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Municipal Waste Combustion Study

Costs of Flue Gas Cleaning Technologies

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MUNICIPAL WASTE COMBUSTION STUDY:

COSTS OF FLUE GAS CLEANING TECHNOLOGIES

For Information Contact

Michael Johnston
U. S. Environmental Protection Agency
OAQPS/ESED (MD-13)
Research Triangle Park, North Carolina 27711
(919) 541-5601

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COSTS OF FLUE GAS CLEANING TECHNOLOGIES
EXECUTIVE SUMMARY

This report is an assessment of emission control costs for municipal waste combustors (MWC's). The details of the cost estimates, including their development, components, and design and cost premises, are addressed in the subsequent sections of this volume.

A model plant approach was used in the sizing and costing of the emission control systems. Due to differences in the feed waste characteristics, combustion parameters, and emissions, separate cost estimates were required for mass burning (MB), modular (MOD), refuse-derived fuel (RDF), and fluid bed combustion (FBC) type furnaces. Table 1 presents the MWC model plant specifications and the flue gas composition data used for sizing and costing of the emission control systems. Table 2 presents the MWC emissions control equipment design premises as reported by a number of air pollution control equipment manufacturers.

Cost estimates were developed for control of particulate matter (PM) emissions only and for control of both acid gas and PM emissions from the MWC model plants. Controlled PM emission levels of 0.03, 0.02, and 0.01 gr/dscf, corrected to 12 percent CO_2, and 90 and 70 percent reductions of HCl and SO_2, respectively, were used to develop the control cost estimates.

Electrostatic precipitators (ESP's) were evaluated as PM controls for all furnace types. Spray dryer/ESP (SD/ESP) and spray dryer/fabric filter (SD/FF) systems were evaluated as acid gas/PM controls for MB, MOD, and RDF model facilities. Fabric filters (FF's) were evaluated as alternative PM controls for FBC combustors. The flue gas from FBC combustors was assumed to contain a negligible amount of acid gas due to the neutralization of the acid gas in the flue gas by limestone which is introduced into the furnace bed.

Capital and annualized operating costs were developed in August 1986 dollars using the cost information received from a number of air pollution control equipment manufacturers for various flue gas flow rates and design capacities. The capital cost estimates for PM and acid gas/PM control systems for new MWC facilities are presented in Table 3. They were developed for 25 percent excess combustor capacity and include a 20 percent factor for contingencies. The capital costs presented in Table 3 represent the cost of the control system and auxiliary equipment (i.e., ductwork and I.D. fan). In addition, a cost credit was applied to facilities with acid gas control to account for the reduction in capital cost required to construct a stack which does not require acid-resistant lining.

The increase in capital cost for requiring acid gas control in addition to PM control for new facilities ranges from 50 to 500 percent. The lower value of the range represents the MB and RDF model facilities while the higher value represents MOD facilities. SD/FF systems require 0.5 to 5.5 percent less capital than SD/ESP systems for 1,000 tpd and larger MB and RDF model facilities at the 0.03 gr/dscf PM emission level, increasing to 5 to 8 percent at the 0.01 gr/dscf specification. For the MOD model facilities, SD/FF systems require an additional 30 percent of capital for acid gas/PM control as compared to a comparably designed SD/ESP systems.

Table 4 presents the annualized operating cost estimates for new MWC facilities for PM and acid gas/PM controls assuming 8,000 operating hours per year and 20 and 15 years of equipment life for PM and acid gas/PM control systems, respectively. Maintenance costs were assumed to be 2 percent of the total capital cost, the waste disposal cost was $15/ton, and taxes and insurance were considered to be 4 percent of the total capital cost. The interest rate for capital recovery charges was assumed to 10 percent.

Indirect operating costs are more significant than direct operating costs in each of the annualized operating cost estimates for the new facilities. Indirect costs represent from 60 to 80 percent of the total annualized cost of operating the emission control systems for MB and MOD facilities. The indirect operating costs are slightly lower (55 to

70 percent of the total annualized operating cost) for the RDF and FBC facilities, and are less than 50 percent of the total annualized operating cost for FBC facilities equipped with fabric filters.

The waste disposal cost is the major direct operating cost. The cost contribution of waste disposal to the total direct operating cost is proportional to the quantity disposed. Waste disposal costs represent from 25 to 40 percent of the total direct operating cost of PM emission control systems for MB facilities. Waste disposal costs for RDF and FBC facilities are 50 to 60 percent of the direct operating costs. The waste disposal costs for acid gas/PM controls are 15 to 30 percent for MB facilities and approximately 40 and 60 percent for RDF and FBC facilities, respectively. The waste disposal cost for MOD facilities is insignificant due to the small quantities of particulate matter generated.

Figures 1 through 4 present the annualized operating cost estimates for the emission control systems for the new MWC model plants in terms of dollars per ton of refuse burned. All figures indicate that the relative costs of operating the emission control systems decrease as the facility size increases. Also, as the PM emission levels become more stringent, the annualized operating costs increase. The additional cost of controlling acid gas along with PM emissions is $4 to $9 per ton for MB facilities. For the RDF model plants, acid gas control accounts for an additional $4 to $5 per ton. The corresponding cost for the model MOD facilities is $5 to $12 per ton.

The SD/ESP system is more costly to operate than the SD/FF system based on the information presented in Figures 1, 2, and 3. MB model plants with a 0.03 gr/dscf outlet PM loading and the MOD model plants are the execeptions. In general, however, the SD/ESP systems for the new MWC model plants require an additional $.20 to $.90 per ton of waste burned to operate per year than do comparable SD/FF systems. Fabric filters for FBC facilities require $1 to $3 per ton of waste burned less in annualized operating costs than do ESP systems.

The presentation of control cost information in terms of dollars per unit amount of PM removed is a convenient measure of the effectiveness of a PM control system. However, such information for acid gas/PM control systems could be misleading due to the additional PM emission quantities generated in the spray dryer. A better measure of the operating cost of acid gas/PM controls is provided by presenting the cost information in terms of dollars per unit of acid gas removed. Figures 5, 6, and 7 present the annualized operating cost in terms of $/lb of acid gas removed for SD/ESP and SD/FF systems for the new MB, MOD, and RDF model facilities.

Similar to the trends observed for the annualized operating costs in terms of dollars per ton of waste burned, acid gas emission control systems, in terms of dollars per pound of acid gas removed, become less costly as the facility size increases. An additional $.02 to $.20 per pound of acid gas removed is required to achieve 90 and 70 percent removal of HCl and SO_2, respectively, at an outlet grain loading of 0.01 gr/dscf than at 0.03 gr/dscf corrected to 12% CO_2. On the average, the annualized operating costs for an SD/FF, in dollars per pound of acid gas removed, is $.03 less costly than SD/ESP systems for the MB and RDF model plants. However, the cost to operate an SD/FF for a model MOD facility, in dollars per pound of acid gas removed, is on the average $.25 greater than an SD/ESP for the same facility.

Retrofit costs for air pollution control equipment for existing municipal waste combustors are also presented in this report. The emission control systems which were coated for the model existing facilities were designed to provide PM control only, or both acid gas and PM control. For the MB and RDF model existing facilities, the control systems evaluated included a spray dryer (SD) system retrofit to those facilities with a high-efficiency ESP currently in place, and a SD/FF system retrofit to facilities which have a wet scrubber or low-efficiency ESP currently in place. The majority of the existing MOD facilities are uncontrolled. Therefore, ESP's and SD/ESP's were evaluated for PM and acid gas/PM control, respectively, for the model MOD existing facilities.

The design parameters for the emission control systems for the model existing MWC facilities are identical to those discussed for the new MWC model facilities. The emission control systems were designed to achieve a PM emission level of 0.02 gr/dscf corrected to 12 percent CO_2, and 90 and 70 percent reduction of HCl and SO_2, respectively. One control unit was assumed for each model MOD existing facility and for each combustion unit in each MB and RDF model existing facility.

Tables 5 and 6 present the capital and annualized operating retrofit costs, respectively, for model existing refractory MB and MOD facilities. Similar cost estimates for existing waterwall MB, MOD, and RDF model facilities are presented in Tables 7 and 8. Retrofit factors were determined based on vendor contacts and previous retrofit studies within EPA with flue gas desulfurization systems in the utility industry. Several considerations should be taken into account when developing retrofit costs including the number and size of the air pollution control units, the spatial limitations, and the effect the retrofit air pollution control equipment will have on current process operation. For the purposes of this report, the capital and annualized operating retrofit cost estimates were intended to bound the potential retrofit costs which would be expected for the existing MWC population.

TABLE 1. MUNICIPAL WASTE COMBUSTOR MODEL PLANT SPECIFICATIONS AND FLUE GAS COMPOSITION DATA

Parameter	Facility type			
	MB	MOD	RDF	FBC
Facility specification				
Waste composition (wt %):				
Carbon	26.73	26.73	33.8	33.8
Hydrogen	3.6	3.6	4.5	4.5
Oxygen	19.74	19.74	27.9	27.9
Sulfur	0.12	0.12	0.2	0.2
Nitrogen	0.17	0.17	0.5	0.5
Water	27.14	27.14	25.2	25.2
Chlorine	0.38	0.32	0.39	0.32
Inerts	22.12	22.18	7.51	7.58
Excess combustion air, %	80	50	50	25
PM emission factor, % of waste inert converted to flyash	10	0.5	80	80
Amount of acid gas reaction products released into flue gas, %				80
Temperature, ^{o}F				
Waterwall	350	350	350	350
Refractory	450	450	450	
Flue gas parameters (calculated)				
Flow rate, dscf/lb of feed waste	83	69	85	70
scf/lb of feed waste	95	82	99	84
Uncontrolled PM emissions,				
gr/dscf at 12% CO_2	2.16	0.11	4.63	6.84
gr/dscf	1.87	0.11	4.98	8.83
Uncontrolled acid gas emissions,				
HCl, ppm dry	500	500	500	50
SO_2, ppm dry	175	211	286	104

TABLE 2. CONTROL EQUIPMENT DESIGN PREMISES FOR MUNICIPAL WASTE COMBUSTORS

Parameter	Facility type			
	MB	MOD	RDF	FBC
ESP system				
Specific collection plate area				
for 0.03 gr/dscf at 12% CO_2 outlet	332	138	409	409
for 0.02 gr/dscf at 12% CO_2 outlet	397	172	504	504
for 0.01 gr/dscf at 12% CO_2 outlet	500	208	545	545
Pressure drop, in. H_2O	2.5	2.5	2.5	2.5
Equipment life, years	20	20	20	20
FF system				
Air-to-cloth ratio, net				4:1
gross				3:1
Pressure drop, in. H_2O				7.5
Equipment life, years				20
Acid gas/PM system[a]				
SD exit temperature, $^{\circ}F$	280	280	280	
Alkali (lime) consumption, % of equivalency ratio	150	150	150	
Pressure drop, in. H_2O				
for SD/ESP system	7.5	7.5	7.5	
for SD/FF system	13	13	13	
Equipment life	15	15	15	

[a]Either SD/ESP system or SD/FF system.

TABLE 3. SUMMARY OF ESTIMATED CAPITAL COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL NEW MUNICIPAL WASTE COMBUSTOR FACILITIES[a] ($1,000s in August 1986 based on 8,000 hrs/yr operation)

PM emission level after control, gr/dscf at 12% CO_2	Mass burning model facilities			Modular model facilities			Refuse-derived fuel model facilities		Fluid bed combustion model facilities	
	250 tpd capacity (Model No. 1)	1,000 tpd capacity (Model No. 2)	3,000 tpd capacity (Model No. 3)	100 tpd capacity (Model No. 4)	250 tpd capacity (Model No. 5)	400 tpd capacity (Model No. 6)	1,500 tpd capacity (Model No. 7)	3,000 tpd capacity (Model No. 8)	250 tpd capacity (Model No. 9)	500 tpd capacity (Model No. 10)
ESP System										
0.03	1,549	3,900	10,230	341	695	1,020	6,919	12,006	1,756	2,762
0.02	1,951	4,693	11,830	447	845	1,194	8,293	14,245	2,204	3,410
0.01	2,252	5,521	14,105	487	929	1,314	9,193	15,881	2,270	3,589
SD/ESP System[b]										
0.03	4,108	9,352	23,197	1,426	2,420	3,149	14,413	25,917		
0.02	4,589	10,246	24,488	1,516	2,526	3,489	15,972	27,423		
0.01	4,868	10,916	26,641	1,564	2,648	3,609	16,539	28,069		
SD/FF System[b]										
0.03	4,242	8,905	21,691	1,960	3,176	4,179	13,170	22,042		
0.02	4,242	8,905	21,691	1,960	3,176	4,179	13,170	22,042		
0.01	4,421	9,463	23,197	2,020	3,296	4,779	13,989	23,119		
FF System										
0.03									996	1,690
0.02									996	1,690
0.01									996	1,690

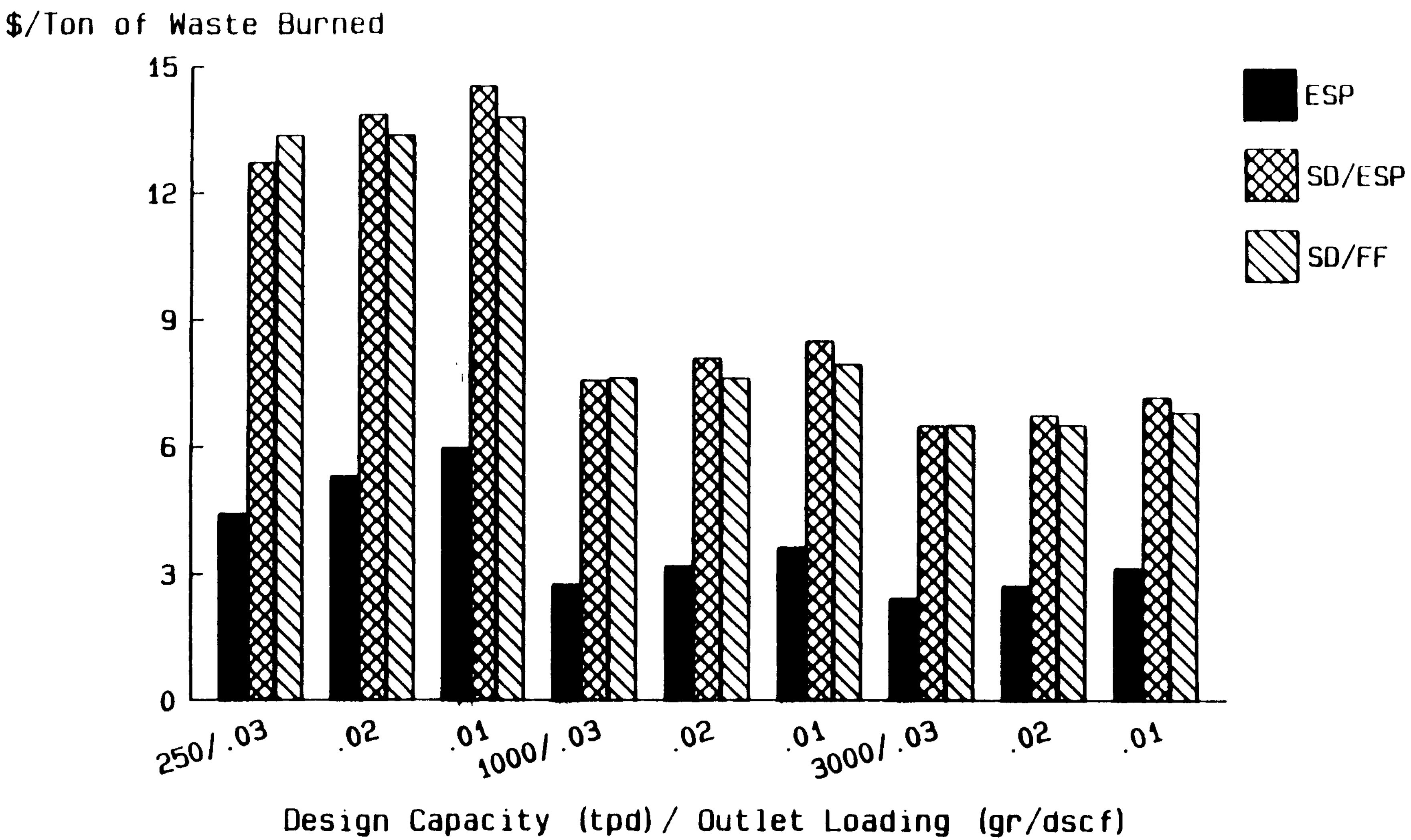
[a]The capital cost estimates were developed for control systems at 125 percent of actual size and include a 20 percent contingency factor.

[b]For 90 and 70 percent control of HCl and SO_2, respectively.

TABLE 4. SUMMARY OF ESTIMATED ANNUALIZED OPERATING COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL NEW MUNICIPAL WASTE COMBUSTOR FACILITIES ($1,000s in August 1986 based on 8,000 hrs/yr operation)

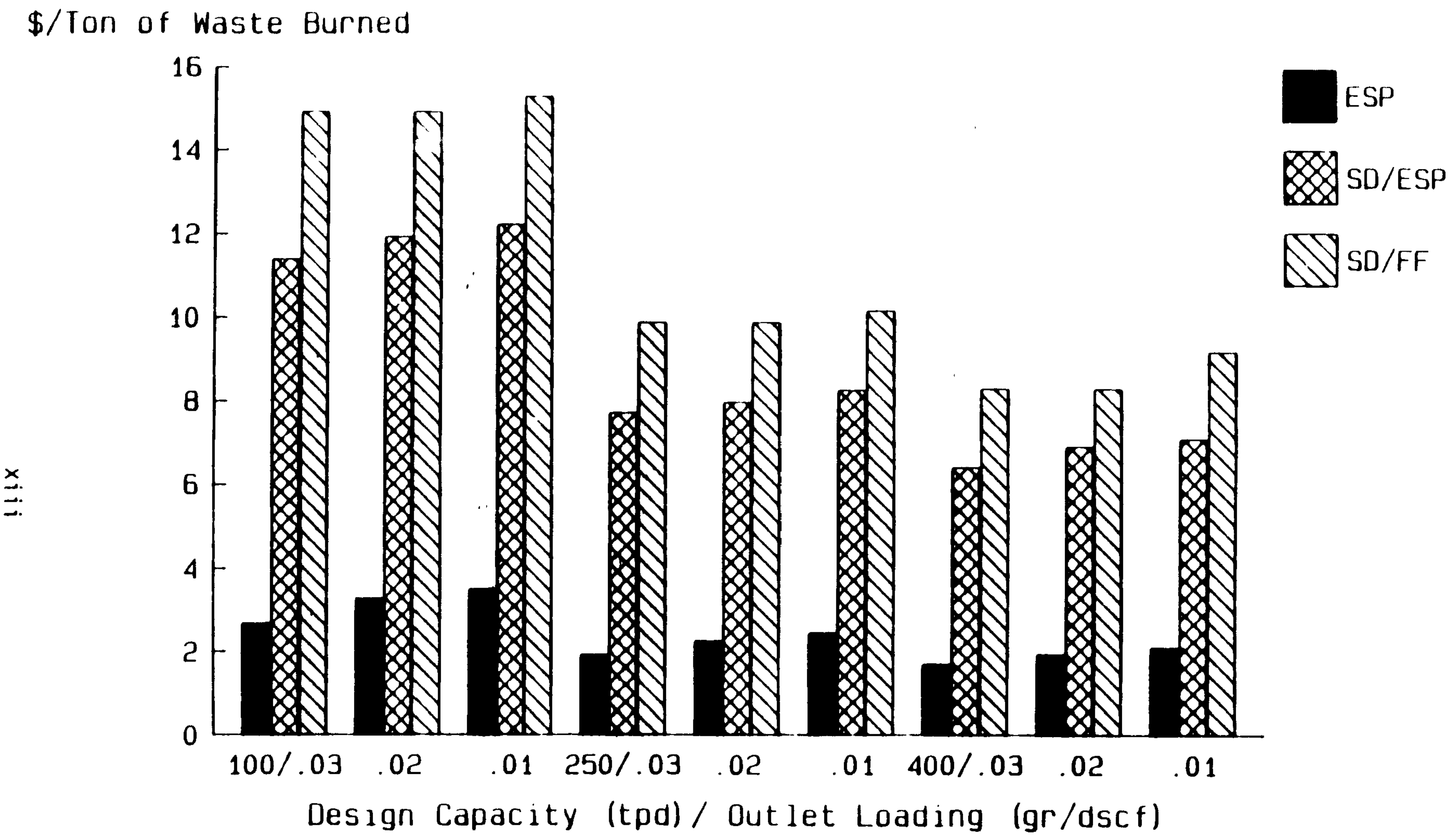
PM emission level after control, gr/dscf at 12% CO_2	Mass burning model facilities			Modular model facilities			Refuse-derived fuel model facilities		Fluid bed combustion model facilities	
	250 tpd capacity (Model No. 1)	1,000 tpd capacity (Model No. 2)	3,000 tpd capacity (Model No. 3)	100 tpd capacity (Model No. 4)	250 tpd capacity (Model No. 5)	400 tpd capacity (Model No. 6)	1000 tpd capacity (Model No. 7)	3,000 tpd capacity (Model No. 8)	250 tpd capacity (Model No. 9)	500 tpd capacity (Model No. 10)
ESP System										
0.03	370	921	2,449	90	162	[illegible]	1,865	3,348	489	795
0.02	443	1,067	2,744	110	190	261	2,118	3,761	571	915
0.01	499	1,220	3,163	117	206	283	2,284	4,063	584	948
SD/ESP System[a]										
0.03	1,061	2,529	6,515	380	645	858	4,278	7,876		
0.02	1,156	2,706	6,771	398	666	925	4,632	8,176		
0.01	1,212	2,839	7,198	408	691	949	4,700	8,305		
SD/FF System[a]										
0.03	1,115	2,549	6,538	498	825	1,110	4,198	7,442		
0.02	1,115	2,549	6,540	498	825	1,110	4,199	7,444		
0.01	1,150	2,661	6,838	510	849	1,229	4,362	7,637		
FF System										
0.03									375	649
0.02									375	649
0.01									375	650

[a] 90 and 70 percent control of HCl and SO_2, respectively.



