permit HEPA filtration. Off-gas solid residues are removed from the spray drier and sintered metal filters by gravity flow into drums.

The efficacy of this method of dry off-gas method of filtration is presently being demonstrated in an R&D program at SRL on a pilot unit.[5]

1.3 Process Assumptions

The beta-gamma incinerator is to be estimated on the basis of initial funding in FY-1982, with construction extending from FY-1982 to FY-1985. The facility is to be located in H Area of the Savannah River Plant, east of Building 299-H, the Waste Management Facility.

Specific items to be included in the budget quality estimate to be delivered by February 1980 include:

1. Two-story building with basement. Standard construction except with 24 inch thick shielding walls around basement ash handling facilities.

2. Outdoor truck receiving area with adjacent 60 hour combustible waste storage area consisting of 6 skip pan stalls with 7 ft-high 1-ft thick concrete walls and outdoor monorail for moving skip pans and introducing cartons of waste into building.

3. Waste carton x-ray inspection and assay facilities.

4. Indoor mechanical handling equipment for conveying/transferring cartons to incinerator.

5. Two-stage controlled air incinerator with auxiliary fuel heating for burning 380 pph prepackaged solid waste.

6. Solvent incinerator for quiescent burning of 380 pph degraded 30% tributyl phosphate (TBP) solvent mixture; the afterburning of combustible gases is to be done in the secondary of the solid waste incinerator.

7. Off-gas cleaning equipment includes:

   - Spray drier
   - Emergency reheater
   - Sintered metal filters
   - Air dilution

- Roughing filters
- HEPA filters
- Option connection to sand filter

8. Mechanical facilities for ash and off-gas solids canning, packing in drums and a 1/2-ton jib crane, operated from behind a 2 ft-thick shield wall for lifting drums and placing on a truck.

9. Cold feed preparation facilities.

10. Closed-loop cooling and heating systems.

11. Other process auxiliaries, building services, piping, instuments and electrical equipment.

12. Offices, Health Protection, and associated personnel facilities for 10 people.

13. Building air conditioning and ventilation equipment.

14. Tie-ins to existing water, steam, and cooling tower services.

It may be assumed that operation and maintenance will be direct and that the facility will not be licensed. The lifetime of the facility will be 20 years; however, it is logical to assume the incinerator combustion chambers will be replaced every 3 years.

The status of commercial incinerator technology in this size range is well established; however, its application to radioactive waste incineration is very limited. Technical uncertainties center on the migration of radionuclides into the combustion chamber ceramics and actual off-gas decontamination factors achievable with current technology. To minimize the effect of these uncertainties on the process, easily replaceable primary combustion chambers should be incorporated into the facility design and waste feed radioactivity is limited by assay to directly releasable quantities. The unit may later be upgraded as actual DF's are established.

The incinerator availability is assumed to be 40% and the feed composition to be: 40% cellulosic, 23% polyethylene, 19% rubber, 8% polyvinylchloride and 5% each of water and ash.

2. FEED DESCRIPTION

2.1 Solid Waste

The solid waste feed has been characterized by reviewing the COBRA (Computerized Radioactive Waste Burial Records Analysis System) records for the period from 1972 through 1978. Based upon these records an average annual solid waste volume of $\sim$200,000 ft^3 of combustible wastes would be processed by the proposed β-γ incinerator. Tabulations are presented which identify the generating sources of the waste, the type of contamination on the waste, the volumetric distribution of the waste and the monthly variation in the volume of the waste generated.

2.1.1 Solid Physical Description

Wastes currently buried in the low-level β-γ trenches include process job control waste, capital equipment, irradiated scrap metal, resins, and naturally radioactive materials. Only the combustible fraction of these wastes is suitable for processing in the β-γ incinerator and is to be found in the job control wastes. Job control wastes consist of cotton coveralls, rags, wipes, cotton and rubber gloves, plastic suits, hoses, bottles, cardboard, paper, wood, polyvinylchloride sheets, shoe covers, polyethylene bags, mops, brushes, floor cleaning materials, and footgear. The average mixed composition of combustible materials should approximate the following:

Material Type	Weight Percentage
Cellulosic	40.0
Polyvinylchloride	8.0
Polyethylene	23.0
Rubber	19.0
Water	5.0
Ash	5.0

Noncombustible wastes will be separated from combustible wastes at the generating point before startup of the incinerator to minimize the possibility of jamming the incinerator feed ram and to prevent slag formation on the incinerator hearth.

2.1.2 Waste Package

It is assumed for the purposes of simplified waste handling and sorting that combustible wastes are segregated at their point

of origin and that the standard container is a 24 x 24 x 24-in. cardboard radioactive waste carton. Larger containers will be permitted; however, these wastes must be repackaged in the β-γ incinerator facility before burning. Waste cartons are collected and transferred to the β-γ incinerator facility by truck. Radiation dose levels will be less than 50 mR/hr at 10 ft from the truck load.

2.1.3 Radioactive Contamination and Distribution

A tabulation was made from COBRA data (Table 2-1) which lists the sources of low-level beta-gamma combustible job control wastes in descending order of volume generated. The separation canyons and control laboratories are the principle sources of fission-product waste. The reactor areas generate a combination of fission product and induced activity contaminated wastes. Naturally radioactive wastes come from the 300/700 Areas. Tritium waste sources are in H-Area. Hence, the type of contamination can be identified with its generating source and this may be used to control the feed to the β-γ incinerator by diverting undesirable types and quantities of isotopic contaminants directly to the burial ground.

The nature of the job control waste is such that 90 to 98% of the waste has little or no contamination (Table 2-2). The radioactive isotopes which are present in these wastes are listed in Table 2-3. Exclusion of a small volume of the higher activity wastes shown in Table 2-2 would appreciably reduce the annual curie load on the β-γ incinerator facility. For example, the activity distribution in fission product contaminated waste for FY-1972-76 indicates that 98% of the combustible waste volume contains only 6% of the radioactivity as shown below:

Activity Range Curies	Volume, ft	% Volume	Curies	% Curies
0	483,685	56	0	0
0.01 - 1	355,957	42	144	6
1 - 10	11,505	1.3	250	10
10 - 100	3,377	0.4	289	11
100 - 1000	88	0.01^{-2}	670	26
>1000	2,600	0.3	1,200	47
Totals for FY-72-76	857,212		2,553	

Hence, if only waste less than 1 curie is processed, no structural shielding is required to maintain an average dose less than 0.5 mrem/hr. Supplemental shielding may be necessary at incinerator and ash-out areas.

TABLE 2-1

Job Control Waste, 5-Year Average, Low β-γ

Facility	*Quantity, Curies*	*Annual Volume, (ft^3)*	*Variety**
221-H	260	52,300	FP
221-F	29.2	29,000	FP
772-F	9.4	17,000	FP
105-K	77	13,400	FP
	0	400	IA
234-H	0.4	3,020	IA
	64	12,800	T
105-C	925	370	IA
	1.7	11,200	FP
105-P	5.52	9,500	FP
	0.27	1,000	IA
241-F	1.7	3,700	FP
	0	3,000	IA
723-F	3.8	5,100	FP
773-A	0.016	3,000	FP
	0.07	1,600	DU
313-M	0.5	4,300	DU
242-F	12	4,300	FP
232-H	19	3,700	T
244-H	5	3,300	FP

*FP - Fission Products
IA - Induced Activity
DU - Depleted Uranium
T - Tritium

TABLE 2-2

Activity Distribution in Low Level β-γ Waste

Variety	*Range of Activity, Ci*	*Waste Volume, ft³* 1972	1973	1974	1975	1976
FP	> 1000	0	2,600	0	0	0
	100 - 1000	0	0	38	0	50
	10 - 100	1,375	1,628	166	0	208
	1 - 10	1,905	3,562	2,531	1,475	2,212
	0.01 - 1	81,029	94,635	58,680	54,784	66,829
	∿ 0	71,422	92,209	129,298	111,305	79,451
	Total	155,731	192,034	190,533	167,564	148,750
IA	> 100	0	0	2	0	0
	10 - 100	2	70	35	0	0
	1 - 10	0	200	200	150	0
	0.01 - 1	5,253	2,463	475	861	191
	∿ 0	1,486	5,078	12,787	48	490
	Total	6,741	7,811	13,497	1,059	681
DU	1 - 10	0	0	0	0	0
	0.1 - 1	1,498	727	34	31	0
	0	675	0	9,876	8,052	10,085
	Total	2,173	727	9,910	8,083	10,085
T	10^4 - 10^5	984	30	0	0	0
	10^3 - 10^4	536	1,104	0	0	0
	10 - 10^3	1,553	996	14	27	190
	∿ 0	8,914	22,065	17,352	25,332	18,960
	Total	11,987	24,195	17,366	25,359	19,150

TABLE 2-3

Radioactive Isotopes in Solid Wastes

Radio-Nuclide	Radioactive Isotopes in Solid Wastes						
	221-F	221-H	241 & 242-F	241 & 242-H	244-H	100 CPK	232, 234 238-H
^{89}Sr	7	5	9.5	6	-	3.5	-
^{90}Sr	0.7	1.1	9.5	6	-	2.7	-
^{90}Y	0.7	1.1	-	-	-	-	-
^{91}Y	10	7.8	-	-	-	7.1	-
^{95}Zr	14	11	-	-	1.9	12	
^{95}Nb	25	21	-	-	9.9		
^{106}Ru	1	1.1	-	2.2	2.8	2	-
^{106}Rh	1	1.1	-	2.2	-	-	
^{137}Cs	0.7	1.1	9.7	6	90	12	-
^{137}Ba	0.7	1	8.9	5.6	-	5	-
^{144}Ce	17	22	22.2	28.5	2.5	-	-
^{144}Pr	17	22	22	28.5	-	5	-
^{147}Pr	3	4	18	14.8	-	-	-
^{32}P	-	-	-	-	-	1.2	
^{35}S	-	-	-	-	-	14	
^{51}Cr	-	-	-	-	-	28	
$^{58,59}Co$	-	-	-	-	-	1	
^{59}Fe	-	-	-	-	-	-	
T	-	-	-	-	-	-	$\sim$ 100

a. Low-Level Beta-Gamma Job Control Waste[13]

A gamma monitoring facility has been installed in the burial ground. This monitor has demonstrated that it can precisely characterize the waste activity identity and concentration except for low-energy β-γ which does not penetrate the container. Examples of two such assays are shown in Table 2-4. Hence, the technology for controlling the β-γ waste feed activity level is in hand and will permit selective processing of more than 90% of the β-γ waste volume.

The month-to-month variation in the volume of waste generated over the last four calendar years is shown in Figure 2-1. Based on these fluctuations, a design throughput of 16,700 ft^3 per month ($\sim$200,000 ft^3/yr) should be adequate to meet maximum waste generation surges with minimal lag storage capacity.

2.2 Radioactive Solvent

Degraded solvent from the chemical separations areas is stored in underground tanks at the burial ground. The present inventory of 150,000 gallons contains about 45 Ci of TRU nuclides (^{238}Pu, ^{239}Pu, ^{244}Cm) and about 500 Ci of fission product nuclides (predominantly ^{106}Ru). (Tables 2-5 and 2-6.) These solvents contain from 3 - 50% tributyl phosphate (TBP) which has been degraded by radiolysis to DBP and MBP. These solutions are decontaminated prior to tank storage with nitric acid forming solvent acid ($TBP \cdot HNO_3$ complex) which is neutralized with NaOH for alkaline pH storage. This treatment results in a multiphase aqueous/organic fluid containing some solids or sludge. The specific gravity of the solvents is nominally 0.81 g/cc, and the viscosity is in the range of 1.5 centipoise. The phosphorous in the solvent upon incineration forms a volatile vapor phosphorous pentoxide.

2.3 Nonradioactive Solvents

About 5000 gallons per year of miscellaneous nonradioactive solvents generated by the Savannah River Plant might also be disposed of in the proposed facility by dilution into the radioactive solvent as it is burned or by separate campaign.[3] Table 2-7 shows a list of liquids that were disposed of in the hazardous chemical pit in 1978. Some of these chemicals were disposed of because they are no longer permitted to be used onsite; however, substitutes for similar quantities of different chemicals may be in current use. The inclusion of these miscellaneous liquid chemicals in the present project is contingent upon their not affecting the cost or design of this project. The suitability of each of the listed chemicals for incineration is currently being reviewed and those deemed unsuitable will be deleted as the design study progresses.

TABLE 2-4

Quantitative Analysis of Samples from the Burial Ground Waste Monitor

A. 1/6/78, Dumpster from 332-M #97358

Estimated 0-Ci, <1 mR/hr, Vol = 81 cu ft[3]
Count time = 600 sec S-D Distance = 30 feet

Gamma	*Nuclide*	*Curies*	
610.3	^{103}Ru	7.4197E-04 + OR-	9.6291E-05
661.6	^{137}Cs	3.0340E-06 + OR-	1.4116E-05
1173.2	^{60}Co	8.5574E-06 + OR-	2.8813E-06

B. 1/6/78, Dumpster from 772-F Lab #98521

<1 mR/hr at 10 ft; Vol = 300 cu ft[3], 0 Ci
Count time = 600 sec S-D Distance = 30 feet

Gamma	*Nuclide*	*Curies*	
604.6	^{134}Cs	1.9885E-05 + OR-	4.8347E-06
621.8	^{106}Ru	2.5785E-04 + OR-	4.3226E-05
661.6	^{137}Cs	2.5103E-04 + OR-	2.4442E-05
756.7	^{95}Zr	3.5088E-05 + OR-	6.6933E-06
765.8	^{95}Nb	1.1529E-05 + OR-	1.0572E-06
795.8	^{134}Cs	3.6767E-05 + OR-	5.1482E-06
1173.2	^{60}Co	1.0718E-06 + OR-	8.3841E-07

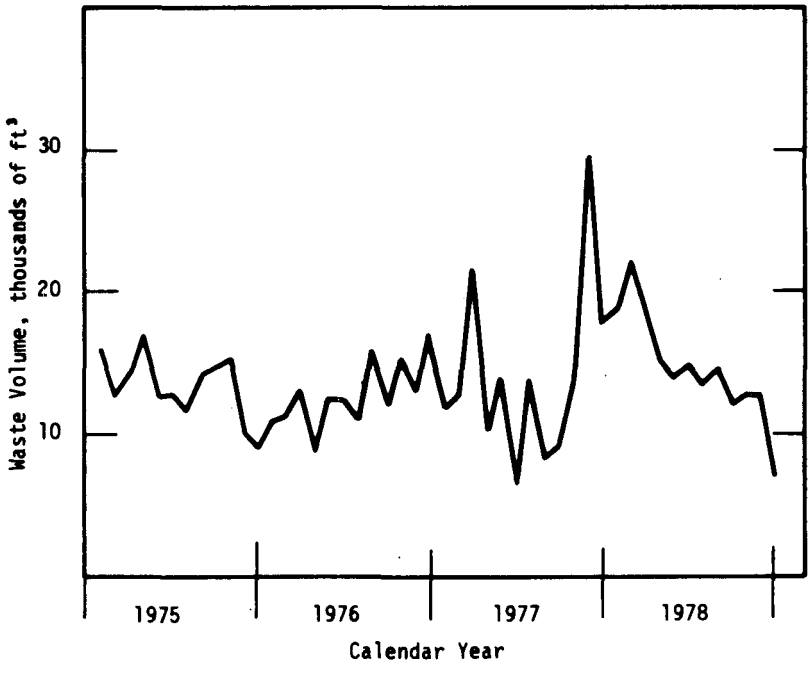


FIGURE 2-1. Monthly Variation of Waste Volume

TABLE 2-5

Radioactivity Content of Stored Waste Solvent[a]