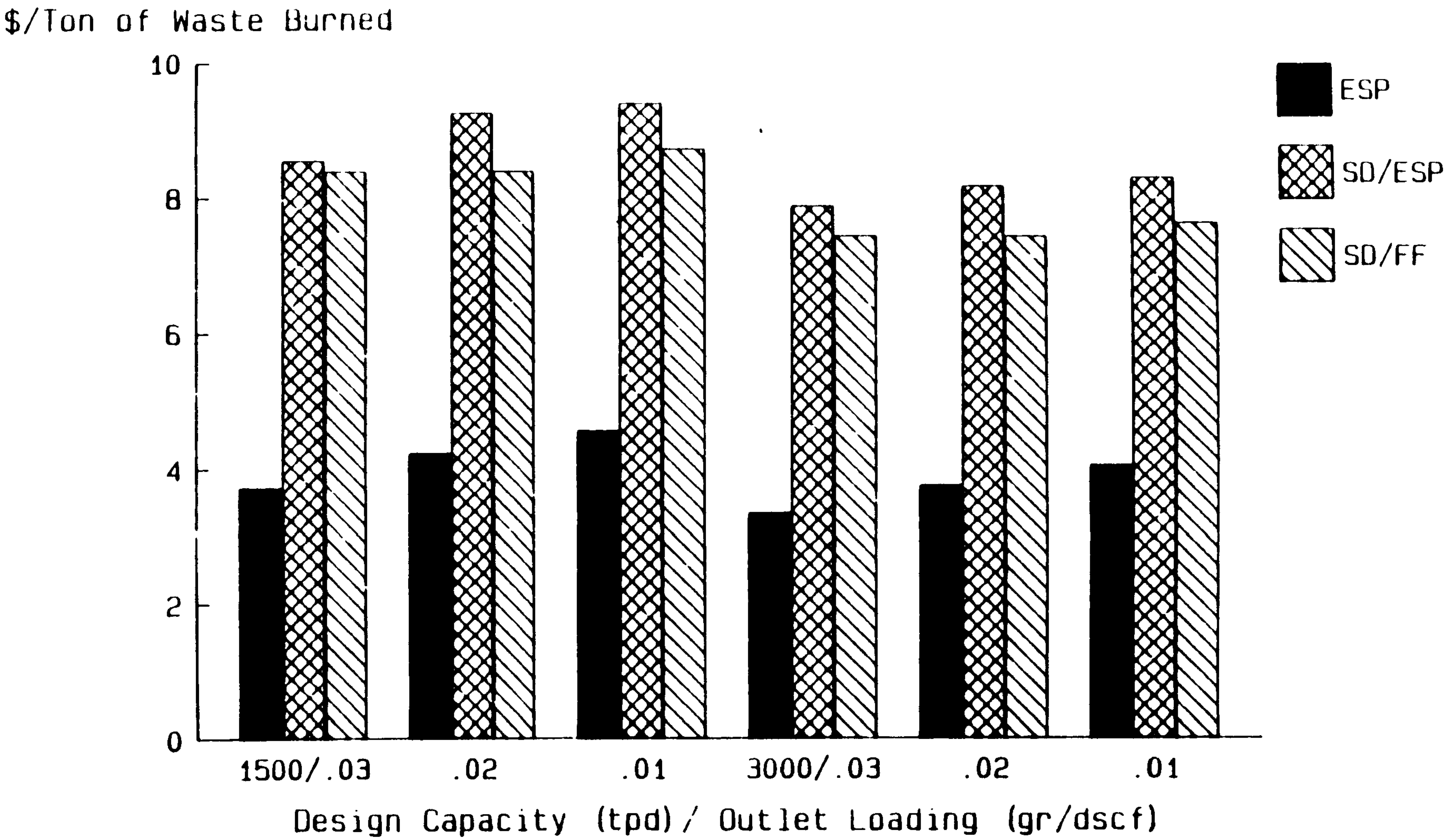
8000 hrs/yr operation
August 1986 dollars

Figure 1. Annualized Operating Cost Estimates for Model New Mass Burning Facilities



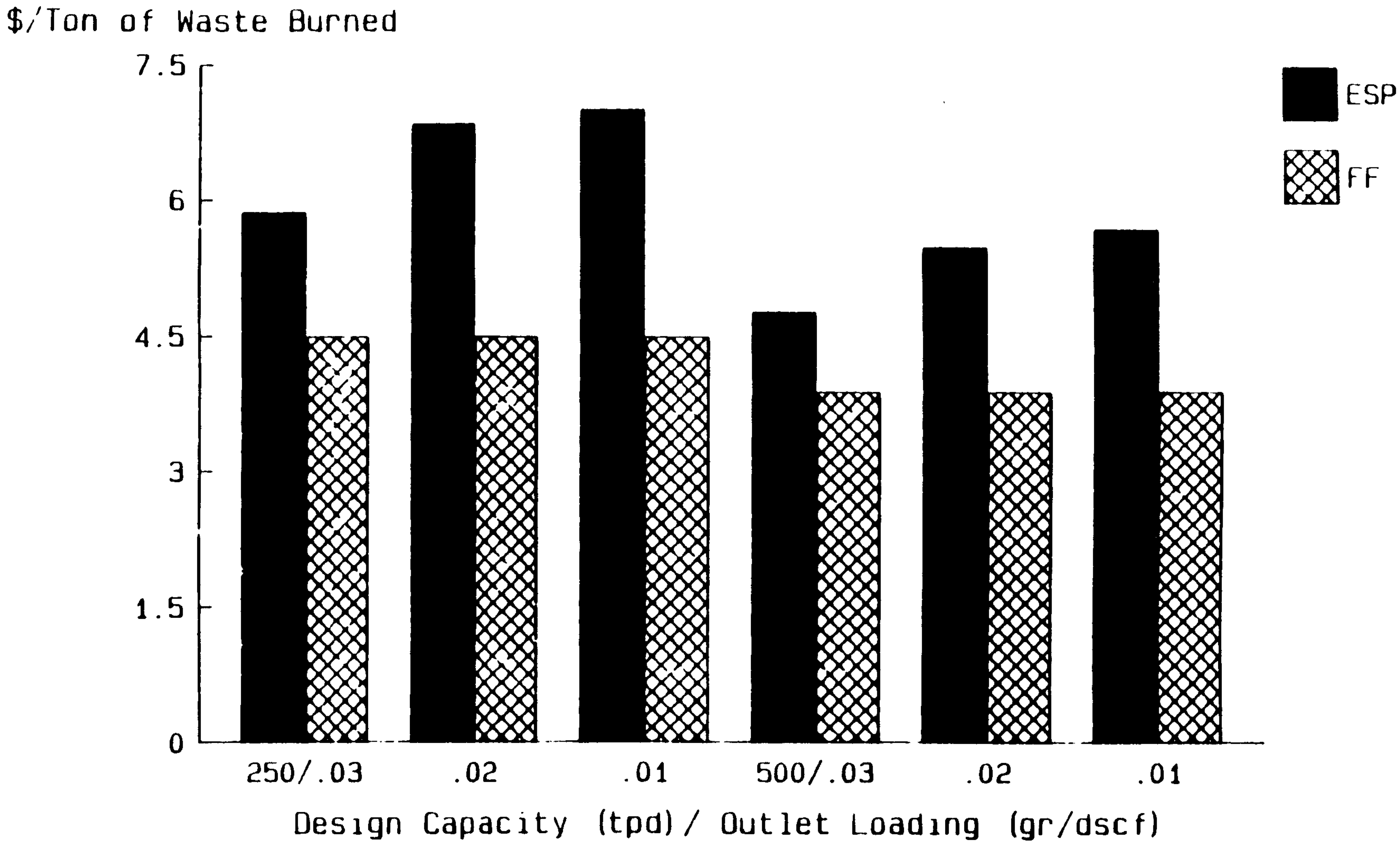
8000 hrs/yr operation
August 1986 dollars

Figure 2. Annualized Operating Cost Estimates for Model New Modular Combustor Facilities



8000 hrs/yr operation
August 1986 dollars

Figure 3. Annualized Operating Cost Estimates for Model New Refuse-Derived Fuel Burning Facilities

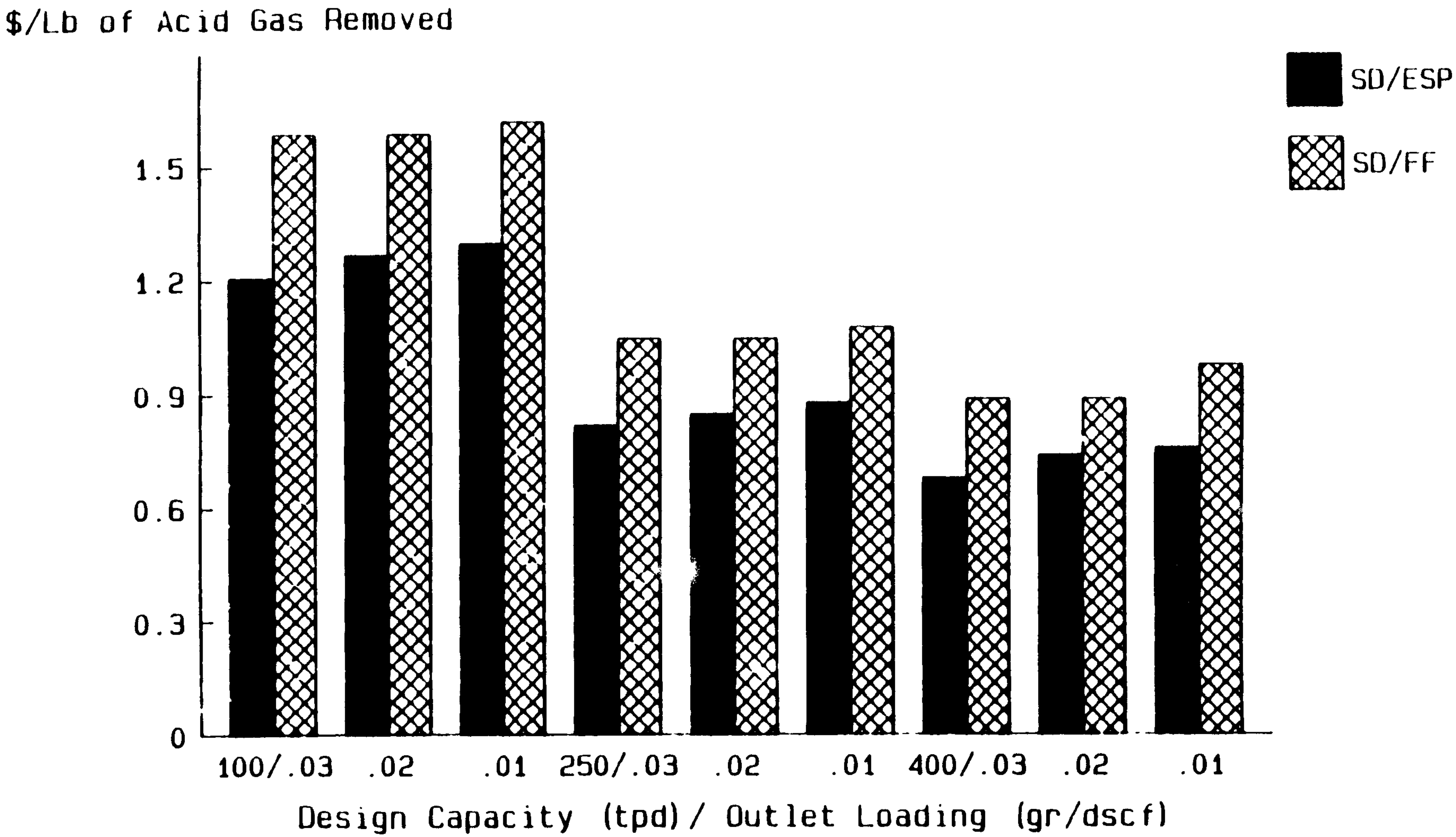


8000 hrs/yr operation
August 1986 dollars

Figure 4. Annualized Operating Cost Estimates for Model New Fluid Bed Combustion Facilities

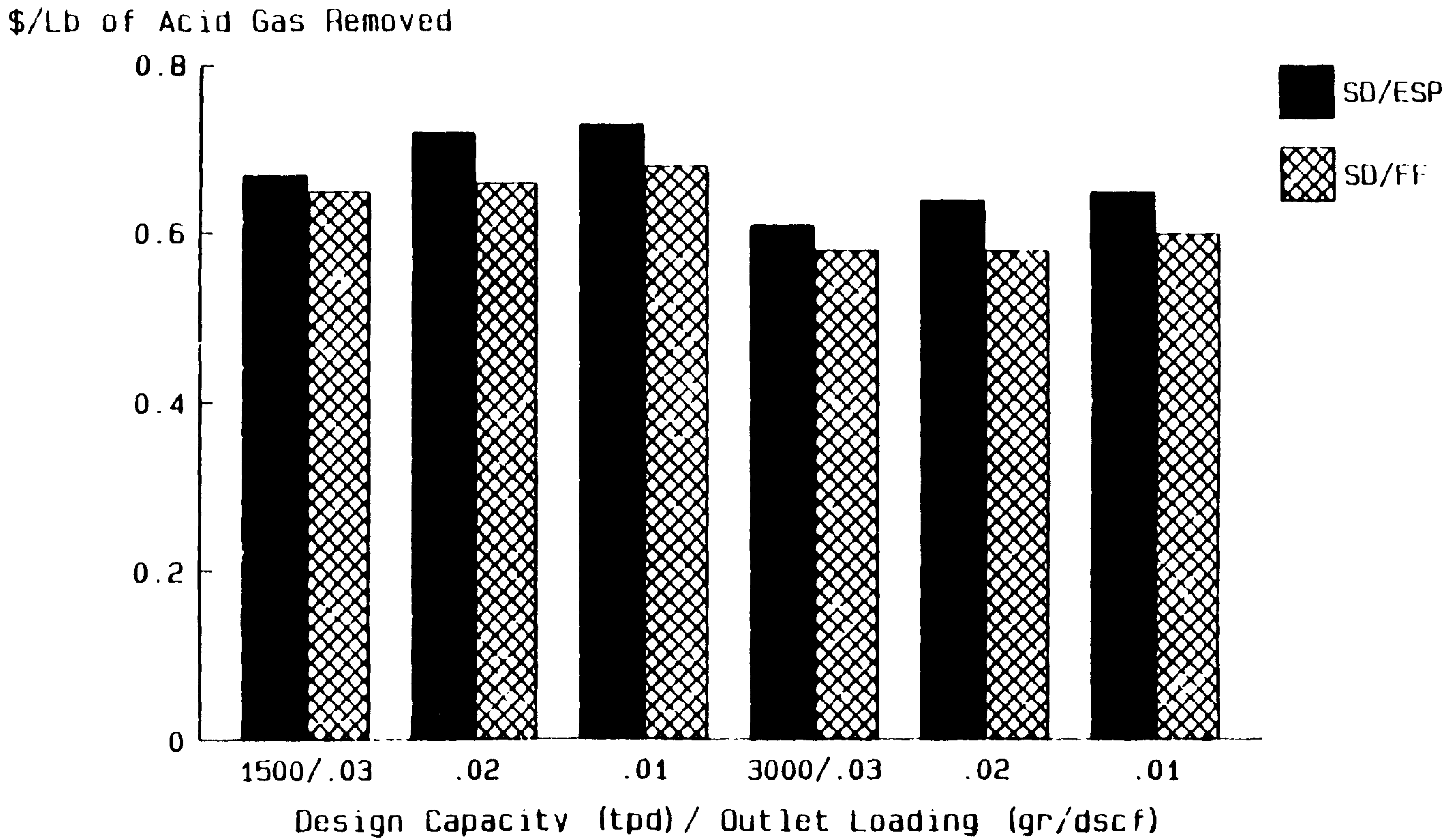
8000 hrs/yr operation
August 1986 dollars

Figure 5. Annualized Operating Cost Estimates for Acid gas Removal for Model New Mass Burning Facilities



8000 hrs/yr operation
August 1986 dollars

Figure 6. Annualized Operating Cost Estimates for Acid gas Removal for Model New Modular Combustor Facilities



8000 hrs/yr operation
August 1986 dollars

Figure 7. Annualized Operating Cost Estimates for Acid gas removal for Model New Refuse-Derived Fuel Burning Facilities

TABLE 5. SUMMARY OF ESTIMATED CAPITAL COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL EXISTING REFRACTORY MUNICIPAL WASTE COMBUSTOR FACILITIES ($1000s in August 1986 based on 6,500 hrs/yr operation)

Control Device	Mass Burning Model Facilities					Modular Model Facilities
	200 tpd capacity (Model No. 1)	450 tpd capacity (Model No.2)	600 tpd capacity (Model No. 3)	750 tpd capacity (Model No. 4)	1200 tpd capacity (Model No. 5)	100 tpd capacity (Model No. 6)
ESP System[a]						526
DS/ESP System[a,b]						2,819
DS System[b]			6,005	6,879	10,325	
DS/FF System[a,b]	6,335	11,346	11,062	12,728	18,745	

[a]0.02 gr/dscf corrected to 12 percent CO_2.

[b]90 and 70 percent reduction of HCl and SO_2, respectively.

TABLE 6. SUMMARY OF ESTIMATED ANNUALIZED OPERATING COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL EXISTING REFRACTORY MUNICIPAL WASTE COMBUSTOR FACILITIES ($1000s in August 1986 based on 6,500 hrs/yr operation)

Control Device	Mass Burning Model Facilities					Modular Model Facilities
	200 tpd capacity (Model No. 1)	450 tpd capacity (Model No. 2)	600 tpd capacity (Model No. 3)	750 tpd capacity (Model No. 4)	1200 tpd capacity (Model No. 5)	100 tpd capacity (Model No. 6)
ESP System[a]						123
DS/ESP System[a,b]						645
DS System[b]			1,669	1,941	2,884	
DS/FF System[a,b]	1,478	2,686	2,692	3,124	4,597	

[a]0.02 gr/dscf corrected to 12 percent CO_2.

[b]90 and 70 percent reduction of HCl and SO_2, respectively.

TABLE 7. SUMMARY OF ESTIMATED CAPITAL COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL EXISTING WATERWALL MUNICIPAL WASTE COMBUSTOR FACILITIES ($1000s in August 1986 based on 6,500 hrs/yr operation)

Control Device	Mass Burning Model Facilities				Modular Model Facilities			Refused-derived Fuel Model Facilities		
	200 tpd capacity (Model No. 1)	400 tpd capacity (Model No. 2)	1000 tpd capacity (Model No. 3)	2200 tpd capacity (Model No. 4)	100 tpd capacity (Model No. 5)	200 tpd capacity (Model No. 6)	300 tpd capacity (Model No. 7)	1000 tpd capacity (Model No. 8)	2200 tpd capacity (Model No. 9)	3000 tpd capacity (Model No. 10)
ESP System[a]					487	788	999			
DS/ESP System[a,b]					2,551	3,853	4,866			
DS System[b]	3,063	4,544	9,901	14,353				10,202	12,926	19,492
DS/FF System[a,b]	5,997	8,539	18,690	25,307				19,189	22,090	34,058

[a]0.02 gr/dscf corrected to 12 percent CO_2.

[b]90 and 70 percent reduction of HCl and SO_2, respectively.

TABLE 8. SUMMARY OF ESTIMATED ANNUALIZED OPERATING COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL EXISTING WATERWALL MUNICIPAL WASTE COMBUSTOR FACILITIES ($1000s in August 1986 based on 6,500 hrs/yr operation)

Control Device	Mass Burning Model Facilities				Modular Model Facilities			Refused-derived Fuel Model Facilities		
	200 tpd capacity (Model No. 1)	400 tpd capacity (Model No. 2)	1000 tpd capacity (Model No. 3)	2200 tpd capacity (Model No. 4)	100 tpd capacity (Model No. 5)	200 tpd capacity (Model No. 6)	300 tpd capacity (Model No. 7)	1000 tpd capacity (Model No. 8)	2200 tpd capacity (Model No. 9)	3000 tpd capacity (Model No. 10)
ESP System[a]					115	177	224			
DS/ESP System[a,b]					578	884	1,124			
DS System[b]	810	1,222	2,724	4,278				3,067	4,574	6,350
DS/FF System[a,b]	1,399	2,030	4,506	6,543				4,876	6,458	9,558

[a]0.02 gr/dscf corrected to 12 percent CO_2.

[b]90 and 70 percent reduction of HCl and SO_2, respectively.

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1. INTRODUCTION

This report is an assessment of emission control costs for municipal waste combustors. The information presented in this report was developed during a comprehensive, integrated study of municipal waste combustion. An overview of the findings of this study may be found in the Report to Congress on Municipal Waste Combustion (EPA/530-SW-87-021a). Other technical volumes issued as part of the Municipal Waste Combustion Study include:

- Emission Data Base for Municipal Waste Combustors (EPA/530-SW-87-021b)
- Combustion Control of Organic Emissions (EPA/530-SW-87-021c)
- Flue Gas Cleaning Technology (EPA/530-SW-87-021d)
- Sampling and Analysis of Municipal Waste Combustors (EPA/530-SW-87-021f)
- Assessment of Health Risks Associated with Exposure to Municipal Waste Combustion Emissions (EPA/530-SW-87-021g)
- Characterization of the Municipal Waste Combustor Industry (EPA/530-SW-87-021h)
- Recycling of Solid Waste (EPA/530-SW-87-021i)

The approach taken for this report was to determine the capital and annualized costs of installing and operating add-on air pollution control devices for new and existing municipal waste combustion facilities.

MWC model plants were developed for the purpose of developing emission control cost information. The model plants are representative of the MWC's which are currently planned, under construction, or in existence in the United States with regard to design capacity and technology. They provide a basis for calculating the flue gas quantity and composition. The model facilities are comprised of mass burning (MB) units, modular combustor (MOD) facilities, refuse-derived fuel burning (RDF) plants, and fluid bed combustion (FBC) facilities.

The air pollution control devices which were costed for these facilities were electrostatic precipitators (ESP's) and fabric filters (FF's) for particulate matter (PM) control, and spray dryer/ESP's

(SD/ESP's) and SD/FF's for acid gas/PM control. They were designed to achieve emission levels of 0.03, 0.02, and 0.01 gr/dscf at 12% CO_2 for PM, and 90 and 70 percent reduction of HCl and SO_2, respectively, for acid gas.

Capital and annualized operating costs were determined for the air pollution control equipment based on cost information received from air pollution control equipment manufacturers. The cost estimates, presented in the following sections of this document, are in August 1986 dollars and assume 8,000 hrs/yr of operation for new MWC's and 6,500 hrs/yr of operation for existing facilities and 25 percent excess design capacity. Annualized operating cost estimates for new MWC facilities are calculated in terms of $/ton of waste burned, $/ton of flyash removed, and $/lb of acid gas removed.

The remainder of the report is divided into five sections. Section 2 describes the model plants and flue gas compositions for new MWC facilities. Section 3 is a discussion of the control system design evaluations. Capital and annualized operating cost estimates for emission control systems for new MWC's are presented in Section 4. Cost analyses for new facilities are presented in Section 5, including costs per ton of waste burned and per unit of pollutant removed. Section 6 is a discussion of retrofit costs for the existing population of municipal waste combustors.

2. NEW MUNICIPAL WASTE COMBUSTOR MODEL PLANTS

For the purpose of developing emission control cost information for new and proposed municipal waste combustors (MWC's), ten model plants were developed. They are representative of the MWC's which are currently planned or under construction in the United States and they are intended to approximate these units with regard to design capacity and technology. The intent of the ɔdel plants was to provide a basis for calculating flue gas quantities and compositions for the sizing and costing of the associated emission control systems. The model plant specifications and flue gas composition data are listed in Table 2-1 and are described in the following sections.