Tank	Volume, kl		Aopha, Ci		Gamma, Ci		Total Ci	
	Solvent	Aqueous	Solvent	Aqueous	Solvent	Aqueous	Alpha	Gamma
1	23.1	6.85	0.50	0.68	3.5	38.0	1.2	42.0
2	30.4	3.03	27.0	37.0	5.2	4.2	64.0	9.4
3	31.8	3.41	0.020	0.019	0.013	0.47	0.037	0.48
4	1.04	3.31	0.0060	.025	0.0010	1.4	0.031	1.4
5	37.0	4.62	17.0	.26	11.0	34.0	17.0	45.0
6	73.2	13.4	0.057	.013	0.26	3.0	0.070	3.3
7	7.85	1.42	0.012	.22	0.014	0.50	0.23	0.51
8	(Contains no liquid)							
9	15.7	5.64	0.0056	.41	2.0	23.0	0.42	25.0
10	5.17	0.81	0.0033	0.0050	0.051	0.41	0.0083	0.46
11	23.4	3.22	0.21	1.7	0.56	27.0	1.9	28.0
12	19.0	1.76	0.15	0.83	0.49	8.6	0.98	9.1
13	43.5	3.02	0.080	0.29	0.20	6.2	0.37	6.4
14	85.9	6.43	0.15	0.22	0.15	7.7	0.37	7.8
15	28.6	5.68	0.18	0.15	1.4	20.0	0.33	21.0
16	7.57	11.0	0.0034	0.018	0.0007	1.0	0.021	1.0
17	0.38	0.95	0.013	0.014	0.29	0.83	0.027	1.1
18	3.65	0.38	0.0068	0.0005	3.5	2.6	0.0073	6.1
19	73.8	11.5	0.11	1.0	2.6	78.0	1.1	81.0
20	27.9	10.4	0.063	0.38	15.0	120.0	0.44	135.0
21	11.7	1.70	0.0014	2.0	0.013	1.8	2.0	1.9
22	11.0	0.76	0.0008	0.82	0.0045	0.12	0.82	0.12
Total →	563.7	99.3	45.57	46.05	46.25	378.83	91.36	436.07

a. Subsequent transfers of solvent from the above indicated tanks have been made and further changes are anticipated; however, these modifications will not alter the overall contamination content of the total volume of solvent to be incinerated.

TABLE 2-6

Analyses of Waste Solvent Tank Samples

Tank	Phase	Gross α, d/m/ml	Major α Nuclide	Total γ, d/m/ml	Major γ, Nuclides
1	Organic	4.8×10^4	66% ^{244}Cm	3.40×10^5	97% ^{106}Ru
	Aqueous	5.6×10^4	-	1.24×10^7	98% ^{106}Ru
	(Centrifuged)	1.1×10^5	∿90% ^{238}Pu	-	-
2	Organic	2.0×10^6	88% ^{238}Pu	3.80×10^5	49% ^{154}Eu, 29% ^{144}Ce
	Aqueous	2.8×10^{7a}	-	3.10×10^6	71% ^{106}Ru
	(Centrifuged)	2.7×10^{7b}	93% ^{238}Pu	-	-
3	Organic	1.4×10^{3c}	∿70% ^{238}Pu	916[d]	81% ^{106}Ru
	Aqueous	6.1×10^3	-	3.06×10^5	68% ^{137}Cs
	(Centrifuged)	6.1×10^3	∿60% ^{238}Pu	-	-
4	Organic	1.3×10^{4c}	67% ^{238}Pu	2.09×10^{3e}	53% ^{106}Ru, 38% ^{125}Sb
	Aqueous	2.2×10^4	-	9.27×10^5	96% ^{137}Cs
	(Centrifuged)	8.4×10^3	65% ^{238}Pu	-	-
5	Organic	1.0×10^6	93% ^{244}Cm	6.42×10^5	95% ^{106}Ru
	Aqueous	7.3×10^5	-	1.65×10^7	97% ^{106}Ru
	(Centrifuged)	6.3×10^{4c}	80% ^{244}Cm	-	-
6	Organic	1.7×10^{3c}	80% ^{244}Cm	7.78×10^{3d}	43% ^{125}Sb, 24% ^{137}Cs, 23% ^{106}Ru
	Aqueous	6.3×10^3	-	5.00×10^5	80% ^{137}Cs
	(Centrifuged)	1.1×10^3	∿60% ^{239}Pu	-	-
7	Organic	3.4×10^3	77% ^{238}Pu	3.92×10^{3d}	89% ^{126}Sb
	Aqueous	2.2×10^{5c}	-	7.77×10^{5c}	52% ^{125}Sb, 45% ^{137}Cs
	(Centrifuged)	1.8×10^{5c}	∿70% ^{238}Pu	-	-
9	Organic	790	∿30% ^{244}Cm, ∿30% ^{239}Pu	2.80×10^5	99% ^{106}Ru
	Aqueous	1.7×10^4	-	9.02×10^6	98% ^{106}Ru
	(Centrifuged)	8.1×10^3	*f*	-	-
10	Organic	1.4×10^3	∿50% ^{238}Pu	2.18×10^4	98% ^{106}Ru
	Aqueous	1.2×10^4	-	1.11×10^6	93% ^{106}Ru
	(Centrifuged)	6.9×10^3	*f*	-	-
11	Organic	2.0×10^4	58% ^{244}Cm	5.33×10^4	53% ^{144}Cs, 32% ^{106}Ru
	Aqueous	6.5×10^5	-	1.86×10^7	72% ^{106}Ru
	(Centrifuged)	5.8×10^5	*f*	-	-
12	Organic	1.7×10^4	63% ^{238}Pu	5.72×10^4	74% ^{106}Ru
	Aqueous	2.1×10^6	-	1.08×10^7	99% ^{106}Ru
	(Centrifuged)	5.2×10^{5c}	∿80% ^{244}Cm	-	-
13	Organic	4.1×10^3	97% ^{238}Pu	1.03×10^{4d}	95% ^{106}Ru
	Aqueous	1.4×10^5	-	4.53×10^6	66% ^{106}Ru
	(Centrifuged)	1.1×10^{5c}	*f*	-	-
14	Organic	3.8×10^3	98% ^{238}Pu	3.75×10^{3d}	88% ^{106}Ru
	Aqueous	2.7×10^4	-	2.70×10^6	57% ^{106}Ru, 42% ^{137}Cs
	(Centrifuged)	3.8×10^4	*f*	-	-
15	Organic	1.4×10^4	63% ^{244}Cm	1.12×10^5	52% ^{106}Ru, 48% ^{125}Sb
	Aqueous	2.1×10^4	-	7.77×10^6	95% ^{106}Ru
	(Centrifuged)	2.9×10^4	*f*	-	-
16	Organic	1.1×10^3	*f*	206[d]	97% ^{106}Ru
	Aqueous	7.1×10^3	-	2.10×10^5	91% ^{137}Cs
	(Centrifuged)	1.8×10^3	∿60% ^{238}Pu	-	-
17	Organic	7.4×10^{4c}	60% ^{239}Pu	1.69×10^6	99% ^{106}Ru
	Aqueous	1.6×10^4	-	1.95×10^6	95% ^{106}Ru
	(Centrifuged)	1.6×10^4	^{238}Pu present	-	-
18	Organic	4.1×10^3	∿30% ^{238}Pu, ∿30% ^{239}Pu, ∿30% ^{237}Np	2.15×10^6	99% ^{106}Ru
	Aqueous	3.0×10^3	-	1.54×10^7	100% ^{106}Ru
	(Centrifuged)	1.6×10^3	*f*	-	-
19	Organic	3.2×10^3	65% ^{244}Cm	7.85×10^4	100% ^{106}Ru
	Aqueous	1.7×10^5	-	1.50×10^7	95% ^{106}Ru
	(Centrifuged)	9.8×10^4	∿50 ^{238}Pu, ∿40 ^{244}Cm	-	-
20	Organic	4.7×10^3	∿70% ^{238}Pu	1.10×10^6	100% ^{106}Ru
	Aqueous	4.9×10^4	-	2.56×10^7	86% ^{106}Ru
	(Centrifuged)	4.1×10^4	∿50% ^{238}Pu, ∿50% ^{244}Cm	-	-
21	Organic	270[c]	*f*	2.41×10^3	88% ^{106}Ru
	Aqueous	2.9×10^6	-	2.35×10^6	100% ^{106}Ru
	(Centrifuged)	1.3×10^6	^{244}Cm present	-	-
22	Organic	160	∿70% ^{244}Cm	912[d]	99% ^{106}Ru
	Aqueous	1.3×10^6	-	3.42×10^5	98% ^{106}Ru
	(Centrifuged)	1.2×10^6	∿90% ^{244}Cm	-	-

a. Alpha dilution is 100/10.08/20.

b. Alpha dilution is 100/10.08/25.

c. Average of two samples.

d. Whole bottle was counted.

e. Direct mounts were made on two samples and the whole bottle was counted on the other.

f. The spectrum could not be resolved.

TABLE 2-7

Miscellaneous Nonradioactive Solvents

	Physical Properties		
Name	*Spec. Gravity, g/cc*	*Vapor Pressure, mm Hg*	*Volume, gal, year*
Trichloroethylene	1.46	60	1500
Toluene	0.87	30	20
F.O. 101	0.8	0.5	500
Freon	1.57	334	1100
Klear All 99	0.96	-	3000
Orthoxylene	0.86	10	10
Diethyl hexyl phosphoric acid	-	-	4
Tri-iso-octylamine	-	-	3
Ethanol	0.79	42	2
Acetone	0.79	200	1

3. PRODUCTS

3.1 Nontransuranic Contaminated ash

Ash from the beta-gamma incinerator which is assayed to be less than 10 nCi TRU/g is stored in 55-gallon drums for onsite burial in high-level beta-gamma trenches. The instantaneous rate of output of these drums is 8 drums per week. Nominal radiation dose of these drums will be ∿5 mrem/hr at one foot from the surface of the drum.

Characteristics of the ash from solid wastes are a density of about 0.2-0.5 g/cc, a carbon content of less than 5%, and a free-flowing particulate with few lumps, clinkers, or slag in it. Major constitutents are oxide of Ca, Al, Si, Fe, Ni, Ti, Sb, Cr, and Pb. These residuals are derived mainly from the cellulosics and additives to the rubbers and plastics. Table 3-1 shows the composition of typical job control waste residues.

Residues from the incineration of degraded solvent accumulate as a dark sludge in the bottom of the burning pan. The residue has a specific activity of about 1.8 and should amount to less than one weight percent of the total solvent feed. Solvent residues will be encased in situ with the disposable burning pan.

3.2 Transuranic Contaminated Ash

Ash from the beta-gamma incinerator which is assayed to be greater than 10 nCi TRU/g is stored in 55-gallon drums and shipped to the burial ground for storage in the retrievable pad storage mode. The instantaneous rate of output of these drums is 2 drums per week. Nominal radiation from these drums will be ∿5 mrem/hr at one foot from the surface of the drum. Ash and solvent residue characteristics are the same as for nontransuranic contaminated ash, the only difference between the types being transuranic content >10 nCi/g.

3.3 Nontransuranic Contaminated Noncombustibles

Noncombustibles that have been included with combustibles, either inadvertently or because of composite structure, are expected to comprise about 2% of the annual waste volume sent to the beta-gamma incinerator. This amount of ∿4,000 ft^3/yr or one "Dumpster" load per week of noncombustibles to be sent to the

TABLE 3-1

Composition[a] of Individual Waste Component Ash by Spark-Source Mass Spectrometry

Polyvinyl Chloride Clear Tubing[b]		*Polyvinyl Chloride White Shoe Covers*		*Polyethylene Tubing*		*Cellulose Ice Cream Cartons*		*Cellulose Atomic Wipes*	
P	47	Ca	39	Si	33	Al	74	Mg	43
Zn	15	Ti	35	Al	19	Si	15	Ca	24
Fe	14	Al	8	Zn	16	Na	2	Fe	12
Ca	6	Si	6	Fe	7	Ca	2	Ti	8
Al	5	P	5	Ca	5	Ti	2	Si	6
Si	3	Mg	4	P	4	Fe	2	Al	3
Ci	3	Ba	2	Ti	3	Mg	1	Sr	0.6
Mg	2	Fe	0.8	B	2	K	0.3	Na	0.5
Na	1	Cl	0.7	Na	2	P	0.2	Mn	0.4
Cr	0.8	Na	0.1	Mg	2	Cl	0.1	Ni	0.4
S	0.6	K	0.06	Ba	2	Mn	0.06	Sb	0.4
K	0.6	Cr	0.04	Pb	1	Cr	0.05	K	0.3
Cu	0.4	S	0.02	K	0.9	S	0.04	Cr	0.3
V	0.2	Mn	0.02	Cu	0.8	Cu	0.04	Cl	0.2
B	0.1	Zn	0.02	S	0.4	Ba	0.03	Cu	0.2
Mn	0.08			Ni	0.3	B	0.02	B	0.1
				Mo	0.3	Ni	0.02	P	0.1
				Cr	0.2	V	0.01	Zn	0.1
				Mn	0.2			S	0.09
				Ce	0.2				
				Sb	0.1				
				Cl	0.08				
				La	0.07				
				V	0.02				

Cellulose Tissue Paper		*Polyethylene Bags*		*Neoprene Gloves*[b]		*Latex Rubber Gloces*		*Latex Rubber Tubing*	
Al	60	Si	79	Mg	76	Mg	41	Zn	64
Si	21	Fe	8	Al	13	Si	32	K	23
Ca	9	Mg	7	Si	9	Ca	17	Mg	3
Mg	5	Al	3	Zn	2	An	6	P	3
Fe	2	K	1	Fe	0.2	P	1	Ca	2
Na	0.9	Ca	0.7	Na	0.1	Fe	1	Na	1
Ti	0.9	Na	0.6	K	0.1	Al	0.8	S	1
K	0.3	Zn	0.6	Ca	0.1	S	0.4	Fe	1
Zn	0.2	Ti	0.3	Ti	0.07	K	0.1	Si	0.5
Sr	0.2	Mn	0.2	Cl	0.02	Na	0.08	Al	0.4
P	0.1	Ni	0.2	Cr	0.02	Cl	0.08	Ni	0.06
Mn	0.08	Cr	0.1	S	0.01	Mn	0.03	Cu	0.04
Cl	0.05	Ce	0.1			Cr	0.02	Cl	0.03
Ba	0.05	P	0.05			Ni	0.02	Mn	0.03
S	0.04	Cu	0.04			Cu	0.02	Cr	0.02
Cr	0.04	Ba	0.04			Sr	0.01	Rb	0.02
Ni	0.03	La	0.04					B	0.01
Cu	0.02	V	0.02						
Ce	0.01	Mo	0.02						
		Pr	0.02						
		Nd	0.02						
		Pb	0.02						
		Cl	0.01						

a. Wt % of all elements constituting 0.01 wt % or more of the ash, excluding carbon, oxygen, and nitrogen.

b. After 2 hours at 1000°C.

burial ground. Nominal radiation from the "Dumpster" skip will be 1 mrem/hr at 3 feet from the skip. The skip is emptied into a low beta-gamma waste burial trench and returned for reloading.