2.1 MODEL PLANTS

The ten model plants developed to represent new and proposed MWC's include three mass burning (MB) facilities, three modular combustor (MOD) facilities, two refuse-derived fuel (RDF) burning facilities, and two fluid bed combustion (FBC) facilities. The design and operation of these facilities is described more fully in "Municipal Waste Combustion Study: Combustion Control of Organic Emissions" (EPA/530-SW-87-021c). The primary design parameters specified for each model plant are listed in Table 2-1 and include: design capacity, excess air rate, feed waste inert composition, and the emission factors for uncontrolled particulate matter (PM) and acid gas (HCl and SO_2).

The excess air rate and feed waste composition are the main parameters which determine the flue gas quantities and compositions generated per unit of waste burned. The excess air rates specified for combustion were 80, 50, 50, and 25 percent of the stoichiometric air requirements for the MB, MOD, RDF, and FBC model plants, respectively. The respective uncontrolled PM emission factors for the models plants were 10, 0.5, 80, and 80 percent of the feed waste inert composition.

Acid gas emission factors were based on the assumption that the entire sulfur and chlorine composition of the incoming feed was converted to SO_2 and HCl upon combustion. For FBC model plants, a negligible amount of acid gas is assumed to be released in the flue gas due to the introduction of

TABLE 2-1. MODEL PLANT SPECIFICATIONS AND FLUE GAS COMPOSITION DATA

Item	Model plants[a]									
	No. 1 (MB)	No. 2 (MB)	No. 3 (MB)	No. 4 (MOD)	No. 5 (MOD)	No. 6 (MOD)	No. 7 (RDF)	No. 8 (RDF)	No. 9 (FBC)	No. 10 (FBC)
Facility Specification										
No. of combustors per model	2	2	4	2	5	8	3	4	2	2
Total daily charge rate, tpd	250	1,000	3,000	100	250	400	1,500	3,000	250	500
Hourly charge rate at 100% utilization, lb/hr	20,833	83,333	250,000	8,333	20,833	33,333	125,000	250,000	20,833	41,667
Ash content of feed waste, %	22.12	22.12	22.12	22.18	22.18	22.18	7.51	7.51	7.58	7.58
Excess combustion air, % of theoretical	80	80	80	50	50	50	50	50	25	25
PM emission factor, % of feed waste ash	10	10	10	0.50	0.50	0.50	80	80	80	80
Acid gas emission factor:										
HCl, ppm dry	500	500	500	500	500	500	500	500	50	50
SO_2, ppm dry	175	175	175	211	211	211	286	286	103	103
Flue gas data per combustor[b]										
Volume flow rate:										
dscfm	14,362	57,447	86,170	4,776	4,776	4,776	58,703	88,055	12,205	24,411
scfm	16,579	66,315	99,473	5,663	5,663	5,663	68,490	102,736	14,653	29,306
acfm	25,337	101,350	152,025	8,654	8,654	8,654	104,674	157,011	22,394	44,788
Outlet Temperature, °F[c]	350	350	350	350	350	350	350	350	350	350
PM emissions[d]:										
gr/dscf	1.87	1.87	1.87	0.11	0.11	0.11	4.98	4.98	8.83	8.83
gr/scf	1.62	1.62	1.62	0.10	0.10	0.10	4.26	4.26	7.35	7.35
gr/acf	1.06	1.06	1.06	0.06	0.06	0.06	2.79	2.79	4.81	4.81
gr/dscf at 12% CO2	2.16	2.16	2.16	0.11	0.11	0.11	4.63	4.63	6.84	6.84
gr/dscf at 7% O2	2.26	2.26	2.26	0.11	0.11	0.11	4.99	4.99	7.36	7.36
lb/hr	230	922	1,383	4.6	4.6	4.6	2,503	3,755	923	1,847
tons/yr at 8,000 hrs/yr	920	3,688	5,532	18	18	18	10,012	15,020	3,692	7,388
Acid gas emissions[d]:										
HCl, lb/hr	41	163	244	14	14	14	167	250	3.4	6.9
tons/yr at 8,000 hrs/yr	164	652	976	56	56	56	668	1000	13.6	27.6
SO2, lb/hr	25	100	150	10	10	10	167	250	12.5	25
tons/yr at 8,000 hrs/yr	100	400	600	40	40	40	668	1,000	50	100

[a]MB - Mass burning, MOD - Modular, RDF - Refuse-derived fuel, and FBC - Fluid bed combustion.

[b]Calculated (except where indicated) based on the facility specifications in this table and the feed waste composition data from Table 2-2.

[c]Assumed.

[d]For FBC model plants (i.e., Model plants 9 and 10), PM emissions consist of the acid gas/limestone reaction products and impurities in addition to the flyash formed from feed waste inerts. Acid gas emissions represent the unreacted HCl and SO_2 quantities only.

limestone into the FBC bed. The SO_2 and HCl formed during combustion react with the limestone thus reducing the acid gas content of the flue gas exiting the combustor. The products of the reaction are released as PM in the flyash.

2.2 FLUE GAS COMPOSITION

The calculated flue gas compositions of PM and acid gas for each model plant are presented following the model facility specifications in Table 2-1. Flue gas composition is a function of combustor type, operating conditions, and feed waste composition. The combustor type establishes two parameters: (a) excess air rate and (b) the uncontrolled PM and acid gas emission rates. The operating conditions establish flue gas temperature and pressure. The feed waste composition determines the amount and composition of the flue gas generated.

Table 2-2 presents the feed waste compositions specified for the model plants. These waste compositions and the specified excess air rates were used to calculate the flue gas quantities and PM and acid gas emission rates presented in Table 2-1. The calculated flue gas compositions for the model plants are presented in Table 2-3. These calculations were based on the assumption that the feed waste utilization rate was 100 percent and combustion was complete.

TABLE 2-2. FEED WASTE COMPOSITION DATA[a]
(Weight Percent)

Constituent	MB facilities	MOD facilities	RDF facilities	FBC facilities
Carbon	26.73	26.73	33.8	33.8
Hydrogen	3.6	3.6	4.5	4.5
Oxygen	19.74	19.74	27.9	27.9
Sulfur	0.12	0.12	0.2	0.2
Nitrogen	0.17	0.17	0.5	0.5
Water	27.14	27.14	25.2	25.2
Chlorine	0.38	0.32	0.39	0.32
Inerts	22.12	22.18	7.51	7.58

[a]Table 2-3 presents dry and wet flue gas compositions for the feed waste characteristics given above.

TABLE 2-3. CALCULATED FLUE GAS COMPOSITIONS[a]
(Volume %)

Constituent[b]	Mass burning units		Modular facilities		RDF facilities		FBC facilities	
	Vol % Dry	Vol % Wet	Vol % Dry	Vol % Wet	Vol % Dry	Vol % Wet	Vol % Dry	Vol % Wet
CO_2	10.41	9.02	12.53	10.56	12.88	11.04	15.49	12.91
SO_2	0.02 (175 ppm)	0.02 (152 ppm)	0.02 (211 ppm)	0.02 (178 ppm)	0.03 (286 ppm)	0.02 (245 ppm)	0.03 (104 ppm)	0.03 (86 ppm)
HCl	0.05 (500 ppm)	0.04 (433 ppm)	0.05 (507 ppm)	0.04 (427 ppm)	0.05 (500 ppm)	0.04 (431 ppm)	0.05 (50 ppm)	0.04 (41 ppm)
O_2	9.39	8.14	7.06	5.96	7.03	6.02	4.23	3.52
N_2	80.13	69.41	80.34	67.75	80.01	68.57	80.2[illegible]	66.80
H_2O		13.37		15.66		14.29		16.70
Mol. wt	30.05	28.44	30.30	28.37	30.36	28.59	30.66	28.55

[a]Results are based on feed waste composition data presented in Table 2-2.

[b]SO_2 and HCl flue gas quantities from FBC facilities represent only those portions remaining following reaction with limestone which is introduced into the combustor at 300 percent of the equivalency ratio.

3. CONTROL SYSTEM DESIGN EVALUATIONS

This section presents design evaluations for the PM and acid gas/PM emission control equipment for the MWC model plants. The emission control systems were evaluated for achieving PM emission levels of 0.03, 0.02, and 0.01 gr/dscf corrected to 12 percent CO_2, and 90 and 70 percent reduction of HCl and SO_2 emissions, respectively. Table 3-1 presents the predicted uncontrolled and controlled PM and acid gas emission quantities, and the required control efficiencies for achieving the specified emission levels, for each new MWC model facility.

The emission control systems which were evaluated for the new MWC model plants included electrostatic precipitators (ESP's) as PM controls for all model plants. Spray dryer/ESP (SD/ESP) and spray dryer/fabric filter (SD/FF) systems were evaluated as acid gas/PM controls for the MB, MOD, and RDF model plants (i.e., Model plants 1 through 8). For FBC model plants (i.e., Model plants 9 and 10), FF's were evaluated as an alternative to ESP's for PM control. Acid gas controls were not evaluated for FBC facilities. Limestone injection, inherent to the process, accounts for acid gas control in these model plants.

The control devices listed above and evaluated in this report are more fully described in "Municipal Waste Combustion Study: Flue Gas Cleaning Technology" (EPA/530-SW-87-021e). There is evidence to suggest that controlling PM and acid gas emissions to the assumed levels with these control devices is effective in reducing emissions of heavy metals and dioxins (see "Municipal Waste Combustion Study: Emission Data Base for Municipal Waste Combustors," EPA/530-SW-87-021b). The design parameters for the emission control systems evaluated in this report and the outlet flue gas composition data are discussed in the following sections.

3.1 CONTROL SYSTEMS DESIGN PARAMETERS

The primary design factors evaluated for the MWC emission control systems were specific collection plate area (SCA) for ESP's, air-to-cloth ratio (A:C) for FF's, and spray dryer outlet temperature and lime consumption rate for spray dryers.

TABLE 3-1. MODEL PLANT CONTROLLED AND UNCONTROLLED EMISSION DATA

Parameter	Model plants									
	No. 1 (MB)	No. 2 (MB)	No. 3 (MB)	No. 4 (MOD)	No. 5 (MOD)	No. 6 (MOD)	No. 7 (RDF)	No. 8 (RDF)	No. 9 (FBC)	No. 10 (FBC)
Total facility daily charge rate, tpd	250	1,000	3,000	100	250	400	1,500	3,000	250	500
No. of combustor units	2	2	4	2	5	8	3	4	2	2
Emissions (Total for Model Plant)										
PM emissions:[a]										
Design inlet (i.e., uncontrolled),										
gr/dscf at 12% CO_2	2.16	2.16	2.16	0.11	0.11	0.11	4.63	4.63	5.84	5.84
lb/hr	460	1,844	5,532	9	23	37	7,509	15,020	1,846	3,694
tons/yr	1,840	7,376	22,128	36	92	148	30,036	60,080	7,384	14,776
Required control efficiency (%) for outlet level of:										
0.03 gr/dscf at 12% CO_2		98.6			72.7		99.4	99.4	99.6	99.6
0.02 gr/dscf at 12% CO_2		99.1			81.8		99.6	99.6	99.7	99.7
0.01 gr/dscf at 12% CO_2		99.5			90.9		99.8	99.8	99.9	99.9
Design outlet (i.e., controlled), lb/hr (tpy) for outlet level of										
0.03 gr/dscf at 12% CO_2	6.4 (26)	25.8 (103)	77.4 (310)	2.5 (10)	6.3 (25)	10.1 (40)	45.1 (180)	90.1 (360)	7.4 (30)	14.8 (59)
0.02 gr/dscf at 12% CO_2	4.1 (16)	16.6 (66)	49.8 (199)	1.6 (6)	4.2 (17)	6.7 (27)	30 (120)	60 (240)	5.5 (22)	11.1 (44)
0.01 gr/dscf at 12% CO_2	2.3 (9)	9.2 (37)	27.7 (111)	0.8 (3)	2.1 (8)	3.3 (13)	15 (60)	30 (120)	1.8 (7)	3.7 (15)
HCl emissions:[b]										
Design inlet (i.e., uncontrolled),										
ppm dry					500				50	50
lb/hr	82	326	976	28	70	112	501	1000	6.8	13.8
tpy	328	1,304	3,904	112	280	448	2,004	4,000	27	55
Control efficiency, (%)					90					
Outlet emissions (i.e., controlled)										
ppm		49			50		49	49		
lb/hr	8.2	32.6	97.6	2.8	7.0	11.2	50.1	100		
tpy	33	130	390	11	28	45	200	400		
SO_2 emissions:[b]										
Design inlet (i.e., uncontrolled),										
ppm dry		175			211		286	286	103	103
lbs/hr	50	200	600	20	50	80	501	1,000	25	50
tpy	200	800	2,400	80	200	320	2,004	4,000	100	200
Control efficiency, %					70					
Outlet emissions (i.e., controlled)										
ppm		53			62		84	84		
lbs/hr	15	60	180	6	15	24	150	300		
tpy	60	240	720	24	60	96	600	1,200		

[a]For FBC facility models (i.e., Models 9 and 10), the PM emissions consist of flyash and acid gas/limestone reaction products and impurities.
[b]HCl and SO_2 emissions from FBC models represent the unreacted acid gas only.

(a) ESP's - Table 3-2 presents the suggested SCA values for ESP's as applied to the different MWC model plants for achieving PM emission levels of 0.03, 0.02, and 0.01 gr/dscf corrected to 12% CO2. These SCA values are the averages of values suggested by several ESP manufacturers. As the inlet loading is increased and/or outlet loading decreased, the SCA requirement of an ESP is greater in order to enhance the collection efficiency of the ESP. Since the SCA is directly related to the size and therefore the cost of an ESP, changing the inlet or outlet loading of the ESP directly affects the cost of that unit.

(b) Fabric Filters - Both reverse air and pulse jet type FF's are applied in the MWC industry. However, pulse jet type FF's, with a net air-to-cloth ratio of 4-to-1, and gross air-to-cloth ratio of as low as 3-to-1, are more commonly used.

(c) Spray Dryers - A key factor to spray dryer operation is the outlet temperature which is controlled by the amount of water in the absorbent feed. During spray dryer operation, the feed water is evaporated into the flue gas thereby reducing its temperature. The rate of water addition is limited by the set temperature at the spray dryer outlet. In addition, the reactions of HCl and SO_2 with the absorbent, hydrated lime, proceed rapidly while surface liquid is present but proceed more slowly when the absorbent is dry. Calcium chloride, the product resulting from the reaction between lime slurry and HCl, is hygroscopic if exposed to high humidity flue gas at temperatures below $250^{o}F$ ($121^{o}C$). Therefore, to obtain a dry waste product, the spray dryer design must ensure that a temperature of at least $250^{o}F$ ($121^{o}C$)is maintained. Thus, the alkaline absorbent spray drying process to neutralize HCl and SO_2 is most effective at a spray dryer outlet temperature between $260^{o}F$ ($127^{o}C$) and $300^{o}F$ ($149^{o}C$). For the purposes of developing cost estimates in this report, the spray dryer outlet temperature was assumed to be $280^{o}F$ ($138^{o}C$).

The rate of addition of hydrated lime in the alkaline feed to the spray dryer is controlled by the HCl and SO_2 composition of the flue gas. Available data indicates that an HCl removal efficiency of at least 90 percent and an SO_2 removal efficiency of up to 70 percent can be achieved in the spray dryer process if the hydrated lime is maintained at approximately 150 percent of the equivalency ratio. The equivalency ratio is defined as the

TABLE 3-2. ESP SPECIFIC COLLECTION PLATE AREA FOR MWC APPLICATIONS

Type of incinerator	Inlet PM loading, gr/dscf corrected to 12% CO_2	Average SCA[a], ft^2/1,000 acfm for outlet loading of		
		0.03 gr/dscf	0.02 gr/dscf	0.01 gr/dscf
MB	1.72	332	397	500
MOD	0.11	138	172	208
RDF & FBC	4.63 and 6.04	409	504	545

[a]SCA - Specific collection plate area. The SCA value listed is the average of values submitted by several ESP manufacturers.

combined stoichiometric molar requirement of hydrated lime per mole of HCl and mole of SO_2 in the entering flue gas. For a given acid gas removal requirement, an SD/FF system would consume approximately 10 to 15 percent less alkali than an SD/ESP system because of the additional acid gas removal that occurs in the fabric filter. However, for the purpose of this report, the same alkali equivalency ratio was assumed for both the SD/FF and SD/ESP systems. Table 3-3 presents the assumed design premises and calculated material balances for the spray dryer as applied to the new MB, MOD, and RDF model plants for acid gas removal.

3.2 CONTROL SYSTEM OUTLET FLUE GAS COMPOSITION

Tables 3-4 and 3-5 present calculated flue gas compositions at the outlet of the PM and acid gas/PM control systems, respectively, for each new MWC model facility. The PM content of the flue gas entering the PM control device of an acid gas/PM system is greater than the PM content of the flue gas entering a system designed for PM control only. The difference in the PM content is due to the introduction of solids into the flue gas as a result of the reaction between the acid gas and alkali in the spray dryer.

For FBC models, the uncontrolled flue gas emission quantities were calculated by estimating the rate of limestone consumed in the combustor for neutralizing 90 percent of the HCl and 70 percent of the SO_2 in the flue gas. Table 3-6 presents the assumed design premises and calculated material balance data for the acid gas/limestone reaction products which enter the emission control system in the FBC model plants.

TABLE 3-3. LIME SPRAY DRYER MATERIAL BALANCE FOR NEW MB, MOD, AND RDF MODELS[a]

Item	Model plants							
	No. 1 (MB)	No. 2 (MB)	No. 3 (MB)	No. 4 (MOD)	No. 5 (MOD)	No. 6 (MOD)	No. 7 (RDF)	No. 8 (RDF)
Waste throughput rate per combustor, tpd	125	500	750	100	250	400	500	750
Alkali equivalency ratio, %[b]	150	150	150	150	150	150	150	150
Lime purity, %[b]	90	90	90	90	90	90	90	90
Lime consumption, lb/hr	88	354	531	64	161	257	457	685
tons/yr	352	1,416	2,124	256	644	1,028	1,828	2,740
SD outlet temperature, °F[b]	280	280	280	280	280	280	280	280
Water consumed, gpm	2	9	13	1	4	6	9	13
<u>Amount of solids at the SD exit,</u> lbs/hr, (tons/yr)								
Flyash	230 (920)	922 (3,688)	1,383 (5,532)	9 (36)	23 (92)	37 (148)	2,503 (10,012)	3,755 (15,020)
Unreacted alkali and impurities	57 (228)	227 (908)	340 (1,360)	41 (164)	104 (416)	167 (688)	302 (1,208)	453 (1,812)
Reaction products	110 (440)	438 (1,752)	657 (2,628)	79 (316)	195 (780)	313 (1,252)	541 (2,164)	811 (3,244)
Solids dropout in SD (10%)	40 (160)	159 (636)	238 (952)	13 (52)	32 (128)	52 (208)	335 (1,340)	502 (2,008)
Total solids in flue gas leaving SD	357 (1,428)	1,428 (5,712)	2,142 (8,568)	116 (464)	290 (1,160)	465 (1,860)	3,011 (12,044)	4,517 (18,068)

[a]Calculations are based on 8,000 hrs of operation per year.

[b]Specified.

TABLE 3-4. FLUE GAS COMPOSITIONS AT THE OUTLET OF PM CONTROL SYSTEMS

Flue gas composition[a]	Model plants									
	No. 1(MB) 250 tpd	No. 2(MB) 1,000 tpd	No. 3(MB) 3,000 tpd	No. 4(MOD) 100 tpd	No. 5(MOD) 250 tpd	No. 6(MOD) 400 tpd	No. 7(RDF) 1,500 tpd	No. 8(RDF) 3,000 tpd	No. 9(FBC) 250 tpd	No. 10(FBC) 500 tpd
Temperature, °F	340	340	340	340	340	340	340	340	340	340
Volume flow rate per combustor:										
dscfm	14,362	57,447	86,170	4,776	4,776	4,776	58,703	88,055	12,205	24,411
scfm	16,579	66,315	99,473	5,663	5,663	5,663	68,490	102,736	14,653	29,306
acfm	25,025	100,099	150,148	8,548	8,548	8,548	103,382	155,073	22,117	44,235
PM emissions:[b]										
gr/acf at 0.03 gr/dscf	<----	0.015	---->	<----	0.017	---->	0.017	0.017	0.020	0.020
at 0.02 gr/dscf	<----	0.01	---->	<----	0.011	---->	0.011	0.011	0.015	0.015
at 0.01 gr/dscf	<----	0.005	---->	<----	0.005	---->	0.006	0.006	0.005	0.005
Acid gas emissions:[b]										
HCl, actual ppm	<----	287	---->	<----	279	---->	284	284	28	28
SO_2, actual ppm	<----	100	---->	<----	118	---->	162	162	57	57

[a]Per combustor.

[b]Corrected to 12 percent CO_2.

TABLE 3-5. FLUE GAS COMPOSITIONS AT THE OUTLET OF ACID GAS/PM CONTROL SYSTEMS

Flue gas composition[a]	MB models No. 1 250 tpd	MB models No. 2 1000 tpd	MB models No. 3 3000 tpd	MOD models No. 4 100 tpd	MOD models No. 5 250 tpd	MOD models No. 6 400 tpd	RDF models No. 7 1,500 tpd	RDF models No. 8 3,000 tpd
Spray Dryer Outlet								
Temperature, °F	<— 280 —>							
Volume flow rate:								
dscfm	14,635	58,540	87,810	9,733	24,332	38,931	59,816	89,724
scfm	17,247	68,987	103,480	11,779	29,449	47,118	71,253	106,879
acfm	24,080	96,321	144,482	16,447	41,117	65,787	99,485	149,227
PM emissions:								
gr/scf	2.41	2.41	2.41	1.15	1.15	1.15	4.93	4.93
gr/acf	1.73	1.73	1.73	0.82	0.82	0.82	3.53	3.53
gr/dscf at 12% CO_2	3.35	3.35	3.35	1.36	1.36	1.36	5.57	5.57
lbs/hr	357	1,428	2,142	116	291	465	3,011	4,517
Acid gas emissions:								
HCl, ppm	<— 49 —>			<— 50 —>			<— 49 —>	
lb/hr	4	16	24	1	1	1	17	25
SO_2, ppm	<— 53 —>			<— 62 —>			84	84
lb/hr	8	30	45	3	3	3	50	75
PM Control Outlet								
Temperature, °F	<— 270 —>							
Volume flow rate:								
dscfm	14,635	58,540	87,810	9,733	24,332	38,931	59,816	89,724
scfm	17,247	69,987	103,480	11,779	29,449	47,118	71,253	106,879
acfm	23,775	96,397	142,529	16,224	40,562	64,898	98,141	147,211
PM emissions:[b]								
gr/acf at 0.03 gr/dscf	0.016	0.016	0.016	0.018	0.018	0.018	0.018	0.018
at 0.02 gr/dscf	0.01	0.01	0.01	0.012	0.012	0.012	0.012	0.012
at 0.01 gr/dscf	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Acid gas emissions:[b]								
HCl, ppm	<— 49 —>			<— 50 —>			<— 49 —>	
lb/hr	4	16	24	1	1	1	17	25
SO_2, ppm	<— 53 —>			<— 62 —>			84	84
lb/hr	8	30	45	3	3	3	50	75

[a]Per combustor.