3.4 Nontransuranic Combustibles

A small fraction of the combustible materials sent to the beta-gamma incinerator might not be incinerated for any of the following reasons:

- The specific activity is too high for low beta-gamma waste categorization.
- A radioisotope is present which would exceed the release limits of DOE Manual 0524
- The composition of the material is inappropriate for incineration.

In the event that such material is indicated during the x-ray or assay feed control steps, the waste package is sent to the repackaging facility. It is anticipated that $\sim$1000 ft^3 of this material will be sent to the burial ground annually. This volume would amount to about 3 drums per week. Maximum radiation dose from this waste would be 50 mrem/hr at 3 feet from the container.

3.5 Off-Gas Cleaning System Wastes

Aqueous sodium carbonate solution is used to neutralize the HCl and SO_2 components in the off-gas. The spray drier is operated at an exit temperature of $\sim$150°C, hence the reacted salt product, unreacted carbonate (70% utilization was assumed), and off-gas particulates are dry flowing solids which may be collected on a shift basis from discharge hoppers below the spray drier and the sintered metal filter compartment. These solids are generated at the rate of 44 lb/hr and consist of 63 wt % NaCl, 8 wt % Na_2SO_4, 2 wt % particulates and 27 wt % unreacted Na_2CO_3. Salt mixtures are packaged in 55-gallon drums and sent to the burial ground for storage with the incinerator ash in trenches if less than 10 nCi TRU/g and in retrievable storage if greater than 10 nCi TRU/g. About 5 drums of off-gas solids will be generated per week.

HEPA filters which are used at the rate of 24 units per year are burned to yield an additional 2 drums per year of nontransuranic, noncombustible ash to be buried onsite in the burial ground.

4. PROCESS DESCRIPTION

4.1 Overall Flowsheet

The process for the incineration of low beta-gamma waste is divided into ten separate functional steps. A block flow diagram, shown in Figure 4-0 outlines the various steps involved in receiving, evaluating suitability for incineration, incineration of wastes, packaging of ash residues, and off-gas cleanup. Associated operations are identified by the number indicated for the main process step followed by a decimal. Those process steps encompassed by a dashed line in Figure 4-0 are carried out behind shield walls. Processing rates and operating times for the various process steps are summarized in Table 4-1. A material balance for the process is listed in Table 4-2.

Radiation levels and shielding requirements are discussed in Section 5 of this report.

4.2 Waste Receiving and Storage

Solid waste is shipped by truck to the beta-gamma incineration facility. The truck is surveyed for contamination before and after unloading. The waste containers are monitored as they are unloaded. The anticipated radiation level of the waste boxes will vary from a nominal 1 mrem/hr at 1 foot $\pm$ a factor of ten. The waste boxes are stacked in a receiving storage area on pallets. Unloading and placement in temporary storage of the waste containers is accomplished with a shadow-shielded fork lift truck.

Delivery rate of the waste containers to the facility receiving is $\sim$3850 ft^3/week or equivalent to $\sim$500 standard cardboard cartons per week. Lag storage in receiving should allow for solid waste burning at the rate of 380 lb/hr for 257 hours/month alternating with solvent burning campaigns of 34 hours/month at the assumed 40% incinerator attainment. These processing rates correspond to a solvent storage tank with a 2000-gallon capacity and a solid waste receiving area to temporarily hold $\sim$500 (24 x 24 x 24-in.) boxes.

4.3 Waste X-Ray

The x-ray inspection of waste packages is intended to prevent entry of noncombustible materials into the incinerator which may jam or block the feed and ash removal mechanisms or form slags

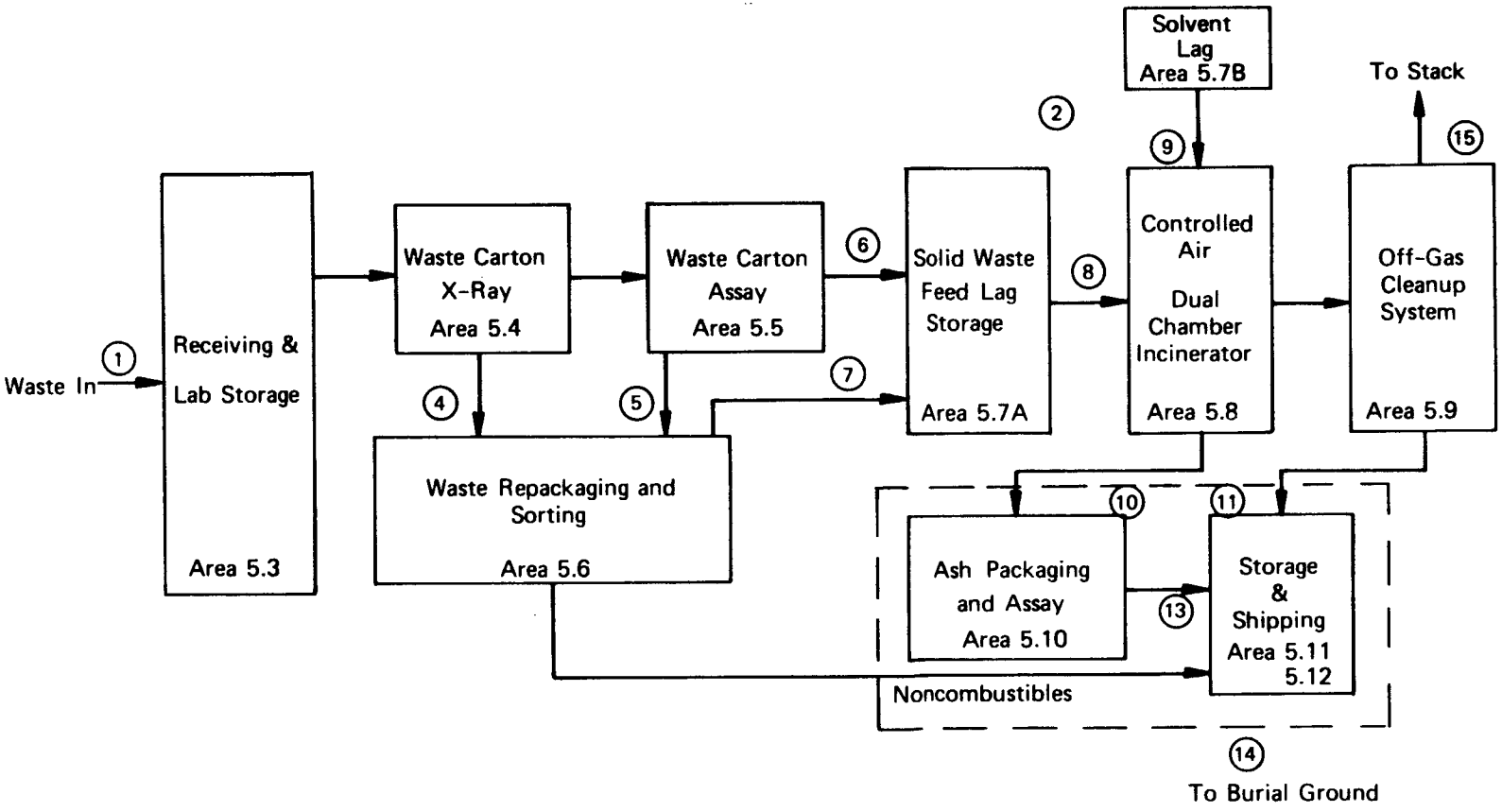


FIGURE 4-0. Process Flow Diagram for Beta-Gamma Incinerator Facility

TABLE 4-1

Process Rates for Nominal Operation

Process Operation	*Operating Time Hours/Year*	*Attainment %*	*Process Rate* ft^3/hr	*lb/hr*
Receiving	7830	90	25	150
X-Ray	6090	70	64	380
Assay	6090	70	32	190
Incineration				
a. Solid	3080	40	64	380
b. Solvent	400	40	7	380
Feed Repackage	7830	90	3	18
Ash Assay	6090	70	0.3	10
Ash Package	3080	40	0.6	19
Shipping	7830	90	1.3	30

TABLE 4-2

β-γ Incineration Material Balance

Process Stream	*Quantity ft^3 per year*	*Description*
1	200,000	Waste from generating facilities
2	5,200*	No. 2 fuel oil
3	180,000	Combustible wastes
4	20,000	Waste containing noncombustibles
5	5,000	High activity combustibles
6	175,000	Low activity combustibles
7	20,000	Repackaged combustible waste
8	195,000	Incinerator solid feed
9	2,700	Degrated solvent feed
10	2,000	Ash drums
10	100	Solvent pan containers
11	1,700	Drummed off-gas solids
11	96	Filters recycled to incinerator
12	5,000	Noncombustibles to Burial Ground
13	2,100	Processed ash to Burial Ground
14	8,800	Solids to Burial Ground
15	$4(10^8)$	Combustion off-gases

*$\sim$39,000 gallons

and clinkers which may have the same effect. Waste boxes containing high-density materials are removed from the main process line and sent to the repackaging facility. Prior to the x-ray step, any waste packages not in the standard 24 x 24 x 24-in. cardboard radioactive waste carton are sent to the repackaging process step. The x-ray machine, a 160 Kilovolt model, will provide a 2800 R/hr beam which is columnated to a flying spot vertical line. The beam of this machine will overpower the background radiation from the contaminated waste and project areas of high-density noncombustible locations upon a low light level fluoroscope screen as the carton passes on a conveyor. The image on the screen is reflected by a mirror into a 100-mil cesium iodide crystal detector. The relative darkness of the transmitted image can be digitalized and programmed for computer scanning and carton rejection for presence of noncombustibles rather than requiring human operator observation and decision. Cartons with noncombustibles of sufficient bulk are sent to the repackaging area. Cartons with less noncombustible content are passed on the the assay area. A non-computerized version of this system is now employed in the 300 Area for fuel tube inspection.

4.4 Waste Assay

After x-ray determination of the suitability for incineration of the contents of the standard cardboard carton of waste, a radiometric assay is made of the contents of the package. Gamma spectrometric measurements, using high-resolution solid-state lithium-drifted germanium detectors, Ge(Li), have demonstrated that specific gamma-emitting radionuclides can be resolved and identified even though they occur as mixtures in the waste package. The low density of the package allows flexibility, accuracy and definition of key radionuclides which if present in greater than allowable concentrations should be excluded from the incinerator. These particular nuclides are excluded from the incinerator because they would result in greater than permissible release concentrations in the stacked offgas as specified in DOE Manual Chapter 0524. The radionuclides of concern and their limits are listed in Table 4-3. Acceptance of a waste package for incineration is determined by a computer coupled to the gamma multichannel analyzer. Particular identifying energies and magnitudes of photon signatures for the volatile radionuclides are few and individual enough to make this inspection system practicable. Cartons exceeding established limits of acceptance are sent to the repackaging facility to be diluted or sent to the burial ground for trench burial. A count time of 5 minutes for each carton should be adequate for this purpose. Cycle times including background determinations should be about 10 minutes. Under

TABLE 4-3

β-γ Incinerator Feed Radionuclide Signatures and Limits

Isotope	*Energy, (keV)*	*Limit*, μCi/lb Waste*[a]
^{90}Y	202	0.80
^{91}Y	1200	0.24
^{95}Zr	724, 756	0.24
^{95}Nb	766	0.80
^{103}Ru	537	0.64
^{134}Cs	600,800	0.08
^{137}Ba	661	0.08
^{140}Ba	44, 537	0.32
^{144}Ce	133	0.05
^{144}Pr	622, 1490, 2189	0.2
^{51}Cr	320	16
^{58}Co	810, 1680	0.4
^{60}Co	1170, 1330	0.07

a. Assumes 1) no decontamination factor for incineration and off-gas scrubbing and filtration.

2) no dilution of incineration gases with building ventilation air.

3) based on ERDA Appendix 0524 Controlled Area Inhaled limits.

nominal operating process rates (Table 4-1) about 4 standard cartons are assayed per hour, hence two assay stations should be adequate to maintain process line continuity with 50 percent excess surge capacity.

4.5 Repackaging Waste, Unloading, Sorting

The repackaging area is a multipurpose shielded facility. Waste packages that are undersize (smaller than the standard 24 x 24 x 24-in. carton) or are rejected from the x-ray station for noncombustible content or rejected from the assay station for greater than allowable activity are unloaded remotely. Contents of the waste packages are sorted to remove the noncombustibles. Combustibles are repacked in standard waste cartons. High-activity combustibles are diluted with lower activity combustibles and repacked in standard containers. The repackaged combustibles are sent to the incinerator lag storage area (4.6). Noncombustibles are collected in a container and sent to the burial ground for trench burial.

4.6 Feed Lag Storage

The incinerator attainment has been conservatively assumed to be 40%. Solid waste will be burned at the rate of 380 lb/hr 89% of the operating time (36% of total elapsed time), and degraded solvent at the rate of 50 gal/hr the remainder of the operating time. Hence, during each month of 730 hours available, solid waste is burned for 257 hours, solvent is burned for 34 hours, and the remaining 439 hours are devoted to heat-up and cool down time, solvent pan change-out, and general maintenance.

Lag storage is required for both solid and solvent waste feed to the incinerator to insure continuity of operation.

At the proposed processing rates a degraded solvent tank of 2000-gal capacity would provide a lag storage volume for one month's operation (34 hr burning) plus 20% excess. Solid processing rates of 380 lb/hr correspond to an 8-hour shift throughput of about 64 standard waste cartons (24 x 24 x 24-in.). A one-shift lag storage capacity is considered adequate to maintain process continuity while minimizing the amount of combustible material in close proximity to the incinerator. The availability differential between waste receipt and incineration is taken up by the 500-box storage space in the receiving area.

4.7 Waste Incineration Process

Two types of waste are to be incinerated in this facility; solid job control waste and degraded solvent. Several options are possible:

(a) Design separate solvent and solid waste incinerators to operate independently.

(b) Design separate primary combustion chambers to burn solvent and solid waste alternatively by campaign coupled to a single secondary combustion chamber.

(c) Design a single incinerator to burn solid waste and use the solvent as an auxiliary fuel for the incinerator burners.

Option (b) appears to be the most attractive because it is less costly than (a) and allows a much greater radioactive effluent decontamination factor than (c) according to Engineering Department specialists.

The term "controlled-air" denotes the incinerator design feature that permits control of the quantity and location of combustion air admitted to the primary chamber to near stoichiometric quantities, air velocity through the burning waste and ash is low enough to avoid excessive particulate entrainment. Products of partial combustion from the primary chamber are oxidized at a high temperature, under excess air conditions, in the secondary chamber. Normal operating temperatures are 650°C to 870°C in the lower chamber and 870°C to 1100°C in the upper chamber. These are maintained by two low-intensity, diesel fuel-fired burners.