[b]Corrected to 12 percent CO_2.

TABLE 3-6. ALKALI MATERIAL BALANCE FOR FBC MODELS[a,b]

Item	Model 9	Model 10
Waste throughput rate per combustor, tpd	125	250
Limestone equivalency ratio, %	300	300
Limestone purity, %	90	90
Carryover of solids into flue gas, %	80	80
Limestone consumption, lbs/hr	374	747
tons/yr	(1,496)	(2,988)
<u>Solids in flue gas at the FBC exit,</u> lbs/hr (tons/yr)		
Flyash	632 (2,528)	1,263 (5,052)
Unreacted limestone and impurities at 80% carryover	209 (836)	418 (1,672)
Reaction products at 80% carryover	82 (328)	165 (660)
Total solids in flue gas leaving FBC	923 (3,692)	1,846 (7,384)

[a]Limestone is injected into the FBC bed.

[b]Calculations are based on 8,000 hrs/yr of operation.

4. CONTROL SYSTEM COST EVALUATIONS

This section presents estimates for the capital and annualized operating costs to control PM and acid gas/PM emissions from new MWC model plants to the specified levels. The cost methodology is presented, and the assumptions are discussed, for calculating the capital and annualized operating costs of the control and auxiliary equipment (i.e., I.D. fan and ductwork).

4.1 CONTROL SYSTEMS

As described earlier, the control systems evaluated for the new MWC model plants include ESP's for all of the models plants, SD/ESP and SD/FF systems for the MB, MOD, and RDF model plants, and FF's for the FBC model plants. The number and size of the control units included in each control system were determined based on common practice at actual MWC installations currently planned or under construction in the United States.

The control systems evaluated for MOD model plants were based on one control unit per model. For all other model facilities, the control systems evaluated were assumed to include one control unit per combustor. Each unit in a control system was designed to handle 125 percent of the actual flue gas flow rate in order to accommodate changes in flue gas flow rates as a result of variations in feed waste composition and operating conditions.

4.2 CAPITAL COSTS

The capital costs of the air pollution control systems in this report include all of the cost items necessary to design, purchase, and install that system. The purchase cost includes the cost of the control device and auxiliaries (i.e., I.D. fan and ductwork). Installation charges include foundation and erection costs, electrical costs, and instrumentation and control costs. Engineering services, taxes, contractor's fee, and contingencies are considered indirect installation costs.

(a) Methodology for Estimating Capital Costs - Capital costs were developed for the PM and acid gas/PM control systems by separately estimating capital costs for the main equipment and the auxiliary equipment. The capital costs for the main equipment (i.e., ESP's, FF's, SD/ESP's, and

SD/FF's) were calculated as follows. Design parameters for one unit of each control system in each model plant were developed assuming 125 percent of actual combustor design capacity. These design parameters were submitted to a number of air pollution control equipment manufacturers with a request for the capital cost information of a control unit for controlling MWC emissions to the specified levels. Table 4-1 presents the control unit design parameters submitted to the equipment manufacturers for each new MWC model plant.

The cost data received were normalized to represent a common set of design and cost premises. The estimated capital cost of one unit of each control system for each model plant are presented in Figures 4-1 to 4-8 in terms of flowrate into the unit for the specified outlet grain loadings of 0.03, 0.02, and 0.01 gr/dscf corrected to 12 percent CO_2.

The normalized cost of each air pollution control unit (CU) was incorporated into the expression below to estimate the total capital cost of main equipment in a multi-unit control system for a model plant.

$$C_1 = C_u \times (0.1375 + 0.8625\ N)$$

where C_1 = Capital cost of main equipment in the control system

C_u = Normalized cost of one unit of the control system

N = Number of units in a control system.

The above expression was developed based on the assumption that 20 and 80 percent of the purchase cost of a control unit was for engineering and fabrication, respectively. Installation charges were considered to be 60 percent of the purchase cost. Engineering and equipment installation costs were assumed to be 50 and 20 percent lower, respectively, for additional units in a multi-unit control system.

TABLE 4-1. SPECIFICATIONS SUBMITTED TO EQUIPMENT MANUFACTURERS FOR CONTROL EQUIPMENT

Specification[a]	Model plants[a]									
	No. 1 (MB)	No. 2 (MB)	No. 3 (MB)	No. 4 (MOD)	No. 5 (MOD)	No. 6 (MOD)	No. 7 (RDF)	No. 8 (RDF)	No. 9 (FBC)	No. 10 (FBC)
Incinerator capacity, tpd	156.25	625	937.5	125	312.5	500	625	937.5	156.25	312.5
Flue gas data										
Volume flow rate:										
scfm	20,724	82,894	124,341	14,157	35,392	56,628	85,613	128,420	18,316	36,632
acfm	31,672	126,687	190,031	21,636	54,090	86,544	130,843	196,264	27,992	55,985
Outlet Temperature, °F	350	350	350	350	350	350	350	350	350	350
Moisture content, %	13.37	13.37	13.37	15.67	15.67	15.67	14.29	14.29	16.70	16.70
PM emissions:										
gr/dscf at 12% CO_2	2.16	2.16	2.16	0.11	0.11	0.11	4.63	4.63	6.84	6.84
gr/scf	1.62	1.62	1.62	0.1	0.1	0.1	4.26	4.26	7.35	7.35
Acid gas emissions:										
HCl, ppm dry	500	500	500	500	500	500	500	500	50	50
SO_2, ppm dry	175	175	175	211	211	211	286	286	104	104

[a]Represents 125 percent of actual combustor capacity and flue gas generated for each model plant.

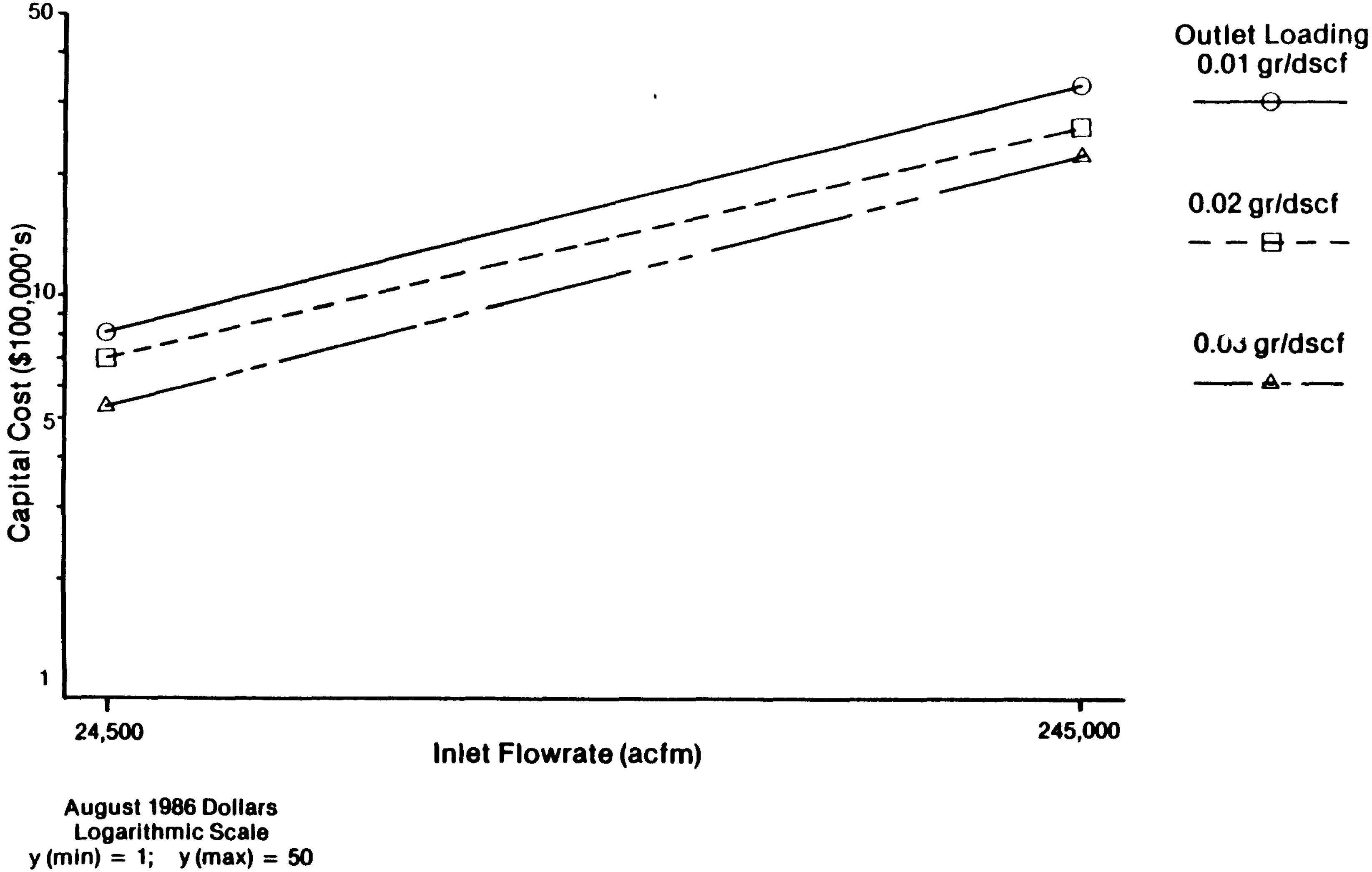
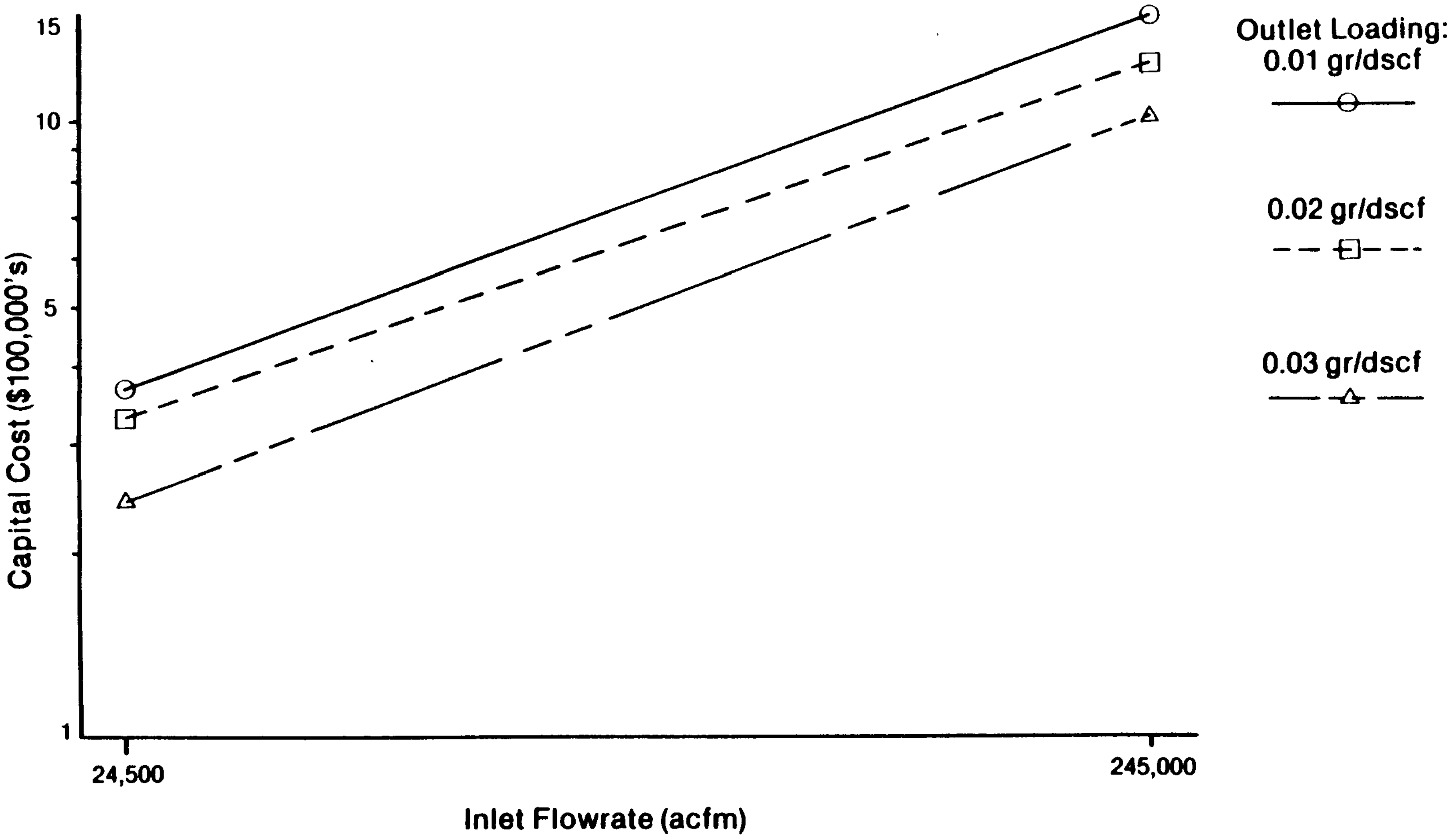


Figure 4 - 1. Capital Cost Estimates of an ESP for a Model Mass Burning Facility



August 1986 Dollars
Logarithmic Scale
y (min) = 1; y (max) = 15

Figure 4 - 2. Capital Cost Estimates of an ESP for a Model Modular Combustor Facility

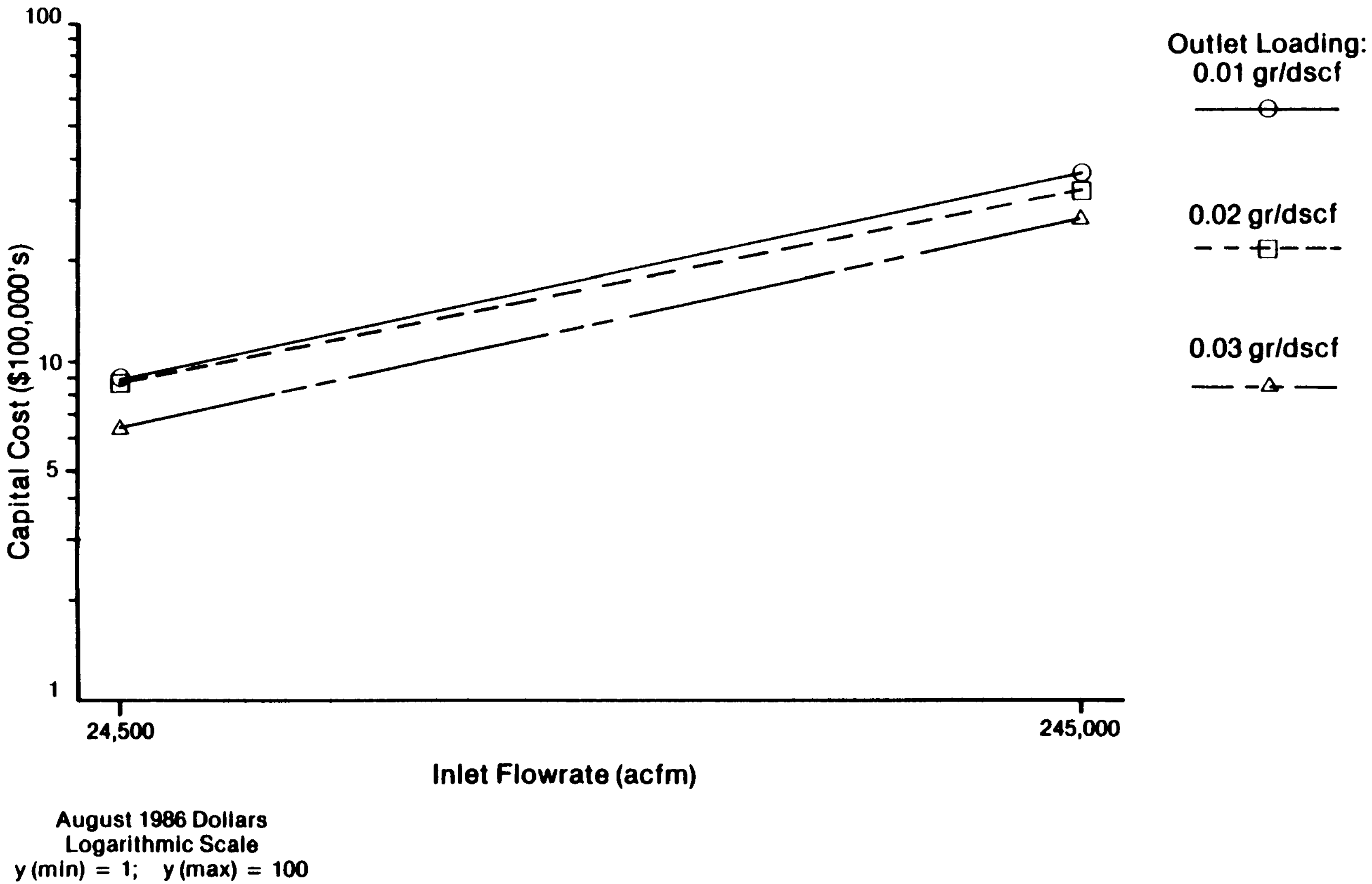
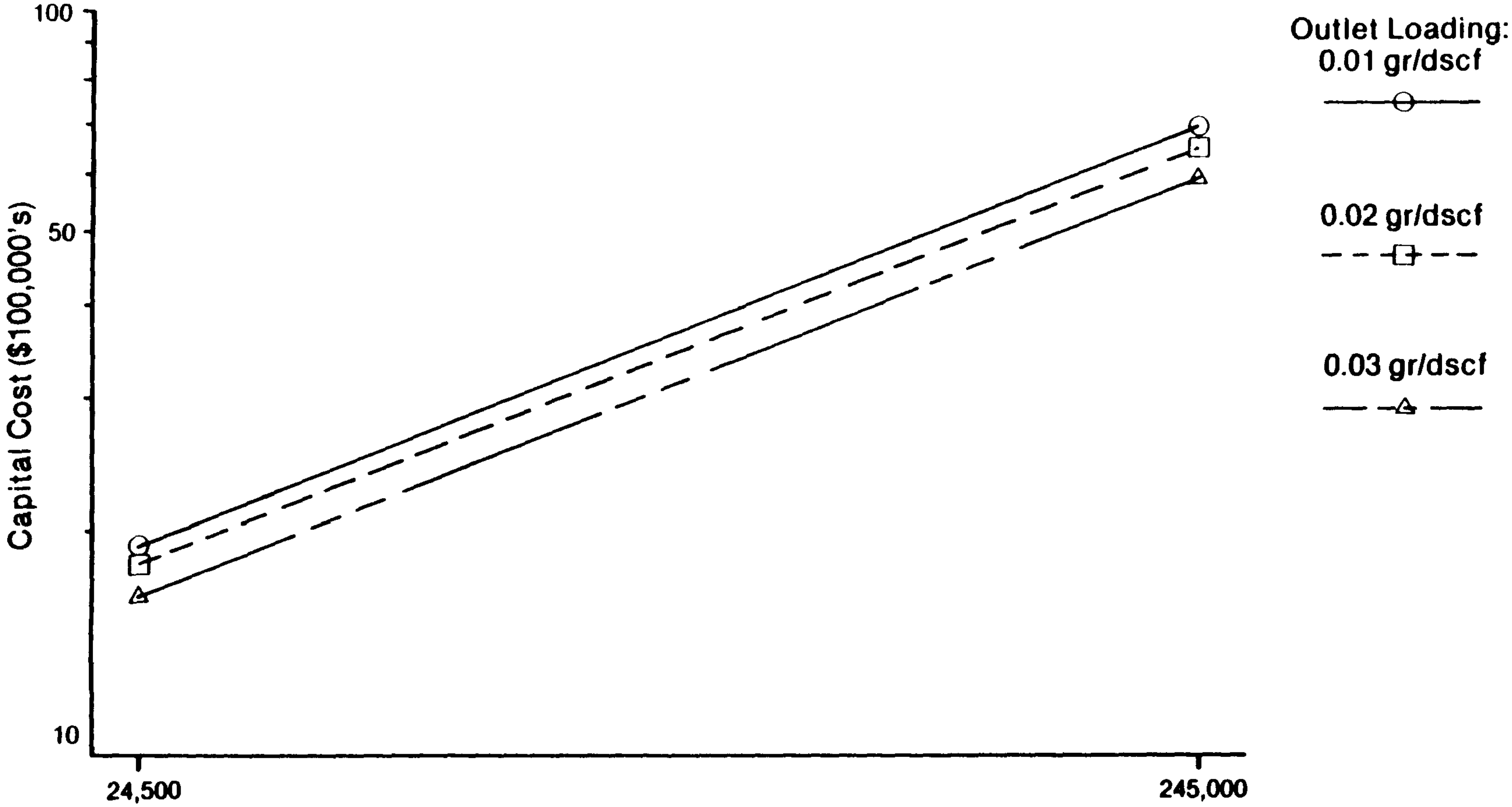
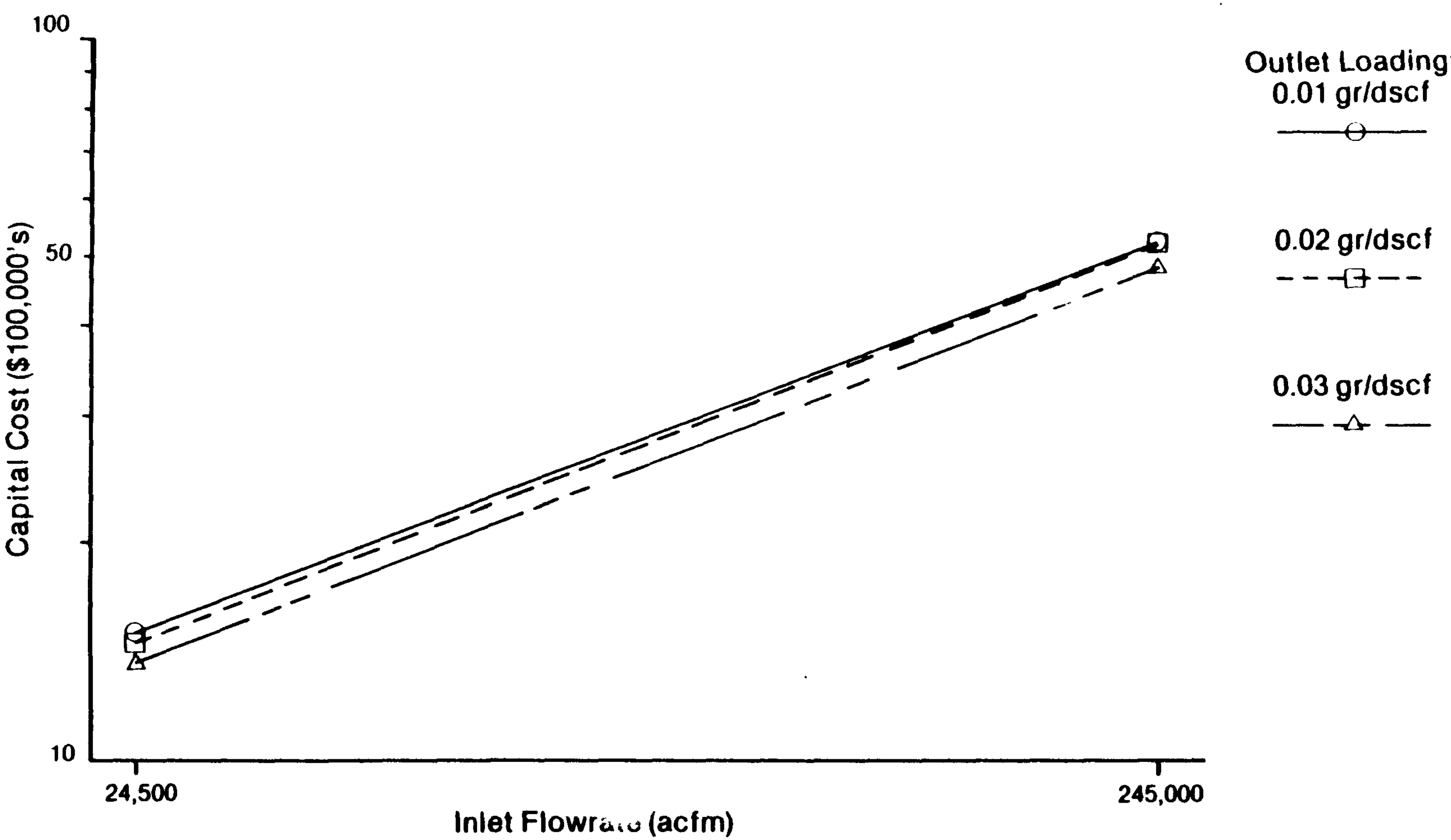