4.7.1 Solid Waste Incineration

During solid waste burning campaigns the waste is incinerated in a semi-batch fashion. Eight standard waste cartons are fed to the incinerator per hour or one carton every 7.5 minutes. Waste packages are fed into the incinerator by a horizontal ram feeder. The feeder is separated from the incinerator by a refractory-lined sliding door. Underfire airflow is reduced in conjunction with the loading cycle to minimize flyash entrainment during movement of the ash bed. Overfire air and secondary airflows are controlled to maintain the desired exhaust oxygen content from each chamber. An oxygen analyzer is used which measures the hot exhaust gases for CO as well as O_2 content in order to optimize the incineration process.

Ash is moved horizontally by displacement as new feed is introduced in the primary chamber. A continuous gravity ash removal system collects ash in a sump at the end of the primary. The ash in the sump is discharged to a drum after every 8 hours of operation.

At the specified feed rate of 8 waste boxes (∿380 lb/hr), a primary combustion chamber volume of 250 ft will provide a 100 percent excess capacity in steady state burning rates at the anticipated heat content (10,000 - 12,000 BTU/lb) of the expected waste composition to be charged. (See Figure 4-1.) The incremental feed batch size during each charge cycle is less than 10% of the incinerator capacity providing a wide margin from heat removal and air requirement overloads.

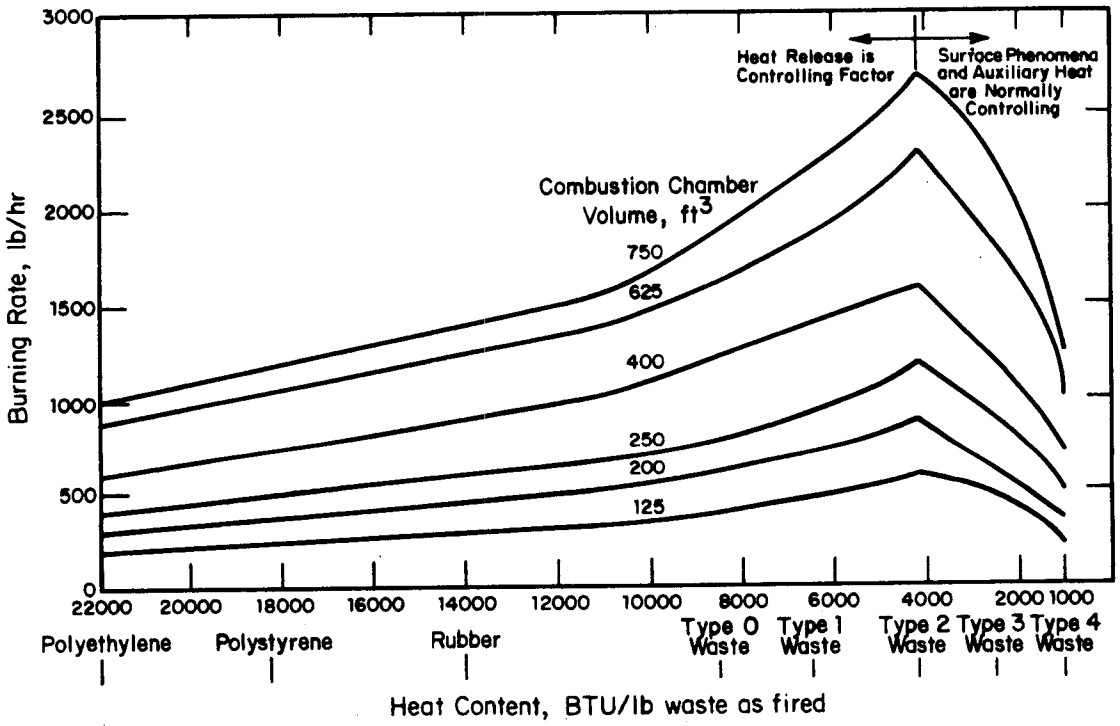


FIGURE 4-1. Burning Capabilities of Solid Waste Incinerators (Reference 10)

4.7.2 Degraded Solvent Incineration

The solvent incinerator (capacity 380 lb/hr) is operated on a campaign basis. TBP solvent is transferred to the area feed tank and then to the incinerator. Solvent feed is controlled to maintain the level in the burning pan situated in the solvent primary combustion chamber. This shallow pan (less than six in. deep) provides a 7 ft^2 burning surface for the solvent. Solvent flow into the pan is established and the solvent is ignited by the incinerator auxiliary burners. The burners are extinguished after solvent burning has been established. Primary air supply to the solvent is from two banks of 2-in. pipes entering on each side of the pan 18 in. above the pan. The pan dimensions are assumed to be approximately 24 x 42 x 6-in. deep.

Solvent incineration rates of 50 gallons per hour can be maintained with the described system. The burning pan area of 7 ft^2 is based on tests performed at the Engineering Test Center in 1975.[4] From these tests, a design basis of 7.2 gal/hr/ft^2 of pan surface area was established for a 30% TBP solvent mixture. Areas for other TBP concentrations are shown in Figure 4-2. The effects on burning of solvent degraded to DBP and other products are not known but are not expected to reduce burning rates. Another recommended design parameter was that the volume of the primary combustion chamber in relation to heat release be less than 40,000 BTU/hr/ft^3. The 250-ft^3 volume of the primary combustion chamber is 40 percent in excess of this design minimum for burning 50 gal/hr.

Control of solvent level in the pan is accomplished by two thermocouples - one about 1 in. from the bottom of the pan and the other about 3 in. above the other thermocouple. The temperature of the solvent is $\sim$400°F lower than the gas temperature above the surface of the solvent. Hence the solvent level can be controlled by maintaining this temperature differential. Dip tubes and a pressure differential cell may also be used to indicate solvent level in the pan.

A thermocouple in the primary chamber exhaust is used to control the air supply. The exit temperature from the first stage is proportional to the percent theoretical air to the first stage. For instance, with 78% theoretical air, the exit temperature in the first stage is around 2000°F. When the theoretical air is decreased to 50%, the cross-over temperature is around 1700°F.[4]

Figure 4-3 shows a plot of predicted combustion temperatures versus theoretical air. The equilibrium temperature starts at a fairly low level at low theoretical air and reaches its maximum point at stoichiometric conditions, then begins to decline as the

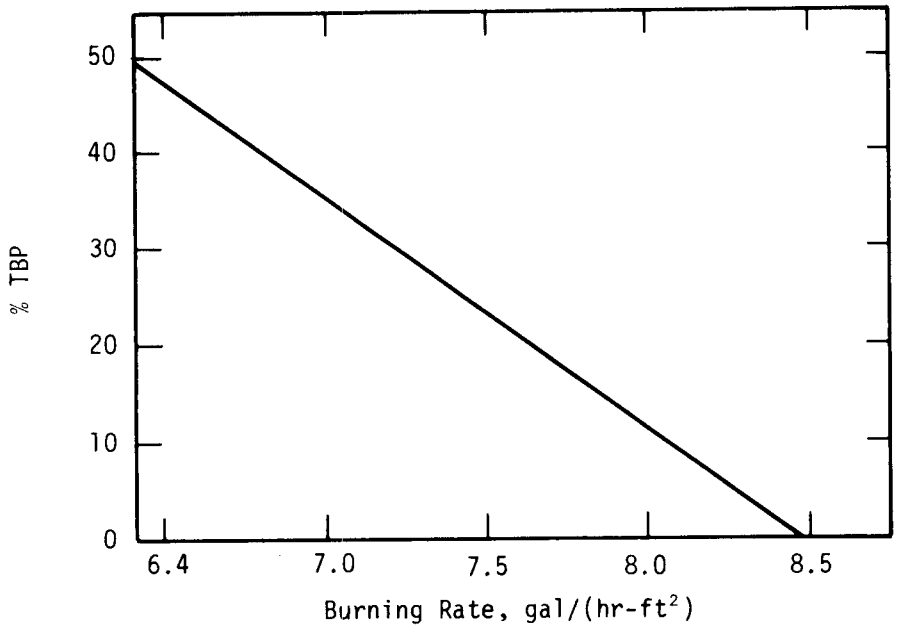


FIGURE 4-2. Burning Rates vs Solvent Types

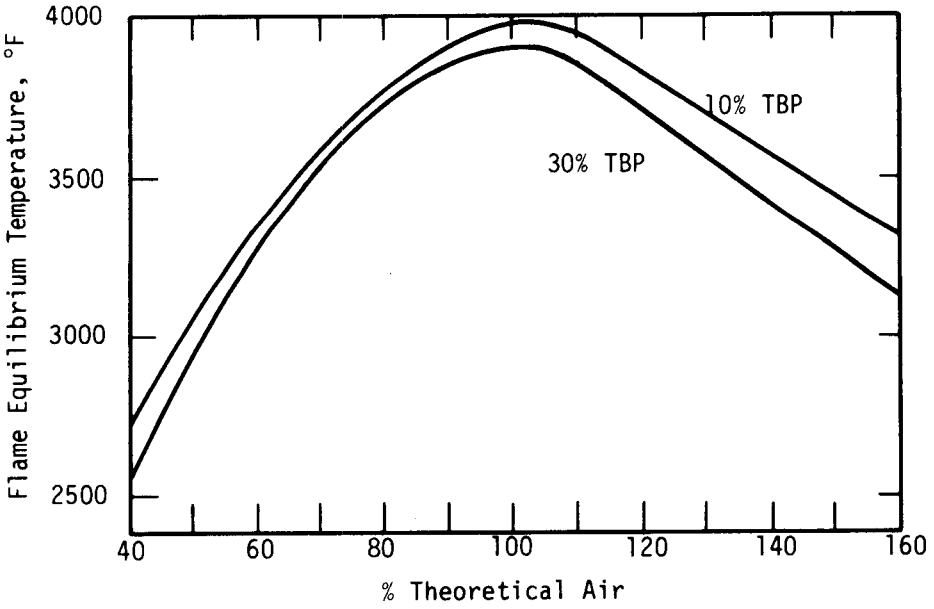


FIGURE 4-3. Flame Temperatures of Solvent Types

mixture gets into the excess air condition. The 10% TBP solution has a slightly higher equilibrium temperature than the 30% solution. All the temperatures on the chart are much higher than will be experienced because the theoretical calculations do not account for heat losses. To maintain the exit gas temperature from the second stage between 1900°F and 2000°F, it is necessary to operate between 40% and 60% excess air.[4]

When the burning pan solvent heel buildup requires, the burning pan is removed from the primary combustion chamber. The pan is packaged and sent to the burial ground for trench burial after assay if the transuranic content is below 10 nCi/g. If the assay is greater than 10 nCi/g, the pan is placed in retrievable pad storage in the burial ground.

Miscellaneous nonradioactive solvents are metered into the degraded solvent as it is burned, or they may be burned separately.

4.7.3 Radioactivity Buildup in the Primary Combustion Chambers

Some radioactive fission products such as strontium have been found to deposit on the ceramic lining of the hearth of the primary combustion chamber. Previous experimenters[5] have determined that up to 20-40% of the Sr content of the waste incinerated migrates into the adjacent refractory material. Thus far, it has been unresolved as to whether this diffusion of radioactive nuclides is into the firebrick, which is rather impervious, or to the mortar which is used to hold the bricks in place. Regardless of the mechanism, it is reasonable to assume that there will be a gradual buildup of radioactivity because of this phenomenom in the beta-gamma incinerator. Assuming that up to 40% of the Sr charged to the incinerator will remain in the incinerator, a buildup of 10 Ci/yr of Sr radioactivity can be anticipated. At this rate of radioactivity accumulation, it will take about 2 years for the background activity of the incinerator to equal the highest expected activity of one batch of waste feed. Whether this continued buildup of radioactivity background or the wearout of the refractory will be limiting as to when the primary chamber should be replaced is indeterminate at this time. In either case, it is recommended that the primary chamber be replaced and the retired primary chamber be buried in the burial ground to decay.

4.8 Off-gas Treatment

The objectives of the incinerator off-gas treatment system are to remove hydrogen chloride, sulfur dioxide, and particles from the off-gas. The HCl and SO_2 are removed from the off-gas in order to reduce downstream corrosion problems and to protect

the environment. A design efficiency for the removal of these two compounds is estimated to be 70%. The particles are removed from the off-gas stream in order to avoid radionuclide release to the environment. The radionuclides represent a small fraction of the total solids in the off-gas and are believed to be associated essentially with the solid airborne particles. No significant quantities of radionuclides will be present. Table 4-4 and Figure 4-4 show the process flow diagram and material balance.

The sulfur dioxide and hydrogen chloride are removed from the off-gas in the spray dryer. In the spray dryer, an aqueous solution of sodium carbonate is sprayed into the gas stream where SO_2 and HCl react with the carbonate solution. As the water evaporates, the gas is cooled. Specifying the dryer exit temperature of 149°C determines a water input flow rate of 3542 lb/hr or ∿7 gpm. The required 40 lb/hr of sodium carbonate to react with the SO_2 and HCl is dissolved in this water, based on the assumed maximum 8% PVC content of the waste feed mixture.

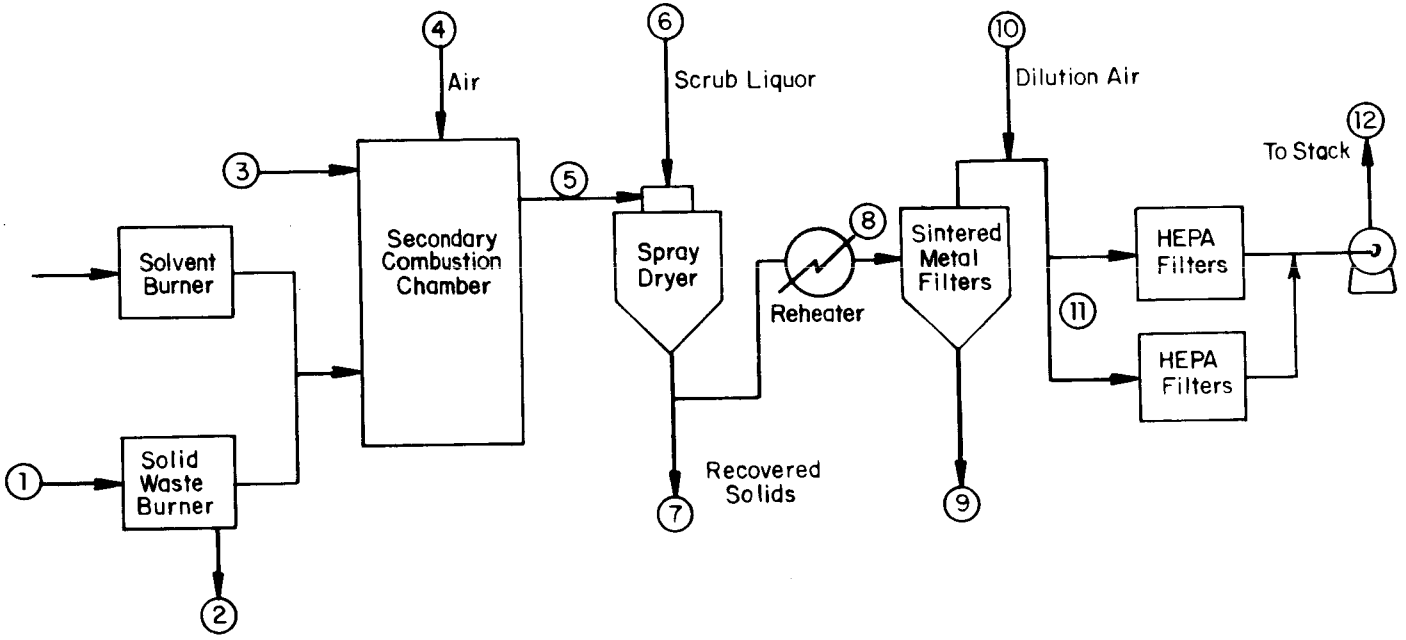
The scrubbed off-gas from the spray dryer flows through a 120 kW reheater. The reheater is intended only to be used in the case of an emergency where the desired superheat of the off-gas above the dew point cannot be maintained. An electric heater is preferred to a steam heater because it is more reliable than steam during emergency conditions.