Figure 4-3. Capital Cost Estimates of an ESP for a Model RDF Facility and FBC Facility



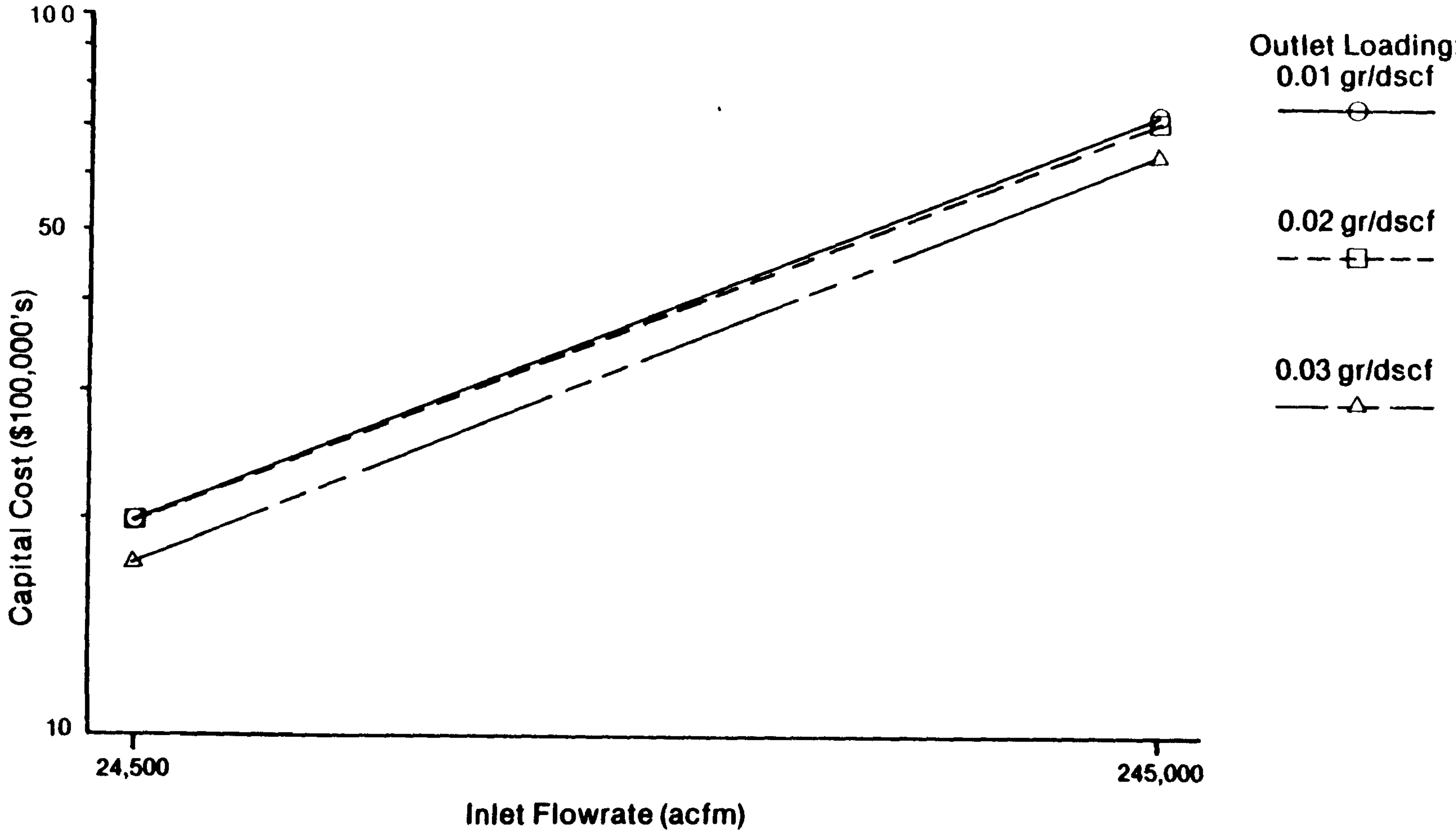
August 1986 Dollars
Logarithmic Scale
y (min) = 10; y (max) = 100

Figure 4-4. Capital Cost Estimates of an SD/ESP for a Model Mass Burning Facility



August 1986 Dollars
Logarithmic Scale
y (min) = 10; y (max) = 100

Figure 4 - 5. Capital Cost Estimates of an SD/ESP for a Model Modular Combustor Facility



August 1986 Dollars
Logarithmic Scale
y (min) = 10; y (max) = 100

Figure 4 - 6. Capital Cost Estimates of an SD/ESP for a Model Refuse-Derived Fuel Burning Facility

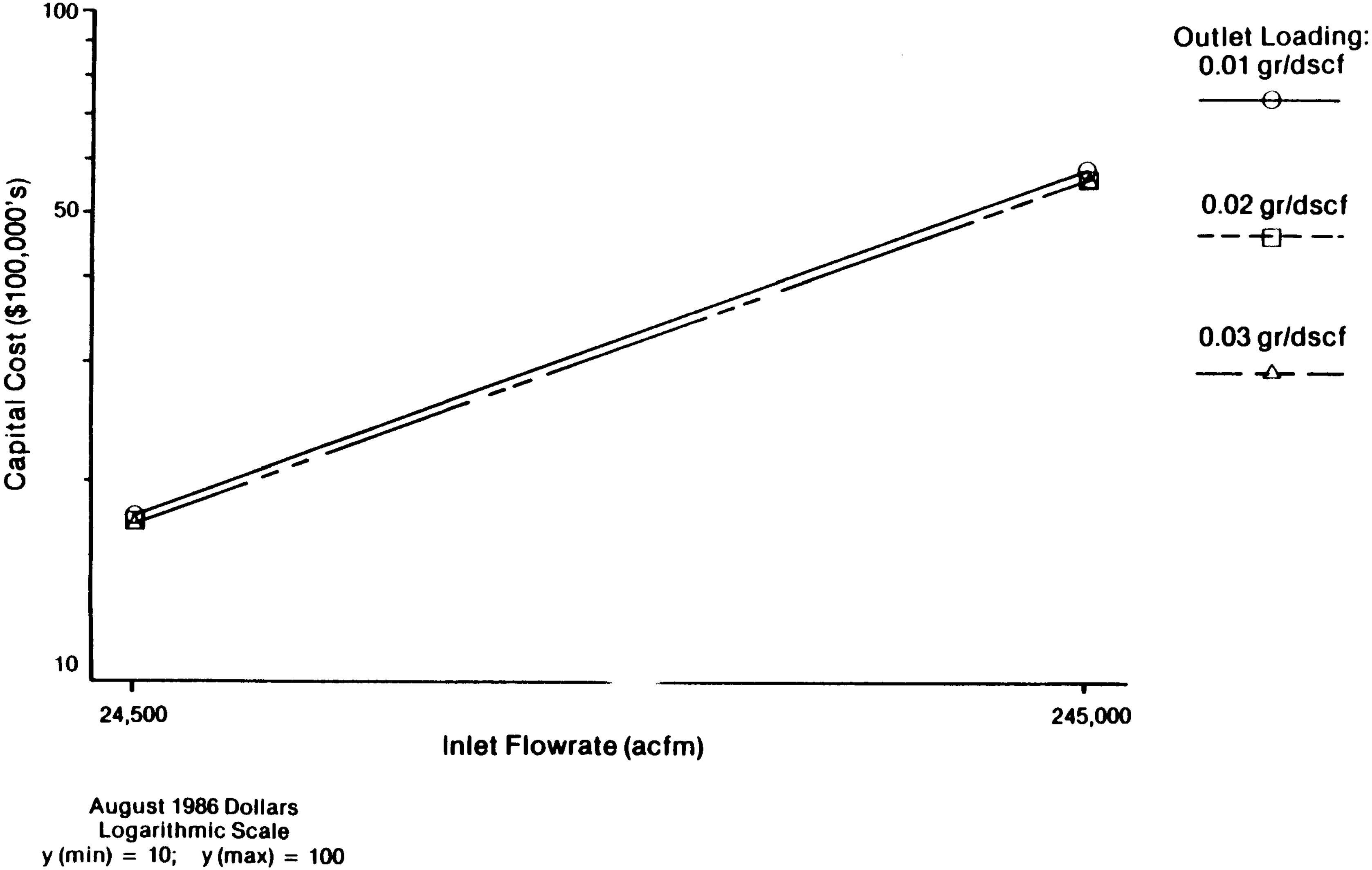


Figure 4-7. Capital Cost Estimates of an SD/FF for a Model MB Facility, MOD Facility, and RDF Facility

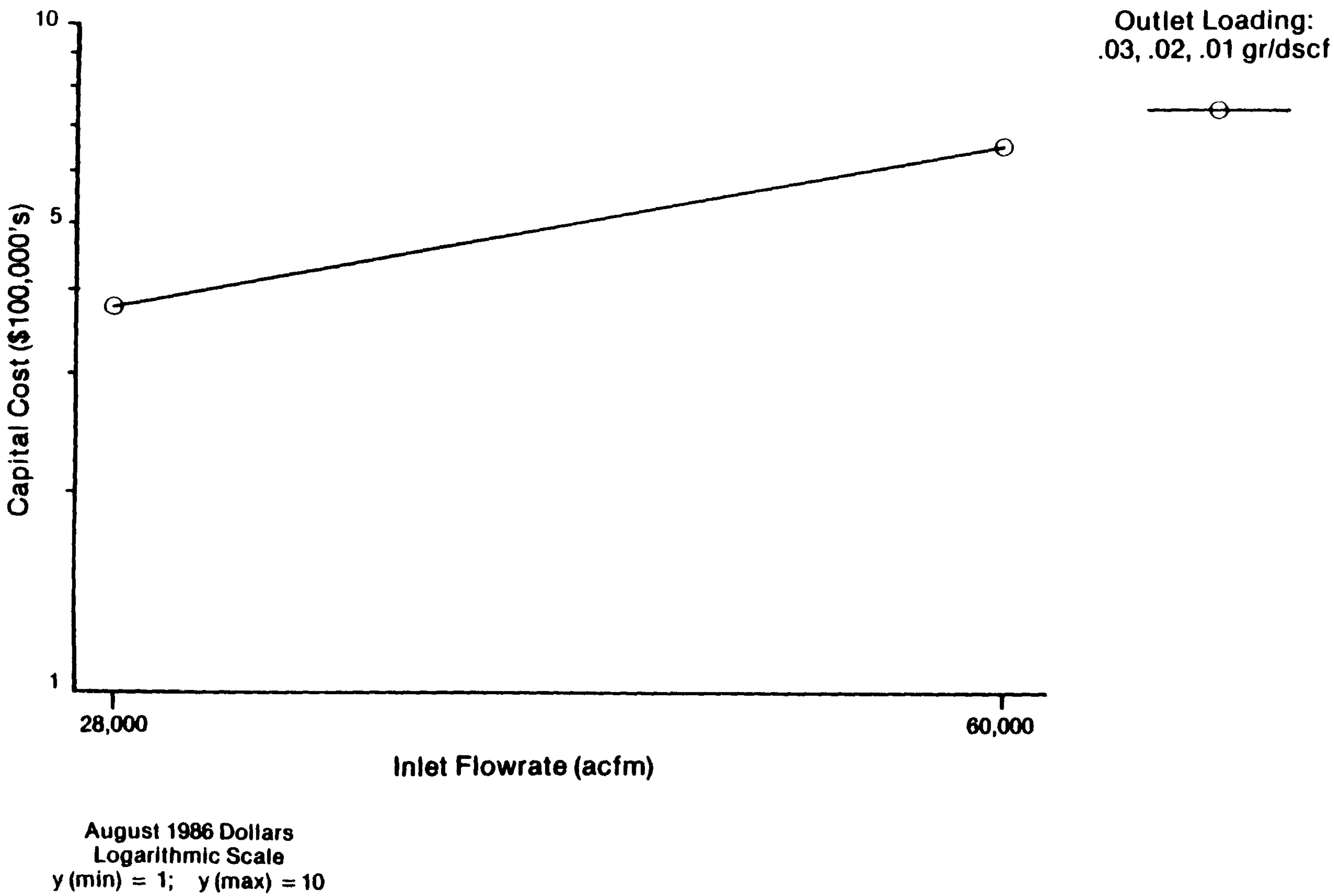


Figure 4 - 8. Capital Cost Estimates of an FF for a Model Fluid Bed Combustion Facility

The following mathematical expressions were used to estimate the capital cost of auxiliary equipment for each control system.

$$C_2 = 2.38 \times (N) \times (Q)0.96$$

$$C_3 = 1.76 \times (L) \times (Q)0.5$$

$$C_4 = (N) \times [25{,}000 + 59.61 \times (H) \times (1 + 2.59\ D)] \quad \text{for } D \geq 5 \text{ ft}$$

$$= (N) \times [25{,}000 + 82.88 \times (H) \times (1 + 2.20\ D)] \quad \text{for } D < 5 \text{ ft}$$

$$C_5 = (N) \times [25{,}000 + 84.79 \times (H) \times (1 + 4.14\ D)] \quad \text{for } D \geq 5 \text{ ft}$$

$$= (N) \times [25{,}000 + 76.73 \times (H) \times (1 + 4.33\ D)] \quad \text{for } D < 5 \text{ ft}$$

where

C_2 = Capital cost of I.D. fans in the control system for each model plant

C_3 = Capital cost of total ductwork in the control system for each model plant

C_4 = Capital cost of stacks in an acid gas/PM control system for each model plant

C_5 = Capital cost of stacks in a PM control system for each model plant

N = Number of control units

Q = Flue gas flow rate at the control unit outlet, acfm

L = Total ductwork length in the control system, ft

H = Stack height, ft

D = Stack diameter, ft

The cost equation for an I.D. fan was developed based on cost information received from fan manufacturers. The cost equation for ductwork was developed based on an average velocity of 3,000 ft/min through the ductwork; material and installation charges specified as $1.50 per lb of duct material; and an additional 20 percent for insulation, fittings, and material wastage. The assumed ductwork length for each new model plant are presented in Tables 4-2 and 4-3.

Double wall stacks, one per unit in each emission control system, were selected for evaluation. Information regarding the capital required for the purchase and installation of the stack were obtained from stack manufacturers. These cost data were incorporated into the mathematical expressions listed above.

Separate stack equations were developed for PM and acid gas/PM control systems because of the need for using acid-resistant lining in the stack with PM control systems. Also, separate equations were developed for stacks less than 5 ft in diameter because of the recommendation by manufacturers that a stack of less than 5 ft in diameter and more than 100 ft in height must be tapered. Stack dimensions for each new MWC model plant are listed in Tables 4-2 and 4-3.

Stack capital cost estimates were developed in order to calculate a cost credit which was applied to the capital costs of those model plants with acid gas control to account for the reduction in capital costs required to build a stack which does not require acid gas-resistant lining. This cost credit was equal to the difference in price for a stack following a PM emission control system and a stack following an acid gas/PM emission control system for each model plant. It is important to note that the stack capital costs would be significantly lower if the capital costs were based on one common stack with multiple flues for the entire control system rather than assuming one stack per control unit.

TABLE 4-2. AUXILIARY EQUIPMENT PARAMETERS FOR PM CONTROLS

Auxiliary equipment	Model plants				Assumed ductwork length, ft	
	No.	Incinerator Units	Unit size[a], tpd	Units in control system	Per control unit[b]	Total
Ductwork	1	2	156.2	2	60	120
	2	2	625	2	150	300
	3	4	937.5	4	200	800
	4	2	62.5	1	130[c]	130[c]
	5	5	62.5	1	250[c]	250[c]
	6	8	62.5	1	370[c]	370[c]
	7	3	625	3	150	450
	8	4	937.5	4	200	800
	9	2	156.2	2	60	120
	10	2	312.5	2	100	200

	Model plant no.	No. of stacks	Velocity, ft/min	Stack diameter, ft	Assumed stack height,[d] ft
Stack	1	2	3,210	3.5	200
	2	2	3,210	7.0	200
	3	4	2,910	9.0	200
	4	1	2,985	3.0	100
	5	1	2,690	5.0	100
	6	1	2,990	6.0	100
	7	3	2,890	7.5	200
	8	4	3,010	9.0	200
	9	2	2,840	3.5	200
	10	2	2,870	5.0	200

[a]Represents 125 percent of actual incinerator capacity.

[b]Includes length of ductwork from boiler outlet to stack inlet.

[c]Includes 40 ft of duct length per combustor from boiler outlet to manifold plus 50 feet from the control system exit to the stack.

[d]Assumed stack heights are 100 ft for modular units and 200 ft for all other units.

TABLE 4-3. AUXILIARY EQUIPMENT PARAMETERS FOR ACID GAS/PM CONTROLS

Auxiliary equipment	Model plants: No.	Model plants: Incinerator Units	Model plants: Unit[a] size, tpd	Model plants: Units in control system	Assumed ductwork length, ft: Per control unit[b]	Assumed ductwork length, ft: Total
Ductwork	1	2	156.2	2	120	240
	2	2	625	2	300	600
	3	4	937.5	4	400	1,600
	4	2	62.5	1	180[c]	180[c]
	5	5	62.5	1	300[c]	300[c]
	6	8	62.5	1	420[c]	420[c]
	7	3	625	3	300	900
	8	4	937.5	4	400	1,600

Auxiliary equipment	Model plant no.	No. of stacks	Velocity, ft/min	Stack diameter, ft	Assumed stack height[d], ft
Stack	1	2	2,885	3.5	200
	2	2	2,885	7.0	200
	3	4	3,310	8.0	200
	4	1	2,985	3.0	100
	5	1	2,690	5.0	100
	6	1	2,990	6.0	100
	7	3	2,980	7.0	200
	8	4	3,030	8.5	200
	9	2	3,470	3.0	200
	10	2	3,090	4.5	200

[a]Represents 125 percent of actual incinerator capacity.

[b]Includes length of ductwork from boiler outlet to stack inlet.

[c]Includes 40 ft of duct length per incinerator from boiler outlet to manifold plus 100 ft from the control system exit to the stack.

[d]Assumed stack heights are 100 ft for modular units and 200 ft for all other units.

The material of construction for ductwork and stack in PM control systems is assumed to be 1/4-inch cast refractory-lined carbon steel for all model plants. For acid gas/PM control systems, the material of construction for the stack is assumed to be 1/4-inch carbon steel for all model plants.

The following equation was used to calculate the total capital cost of a control system:

$$CS = 1.20 \times [C1 + C2 + C3]$$

where CS = Total capital cost of the control system.

C1 = Capital cost of main equipment.

C2 + C3 = Capital cost of auxiliary equipment (i.e., fan and ductwork).

The above equation includes a 20 percent contingency factor. It does not include the cost credit applied to those model plants with acid gas control for stack capital costs as discussed above.

(b) Capital Cost Estimates - Tables 4-4 through 4-7 present capital cost estimates for the PM and acid gas/PM control systems for new MB, MOD, RDF, and FBC model plants, respectively. The capital cost estimates indicate that the cost of ESP's designed for an emission level of 0.01 gr/dscf are approximately 35 percent more expensive than ESP's designed for 0.03 gr/dscf for new MWC model plants. The corresponding values for SD/ESP systems and SD/FF systems are 13 percent and 6 percent, respectively. The capital cost required for a SD/FF system to achieve PM emission levels of 0.03 and 0.02 gr/dscf are identical because the reduced emission level does not affect baghouse sizing. However, to achieve an emission level of 0.01 gr/dscf with a SD/FF, a more expensive bag material is required. Therefore, the capital cost increases. The FF capital costs for the FBC model plants were reported to be identical at all three PM emission levels by the manufacturers.

TABLE 4-4. SUMMARY OF ESTIMATED CAPITAL COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL NEW MASS BURNING FACILITIES ($1,000s in August 1986 based on 8,000 hrs/yr operation)

Controlled PM emission level, gr/dscf at 12% CO_2	Model plant 1 (250 tpd)	Model plant 2 (1,000 tpd)	Model plant 3 (3,000 tpd)
ESP System			
0.03	1,549	3,900	10,230
0.02	1,951	4,693	11,830
0.01	2,252	5,521	14,105
SD/ESP System[a]			
0.03	4,108	9,352	23,197
0.02	4,589	10,246	24,488
0.01	4,868	10,916	26,641
SD/FF System[a]			
0.03	4,242	8,905	21,691
0.02	4,242	8,905	21,691
0.01	4,421	9,463	23,197

[a]90 and 70 percent reduction of HCl and SO_2, respectively.

TABLE 4-5. SUMMARY OF ESTIMATED CAPITAL COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL NEW MODULAR COMBUSTOR FACILITIES ($1,000s in August 1986 based on 8,000 hrs/yr operation)

Controlled PM emission level, gr/dscf at 12% CO2	Model Plant 4	Model Plant 5	Model Plant 6
ESP System			
0.03	341	695	1,020
0.02	447	845	1,194
0.01	487	929	1,314
SD/ESP System[a]			
0.03	1,426	2,420	3,149
0.02	1,516	2,526	3,489
0.01	1,564	2,648	3,609
SD/FF System[a]			
0.03	1,960	3,176	4,179
0.02	1,960	3,176	4,179
0.01	2,020	3,296	4,779

[a]90 and 70 percent reduction of HCl and SO_2, respectively.