After the reheater, the off-gas is filtered through porous sintered metal filters to remove particulate and dried salts. These metal prefilters are the main particulate removal step and protect against rapid particulate buildup on the high efficiency particulate air (HEPA) filters. The design approach velocity of the gas to the filters is 4 ft/min. At the nominal airflow of 4109 ACFM this requires an area of 1027 ft^2. Assuming a filter 2.55-in OD x 3 ft long, more than 500 sintered metal filters are required. Two sets of filters in arrays of 16 x 16 of the above dimension would provide adequate flow area. The particulate decontamination factor across these filters is assumed to be >0.99 if a 10-micron pore size filter is used. Particulate cake on the filters can be removed with intermittent blow-back (or gas flow reversal). The caked particulate falls into a hopper for later gravity discharge. This technique has been demonstrated at SRL on a pilot sintered metal prefilter test unit.[5] Figure 4-5 shows experimental test results that indicate the increased metal filter pressure drop equilibrates at ∿10 inches H_2O with carbon soot cake. No filter precoat was found to be necessary because the incinerator off-gas soot and particulate is more than 50% less than 6 micron (Figure 4-6) and forms an ideal precoat. During the tests, no sudden flinding of the metal filters was observed under full sooting conditions; even though the off-gas was allowed to reach its dew point. Cake thicknesses of up to 1/4 inch were observed on the filters (Figure 4-7). These experimental results

TABLE 4-4

Incinerator Material Balance

	See Figure 4-4 for Location											
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Component, lb/hr												
Waste	380											
Ash		19										
No. 2 oil			60									
H_2O				79	474	3542		4016		104	4120	4120
O_2				2048	1024			1024		2690	3714	3714
N_2				6780	6780			6780		8904	15684	15684
CO_2					1039			1039			1039	1039
HCl					17.3							
SO_2					1.5							
Na_2CO_3						39.5	7.9	4.0	4.0			
NaCl							18.5	9.2	9.2			
Na_2SO_4							2.2	1.1	1.1			
Particulate							0.4	0.4	0.4			
TOTALS	380	19	60	8907	9336	3582	29	12874	14.7	11594	24557	24557
ACFM				1954	8973			4109		2567	6694	6694
TEMPERATURE °C				20	1000	20	149	149	149	20	88	88
PRESSURE in H_2O					-36			-24			-6	0



Note: Circled numbers correspond to material balance on Table 4-4.

FIGURE 4-4. Incineration Process Flow Diagram

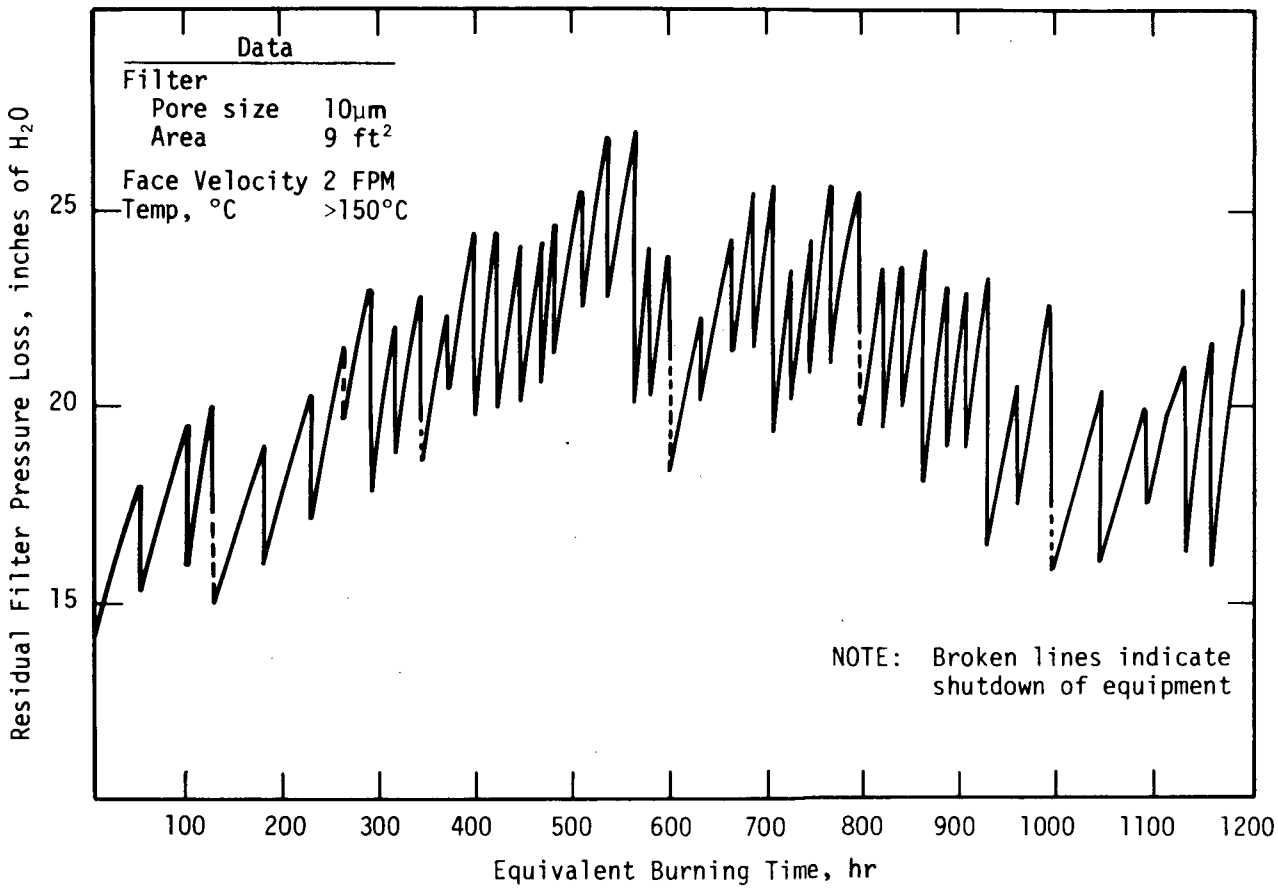


FIGURE 4-5. Sintered Metal Filter Performance in an Incinerator Off-gas Stream

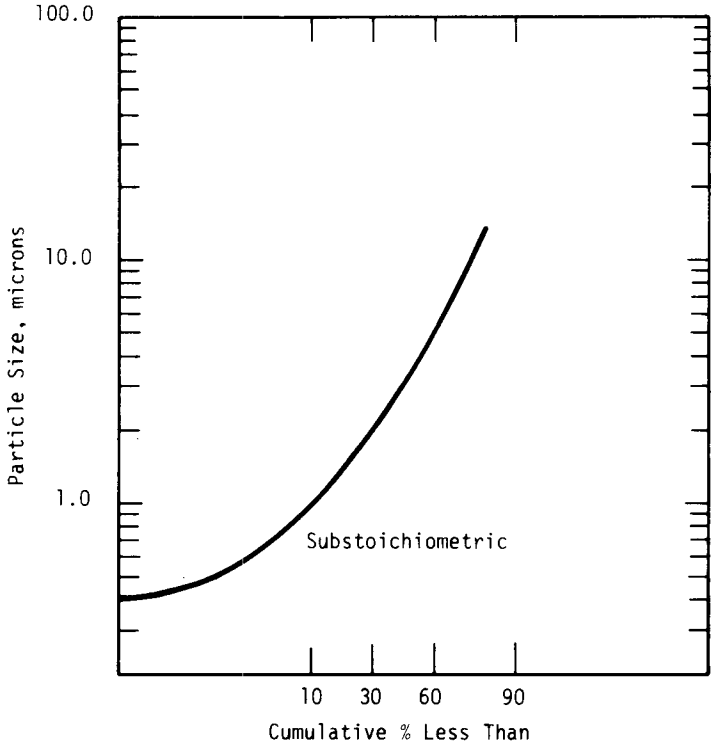


FIGURE 4-6. Particulate Size in Exhaust of Incinerator When Burning Typical Solid Waste Mix with Substoichiometric Air

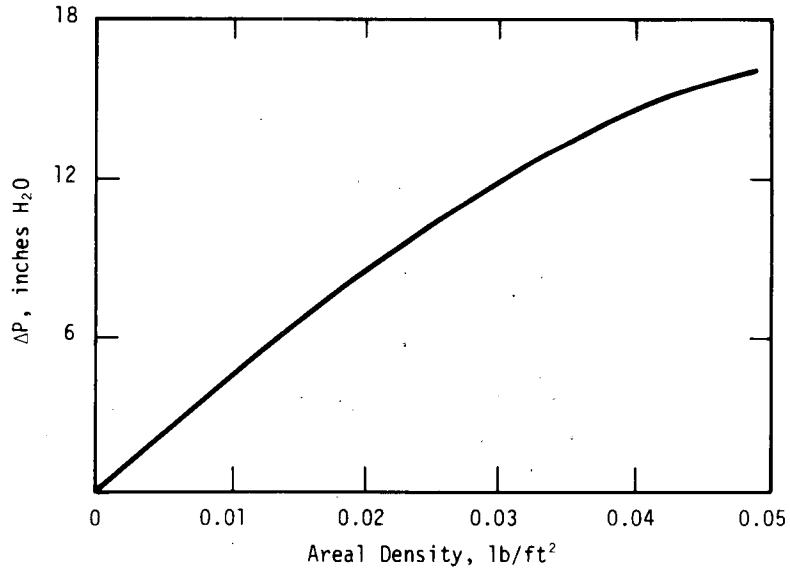


FIGURE 4-7. Cake Buildup on Sintered Metal Filters
Filter Size: 2" OD x 13" Long
1 FT/MIN Gas Approach Velocity

do not include the effect of neutralized salts from a spray dryer. If the off-gas superheat is maintained at the design temperatures (e.g., 53°C above the dew point) behavior of these hygroscopic salts should not be appreciably different than that shown in Figure 4-5. Further experiments are planned at SRL to verify the effect of temperature, salts and volatile off-gas components on sintered metal filters.

The prefiltered off-gases are cooled by air dilution prior to HEPA filtering to allow the use of conventional HEPA filters at 88°C. Eight 24 x 24 x 11-3/4-in. HEPA filters (1000 ft^3/min rating) will provide 20% excess flow capacity. Filter use is conservatively estimated to be 24 filters per year. The use of air dilution for cooling avoids heat exchanger corrosion and increases HEPA needs by only 80%.

An induced draft fan provides the flow of off-gas through the system. A capacity of 8000 cfm at 5 inches Hg should be adequate for the addition of ducting and excess capacity for control purposes.

4.9 Ash Packaging and Assay

The residue from the incinerator operation consists of ash refuge from burning solids which is collected in a metal drum and a sludge residue from burning degraded solvent in solvent burning pans. Both types of residue are assayed to determine if the transuranic content is >10 nCi/g.

4.9.1 Solid Ash Residue

The ash from incinerating solid waste is collected in metal drums at the rate of about one 55-gal drum/shift. The drums are filled by a gravity system which is airlocked from the incinerator combustion chamber to prevent backflow of air into the incinerator. A hood and blower control the airflow during the drum loading to minimize the dispersion of the fine ash particles. Exhaust air is recycled to the combustion chamber. The ash is deposited a 55-gallon drum which only has its interior exposed to the contaminated ash discharge room. A double-lid system is used to seal the outer 55-gal drum to minimize surface contamination on the surfaces of the container. The sealed drum is assayed for transuranic content by neutron activation. Drums containing >10 nCi/g of transuranics are segregated from drums containing <10 nCi/g.

4.9.2 Solvent Pan Packaging

The solvent burning pan is removed from the primary combustion chamber with a shielded fork-lift tractor and placed in a custom-made metal container and sealed. The sealed container is assayed for transuranic content by neutron activation. Solvent pans containing 10 nCi/g of transuranic nuclides are segregated from those containing <10 nCi/g.

4.10 Product Storage and Shipping

A shielded area is provided for the segregated storage of the processed wastes. Transuranic wastes (>10 NCi/g) are separated from nontransuranic wastes because they are to be placed in retrievable storage in the burial ground rather than buried in trenches. Lag storage area is provided for at least one month's production. Transfer of the waste drums to the burial ground is made by waste truck. Surface contamination should not exceed 1000 counts/min β-γ or 500 dpm α, per 100 $cm.^2$

4.11 Onsite Burial

Noncombustibles and off-gas cleaning wastes from the process are placed in trench burial with the beta-gamma ash. Normal burial ground procedures are used in receipt, recording and storage of these wastes associated with the β-γ incinerator process.

5. FACILITY DESCRIPTION

5.1 General Facility Description

Major design considerations are the shielding of gamma radiation, materials handling, and the incineration of combustible wastes under controlled conditions. Whenever practical, waste should be handled remotely to protect operating personnel from unnecessary exposure to radiation. The facility is not a plutonium processing facility subject to DOEM-6301 design criteria.

The individual processing steps will present a potential for surface and airborne contamination. The design of the processing facility must provide for isolation of unit operations to prevent the spread of contamination and should allow for routine decontamination. Provisions must be made to remotely move waste through the process. Extra machinery equipment and any other critical items that are susceptible to failure should be provided as part of this project. Simple equipment change-out and contact maintenance and repair of equipment are also design considerations.

Shielding and Nuclear Criticality Considerations

Nuclear safety is not a problem in this process facility because of the extremely low transuranic content of the wastes; however, in the case of depleted uranium wastes, balances of fissile materials will be maintained. Shielding may be required, primarily for gamma radiation.

Table 5-1 shows a static inventory of waste and its attendant radioactivity in each of the separate process and storage areas of the facility, assuming the average annual throughput of 200,000 ft^3 of solid waste and 20,000 gal of degraded solvent. These area inventories should provide the necessary parameters to calculate the shielding requirements.

The facility design must provide sufficient shielding against gamma radiation to limit the normal exposure rate to operating personnel <0.5 mrem/hr at the surface of the shield. The annual personnel dose limit is 3 rem.

Radiations from the beta-gamma solid waste will be present from:

- Fission products
- Transplutonium isotopes
- Induced activities

TABLE 5-1

Process and Storage Area Waste Inventories

Process Area	*FP Activity, Curies*	*Volume ft*	*Form*	*Container*
5.2 Receiving	2	4000	Combustible	Cardboard Box
5.3 X-ray & Assay	0.03	64	Combustible	Cardboard Box
5.4 Repackaging	0.06	128	Combustible	Cardboard Box
5.5 Feed Lag	0.03	64	Combustible	Cardboard Box
5.6 Solvent Lag	0.1	268	Liquid	Tank
5.7 Incinerator	0.3	6	Ash	None
5.8 Off-Gas System	0.001	4	Particulates	Drum
5.9 Ash Lag	1	105	Ash	Drum

Shielding requirements for the β-γ wastes have been computed and the results are summarized in the Figure 5-1.

The following additional comments are included to facilitate use of these graphs:

1. Design doses are 5 mrem/hr in locations occupied less than 10% of the normal working period; and 0.5 mrem/hr for locations occupied with higher frequency.

2. Shielding may be estimated as shown in the following example: Table 5-1, Process and Storage Waste Inventories, Calculate shielding for 0.5 mrem/hr from 1 drum contents of ash waste.

   $\frac{1 \text{ Curie}}{105 \text{ ft}}$ x 6 ft^3 drum $\simeq$0.5 Ci requires: 6 inches Iron or 19 inches Concrete

3. Source-shield and shield receptor distance is 1 ft, use inverse square law for other distances.

4. Although an SRP shielding code (SDC) was used to generate these data, the graphs because of their general nature are intended only for shield design estimation.

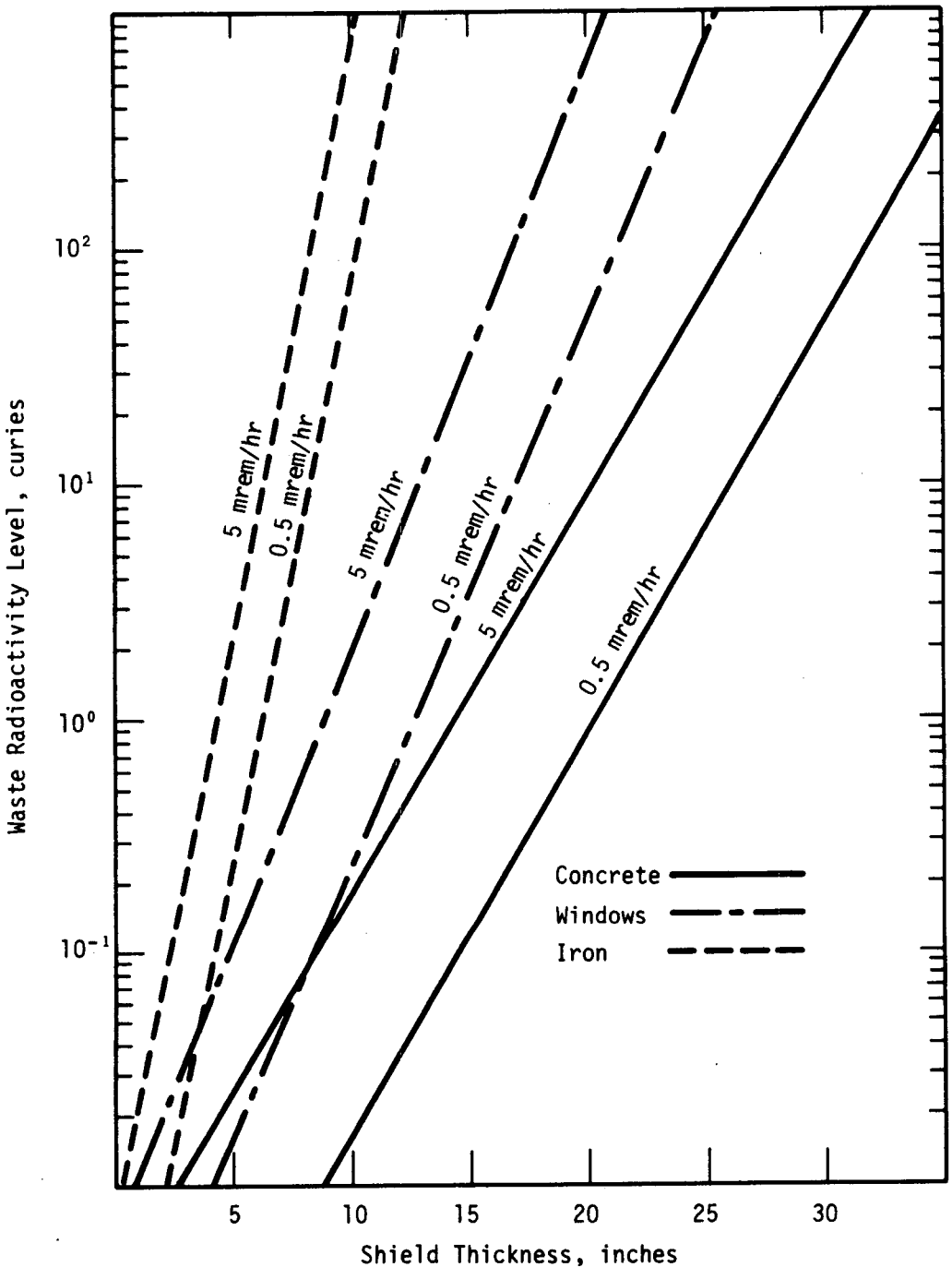


FIGURE 5-1. Solid β-γ Waste Shielding Requirement

Standard Design Considerations

1. Any equipment in any system which governs the protection of personnel on or offsite should be designed so that in case of failure alternate equipment will automatically come on line.

2. All facilities should be designed for the safe confinement under all credible conditions of all waste handled and processed.

3. Shielding shall be provided to protect plant personnel from all sources of radiation to ensure their exposure is within limits (0.5 mrem/hr continuously occupied area and <5 mrem/hr in intermittently occupied areas).

4. It must be shown that the facility can be returned to normal after any abnormal event or credible accident.

5. All effluents shall be decontaminated to meet U.S. Government standards and monitored before release to the environment.

Heating and Ventilation

All ventilating air for the new process building should be used once and exhausted through the stack. Air should flow from clean areas to less clean eventually passing through the process areas which exit to the stack.

Air to the process building should be conditioned for comfort. A process vessel vent exhaust system will be required.

Safety System

1. Emergency power should be provided for ventilation fans, lighting, instruments, the public address system, fire and safety systems, breathing air and instrument air compressors, critical processing and handling equipment, certain transfer pumps and valves and heat removal equipment.

2. Breathing air compressor should be provided for air to maintenance and operating areas. A back-up bottle system should be provided.

3. An automatic sprinkler system should be provided. Drains should go to a retention tank rather than the storm drains because of the possibility of contamination.

4. Analytical instrumentation and alarms should be provided on all gas and liquid streams exiting the facilities to measure radioactivity.

5. Permanently installed radiation and air monitoring equipment should be provided in the main process building.

6. Evacuation and warning alarms should be provided.

Instrumentation

Instrumentation and controls should be provided for all process equipment and spares if the service of the component is critical to the operation of the process. An allowance will be specified for all portable radiation monitoring and health physics instruments.

Extra Machinery

Extra machinery equipment should be provided for major items and for any critical items susceptible to failure.

5.2 Auxiliary and Outside Facilities

Equipment Decontamination Area

A decontamination area should be provided in the process building to decontaminate operating equipment for repair. Standard equipment for β-γ decontamination should be provided.

Warm Canyon Shop

A warm shop should be provided next to the decontamination area. Standard facilities should be provided.

Crane Maintenance Area

Crane maintenance facilities should be provided for the decontamination and maintenance of all cranes.

Truck Docks

Truck docks should be provided for receiving clean equipment and supplies and separate facilities should be provided for handling regulated equipment, samples, and burial ground waste.

Shops

Standard facilities should be provided for Maintenance and E&I or may be shared with Waste Management and Maintenance Facility (WMMF).

Process Area

Contaminated process areas and container handling cells should be equipped with stainless steel liners for ease of decontamination.

Cold Feed Preparation

A cold feed preparation area should be provided

Personnel Facilities

1. Shower, change room and toilet facilities for males and females to be shared with WMMF.
2. Locker facilities for males and females at WMMF.
3. Provide one personnel decontamination room.
4. Provide one HP counting room.
5. Provide offices for:
   - Shift Supervisor
   - HP Inspectors
   - Maint. Supervisor

Communications

Phone and intercom systems should be provided.

Building Arrangement

The beta-gamma incinerator facility is envisioned for the purposes of this reference process and technical data summary as a linear dual level building. The waste receiving and shipping areas are located at each end of the building. The processing areas are located within two long walls running down

the central section of the building with operating aisles running along outside the process walls. The process areas are partitioned and materials are moved over the partitions by overhead cranes. With the exception of the repackaging and incinerator and ash packaging areas, complete containment is not necessary because the waste is in cartons or drums. Overhead transfer of these containers from section to section is feasible because of the very low alpha contamination and the lack of skyshine from the low gamma radiation levels. A higher roof over the incinerator and off-gas cleanup areas should be equipped with a heavy duty overhead crane for equipment changeout. With the exception of the central shielded areas, lightweight building construction for the remainder of the building may be acceptable.

5.3 Receiving and Storage Areas

Facilities shall be provided for receiving and segregated storage of incoming waste containers. The unloading area will be accessible to truck delivery of the containers. Remote unloading equipment will be required. The area should be enclosed from the weather and provided limited access.

Local facilities shall be provided to decontaminate the R&S areas in the event they become contaminated.

Lag storage areas will be provided with a sprinkler fire protection system and ionization detectors. The remaining portion of the areas will be provided with portable fire extinguishers.

Waste cartons are stored on pallets. Most of the cartons will be of very low radiation level and may be handled directly (as they were at their point of generation). A small fraction of the cartons (5-10%) may be much more radioactive. These containers should be stored behind a portable shield wall.

5.4 Waste X-ray Area

This area is located within the central process walls. All electronic and control equipment is located outside the process area to facilitate operation and maintenance. Waste cartons are placed on a moving belt conveyor by overhead crane from the receiving lag area (5.3). The conveyor transports the carton past the X-ray station in a similar fashion to airport luggage X-ray machines.

5.5 Waste Assay Area

This area is located adjacent to the X-ray area within the central shield walls. All electronic and control equipment is located outside the shielded area to facilitate operation and maintenance. Waste cartons are transferred from the X-ray conveyor to one of two assay station conveyors. The waste carton is then positioned in front of the detector probe within a shielded tunnel. After assay, the carton is conveyed to the pickup point for transfer to the feed lag area (5.7) or the repackaging area (5.6).

5.6 Repackaging Area

Provide facilities for remotely repackaging the waste from rejected and oversize containers. Packages of combustible material which have been x-rayed or assayed and determined to require further sorting of the contents are processed here. Waste is repacked and routed to appropriate areas for further processing. Shipment waste containers of separated noncombustibles are checked for contamination before release to the burial ground.

Interior surfaces of the secondary sorting Area 5.6 will be finished in a manner to facilitate decontamination. Partitions will be used to separate the different operation areas within the facility into zones according to contamination potential.

The sorting areas will be provided with a Halon fire protection system and ionization detectors. The remaining portion of the areas will be provided with portable fire extinguishers.

5.7 Incinerator Feed Lag Storage Area

5.7.1 Incinerator Feed Carton Lag Storage

This area is located adjacent to the waste assay Area 5.5 within the central shield walls. Waste cartons are moved by an overhead crane from the assay area pickup point to temporary storage in the feed lag area. Space should be provided for 8 hours of incinerator operation ($\sim$ 64 cartons). As they are required, cartons (1 at a time) are removed from the lag storage area by crane and placed in the incinerator feed mechanism. The lag storage area is separated from the incinerator and feed mechanism by a firewall partition.

5.7.2 Incinerator Solvent Storage Tank

The degraded solvent is stored in a tank outside the incinerator facility. A feed line and metering pump are used to fill the burning pan during solvent burning campaigns. The storage tank should have a capacity of ∿2000 gallons.

5.8 Waste Incinerator Area

The area for incinerating beta-gamma contaminated combustibles contains only the primary and secondary combustion chambers, ram feed and ash removal mechanisms. Conventional incinerator design and layout will be modified to shield the incinerator and waste flow stream from all auxiliary equipment. Controls, air inlet and off-gas piping should be situated in a low radiation area for ease of operation and maintenance.

The incinerator is separated from the feed preparation area to minimize the possibility of fire or release of contamination in the case of incinerator pressurization or blow-back. The incinerator is to be situated within a shielded negative pressure cell which can be entered for maintenance by remotely operated crane. Repair or replacement of equipment is done after decontamination in a warm shop.

Ash will be removed from the incinerator to a shielded annex to the incinerator cell. A 55-gal drum full of ash emits 5 mrem/hr at one foot.

Interior surfaces of the complete incineration cell will be finished in a manner to facilitate decontamination.

Special design consideration should be given to minimizing the explosion and external fire potential during incineration. The potential for explosion of accumulated flammable vapor is greatest during periods of interrupted power; therefore, automatic control and emergency power should be provided. Automatic shutdown should be initiated in incinerators by monitors for low temperature or low air flow. Flanged cleanout ports should provide access to all sections of the incinerator and off-gas system for removal of accumulated tar and soot. The waste feed mechanism should be carefully designed to prevent preignition of the feed outside the firebox and also to prevent the release of combustible gases into the containment.

Automatic fire detection and suppression must be provided. Emergency power and lighting must be provided at critical locations.

A heavy-duty crane is to be provided for removal and replacement of the incinerator combustion chambers.

An access door should be provided to the rear of the incinerator to install and remove the solvent burning pan in the primary combustion chamber.

5.9 Off-Gas Cleanup Area

The off-gas cleanup system should be designed for 20% greater than the nominal incinerator capacity. All equipment subject to failure should be duplicated and available for immediate substitution to avoid shutdown. The materials upstream of the spray dryer in this system should be resistant to HCL and designed for ease of inspection and pluggage removal. Replaceable components (HEPA filters) should be mounted in convenient locations for changeout.

No shielding is required in the off-gas cleaning area and contact maintenance is anticipated. Radiation buildup is to be expected in filter dust hoppers from volatile fission products and entrained ash; however, the level of radiation will be maintained at a low value by the continuous replacement of the scrub solution as it is dried and removed from the incinerator off-gas.

The heavy duty crane used to service the incinerator may also be used to replace off-gas process equipment.

5.10 Ash Packaging and Assay

This area is located adjacent to the incinerator area (5.8) within the central shield walls. There is a high potential for surface and airborne contamination from ash. Interior surfaces will be finished in a manner to facilitate decontamination.

The area consists of two sections connected by an airlock through which ash is charged into 55-gallon drums in such a manner as to minimize external contamination of the outer container (less than 1000 cpm β-γ and 500 dpm α per 100 sq. cm.). A neutron activation source assay is included in the second section to assay the sealed 55-gallon drums for transuranic content. An overhead crane is used to transfer the ash drums to the storage and shipping areas (5.11 and 5.12).