TABLE 4-6. SUMMARY OF ESTIMATED CAPITAL COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL NEW REFUSE-DERIVED FUEL BURNING FACILITIES ($1,000s in August 1986 based on 8,000 hrs/yr operation)

Controlled PM emission level, gr/dscf at 12% CO_2	Model plant 7 (1,500 tpd)	Model plant 8 (3,000 tpd)
ESP System		
0.03	6,919	12,006
0.02	8,293	14,245
0.01	9,193	15,881
SD/ESP System[a]		
0.03	14,413	25,917
0.02	15,972	27,423
0.01	16,539	28,069
SD/FF System[a]		
0.03	13,170	22,042
0.02	13,170	22,042
0.01	13,989	23,119

[a]90 and 70 percent reduction of HCl and SO_2, respectively.

TABLE 4-7. SUMMARY OF ESTIMATED CAPITAL COSTS OF PM CONTROLS FOR MODEL NEW FLUID BED COMBUSTION FACILITIES ($1,000s in August 1986 based on 8,000 hrs/yr operation)

Controlled PM emission level, 10 gr/dscf at 12% CO_2	Model plant 9 (250 tpd)	Model plant (500 tpd)
ESP System		
0.03	1,756	2,762
0.02	2,204	3,410
0.01	2,270	3,589
FF System		
0.03	996	1,690
0.02	996	1,690
0.01	996	1,690

A comparison of capital costs for acid gas/PM control systems and PM control systems indicates that 40 to 170 percent additional capital is required for controlling both PM and acid gas emissions as compared to controlling PM emissions alone for new MB and RDF model facilities. For the MOD model facilities, the additional capital cost required to control acid gas emissions as well as PM emissions with a SD/ESP or SD/FF is 200 to 500 percent than for an ESP alone. PM emissions at the outlet of a MOD combustor are generally very low. With the addition of a SD, PM emissions at the inlet of the PM emission control device increase to twelve times their normal level. Thus a large amount of additional capital is necessary for the PM control device. In general, as the model facility size increases the percentage of additional capital required to control both PM and acid gas emissions decreases.

A comparison of capital cost estimates for SD/ESP and SD/FF systems indicates that SD/FF systems are generally less expensive than SD/ESP systems at all PM emission levels for new MB and RDF facilities except for the 250 tpd MB model plant at the 0.03 gr/dscf outlet grain loading. The opposite is true for the MOD model facilities. Assuming SD capital costs are similar, the capital cost of an ESP is approximately 30 percent less than a FF for a MOD model plant equipped with a spray dryer for acid gas control. As discussed in Section 3, an increase in PM loading at the inlet of an ESP would require an increase in the SCA of that ESP to achieve the same outlet loading. This directly affects the capital cost of the unit. However, FF size, and therefore capital cost, is based on the air-to-cloth ratio. For MOD model facilities equipped with a SD, the increase in the PM loading at the inlet of the PM control device, which initially is very low, is not great enough to require an increase in the SCA of the ESP to cause the capital cost of that unit to exceed the capital cost of a FF in an acid gas/PM control system.

According to the capital cost estimates for FBC facilities (Table 4-7), FF's are 40 to 55 percent less expensive than ESP's at all outlet grain loadings. As discussed above, the capital cost of an ESP is directly affected by the inlet grain loading while the capital cost of a FF is based on air flow. Therefore, one would expect the capital cost of an ESP for an FBC model facility, which has a high outlet grain loading from the combustor, to be greater than the capital cost of a FF.

4.3 ANNUALIZED OPERATING COSTS

The annualized operating cost of an emission control system is the annual cost to own and operate that control system. The annualized operating cost includes direct operating costs, such as the cost of utilities, maintenance, and operating labor, and indirect operating costs or capital-related charges, such as the cost of depreciation, interest, administrative overhead, property taxes, and insurance.

Table 4-8 presents the cost bases used in calculating each control system's annualized operating costs. While actual costs experienced by individual plants can vary, the values listed are those selected as typical and they provide a reasonable estimate of the annualized operating costs of each control system. Tables 4-9 through 4-12 present the annualized operating cost estimates based on 8,000 hours of annual operation for the new MB, MOD, RDF, and FBC model plants. Tables 4-13 through 4-23 present detailed breakdowns of these estimates.

As one might expect, the cost estimates indicate that the increases in control system annualized operating costs coincide with a decrease in the PM emission level requirement from 0.03 to 0.01 gr/dscf at 12% CO_2. For ESP's, this cost increase is generally 25 percent. For SD/ESP's and SD/FF's, the cost increase is 10 and 4 percent, respectively.

The SD/FF control system annualized operating costs are 2 to 10 percent lower than the corresponding SD/ESP systems for the new MB and RDF model facilities. However, for new MB model plants with a PM emission level of 0.03 gr/dscf, SD/FF's are slightly more expensive to operate than a SD/ESP. Annualized operating cost estimates for FBC models indicate that FF's are approximately 30 percent less costly to operate than ESP's for the same facility. The annualized costs of operating a SD/FF for acid gas/PM control for a MOD model facility are generally 25 percent greater than for a SD/ESP for that facility.

TABLE 4-8. ANNUALIZED OPERATING COST BASES

Item	Cost base
Direct costs[a]	
Operating labor:	
Labor hours	1-man hr/shift for PM control systems and 2-man hr/shift for acid gas/PM control systems
Supervision	15% of total operating labor
Cost	\$12.02/hr for operating labor and \$14.42/hr for supervision
Utilities:	
System pressure drop,	
For ESP system	2.5 in. w.c.
For SD/ESP	7.5 in. w.c.
For SD/FF	13 in. w.c.
For FF	8 in. w.c.
Power requirements of spray	
dryer atomizer	6 kw/1,000 lbs/hr feed + 15 kw
ESP	1.5 watts/ft^2 plate area
Electricity cost	\$0.064/kwh
Water	\$0.85/1,000 gallons
Chemicals (lime)	\$55/ton
Annual maintenance[b]	2% of total capital cost
Waste disposal	\$15.00/ton of waste disposed
Indirect costs	
Overhead	60% of operating and maintenance labor
Taxes, insurance, and administrative overhead	4% of total capital cost
Capital recovery	20 years life for ESPs and FFs and 15 years life for SD/ESP and SD/FF systems; and 10% interest rate on money.

[a]Based on 8,000 hours per year of operation.

[b]One-half of the total is assumed to be for labor.

TABLE 4-9. SUMMARY OF ESTIMATED ANNUALIZED OPERATING COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL NEW MASS BURNING FACILITIES ($1,000s in August 1986 based on 8,000 hrs/yr operation)

Controlled PM emission level, gr/dscf at 12% CO_2	Model plant 1 (250 tpd)	Model plant 2 (1,000 tpd)	Model plant 3 (3,000 tpd)
ESP System			
0.03	370	921	2,449
0.02	443	1,067	2,744
0.01	499	1,220	3,163
SD/ESP System[a]			
0.03	1,061	2,529	6,515
0.02	1,156	2,706	6,771
0.01	1,212	2,839	7,198
SD/FF System[a]			
0.03	1,115	2,549	6,538
0.02	1,115	2,549	6,540
0.01	1,150	2,661	6,838

[a]90 and 70 percent reduction of HCl and SO_2, respectively.

TABLE 4-10. SUMMARY OF ESTIMATED ANNUALIZED OPERATING COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL NEW MODULAR COMBUSTOR FACILITIES ($1,000s in August 1986 based on 8,000 hrs/yr operation)

Controlled PM emission level, gr/dscf at 12% CO_2	Model Plant 4	Model Plant 5	Model Plant 6
ESP System			
0.03	90	162	229
0.02	110	190	261
0.01	117	206	283
SD/ESP System[a]			
0.03	380	645	858
0.02	398	666	925
0.01	408	691	949
SD/FF System[a]			
0.03	498	825	1110
0.02	498	825	1110
0.01	510	849	1229

[a]90 and 70 percent reduction of HCl and SO_2, respectively.

TABLE 4-11. SUMMARY OF ESTIMATED ANNUALIZED OPERATING COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL NEW REFUSE-DERIVED FUEL BURNING FACILITIES
($1,000s in August 1986 based on 8,000 hrs/yr operation)

Controlled PM emission level, gr/dscf at 12% CO_2	Model plant 7 (1,500 tpd)	Model plant 8 (3,000 tpd)
ESP System		
0.03	1,865	3,348
0.02	2,118	3,761
0.01	2,284	4,063
SD/ESP System[a]		
0.03	4,278	7,876
0.02	4,632	8,176
0.01	4,700	8,305
SD/FF System[a]		
0.03	4,198	7,442
0.02	4,199	7,444
0.01	4,362	7,637

[a]90 and 70 percent reduction of HCl and SO_2, respectively.

TABLE 4-12. SUMMARY OF ESTIMATED ANNUALIZED OPERATING COSTS OF PM CONTROLS FOR MODEL NEW FLUID BED COMBUSTION FACILITIES
($1,000s in August 1986 based on 8,000 hrs/yr operation)

Controlled PM emission level, gr/dscf at 12% CO_2	Model plant 9 (250 tpd)	Model plant 10 (500 tpd)
ESP System		
0.03	489	795
0.02	571	915
0.01	584	948
FF System		
0.03	375	649
0.02	375	649
0.01	375	650

TABLE 4-13. ESTIMATED ANNUALIZED OPERATING COSTS FOR ESP SYSTEMS FOR MODEL NEW MASS BURNING FACILITIES (August 1986 dollars based on 8,000 hrs/yr operation)

Item	Model plant 1 (250 tpd) for outlet PM level[a] of			Model plant 2 (1,000 tpd) for outlet PM level[a] of			Model plant 3 (3,000 tpd) for outlet PM level[a] of		
	0.03	0.02	0.01	0.03	0.02	0.01	0.03	0.02	0.01
Direct Cost									
Operating labor	24,000	24,000	24,000	24,000	24,000	24,000	48,000	48,000	48,000
Supervision	4,300	4,300	4,300	4,300	4,300	4,300	8,700	8,700	8,700
Utilities:									
Electricity	12,800	12,800	12,800	51,300	51,300	51,300	154,000	154,000	154,000
Water	0	0	0	0	0	0	0	0	0
Chemicals (lime)	0	0	0	0	0	0	0	0	0
Maintenance[b]	31,000	39,000	45,000	78,000	93,900	110,400	204,600	236,600	282,100
Waste disposal	27,200	27,400	27,500	109,100	109,700	110,100	327,300	328,900	330,300
Total direct	99,300	107,500	113,600	266,700	283,200	300,100	742,600	776,200	823,100
Indirect Cost									
Overhead (60% of operating labor and maintenance labor)	26,300	28,700	30,500	40,400	45,200	50,100	95,400	105,000	118,700
Taxes, insurance, and general administration	62,000	78,000	90,100	156,000	187,700	220,800	409,200	473,200	564,200
Capital recovery	181,900	229,200	264,500	458,100	551,200	648,500	1,201,600	1,389,500	1,656,800
Total indirect	270,200	335,900	385,100	654,500	784,100	919,400	1,706,200	1,967,700	2,339,700
Total Annualized Cost	369,500	443,400	498,700	921,200	1,067,300	1,219,500	2,448,800	2,743,900	3,162,800

[a]In units of gr/dscf at 12 percent CO_2.

[b]Assumes 50 percent of maintenance cost for labor.

TABLE 4-14. ESTIMATED ANNUALIZED OPERATING COSTS FOR SD/ESP SYSTEMS FOR MODEL NEW MASS BURNING FACILITIES[a]
(August 1986 dollars based on 8,000 hrs/yr operation)

Item	Model plant 1 (250 tpd) for outlet PM level[b] of			Model plant 2 (1,000 tpd) for outlet PM level[b] of			Model plant 3 (3,000 tpd) for outlet PM level[b] of		
	0.03	0.02	0.01	0.03	0.02	0.01	0.03	0.02	0.01
Direct Cost									
Operating labor	48,100	48,100	48,100	48,100	48,100	48,100	96,200	96,200	96,200
Supervision	8,700	8,700	8,700	8,700	8,700	8,700	17,300	17,300	17,300
Utilities:									
Electricity	60,700	60,700	60,700	199,000	199,000	199,000	575,200	575,200	575,300
Water	2,400	2,400	2,400	9,000	9,000	9,000	26,100	26,100	26,100
Chemicals (lime)	48,800	48,800	48,800	194,500	194,500	194,500	584,300	584,300	584,300
Maintenance[c]	82,200	91,800	97,400	187,000	204,900	218,300	463,900	489,800	532,800
Waste disposal	47,300	47,400	47,500	188,900	189,500	189,900	566,600	568,200	569,500
Total indirect	298,200	307,900	313,600	835,200	853,700	867,500	2,329,600	2,351,100	2,401,500
Indirect Cost									
Overhead (60 percent of operating labor and maintenance labor)	58,700	61,600	63,300	90,200	95,600	99,600	207,300	215,000	227,900
Taxes, insurance, and general administration	164,300	183,600	194,700	374,100	409,800	436,600	927,900	979,500	1,065,600
Capital recovery	540,100	603,300	640,000	1,229,500	1,347,100	1,435,200	3,049,800	3,219,500	3,502,600
Total indirect	763,100	848,500	898,000	1,693,800	1,852,500	1,971,400	4,185,000	4,414,000	4,796,100
Total Annualized Cost	1,061,300	1,156,400	1,211,600	2,529,000	2,706,200	2,838,900	6,514,600	6,771,100	7,197,600

[a]For 90 and 70 percent control of HCl and SO_2, respectively.

[b]In units of gr/dscf at 12 percent CO_2.

[c]Assumes 50 percent of maintenance cost for labor.

TABLE 4-15. ESTIMATED ANNUALIZED OPERATING COSTS FOR SD/FF SYSTEMS FOR MODEL NEW MASS BURNING FACILITIES[a]
(August 1986 dollars based on 8,000 hrs/yr operation)

Item	Model plant 1 (250 tpd) for outlet PM level[b] of			Model plant 2 (1,000 tpd) for outlet PM level[b] of			Model plant 3 (3,000 tpd) for outlet PM level[b] of		
	0.03	0.02	0.01	0.03	0.02	0.01	0.03	0.02	0.01
Direct Cost									
Operating labor	48,100	48,100	48,100	48,100	48,100	48,100	96,200	96,200	96,200
Supervision	8,700	8,700	8,700	8,700	8,700	8,700	17,300	17,300	17,300
Utilities:									
Electricity	87,500	87,500	87,500	307,500	307,500	307,500	896,100	896,100	896,100
Water	2,400	2,400	2,400	9,000	9,000	9,000	26,100	26,100	26,100
Chemicals (lime)	48,800	48,800	48,800	194,500	194,500	194,500	584,300	584,300	584,300
Maintenance[c]	84,800	84,800	88,400	178,100	178,100	189,300	433,800	433,800	463,900
Waste disposal	47,300	47,400	47,500	188,900	189,500	189,900	566,600	568,200	569,500
Total direct	327,600	327,700	331,400	934,800	935,400	947,000	2,620,400	2,622,000	2,653,400
Indirect Cost									
Overhead (60 percent of operating labor and maintenance labor)	59,500	59,500	60,600	87,500	87,500	90,900	198,200	198,200	207,300
Taxes, insurance, and general administration	169,700	169,700	176,800	356,200	356,200	378,500	867,600	867,600	927,900
Capital recovery	557,700	557,700	581,200	1,170,800	1,170,800	1,244,100	2,851,800	2,851,800	3,049,800
Total indirect	786,900	786,900	818,600	1,614,500	1,614,500	1,713,500	3,917,600	3,917,600	4,185,000
Total Annualized Cost	1,114,500	1,114,600	1,150,000	2,549,300	2,549,900	2,660,500	6,538,000	6,539,600	6,838,400

[a]For 90 and 70 percent control of HCl and SO_2, respectively.

[b]In units of gr/dscf at 12 percent CO_2.

[c]Assumes 50 percent of maintenance cost for labor.

TABLE 4-16. ESTIMATED ANNUALIZED OPERATING COSTS FOR ESP SYSTEMS FOR MODEL NEW MODULAR COMBUSTOR FACILITIES (August 1986 dollars based on 8,000 hrs/yr operation)

Item	Model plant 4 (100 tpd) for outlet PM level[a] of			Model plant 5 (250 tpd) for outlet PM level[a] of			Model plant 6 (400 tpd) for outlet PM level[a] of		
	0.03	0.02	0.01	0.03	0.02	0.01	0.03	0.02	0.01
Direct Cost									
Operating labor	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000
Supervision	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200
Utilities:									
Electricity	4,400	4,400	4,400	11,000	11,000	11,000	17,500	17,500	17,500
Water	0	0	0	0	0	0	0	0	0
Chemicals (lime)	0	0	0	0	0	0	0	0	0
Maintenance[b]	6,800	8,900	9,700	13,900	16,900	18,600	20,400	23,900	26,300
Waste disposal	400	500	500	1,000	1,100	1,300	1,600	1,800	2,000
Total direct	25,800	28,000	28,800	40,100	43,200	45,100	53,700	57,400	60,000
Indirect Cost									
Overhead (60% of operating labor and maintenance labor)	10,600	11,200	11,400	12,700	13,600	14,100	14,600	15,700	16,400
Taxes, insurance, and general administration	13,600	17,900	19,500	27,800	33,800	37,200	40,800	47,800	52,600
Capital recovery	40,100	52,500	57,200	81,600	99,300	109,100	119,800	140,200	154,300
Total indirect	64,300	81,600	88,100	122,100	146,700	160,400	175,200	203,700	223,300
Total Annualized Cost	90,100	109,600	116,900	162,200	189,900	205,500	228,900	261,100	283,300

[a]In units of gr/dscf at 12 percent CO_2.

[b]Assumes 50 percent of maintenance cost for labor.

TABLE 4-17. ESTIMATED ANNUALIZED OPERATING COSTS FOR SD/ESP SYSTEMS FOR MODEL NEW MODULAR COMBUSTOR FACILITIES[a]
(August 1986 dollars based on 8,000 hrs/yr operation)

	Model plant 4 (100 tpd) for outlet PM level[b] of			Model plant 5 (250 tpd) for outlet PM level[b] of			Model plant 6 (400 tpd) for outlet PM level[b] of		
	0.03	0.02	0.01	0.03	0.02	0.01	0.03	0.02	0.01
Direct Cost									
Operating labor	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
Supervision	4,300	4,300	4,300	4,300	4,300	4,300	4,300	4,300	4,300
Utilities:									
Electricity	27,400	27,400	27,400	56,900	56,900	56,900	86,500	86,500	86,500
Water	800	800	800	2,000	2,000	2,000	2,900	2,900	2,900
Chemicals (lime)	17,600	17,600	17,600	44,200	44,200	44,200	70,600	70,600	70,600
Maintenance[c]	28,500	30,300	31,300	48,400	50,500	53,000	63,000	69,800	72,200
Waste disposal	7,600	7,700	7,700	18,900	19,100	19,200	30,400	30,600	30,800
Total direct	110,200	112,100	113,100	198,700	201,000	203,600	281,700	288,700	291,300
Indirect cost									
Overhead (60% of operating labor and maintenance labor)	25,500	26,100	26,400	31,500	32,100	32,900	35,900	37,900	38,600
Taxes, insurance, and general administration	57,000	60,600	62,600	96,800	101,000	105,900	126,000	139,600	144,400
Capital recovery	187,500	199,300	205,600	318,200	332,100	348,100	414,000	458,700	474,500
Total indirect	270,000	286,000	294,600	446,500	465,200	486,900	575,900	636,200	657,500
Total Annualized Cost	380,200	398,100	407,700	645,200	666,200	690,500	857,600	924,900	948,800

[a]For 90 and 70 percent control of HCl and SO_2, respectively.

[b]In units of gr/dscf at 12 percent CO_2.

[c]Assumes 50 percent of maintenance cost for labor.

TABLE 4-18. ESTIMATED ANNUALIZED OPERATING COSTS FOR SD/FF SYSTEMS FOR MODEL NEW MODULAR COMBUSTOR FACILITIES[a]
(August 1986 dollars based on 8,000 hrs/yr operation)

	Model plant 4 (100 tpd) for outlet PM level[b] of			Model plant 5 (250 tpd) for outlet PM level[b] of			Model plant 6 (400 tpd) for outlet PM level[b] of		
	0.03	0.02	0.01	0.03	0.02	0.01	0.03	0.02	0.01
Direct Cost									
Operating labor	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
Supervision	4,300	4,300	4,300	4,300	4,300	4,300	4,300	4,300	4,300
Utilities:									
Electricity	39,600	39,600	39,600	87,400	87,400	87,400	135,200	135,200	135,200
Water	800	800	800	2,000	2,000	2,000	2,900	2,900	2,900
Chemicals (lime)	17,600	17,600	17,600	44,200	44,200	44,200	70,600	70,600	70,600
Maintenance[c]	39,200	39,200	40,400	63,500	63,500	65,900	83,600	83,600	95,600
Waste disposal	7,600	7,700	7,700	18,900	19,100	19,200	30,400	30,600	30,800
Total direct	133,100	133,200	134,400	244,300	244,500	247,000	351,000	351,200	363,400
Indirect cost									
Overhead (60% of operating labor and maintenance labor)	28,700	28,700	29,100	36,000	36,000	36,800	42,100	42,100	45,700
Taxes, insurance, and general administration	78,400	78,400	80,800	127,000	127,000	131,800	167,200	167,200	191,200
Capital recovery	257,700	257,700	265,600	417,600	417,600	433,300	549,400	549,400	628,300
Total indirect	364,800	364,800	375,500	580,600	580,600	601,900	758,700	758,700	865,200
Total Annualized Cost	497,900	498,000	509,900	824,900	825,100	848,900	1,109,700	1,109,900	1,228,600

[a]For 90 and 70 percent control of HCl and SO_2, respectively.

[b]In units of gr/dscf at 12 percent CO_2.

[c]Assumes 50 percent of maintenance cost for labor.

TABLE 4-19. ESTIMATED ANNUALIZED OPERATING COSTS FOR ESP SYSTEMS FOR MODEL NEW REFUSE-DERIVED FUEL BURNING FACILITIES (August 1986 dollars based on 8,000 hrs/yr operation)

Item	Model plant 7 (1,500 tpd) for outlet PM level[a] of			Model plant 8 (3,000 tpd) for outlet PM level[a] of		
	0.03	0.02	0.01	0.03	0.02	0.01
Direct Costs						
Operating labor	36,100	36,100	36,100	48,100	48,100	48,100
Supervision	6,500	6,500	6,500	8,700	8,700	8,700
Utilities:						
Electricity	79,500	79,500	79,500	159,000	159,000	159,100
Water	0	0	0	0	0	0
Chemicals (limestone)	0	0	0	0	0	0
Maintenance[b]	138,400	165,900	183,900	240,100	284,900	317,600
Waste disposal	447,800	448,700	449,600	895,800	897,600	899,400
Total direct	708,300	736,700	755,600	1,351,700	1,398,300	1,432,900
Indirect Costs						
Overhead	67,000	75,300	80,700	106,100	119,600	129,400
Taxes, insurance, and general administration	276,800	331,700	367,700	480,200	569,800	635,200
Capital recovery	812,700	974,100	1,079,800	1,410,200	1,673,200	1,865,400
Total indirect	1,156,500	1,381,100	1,528,200	1,996,500	2,362,600	2,630,000
Total Annualized Costs	1,864,800	2,117,800	2,283,800	3,348,200	3,760,900	4,062,900

[a] In units of gr/dscf at 12 percent CO_2.