5.11 Product Storage

Provide shielded storage facilities for up to 15 drums of ash and one solvent pan container. Transuranic residues should be segregated from nontransuranic drums and pan containers.

5.12 Shipping Area

Facilities should be provided for shipping processed waste containers to the burial ground by waste (regulated) trucks. Shielded fork-lift tractors are used for loading. Decontamination and monitoring facilities should be included.

6. PROCESS EQUIPMENT

6.1 Receiving and Storage Area

The incoming waste containers and solvent will be delivered by truck. Shipments of solids are brought into a covered inspection area. After inspection, the containers are placed in lag storage areas.

6.1.1 Inspection and Decontamination (Vehicle)

Provide facilities for radiation and contamination survey of truck and waste cargo. Include spray system for washing external surfaces with detergent and water solutions. Control liquid drainage and direct to contaminated liquid storage tank (1000 gal. capacity).

6.1.2 Unloading

Provide lift truck and spare to unload large boxes (2 ton capacity) and pallets of waste cartons. Solvent truck will include self-contained pump and hose for transfer to solvent feed tank.

6.1.3 Monitoring

Provide radiometric instrumentation to survey vehicles, casks and water containers for β-γ. Include capability for obtaining α smear samples for contamination assessments.

6.1.4 Crane

Provide overhead crane to move waste boxes from receiving storage area to processing area over shield wall separation. A pallet or single box may be moved (2 ton capacity).

6.2 X-Ray

6.2.1 Conveyor for X-Ray

Provide a conveyor to move the waste cartons through the X-ray machine.

6.2.2 Waste Package X-ray

Provide a collimated, shielded, flying-spot x-ray machine to examine waste packages for high density materials. 160-Kev CsI detector, computer read-out.

6.2.3 Waste Package Metal Detector (Back-up or Alternative)

Provide an electromagnetic, inductance-type metal detector to examine waste packages for metal.

6.3 Monitoring (Assay & Inventory)

Provide the following:

a. Detector and Multichannel Analyzer (2 each)

Provide a high resolution, solid-state, lithium-drifted germanium detector Ge(Li) for gamma spectrometric measurements, and a multichannel analyzer similar in specifications to the Canberra Model 8180.*

b. Computer

Provide computer to control read-out and record spectral data from the waste cartons. Reject of waste cartons with high concentrations of undesirable contaminants (Table 4-3) should be automatic.

6.4 Repackaging

Incoming waste not in standard cartons (24 x 24 x 24-in.) or containing suspect materials is opened, sorted and repackaged remotely. Noncombustibles are packaged for shipment to the burial trenches in the burial ground.

6.4.1 Waste Package Unfoldment

Provide a remotely operated and shielded work cell where packages containing mixed combustibles and noncombustibles can be opened and the contents sorted by manipulator and repackaged.

---

*Canberra Industries Inc., Meridan, CT

6.4.2 Waste Assay

Provide radiometric survey equipment to determine alpha contamination on noncombustibles. Provide gamma instrumentation for ascertaining activities shown in Table 4-3.

6.5 Feed Lag

An eight hour lag $\sim$ 64 waste cartons (24 x 24 x 24-in.) is required.

6.5.1 Feed Crane

Provide overhead crane to move waste cartons (1 at a time) to the incinerator ram feed (2 ton capacity). Cycle time for charging ram feed is 7.5 minutes.

6.5.2 Solvent Tank

Provide a 2000-gal capacity tank with pump, feed line to incinerator and level gage.

6.6 Incinerator

Provide a dual chamber, controlled-air incinerator with a ram feed mechanism and an ash recovery system. All operations should be designed to be carried out mechanically.

6.6.1 Ram Feed Mechanism

Provide a ram feeder that will charge one standard waste box at a time directly into the ignition chamber of the incinerator through an air lock equipped with guillotine doors. In all, there are three barriers - the hatch, the power door and the ram head - to prevent blow-back of contaminated gases during combustion. Provide sufficient interlocks for safe operation.

6.6.2 Incinerator

a. Solid Waste Primary Combustion Chamber

1. The first stage of the incinerator should be cylindrical with a volume of 250 ft^3 and dimensions 6-1/2 ft OD by 10 ft long. Effective Grate Area 40 ft^2 made up of

refractory brick covering lower 90° sector of chamber, cast refractory may be used for upper chamber lining. Chamber lining from inside out should be 5 inches high-density refractory, 2 inches mineral wool, mastic covered 3/8 inch steel casing.

2. Air to first stage is supplied by 2-in. diameter manifolds outside and 10-2" pipes from each manifold entering at ∿ 18" from the base of the hearth. Exhaust piping 32 in. ID.

3. Fuel oil No. 2 fueled burner rated at 2,300,000 BTU/HR. Flame port area 650 in^2.

4. Back end of the first stage chamber is equipped with oversize door for inspection, cleanout and maintenance.

5. Combustion control of air supply is by thermocouple in the exhaust of 1st stage. Oxygen and CO levels are also monitored.

6. Two steam injectors are to be installed in the upper front end of the chamber to promote the oxidation of carbon and to quench the chamber temperature for rapid cooldown. Steam 50 lb/hr maximum at 125 psi and saturated conditions.

7. Provide an opening for ash to drop out of the incinerator into a cooling pit. The ash is to be displaced horizontally by unburned feed material charged to the incinerator.

b. Solvent Primary Combustion Chamber

1. Provide a cylindrical chamber 250 ft^3 to contain a removable burning pan 24 in. wide x 42 in. long x 6 in. high.

2. Air to the first stage should be supplied with air distribution 6 in. diameter manifolds and ten 2 in. distributor pipes on each side of burning pan.

3. Liquid level in burning pan to be monitored and controlled with dip tubes and differential pressure cell or thermocouples.

4. Pilot light which will reach liquid level for ignition of solvent.

c. Secondary Combustion Chamber

1. The second stage of the incinerator should be cylindrical with a volume of at least 400 ft^3 and dimensions 6 ft. ID by 15 ft. long. Walls, entrance, and exhaust piping lined with 5 inches of refractory, 2 inches of mineral wool, mastic covered 3/8" steel casing.

2. Air for second stage burning is injected in the pipe connection between the first and second stage.

3. Fuel oil No. 2 fueled burners mounted on each side of the entrance to the second stage rates total 1,200,000 BTU/hr.

4. Exhaust pipe 32-in ID ceramic lined.

5. Combustion control of air supply is by thermocouple in the exhaust of 2nd stage. Oxygen and CO levels are monitored.

6.6.3 Blowers (Air Supply)

Provide a combustion air supply blower with a capacity of 2000 scfm air at a pressure of -2 inches H_2O. One blower to supply air for both stages: 700 scfm to either first stage and 1300 scfm to second stage. Provide 2400 scfm dilution air to off-gas system.

6.6.4 Ash Recovery

Provide a gravity system to remove ash from the floor of the primary combustion chamber of the incinerator. After the ash receiver, the product stream should exit through an air lock ash removal system into a 55-gal drum. Recycle the exhaust air to the ignition chamber.

6.7 Off-Gas Cleanup System

Provide an integrated off-gas treatment system which will insure that the gas effluent from the incinerator conforms with the South Carolina Air Pollution Control Regulations and Standards.

6.7.1 Spray Dryer Shell

Detailed performance data and design parameters of the spray dryer are proprietary information. In this process apart from

SO_2 and HCl removal, a major function of the spray dryer is to reduce the temperature of the off0gas stream from 1000°C to 150°C by evaporation of water from the sodium carbonate solution. Accordingly, the dryer was sized on the basis of the chart shown in Figures 20-72 of the Chemical Engineers Handbook, 5th Edition. The required vessel diameter is 12 ft with the top a vertical cylindrical section of 5 ft and a bottom 60° conical section 12 ft. high.

6.7.2 Spray Head

No vendor performance data are available on spray dryer nozzles in this application. Two units are required for redundancy.

6.7.3 Spray Pumps

The pumps should be sized to deliver 3600 lb/hr (7.1 gpm) and provide sufficient capacity for circulating the sodium carbonate in the tanks as well as supplying the spray heads.

6.7.4 Sodium Carbonate Tanks

The sodium carbonate tanks were sized on the basis of 70% utilization of 1 wt % sodium carbonate solution as required to neutralize the SO_2 and HCl content of the off-gas for 12 hours. At 80% maximum filling, a 6400 gallon tank is required. Two tanks are required to permit feeding process from one tank while making up solution from the other.

6.7.5 Solids Hoppers

Each hopper was sized to hold the amount of soda ash used plus the amount of particulate (700 lb) collected in 24 hours. The required hopper size is 16 ft^3 with a 60° bottom.

6.7.6 Sintered Metal Filter

The sintered metal filter was sized to process the off-gas at actual conditions. Provide 512 ten micron pore size sintered metal tubes (3 ft) long by 2.5-in. OD with a wall thickness of 0.16 cm (1/16 in.). The tubes are suspended from two rectangular tube sheets in enclosures. Each of the filter sections has a bottom pyramidal hopper. To provide redundancy, a third filter unit should be provided so that one section at a time can be remotely removed for repair while continuing to operate the incinerator.

6.7.7 HEPA Filter Plenum

The HEPA filter plenum is sized to contain two banks in series of 8 (1000 cfm) HEPA filter elements. Two plenum units are required for redundancy.

6.7.8 Induced-Draft Fan

An induced-draft fan with a capacity of 8000 cfm at 5 inches of Hg should be provided.

6.7.9 Reheater

The 120 kW reheater was sized to heat the off-gas at the inlet of the sintered metal filters from 78°C to 150°C based on the dew point of the process off-gas.

6.8 Monitoring Equipment

6.8.1 Solid Product Assay

Provide radiometric instrumentation to assay ^{239}Pu and other TRU. The only system capable of nondestructively measuring the fissile content of metallic waste in a metal drum is the neutron interrogation method being developed at Los Alamos.[13] The device is known as the "^{252}Cf Shuffler." In operation a ^{252}Cf neutron source is placed near the sample to be assayed, the neutrons cause some of the ^{239}Pu atoms to fission, the ^{252}Cf is quickly withdrawn by a mechanical or pneumatic system, and the delayed neutrons that are produced by the fission reaction are counted by neutron detectors placed near the sample. The neutron counters must be shielded from stray neutrons from either the ^{252}Cf or from the α-n reactions in the vicinity.

6.8.2 Exhaust Gas Monitors

Provide particulate and off-gas monitoring equipment for determining CO, CO_2, SO_x, HCl, NO_x and solids in the exhaust gas.

6.8.3 Product Weighing

Provide scale to weigh ash drum and burning pan.

6.9 Drum Loading

Provide gamma shielded area equipped with master-slave manipulators and hoists for the 55-gal drum for convenience of loading, and a drum capper that can be actuated by master-slave manipulators. Provide hoist facilities to transfer loaded 55-gal drums to a waste truck for transport to the storage and shipping area.

6.10 Shielded Lag Storage

Provide shielded storage space for fifteen 5-gal drums containing gamma-emitting ash.

6.11 Loading and Shipment

Provide remotely operated crane to load these drums into the regulated transport truck that will deliver the casks to burial ground for onsite burial. Radiation from an unshielded drum is 5 mrem/hr at one foot.

7. DEDICATED OR SHARED SERVICES

7.1 Stack

Provide a 100-ft. stack to provide sufficient elevation for the release of incinerator off-gases combined with all building air.

7.2 Exhaust Fans

Provide exhaust fans of sufficient air capacity to remove all air required to ventilate through the stack.

7.3 Water Chiller

Provide chilled water services to all necessary process areas.

7.4 Cooling Tower

Provide a cooling tower with sufficient excess capacity for maximum summer temperature at full process capacity.

7.5 Air Conditioning

Provide air conditioning for all operating and administrative areas.

7.6 Emergency Generator

Provide an emergency generator to power critical building operations during periods of normal power interruption.

7.7 Sand Filter

Provide for optional connection of the incinerator facility exhaust to the adjacent H-Area sand filter.

8. EFFLUENT RELEASES TO THE ENVIRONMENT

8.1 Off-Gas Composition

HCl will be formed as a combustion product. Sulfur in the fuel oil and waste feed will result in the formation of SO_x (primarily SO_2). The high temperatures will create some NO_x from the air constituents. Estimates have been made of the concentrations expected for these species. (See Figures 8-1 and 8-2).

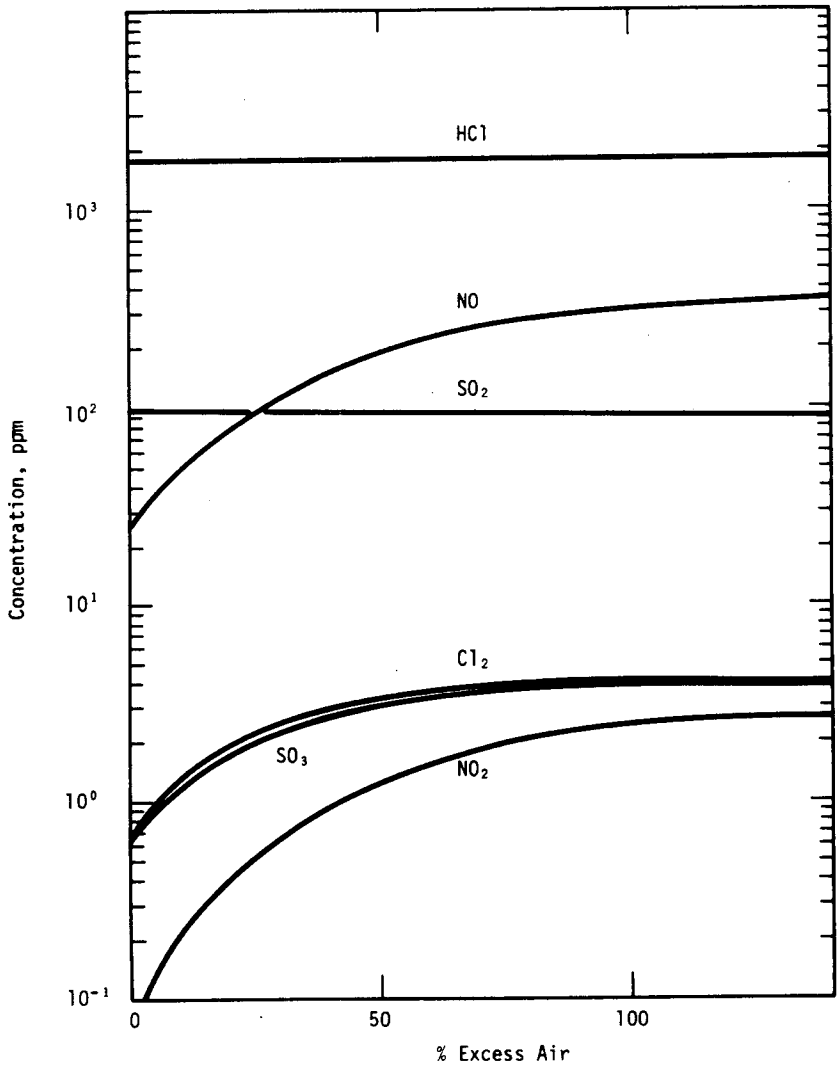


FIGURE 8-1. Unscrubbed Incinerator Exhaust versus Excess Combustion Air

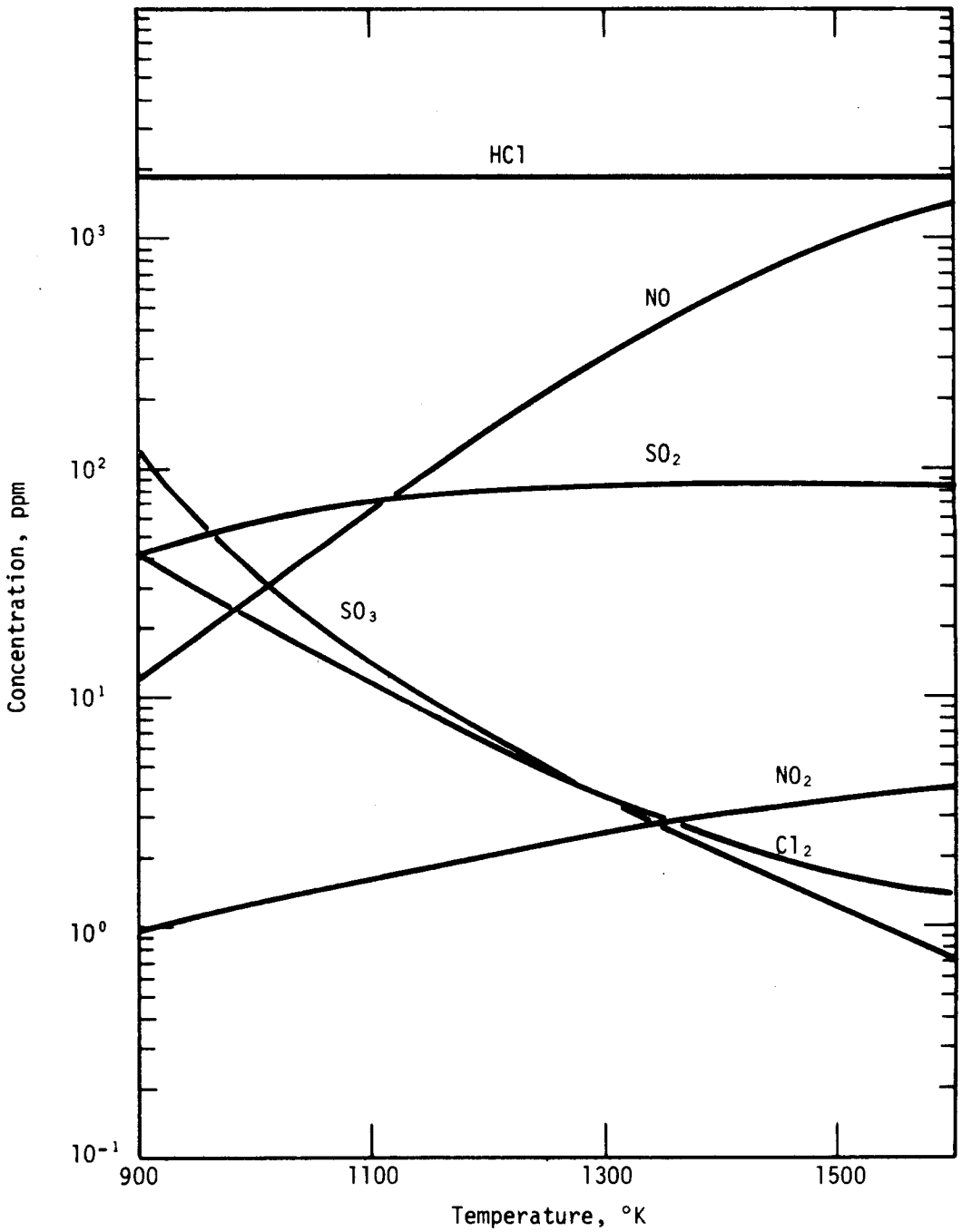


FIGURE 8-2. Unscrubbed Incinerator Exhaust versus Temperature at 100% Excess Air

The ambient air quality standards for the state of South Carolina are compared to the calculated pollutant generation rate in the following table for the nominal waste composition incinerated at 380 lb/hr rate at 1000°C and with no off-gas treatment. HEPA filters, which will be in the off-gas system for the containment of radioactivity, will eliminate suspended particulates. Spray drying of the incinerator off-gas will reduce HCl, and SO_2 to a very low level.

Pollutant	*Calculated Air Quality* $\mu g/M^3$	*State Standard* $\mu g/M^3$	*Measuring Interval*
SO_2	5	1,300	3 hour
NO_x	8	100	annual
CO	10^{-3}	25,000	1 hour
non-methane hydrocarbons	~0	130	3 hour
HCl	6	not specified	not specified

8.2 Radioactivity

The overall decontamination factor of the beta-gamma incinerator will result in an effluent that is lower than the natural background of radioactivity. The decontamination factor is defined as the ratio of the activity in the waste divided by the activity of the incineration off-gas effluent as released from the stack of the beta-gamma incineration facility.

Previous incinerator demonstrations[7] have reported overall radioactivity decontamination factors for the combustion chamber alone on the order of 200. This is an average value and individual isotopic behavior may be expected to vary considerably[6] (e.g., tritium and ^{14}C all to stack, 80% I to stack, 50% of ^{35}S to stack, 10% P to stack). A key factor in the combustion chamber decontamination factor is reduced turbulence which should be minimized to eliminate ash entrainment in the off-gas. Hence, the TBP-kerosene is pan-burned rather than sprayed into the primary combustion chamber, and underfire airflow is reduced during feeding a batch of solid waste.

8.3 Monitoring

The purpose of monitoring the off-gas from the incinerator is: (1) to determine operating efficiencies of the decontamination components (process control); (2) to determine concentrations

in the final stream after the decontamination system (effluent monitoring); and (3) to determine ambient concentrations in the immediate vicinity of the facility (environmental monitoring). The primary contaminants that require measurement are sulfur dioxide, nitrogen oxides, hydrogen chloride, and particulate particle size, dust load and associated radioactivity).

Several locations in the dry process off-gas must be sampled to determine the operating efficiencies of process components:

1. Before the spray dryer

2. Before the sintered metal filters

3. Before the HEPA filters

4. After the HEPA filters but before the combination point of the off-gas with the cell ventilation air. (This sample point will also be used for continuous monitoring of sulfur dioxide, hydrogen chlorides, and nitrogen oxides.)

Particulates will be sampled periodically using cascade impactors. Each stage of the impactor can be analyzed in the laboratory for particle size distribution, radioactivity associated with particle size, and total particle concentration. Laboratory equipment and instrumentation required will include a semi-micro balance and a multi-channel analyzer with alpha and gamma detection systems for measuring gross radioactivity and isotopic concentrations of radionuclide activity associated with particulates.

After filtration, the stack gas will be continuously analyzed for sulfur dioxide and nitrogen oxides with a chemiluminescent analyzer.

Hydrogen chloride, carbon monoxide, and carbon dioxide can be monitored either continuously or periodically by individual IR instruments.

The particulates will be continuously analyzed for gross radioactivity and particle size distribution. The particulates will be collected on a HEPA sample filter, and gross radioactivity will be counted. The detector will be shielded and connected, by appropriate electronics, to an alarm for a sudden radioactivity increase. Plant upsets, particularly a breach of a HEPA filter, will also be detected by a stack monitor.

9. SAFETY

9.1 Facility Design and Operation

9.1.1 Ventilation

Radioactive particles will be removed from the exhaust from process cells by a filtration system. Each process cell will be individually exhausted through a fireproof, high-efficiency particulate air filter (HEPA). The air is then passed through an isolated HEPA filter bank. All process cell ventilation air will be discharged through a new 100 ft. stack. Thus, the above two-step filtration system, arranged in series would minimize the possibility of radioactive contaminants reaching the stack.

Clean areas would be ventilated to regulated process areas. The ventilation systems will be designed so that the highly contaminated areas, the process cells would be under a slightly lower air pressure than surrounding areas to insure that any air leakage is into and not out of the contaminated areas. In addition, the contaminated areas would be surrounded by regulated zones which would have a positive air with respect to the cells, but a negative pressure with respect to the clean areas. The personnel occupancy areas would be maintained under a negative pressure with respect to outdoors; the total system would provide two buffer zones between the outdoors and process cells.

9.1.2 Radiation and Contamination Control

Monitors and metering devices would be provided for protection of personnel and environs. Passage of personnel between clean and regulated areas would be through airlocks. Protective clothing would be required for all personnel in regulated and contaminated areas, although normally there will be no contamination in regulated areas. At each exit from one zone to another, some protective clothing must be removed and monitoring instruments would be provided to verify that no transfer of contamination takes place. All personnel would be trained in these techniques.

The adequacy of safeguards for protecting the environment is verified by an extensive environmental monitoring program to determine concentrations of radioactivity in environmental media in a 1200-square mile area outside the plant site. Air,

precipitation, and water are sampled continuously at numerous established stations and drinking water, soil, vegetation, wildlife, and milk are sampled on a regular frequency. Analytical methods capable of detecting radioactive materials within expected natural levels are used to analyze samples for radioactivity. Results and details of the environmental monitoring program are published and made available to the public in semi-annual reports prepared by the Savannah River Plant.

9.1.3 Emergency Electrical System

An emergency self-starting diesel generator will be installed as a back-up power supply in the event of normal power failure to maintain operation of process equipment, ventilation equipment, monitoring instruments and controls essential to the protection of personnel and environment. Routine testing of the emergency diesel generator would be performed to assure its reliability.

9.1.4 Fire Detection System

A system will be provided for automatic detection and suppression of fire within the process cells using water sprinklers. The clean areas and rooms immediately surrounding the process cells will be equipped with portable extinguishers in addition to sprinklers. In addition to these provisions a fire station responds to the area full time and is equipped with two pumper trucks provided with high volume foam systems for extinguishing extensive fires.

9.2 Hazardous Materials

Since the assemblies reprocessed in the canyons will be cooled for 200 days, the hazardous short-lived fission product gases (such as ^{131}I) will have decayed to negligible levels and will not represent a significant hazard when released. The principal isotopes contained in the waste are given in Table 2-3.

9.3 Safety Evaluation

This section of the Technical Data Summary is a preliminary safety evaluation of storage and reprocessing operations to be carried out in the new incineration facility. The safety of the operation was evaluated for three sets of conditions defined below for the purpose of this analysis:

1. Normal Operating Conditions - These conditions cover operation of the system under normal design conditions.

2. Abnormal Operating Conditions - Operational transients which are a result of equipment malfunction or operator error. Although the probability of these events is considered to be low, safety systems should be incorporated into the equipment in order to terminate these events in a safe manner.

3. Design Basis Accidents - Postulated serious accidents for which protection must be provided to prevent unacceptable off-site consequences. The probability of occurence of these events is considered to be very low.

9.3.1 Normal Operating Conditions

The main hazards to be encountered by personnel during the normal course of operations will be the potential exposure to radiation and ingestion of radioactive particles. Shielding materials and/or distance will be provided so that personnel will not be exposed to radiation that exceeds allowable limits as specified in the Technical Standards. The radiation exposure hazard will be greatest during operations in which contaminated material is removed from the facilities, such as maintenance operations and solid waste removal. Each job will be planned so as to provide adequate safeguards. Extensive monitoring for contamination will be provided in all areas occupied by personnel. Detection equipment will warn operating personnel in the event of a release.

9.3.2 Abnormal Operating Conditions

9.3.2.1 Loss of Power

A backup utility system provides secondary utilities for an orderly process shutdown under emergency circumstances. An on-line, floating battery system provides electrical power for process controls, data collection, and to avert momentary power interruptions during switching which could result in control relay drop-out. A diesel-powered generator supplies standby power to high consumption equipment and vital motor driven equipment so as to not leave components stranded in a vulnerable phase of operation. Automatic switchgear is incorporated.

9.3.2.2 Process Upsets

Design consideration was given to the performance of the system under emergency, adverse or process upset conditions. Those considered are:

- Secondary combustion chamber fails to burn pyrolysis gases and tars
- Spray dryer does not cool gases
- Spray dryer or sintered metal filters cake particulates, plugs

In the event that the secondary combustion process fails the pyrolysis gases and tars must be removed ahead of the sintered metal filters to prevent their blinding and before dilution air is added, otherwise combustion can occur in the off-gas system. This can be accomplished by designing into the spray dryer, nozzles for adding sufficient quantities of deluging water to scrub the gases. An emergency collection vessel should be provided. Since this would saturate the gases with water, the emergency reheater would be turned on to heat them well above the dew point ahead of the sintered metal filters.

If the spray dryer should plug, it can be bypassed by switching a valve and additional air dilution activated to cool the gases from 1000°C to 88°C ahead of the HEPA filters.

The additional air dilution required for emergency cooling will require additional standby HEPA filters that can be placed in service during the emergency condition to maintain acceptable flow velocity at the filters.

Failure of some sintered metal filter elements will not cause severe operational problems because a spare bank will normally be available. The only serious difficulty could arise if the filters should generally become blinded by a wet cake or tars. If this were to occur, the sintered metal filters would have to be bypassed. The spare set of SMFs should be available. Then, if the source of the problem which causes the plugging is corrected, normal operations can continue, using the spare SMFs to protect the HEPA filters, while the original SMFs are cleaned or replaced as necessary.

In the case of sudden formation of a wet cake on the sintered metal filters, the cake could probably be removed by drying and blowback. During the initial bypassing of the sintered metal filters, the HEPA filters could operate for a moderate period of time; the normal air dilution would maintain the gas stream above the dew point. If longer operating time were required, activation of the flooding mode of the spray dryer, with emergency reheat, would provide some protection of the HEPA filters to prolong their use.

In the more serious case of tar formation on the sintered metal filters, they would have to be taken out of service for cleaning or replacement. If the source of tars cannot be quickly eliminated, activation of the flooding mode of the spray dryer would be required, with emergency reheat to above the dew point. While tar formation on the sintered metal filters may be considered the most serious type of process upset, it is also one of the least likely to occur. The secondary combustion chamber has a large heat capacity and would continue to quantitatively burn the pyrolysis gases and tars for several hours, even in the absence of a flame, providing sufficient oxygen were supplied.

9.3.3 Maximum Credible Accident

The maximum credible accident in the incinerator facility would be a raw combustible waste fire in the feed lag storage area which would then spread to the receiving area lag storage waste. The feed lag storage contains ∿64 waste boxes containing ∿18 mCi of fission products. The receiving lag storage contains up to 500 waste boxes containing 2 Ci of fission products and induced activity. During the conflagration 72 million BTU of energy may be released from the complete combustion of this stored waste.

Assuming 3 curies of fission product are released to the atmosphere, the maximum potential uptake of an active human being at the nearest plant boundary (∿10 km) would be 2 mrem lung and 1 mrem bone using the 70 year dose conversion factors and a 95th percentile distribution function.

These consequences, although not appreciable, would be very unlikely to occur because the lag storage areas are equipped with smoke and heat sensors, automatic fire extinguishing facilities and auxiliary manually operated extinguishers.

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