[b] Assumes 50 percent of maintenance cost for labor.

TABLE 4-20. ESTIMATED ANNUALIZED OPERATING COSTS FOR SD/ESP SYSTEMS FOR MODEL NEW REFUSE-DERIVED FUEL BURNING FACILITIES[a] (August 1986 dollars based on 8,000 hrs/yr operation)

Item	Model plant 7 (1,500 tpd) for outlet PM level[b] of			Model plant 8 (3,000 tpd) for outlet PM level[b] of		
	0.03	0.02	0.01	0.03	0.02	0.01
Direct Cost						
Operating labor	72,000	72,000	72,000	96,200	96,200	96,200
Supervision	13,000	13,000	13,000	17,300	17,300	17,300
Utilities:						
Electricity	305,900	305,900	305,900	596,500	596,500	596,500
Water	13,500	13,500	13,500	27,700	27,700	27,700
Chemicals (lime)	376,900	376,900	376,900	753,300	753,300	753,300
Maintenance[c]	288,300	319,400	330,800	518,300	548,500	561,400
Waste disposal	599,600	600,500	601,400	1,199,200	1,201,000	1,202,800
Total direct	1,669,200	1,701,200	1,713,500	3,208,500	3,240,500	3,255,200
Indirect Cost						
Overhead (60 percent of operating labor and maintenance labor)	137,500	146,800	150,200	223,600	232,700	236,500
Taxes, insurance, and general administration	576,500	683,900	661,600	1,036,700	1,096,900	1,122,800
Capital recovery	1,894,900	2,099,900	2,174,400	3,407,400	3,605,400	3,690,300
Total indirect	2,608,900	2,930,600	2,986,200	4,667,700	4,935,000	5,049,600
Total Annualized Cost	4,278,100	4,631,800	4,699,700	7,876,200	8,175,500	8,304,800

[a]For 90 and 70 percent control of HCl and SO_2, respectively.

[b]In units of gr/dscf at 12 percent CO_2.

[c]Assumes 50 percent of maintenance cost for labor.

TABLE 4-21. ESTIMATED ANNUALIZED OPERATING COSTS FOR SD/FF SYSTEMS FOR MODEL NEW REFUSE-DERIVED FUEL BURNING FACILITIES[a] (August 1986 dollars based on 8,000 hrs/yr operation)

Item	Model plant 7 (1,500 tpd) for outlet PM level[b] of			Model plant 8 (3,000 tpd) for outlet PM level[b] of		
	0.03	0.02	0.01	0.03	0.02	0.01
Direct Cost						
Operating labor	72,000	72,000	72,000	96,200	96,200	96,200
Supervision	13,000	13,000	13,000	17,300	17,300	17,300
Utilities:						
Electricity	471,600	471,600	471,600	927,900	927,900	927,000
Water	13,500	13,500	13,500	27,700	27,700	27,700
Chemicals (lime)	376,900	376,900	376,900	753,300	753,300	753,300
Maintenance[c]	263,400	263,400	279,800	440,800	440,800	462,400
Waste disposal	599,600	600,500	601,400	1,199,200	1,201,000	1,202,800
Total direct	1,810,000	1,810,900	1,828,200	3,462,400	3,464,200	3,466,000
Indirect Cost						
Overhead (60 percent of operating labor and maintenance labor)	130,000	130,000	134,900	200,300	200,300	206,800
Taxes, insurance, and general administration	526,800	526,800	559,600	881,700	881,700	924,800
Capital recovery	1,731,500	1,731,500	1,839,200	2,897,900	2,897,900	3,039,500
Total indirect	2,388,300	2,388,300	2,533,700	3,979,900	3,979,900	4,171,100
Total Annualized Cost	4,198,300	4,199,200	4,361,900	7,442,300	7,444,100	7,637,100

[a]For 90 and 70 percent control of HCl and SO_2, respectively.

[b]In units of gr/dscf at 12 percent CO_2.

[c]Assumes 50 percent of maintenance cost for labor.

TABLE 4-22. ESTIMATED ANNUALIZED OPERATING COSTS FOR ESP SYSTEMS FOR MODEL NEW FLUID BED COMBUSTION FACILITIES (August 1986 dollars based on 8,000 hrs/yr operation)

Item	Model plant 9 (250 tpd) for outlet PM level[a] of			Model plant 10 (500 tpd) for outlet PM level[a] of		
	0.03	0.02	0.01	0.03	0.02	0.01
Direct Cost						
Operating labor	24,000	24,000	24,000	24,000	24,000	24,000
Supervision	4,300	4,300	4,300	4,300	4,300	4,300
Utilities:						
Electricity	11,300	11,300	11,300	22,700	22,700	22,700
Water	0	0	0	0	0	0
Chemicals (limestone)	0	0	0	0	0	0
Maintenance[b]	35,100	44,100	45,400	55,200	68,200	71,800
Waste disposal	110,300	110,400	110,700	220,800	221,000	221,400
Total direct	185,000	194,100	195,700	327,000	340,200	344,200
Indirect Cost						
Overhead (60 percent of operating labor and maintenance labor)	27,500	30,200	30,600	33,500	37,400	38,500
Taxes, insurance, and general administration	70,200	88,200	90,800	110,500	136,400	143,600
Capital recovery	206,300	258,900	266,600	324,400	400,500	421,600
Total indirect	304,000	377,300	388,000	468,400	574,300	603,700
Total Annualized Cost	489,000	571,400	583,700	795,400	914,500	947,900

[a]In units of gr/dscf at 12 percent CO_2.

[b]Assumes 50 percent of maintenance cost for labor.

TABLE 4-23. ESTIMATED ANNUALIZED OPERATING COSTS FOR FF SYSTEMS FOR MODEL NEW FLUID BED COMBUSTION FACILITIES (August 1986 dollars based on 8,000 hrs/yr operation)

Item	Model plant 9 (250 tpd) for outlet PM level[a] of			Model plant 10 (500 tpd) for outlet PM level[a] of		
	0.03	0.02	0.01	0.03	0.02	0.01
Direct Cost						
Operating labor	24,000	24,000	24,000	24,000	24,000	24,000
Supervision	4,300	4,300	4,300	4,300	4,300	4,300
Utilities:						
Electricity	36,200	36,200	36,200	72,500	72,500	72,500
Water	0	0	0	0	0	0
Chemicals (limestone)	0	0	0	0	0	0
Maintenance[b]	19,900	19,900	19,900	33,800	33,800	33,800
Waste disposal	110,300	110,400	110,700	220,800	221,000	221,400
Total direct	194,700	194,800	195,100	355,400	355,600	356,000
Indirect Cost						
Overhead (60 percent of operating labor and maintenance labor)	23,000	23,000	23,000	27,500	27,500	27,500
Taxes, insurance, and general administration	39,800	39,800	39,800	67,600	67,600	67,600
Capital recovery	117,000	117,000	117,000	198,500	198,500	198,500
Total indirect	179,800	179,800	179,800	293,600	293,600	293,600
Total Annualized Cost	374,500	374,600	374,900	649,000	649,200	649,600

[a]In units of gr/dscf at 12 percent CO_2.

[b]Assumes 50 percent of maintenance cost for labor.

The waste disposal cost is the major direct operating cost of the emission control systems for the new MWC model plants. The contribution of waste disposal costs to the total direct operating cost is proportional to the quantity of waste disposed. For the purpose of this report, waste disposal costs were conservatively estimated to be $15/ton. Nevertheless, they represent from 15 to 45 percent of the total direct operating cost for new MB facilities. Waste disposal costs for RDF and FBC facilities range from 50 to 70 percent of the direct operating cost of the emission control system. The waste disposal cost for MOD facilities is insignificant due to the small quantity of solid waste generated. However, with the addition of a SD, the waste disposal costs for MOD model facilities can be expected to increase to as much as 10 percent of the total direct operating cost.

Due to the variability of waste disposal costs across the country, one could reasonably assume the cost of waste disposal to range as high as $30 to $50 per ton. If this were the case, the waste disposal cost for MB facilities would be 30 to 70 percent of the total direct operating cost of the emission control system. For RDF and FBC facilities, the waste disposal cost would represent 60 to 90 percent of the direct operating costs. If disposal of flyash in a hazardous waste landfill becomes appropriate, owing to the fact that flyash exhibits characteristics of hazardous waste as indicated by the EP toxicity test, and assuming waste disposal would, therefore, cost $150 per ton, the cost of waste disposal for emission control systems for MWC's would be as high as 80 to 95 percent of the total direct operating cost.

5. FURTHER COST ANALYSES

Further cost analyses were performed by developing cost estimates based on the new MWC model plant control system annualized operating cost data from Tables 4-9 through 4-12, and the data on flyash (PM) collected from the emission control systems which are presented in Table 5-1. Tables 5-2 through 5-5 present summaries of the annualized operating cost estimates in terms of dollars per ton of waste burned and dollars per ton of flyash collected from the emission control systems for new MB, MOD, RDF, and FBC model plants.

The cost data presented in Tables 5-2 through 5-5 indicate that the annualized operating cost for controlling MWC emissions to the specified outlet levels is approximately $4 to $9 per ton of refuse burned, respectively, for new MB and RDF model facilities. For MOD model plants, the corresponding costs are $5 and $10 per ton of refuse burned. For FBC models, the cost of controlling PM emissions is $5 per ton of refuse burned. In general, the annualized operating cost per ton of refuse burned for the emission control systems for new MWC model plants decreases as facility size increases. The additional cost for controlling acid gas and PM emissions, as compared to controlling PM emissions alone, also decreases with increasing facility size.

The unit cost data in terms of $/ton of PM collected can be used to analyze the annualized operating cost of PM controls, but are misleading when comparing the costs of acid gas/PM and PM controls due to the fact that a major portion of particulate matter collected by acid gas/PM control systems is generated as a result of the introduction of alkali feed in the spray dryer equipment. The additional solids in the flue gas of acid gas/PM emission control systems were not considered when calculating the data presented in Tables 5-2 through 5-5.

The cost data were also analyzed to obtain an indication of the annualized operating costs of installing and operating an acid gas removal control system in terms of dollars per unit of acid gas removed. Table 5-6 presents cost estimates in terms of $/lb of acid gas removed for the SD/FF and SD/ESP control systems. The quantity of acid gas removed includes both HCl and SO_2.

TABLE 5-1. SUMMARY OF FLYASH COLLECTED FROM THE EMISSION CONTROL SYSTEMS FOR THE NEW MWC MODEL PLANTS, tpy

Model plant and capacity	PM collected, tons/yr for outlet loading of		
	0.03 gr/dscf	0.02 gr/dscf	0.01 gr/dscf
PM controls			
No. 1 (250 tpd MB)	1,814	1,824	1,831
No. 2 (1,000 tpd MB)	7,273	7,310	7,339
No. 3 (3,000 tpd MB)	21,818	21,929	22,017
No. 4 (100 tpd MOD)	26	30	33
No. 5 (250 tpd MOD)	67	75	84
No. 6 (400 tpd MOD)	108	121	135
No. 7 (1,500 tpd RDF)	29,856	29,916	29,976
No. 8 (3,000 tpd RDF)	59,720	59,840	59,960
No. 9 (250 tpd FBC)	7,354	7,362	7,377
No. 10 (500 tpd FBC)	14,717	14,732	14,761

TABLE 5-2. SUMMARY OF EMISSION CONTROL SYSTEM ANNUALIZED OPERATING COST ESTIMATES FOR MODEL NEW MASS BURNING FACILITIES

Controlled PM emission level[a]	Model plants					
	No. 1 (250 tpd MB)		No. 2 (1,000 tpd MB)		No. 3 (3,000 tpd MB)	
	$/ton of waste burned	$/ton of PM collected	$/ton of waste burned	$/ton of PM collected	$/ton of waste burned	$/ton of PM collected
ESP						
0.03	4.44	204	2.76	127	2.45	112
0.02	5.32	242	3.20	146	2.74	125
0.01	5.99	272	3.66	166	3.16	144
SD/ESP						
0.03	12.73	584	7.59	348	6.52	299
0.02	13.87	632	8.12	370	6.77	309
0.01	14.54	660	8.52	387	7.20	327
SD/FF						
0.03	13.38	613	7.65	351	6.54	300
0.02	13.38	610	7.65	349	6.54	298
0.01	13.80	627	7.98	363	6.84	311

[a]At 12 percent CO_2.

TABLE 5-3. SUMMARY OF EMISSION CONTROL SYSTEM ANNUALIZED OPERATING COST ESTIMATES FOR MODEL NEW MODULAR COMBUSTOR FACILITIES

Controlled PM emission level[a]	Model plants					
	No. 4 (100 tpd MOD)		No. 5 (250 tpd MOD)		No. 6 (400 tpd MOD)	
	$/ton of waste burned	$/ton of PM collected	$/ton of waste burned	$/ton of PM collected	$/ton of waste burned	$/ton of PM collecte
ESP						
0.03	2.70	3,462	1.94	2,418	1.72	2,120
0.02	3.30	3,667	2.28	2,533	1.96	2,157
0.01	3.51	3,545	2.47	2,452	2.12	2,096
SD/ESP						
0.03	11.40	14,615	7.74	9,627	6.44	7,944
0.02	11.94	13,267	7.99	8,880	6.94	7,645
0.01	12.24	12,364	8.29	8,226	7.12	7,030
SD/FF						
0.03	14.94	19,154	9.90	12,313	8.33	10,278
0.02	14.94	16,600	9.90	11,000	8.33	9,174
0.01	15.30	15,455	10.19	10,107	9.22	9,104

[a]At 12 percent CO_2.

TABLE 5-4. SUMMARY OF EMISSION CONTROL SYSTEM ANNUALIZED OPERATING COST ESTIMATES FOR MODEL NEW REFUSE-DERIVED FUEL BURNING FACILITIES

PM emission level[a] after control	Model plants: No. 7 (1,500 tpd RDF)		Model plants: No. 8 (3,000 tpd RDF)	
	$/ton of waste burned	$/ton of PM collected	$/ton of waste burned	$/ton of PM collected
ESP				
0.03	3.73	62	3.35	56
0.02	4.24	71	3.76	63
0.01	4.57	76	4.06	68
SD/ESP				
0.03	8.56	143	7.88	132
0.02	9.26	155	8.18	137
0.01	9.40	157	8.31	139
SD/FF				
0.03	8.40	141	7.44	125
0.02	8.40	140	7.44	124
0.01	8.72	146	7.64	128

[a]At 12 percent CO_2.

TABLE 5-5. SUMMARY OF PM CONTROL SYSTEM ANNUALIZED OPERATING ESTIMATES FOR MODEL NEW FLUID BED COMBUSTION FACILITIES

PM emission level[a] after control	Model plants			
	No. 9 (250 tpd FBC)		No. 10 (500 tpd FBC)	
	$/ton waste burned	$/ton PM collected	$/ton waste burned	$/ton PM collected
ESP				
0.03	5.87	66	4.77	54
0.02	6.85	78	5.49	62
0.01	7.01	79	5.69	64
FF				
0.03	4.50	51	3.89	44
0.02	4.50	51	3.89	44
0.01	4.50	51	3.90	44

[a]At 12 percent CO_2.

TABLE 5-6. SUMMARY OF ACID GAS REMOVAL ANNUALIZED OPERATING COST ESTIMATES FOR MODEL NEW MASS BURNING, MODULAR COMBUSTOR, AND REFUSE-DERIVED FUEL BURNING FACILITIES

Model facility		Acid gas removed,[a] tpy	Cost effectiveness[a,b] $/lb of acid gas removed		
			0.03	0.02	0.01
No. 1 (250 tdp MB)	SD/ESP	435	1.22	1.33	1.39
	SD/FF		1.28	1.28	1.32
No. 2 (1,000 tpd MB)	SD/ESP	1,734	.73	.78	.82
	SD/FF		.73	.72	.77
No. 3 (3,000 tpd MB)	SD/ESP	5,194	.63	.65	.69
	SD/FF		.63	.63	.66
No. 4 (100 tpd MOD)	SD/ESP	157	1.21	1.27	1.30
	SD/FF		1.59	1.59	1.62
No. 5 (250 tpd MOD)	SD/ESP	392	.82	.85	.88
	SD/FF		1.05	1.05	1.08
No. 6 (400 tpd MOD)	SD/ESP	627	.68	.74	.76
	SD/FF		.89	.89	.98
No. 7 (1,500 tpd RDF)	SD/ESP	3,208	.67	.72	.72
	SD/FF		.65	.66	.68
No. 8 (,000 tpd RDF)	SD/ESP	6,400	.61	.64	.65
	SD/FF		.58	.58	.60

[a]The values indicated apply to HCl and SO_2 for Model plants 1 through 8.

[b]The values are listed according to the outlet PM emission level (gr/dscf corrected to 12 percent CO_2).

6. RETROFIT COSTS

Retrofit costs for air pollution control equipment for existing municipal waste combustors are presented in this section. The same methodology and design and cost premises were employed for estimating retrofit costs for existing facilities as were used to determine costs for emission control systems for new MWC facilities. Model plants were developed which were intended to be representative of the existing population of MWC's with regard to design capacity and technology. Retrofit factors were determined based on vendor contacts and previous retrofit studies within EPA with flue gas desulfurization (FGD) systems in the utility industry. The capital and annualized operating retrofit cost estimates were intended to bound the potential retrofit costs which would be expected for the existing MWC population. More detailed retrofit cost studies than presented in this section are currently underway.

6.1 MODEL PLANTS

Sixteen model plants were selected to represent the existing population of MWC's with regard to design capacity and technology. Six of the model plants were refractory, non-heat recovering facilities of which five were mass burning (MB) units and one was a modular combustor (MOD) facility. The remaining ten model plants were waterwall, heat-recovering units which included four MB units, three MOD facilities, and three RDF facilities. The primary design parameters and calculated flue gas quantities and compositions for each refractory and waterwall model plant are listed in Tables 6-1 and 6-2, respectively.

6.2 CONTROL SYSTEMS

The emission control systems which were costed for the model existing facilities were designed to provide PM control only, or both acid gas and PM control. For the MB and RDF model existing facilities, the control systems evaluated included a spray dryer (SD) system retrofit to those facilities with a high-efficiency ESP currently in place, and a SD/FF system retrofit to facilities which have a wet scrubber or low-efficiency ESP currently in

TABLE 6-1. REFRACTORY MODEL PLANT SPECIFICATIONS AND FLUE GAS COMPOSITION DATA

Item	Model plants[a]					
	No. 1 (MB)	No. 2 (MB)	No. 3 (MB)	No. 4 (MB)	No. 5 (MB)	No. 6 (MOD)
Facility Specification						
No. of combustors per model	2	3	2	2	3	2
Total daily charge rate, tpd	200	450	600	750	1,200	100
Hourly charge rate at 100% utilization, lb/hr	16,667	37,500	50,000	62,500	100,000	8,333
Ash content of feed waste, %	22.12	22.12	22.12	22.12	22.12	22.18
Excess combustion air, % of theoretical	80	80	80	80	80	50
PM emission factor, % of feed waste ash	10	10	10	10	10	0.5
Acid gas emission factor:						
HCl, ppm dry	500	500	500	500	500	500
SO_2, ppm dry	175	175	175	175	175	211
Flue gas data per combustor[b]						
Volume flow rate:						
dscfm	11,489	17,234	34,468	43,085	45,958	4,776
scfm	13,263	19,895	39,789	49,737	53,052	5,663
acfm	22,772	34,159	68,317	85,397	91,090	9,723
Outlet Temperature, °F[c]	450	450	450	450	450	450
PM Emissions:						
gr/dscf	1.87	1.87	1.87	1.87	1.87	0.11
gr/scf	1.62	1.62	1.62	1.62	1.62	0.10
gr/acf	0.94	0.94	0.94	0.94	0.94	0.06
gr/dscf at 12% CO_2	2.16	2.16	2.16	2.16	2.16	0.11
gr/dscf at 7% O_2	2.26	2.26	2.26	2.26	2.26	0.11
lb/hr	184	277	553	691	400	4.6
tons/yr at 6500 hrs/yr	598	970	1,936	2,419	1,400	16
Acid Gas Emissions:						
HCl, lb/hr	33	49	98	122	131	14
tons/yr at 6500 hrs/yr	107	159	319	397	426	49
SO_2, lb/hr	20	30	60	75	80	10
tons/yr at 6500 hrs/yr	65	98	95	244	260	35

[a]MB - Mass burning and MOD - Modular.
[b]Calculated (except where indicated) based on the facility specifications in this table and the feed waste composition data from Table 2-2.
[c]Assumed.

TABLE 6-2. WATERWALL MODEL PLANT SPECIFICATIONS AND FLUE GAS COMPOSITION DATA

Item	Model plants[a]									
	No. 1 (MB)	No. 2 (MB)	No. 3 (MB)	No. 4 (MB)	No. 5 (MOD)	No. 6 (MOD)	No. 7 (MOD)	No. 8 (RFD)	No. 9 (RFD)	No. 10 (RFD)
<u>Facility Specification</u>										
No. of combustors per model	2	2	4	3	2	4	4	4	2	4
Total daily charge rate, tpd	200	400	1,000	2,200	100	200	300	1,000	2,200	3,000
Hourly charge rate at 100% utilization, lb/hr	16,667	33,333	83,333	183,333	8,333	16,667	25,000	83,333	183,333	250,000
Ash content of feed waste, %	22.12	22.12	22.12	22.12	22.18	22.18	22.18	7.51	7.51	7.51
Excess combustion air, % of theoretical	80	80	80	80	50	50	50	50	50	50
PM emission factor, % of feed waste ash	10	10	10	10	0.5	0.5	0.5	80	80	80
Acid gas emission factor:										
HCl, ppm dry	500	500	500	500	500	500	500	500	500	500
SO_2, ppm dry	175	175	175	175	211	211	211	286	286	286
<u>Flue gas data per combustor</u>[b]										
Volume flow rate:										
dscfm	11,489	22,987	28,723	84,217	4,776	4,776	7,164	29,352	129,148	88,055
scfm	13,263	26,526	33,158	97,218	5,663	5,663	8,494	34,245	150,679	102,736
acfm	20,270	40,540	50,675	148,579	8,654	8,654	12,982	52,337	230,283	157,011
Outlet Temperature, °F[c]	350	350	350	350	350	350	350	350	350	350
PM Emissions:										
gr/dscf	1.87	1.87	1.87	1.87	0.11	0.11	0.11	4.98	4.98	4.98
gr/scf	1.62	1.62	1.62	1.62	0.10	0.10	0.10	4.26	4.26	4.26
gr/acf	1.06	1.06	1.06	1.06	0.06	0.06	0.06	2.79	2.79	2.79
gr/dscf at 12% CO_2	2.16	2.16	2.16	2.16	0.11	0.11	0.11	4.63	4.63	4.63
gr/dscf at 7% O_2	2.26	2.26	2.26	2.26	0.11	0.11	0.11	4.99	4.99	4.99
lb/hr	184	369	461	1,351	5	5	7	1,252	5,507	3,755
tons/yr at 6500 hrs/yr	598	1,199	1,498	4,391	16	16	23	4,069	17,898	12,204
Acid Gas Emissions:										
HCl, lb/hr	33	65	82	239	14	14	21	83	367	250
tons/yr at 6500 hrs/yr	107	211	267	777	46	46	68	270	1,193	813
SO_2, lb/hr	20	40	50	147	10	10	15	83	367	250
tons/yr at 6500 hrs/yr	65	130	163	478	33	33	49	270	1,193	813

[a]MB - Mass burning , MOD - Modular, and RDF - refuse-derived fuel.
[b]Calculated (except where indicated) based on the facility specifications in this table and the feed waste composition data from Table 2-2.
[c]Assumed.

place. The majority of the existing MOD facilities are uncontrolled. Therefore, ESP's and SD/ESP's were evaluated for PM and acid gas/PM control, respectively, for the model MOD existing facilities.

The design parameters for the emission control systems for the model existing MWC facilities are identical to those discussed for the new MWC model facilities. The emission control systems were designed to achieve a PM emission level of 0.02 gr/dscf corrected to 12 percent CO_2, and 90 and 70 percent reduction of HCl and SO_2, respectively. One control unit was assumed for each model MOD existing facility and for each combustion unit in each MB and RDF model existing facility.

6.3 CONTROL SYSTEM COST EVALUATIONS

This section presents estimates for the capital and annualized operating retrofit costs to control PM and acid gas/PM emissions from the existing MWC model plants to the specified levels. Each unit in a control system was designed to accommodate 125 percent of the actual flue gas flow rate to account for fluctuations in gas flow due to variations in feed waste composition or operating conditions.

(a) Methodology for Estimating Capital Costs - Capital costs for the emission control systems were calculated by estimating retrofit factors which would provide an upper and lower bound to the costs for retrofitting an existing MWC facility. The retrofit factor for a dry scrubber, applied to existing MB or RDF model facilities, and an ESP, applied to existing MOD facilities, was assumed to be 1.4 based on vendor contacts. The retrofit factor for SD/ESP and SD/FF systems was assumed to be 1.8 based on the upper limit for retrofit factors observed for flue gas desulfurization systems in the utility industry.

The capital cost for one unit in each control system was estimated based on the vendor data presented in Figures 4-1, 4-2, 4-4, 4-5, and 4-7. Figures 4-1 and 4-2 present capital cost estimates for an ESP for the control of PM emissions from MB and MOD facilities, respectively. Capital cost estimates of SD/ESP's for the control of acid gas/PM emissions from MB and MOD facilities are presented in Figures 4-4 and 4-5, respectively. SD/FF capital cost estimates are presented in Figure 4-7. The capital cost for SD units for the model existing MB and RDF facilities were estimated to be the difference between the capital costs of a SD/ESP for MB facilities, obtained from Figure 4-4, and the cost of an ESP for the same MB facility, obtained from Figure 4-1.

As previously stated, one control unit was assumed for each model MOD existing facility and for each combustion unit in each MB and RDF model existing facility. Where multi-unit control systems were required, the capital cost for one unit of each system (CU) was incorporated into the expression presented in Section 4 for calculating the total cost of the main equipment for the entire system:

$$C_1 = C_u \times (0.1375 + 0.8625\ N)$$

where C_1 = Capital cost of main equipment in the control system.

C_u = Cost of one unit of the control system.

N = Number of units in a control system.

In addition to the costs for the main equipment, the capital cost estimates also included the ductwork cost. The length of ductwork required for each emission control system, from boiler outlet to stack inlet, was assumed to be double the length that was discussed in Section 4. Fan and stack costs were not considered. The total capital cost for each control system for the model existing MWC facilities was calculated by adding the cost for each control system and the ductwork cost as follows:

$$CS = [R_f \times C_1] + C_2$$

where CS = Total capital cost of the control system.

C_1 = Capital cost of main equipment.

C_2 = Capital cost of ductwork.

R_f = Retrofit factor (i.e., 1.4 for SD and ESP control systems; 1.8 for SD/ESP and SD/FF control systems).

(b) Capital Cost Estimates - Tables 6-1 through 6-5 present the capital cost estimates for the PM and acid gas/PM control systems for the MB, MOD, and RDF model existing facilities, respectively. Based on these estimates, one can expect the capital cost of a retrofit acid gas/PM control to be nearly twice the cost of a SD alone for MB and RDF model existing facilities. For the MOD model existing facilities, a SD/ESP system applied to an uncontrolled facility will be as much as five times more costly than for an ESP for PM control only.

(c) Annualized Operating Cost Estimates - The annualized operating costs of emission control systems for model existing MWC facilities were calculated using the cost bases listed in Table 4-8 and are presented in Tables 6-6 through 6-10 based on 6,500 hours of annual operation. Tables 6-11 through 6-22 present detailed breakdowns of these estimates.

TABLE 6-3. SUMMARY OF ESTIMATED CAPITAL COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL EXISTING REFRACTORY MASS BURNING FACILITIES
($1,000s in August 1986 based on 6,500 hrs/yr operation)

Control Device	Model plant 1 (200 tpd)	Model plant 2 (450 tpd)	Model plant 3 (600 tpd)	Model plant 4 (750 tpd)	Model plant 5 (1,200 tpd)
SD System	NA[a]	NA[a]	6,005	6,879	10,325
SD/FF System	6,335	11,346	11,062	12,728	18,745

[a]Current controls consist of only a wet scrubber or low-efficiency ESP.

TABLE 6-4. SUMMARY OF ESTIMATED CAPITAL COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL EXISTING REFRACTORY MODULAR COMBUSTOR FACILITIES ($1,000s in August 1986 based on 6,500 hrs/yr operation)

Control Device	Model plant 6 (100 tpd)
ESP System	526
SD/ESP System	2,819

TABLE 6-5. SUMMARY OF ESTIMATED CAPITAL COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL EXISTING WATERWALL MASS BURNING FACILITIES
($1,000s in August 1986 based on 6,500 hrs/yr operation)

Control Device	Model plant 1 (200 tpd)	Model plant 2 (400 tpd)	Model plant 3 (1,000 tpd)	Model plant 4 (2,200 tpd)
SD System	3,063	4,544	9,901	14,353
SD/FF System	5,997	8,539	18,690	25,307

TABLE 6-6. SUMMARY OF ESTIMATED CAPITAL COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL EXISTING WATERWALL MODULAR COMBUSTOR FACILITIES ($1,000s in August 1986 based on 6,500 hrs/yr operation)

Control Device	Model plant 5 (100 tpd)	Model plant 6 (200 tpd)	Model plant 7 (300 tpd)
ESP System	487	783	999
SD/ESP System	2,551	3,853	4,865

TABLE 6-7. SUMMARY OF ESTIMATED CAPITAL COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL EXISTING REFUSE-DERIVED FUEL BURNING FACILITIES ($1,000s in August 1986 based on 6,500 hrs/yr operation)

Control Device	Model plant 8 (1,000 tpd)	Model plant 9 (2,200 tpd)	Model plant 10 (3,000 tpd)
SD System	10,202	12,926	19,492
SD/FF System	19,189	22,090	34,058

TABLE 6-8. SUMMARY OF ESTIMATED ANNUALIZED OPERATING COSTS OF EMISSION CONTROL SYSTEMS
FOR MODEL EXISTING REFRACTORY MASS BURNING FACILITIES
($1,000s in August 1986 based on 6,500 hrs/yr operation)

Control Device	Model plant 1 (200 tpd)	Model plant 2 (450 tpd)	Model plant 3 (600 tpd)	Model plant 4 (750 tpd)	Model plant 5 (1,200 tpd)
SD System	NA[a]	NA[a]	1,669	1,941	2,884
SD/FF System	1,478	2,686	2,692	3,124	4,597

[a]Current controls consist of only a wet scrubber or low-efficiency ESP.

TABLE 6-9. SUMMARY OF ESTIMATED ANNUALIZED OPERATING COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL EXISTING REFRACTORY MODULAR COMBUSTOR FACILITIES ($1,000s in August 1986 based on 6,500 hrs/yr operation)

Control Device	Model Plant 6 (100 tpd)
ESP System	123
SD/ESP System	645

TABLE 6-10. SUMMARY OF ESTIMATED ANNUALIZED OPERATING COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL EXISTING WATERWALL MASS BURNING FACILITIES ($1,000s in August 1986 based on 6,500 hrs/yr operation)

Control Device	Model plant 1 (200 tpd)	Model plant 2 (400 tpd)	Model plant 3 (1,000 tpd)	Model plant 4 (2,200 tpd)
SD System	810	1,222	2,724	4,278
SD/FF System	1,399	2,030	4,506	6,543

TABLE 6-11. SUMMARY OF ESTIMATED ANNUALIZED OPERATING COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL EXISTING WATERWALL MODULAR COMBUSTOR FACILITIES ($1,000s in August 1986 based on 6,500 hrs/yr operation)

Control Device	Model plant 5 (100 tpd)	Model plant 6 (200 tpd)	Model plant 7 (300 tpd)
ESP System	115	177	224
SD/ESP System	587	884	1,124

TABLE 6-12. SUMMARY OF ESTIMATED ANNUALIZED OPERATING COSTS OF EMISSION CONTROL SYSTEMS FOR MODEL EXISTING REFUSE-DERIVED FUEL BURNING FACILITIES ($1,000s in August 1986 based on 6,500 hrs/yr operation)

Control Device	Model plant 8 (1,000 tpd)	Model plant 9 (2,200 tpd)	Model plant 10 (3,000 tpd)
SD System	3,067	4,574	6,350
SD/FF System	4,876	6,458	9,558

TABLE 6-13. ESTIMATED ANNUALIZED OPERATING COSTS FOR SD SYSTEMS FOR MODEL EXISTING REFRACTORY MASS BURNING FACILITIES[a]
(August 1986 dollars based on 6,500 hrs/yr operation)

	Model plant 1 (200 tpd)	Model plant 2 (450 tpd)	Model plant 3 (600 tpd)	Model plant 4 (750 tpd)	Model plant 5 (1,200 tpd)
Direct Cost					
Operating labor			39,100	39,100	1,200
Supervision			7,000	7,000	10,500
Utilities:	NA[b]	NA[b]			
Electricity			188,300	232,300	370,359
Water			10,600	13,300	20,900
Chemicals (lime)			94,700	118,700	189,800
Maintenance[c]			120,100	165,100	206,500
Waste disposal			115,400	144,200	153,900
Total direct			575,200	719,700	1,010,500
Indirect cost					
Overhead (60% of operating labor and maintenance labor)			63,700	77,200	103,400
Taxes, insurance, and general administration			240,200	330,200	413,000
Capital recovery			789,500	1,085,300	1,357,500
Total indirect			1,093,400	1,248,500	1,873,900
Total Annualized Cost			1,668,600	2,212,400	2,884,400

[a]0.02 gr/dscf corrected to 12 percent CO_2 and 90 and 70 percent reduction of HCl and SO_2, respectively.

[b]Current controls consist of only a wet scrubber or low-efficiency ESP.

[c]Assumes 50 percent of maintenance cost for labor.

TABLE 6-14. ESTIMATED ANNUALIZED OPERATING COSTS FOR SD/FF SYSTEMS FOR MODEL EXISTING REFRACTORY MASS BURNING FACILITIES[a]
(August 1986 dollars based on 6,500 hrs/yr operation)

	Model plant 1 (200 tpd)	Model plant 2 (450 tpd)	Model plant 3 (600 tpd)	Model plant 4 (750 tpd)	Model plant 5 (1,200 tpd)
Direct Cost					
Operating labor	39,100	58,600	39,100	39,100	58,600
Supervision	7,000	10,500	7,000	7,000	10,500
Utilities:					
Electricity	79,500	169,400	213,400	263,600	420,600
Water	3,300	8,000	10,600	13,300	20,900
Chemicals (lime)	31,500	71,300	94,700	118,700	189,800
Maintenance[b]	126,700	226,900	221,200	254,600	374,900
Waste disposal	38,500	86,600	115,400	144,200	153,900
Total direct	325,600	631,300	701,400	837,500	1,229,200
Indirect cost					
Overhead (60% of operating labor and maintenance labor)	65,700	109,500	94,000	104,000	153,900
Taxes, insurance, and general administration	253,400	453,800	442,500	509,100	749,800
Capital recovery	832,900	1,491,700	1,454,400	1,673,400	2,464,500
Total indirect	1,152,000	2,055,000	1,990,900	2,286,500	3,368,200
Total Annualized Cost	1,477,600	2,686,300	2,692,300	3,124,000	4,597,400

[a]0.02 gr/dscf corrected to 12 percent CO_2 and 90 and 70 percent reduction of HCl and SO_2, respectively.

[b]Assumes 50 percent of maintenance cost for labor.

TABLE 6-15. ESTIMATED ANNUALIZED OPERATING COSTS FOR ESP SYSTEMS FOR MODEL EXISTING REFRACTORY MODULAR COMBUSTOR FACILITIES[a]
(August 1986 dollars based on 6,500 hrs/yr operation)

	Model plant 6 (100 tpd)
Direct Cost	
Operating labor	9,800
Supervision	1,800
Utilities:	
Electricity	7,600
Water	0
Chemicals (lime)	0
Maintenance[b]	10,500
Waste disposal	500
Total direct	30,200
Indirect cost	
Overhead (60% of operating labor and maintenance labor)	10,100
Taxes, insurance, and general administration	21,000
Capital recovery	61,800
Total indirect	92,900
Total Annualized Cost	123,100

[a]0.02 gr/dscf corrected to 12 percent CO_2.

[b]Assumes 50 percent of maintenance cost for labor.

TABLE 6-16. ESTIMATED ANNUALIZED OPERATING COSTS FOR SD/ESP SYSTEMS FOR MODEL EXISTING REFRACTORY MODULAR COMBUSTOR FACILITIES[a]
(August 1986 dollars based on 6,500 hrs/yr operation)

	Model plant 6 (100 tpd)
Direct Cost	
Operating labor	19,500
Supervision	3,500
Utilities:	
Electricity	27,600
Water	1,700
Chemicals (lime)	14,300
Maintenance[b]	56,400
Waste disposal	7,700
Total direct	130,700
Indirect cost	
Overhead (60% of operating labor and maintenance labor)	30,700
Taxes, insurance, and general administration	112,900
Capital recovery	370,600
Total indirect	514,100
Total Annualized Cost	644,800

[a]0.02 gr/dscf corrected to 12 percent CO_2 and 90 and 70 percent reduction of HCl and SO_2, respectively.

[b]Assumes 50 percent of maintenance cost for labor.

TABLE 6-17. ESTIMATED ANNUALIZED OPERATING COSTS FOR SD SYSTEMS FOR MODEL EXISTING WATERWALL MASS BURNING FACILITIES[a] (August 1986 dollars based on 6,500 hrs/yr operation)

	Model plant 1 (200 tpd)	Model plant 2 (400 tpd)	Model plant 3 (1,000 tpd)	Model plant 4 (2,200 tpd)
Direct Cost				
Operating labor	39,100	39,100	78,100	58,600
Supervision	7,000	7,000	14,100	10,500
Utilities:				
Electricity	60,400	108,400	264,800	546,300
Water	1,300	2,700	6,600	15,900
Chemicals (lime)	31,500	63,300	158,000	348,000
Maintenance[b]	61,300	90,900	198,000	287,100
Waste disposal	38,500	76,900	192,400	423,200
Total direct	239,100	388,300	912,000	1,689,600
Indirect cost				
Overhead (60% of operating labor and maintenance labor)	46,100	54,900	114,720	127,600
Taxes, insurance, and general administration	122,500	181,800	396,000	574,100
Capital recovery	402,700	597,400	1,301,700	1,887,000
Total indirect	571,300	834,100	1,812,400	2,588,700
Total Annualized Cost	810,400	1,222,400	2,724,400	4,278,300

[a] 0.02 gr/dscf corrected to 12 percent CO_2 and 90 and 70 percent reduction of HCl and SO_2, respectively.

[b] Assumes 50 percent of maintenance cost for labor.

TABLE 6-18. ESTIMATED ANNUALIZED OPERATING COSTS FOR SD/FF SYSTEMS FOR MODEL EXISTING WATERWALL MASS BURNING FACILITIES[a] (August 1986 dollars based on 6,500 hrs/yr operation)

	Model plant 1 (200 tpd)	Model plant 2 (400 tpd)	Model plant 3 (1,000 tpd)	Model plant 4 (2,200 tpd)
Direct Cost				
Operating labor	39,100	39,100	78,100	58,600
Supervision	7,000	7,000	14,100	10,500
Utilities:				
Electricity	69,600	126,800	310,700	647,400
Water	1,300	2,700	6,600	15,900
Chemicals (lime)	31,500	63,300	158,000	348,000
Maintenance[b]	119,900	170,800	373,800	506,100
Waste disposal	38,500	76,900	192,400	423,200
Total direct	306,900	486,600	1,133,700	2,009,700
Indirect cost				
Overhead (60% of operating labor and maintenance labor)	63,600	78,900	167,500	193,300
Taxes, insurance, and general administration	239,900	341,600	747,600	1,012,300
Capital recovery	788,500	1,122,600	2,457,200	3,327,200
Total indirect	1,092,000	1,543,100	3,372,300	4,532,800
Total Annualized Cost	1,398,900	2,029,700	4,506,000	6,542,500

[a]0.02 gr/dscf corrected to 12 percent CO_2 and 90 and 70 percent reduction of HCl and SO_2, respectively.

[b]Assumes 50 percent of maintenance cost for labor.

TABLE 6-19. ESTIMATED ANNUALIZED OPERATING COSTS FOR ESP SYSTEMS FOR MODEL EXISTING WATERWALL MODULAR COMBUSTOR FACILITIES[a]
(August 1986 dollars based on 6,500 hrs/yr operation)

	Model plant 5 (100 tpd)	Model plant 6 (200 tpd)	Model plant 7 (300 tpd)
Direct Cost			
Operating labor	9,800	9,800	9,800
Supervision	1,800	1,800	1,800
Utilities:			
Electricity	6,800	13,500	20,300
Water	0	0	0
Chemicals (lime)	0	0	0
Maintenance[b]	9,700	15,700	20,000
Waste disposal	500	900	1,400
Total direct	28,600	41,700	53,300
Indirect cost			
Overhead (60% of operating labor and maintenance labor)	10,000	11,700	13,000
Taxes, insurance, and general administration	19,500	31,300	40,000
Capital recovery	57,200	92,000	117,300
Total indirect	86,700	135,000	170,300
Total Annualized Cost	115,300	176,700	223,600

[a]0.02 gr/dscf corrected to 12 percent CO_2.

[b]Assumes 50 percent of maintenance cost for labor.

TABLE 6-20. ESTIMATED ANNUALIZED OPERATING COSTS FOR SD/ESP SYSTEMS FOR MODEL EXISTING WATERWALL MODULAR COMBUSTOR FACILITIES[a]
(August 1986 dollars based on 6,500 hrs/yr operation)

	Model plant 5 (100 tpd)	Model plant 6 (200 tpd)	Model plant 7 (300 tpd)
Direct Cost			
Operating labor	19,500	19,500	19,500
Supervision	3,500	3,500	3,500
Utilities:			
Electricity	23,600	40,900	58,300
Water	700	1,300	2,000
Chemicals (lime)	14,300	28,800	43,100
Maintenance[b]	51,000	77,100	97,300
Waste disposal	7,700	15,500	23,300
Total direct	120,300	186,600	247,000
Indirect cost			
Overhead (60% of operating labor and maintenance labor)	29,100	36,900	43,000
Taxes, insurance, and general administration	102,000	154,100	194,600
Capital recovery	335,400	506,600	639,600
Total indirect	466,500	697,600	877,200
Total Annualized Cost	586,800	884,200	1,124,200

[a]0.02 gr/dscf corrected to 12 percent CO_2 and 90 and 70 percent reduction of HCl and SO_2, respectively.

[b]Assumes 50 percent of maintenance cost for labor.

TABLE 6-21. ESTIMATED ANNUALIZED OPERATING COSTS FOR SD SYSTEMS FOR MODEL EXISTING WATERWALL REFUSE-DERIVED FUEL BURNING FACILITIES[a]
(August 1986 dollars based on 6,500 hrs/yr operation)

	Model plant 8 (1,000 tpd)	Model plant 9 (2,200 tpd)	Model plant 10 (3,000 tpd)
Direct Cost			
Operating labor	78,100	39,100	78,100
Supervision	14,100	7,000	14,100
Utilities:			
Electricity	287,000	588,900	596,500
Water	8,000	15,900	27,700
Chemicals (lime)	203,800	449,000	753,300
Maintenance[b]	204,000	258,500	398,800
Waste disposal	406,100	893,500	975,800
Total direct	1,201,100	2,251,900	2,835,300
Indirect cost			
Overhead (60% of operating labor and maintenance labor)	116,500	105,200	172,300
Taxes, insurance, and general administration	408,100	517,000	779,700
Capital recovery	1,341,300	1,699,400	2,562,700
Total indirect	1,865,900	2,321,600	3,514,700
Total Annualized Cost	3,067,000	4,573,500	6,350,000

[a]0.02 gr/dscf corrected to 12 percent CO_2 and 90 and 70 percent reduction of HCl and SO_2, respectively.

[b]Assumes 50 percent of maintenance cost for labor.

TABLE 6-22. ESTIMATED ANNUALIZED OPERATING COSTS FOR SD/FF SYSTEMS FOR MODEL EXISTING WATERWALL REFUSE-DERIVED FUEL BURNING FACILITIES[a]
(August 1986 dollars based on 6,500 hrs/yr operation)

	Model plant 8 (1,000 tpd)	Model plant 9 (2,200 tpd)	Model plant 10 (3,000 tpd)
Direct Cost			
Operating labor	78,100	39,100	78,100
Supervision	14,100	7,000	14,100
Utilities:			
Electricity	321,000	663,800	927,900
Water	8,000	15,900	27,700
Chemicals (lime)	203,800	449,000	753,300
Maintenance[b]	383,800	441,800	681,200
Waste disposal	406,100	893,500	975,800
Total direct	1,414,900	2,510,100	3,458,100
Indirect cost			
Overhead (60% of operating labor and maintenance labor)	170,500	160,200	259,700
Taxes, insurance, and general administration	767,600	883,600	1,362,300
Capital recovery	2,522,800	2,904,200	4,477,700
Total indirect	3,460,900	3,948,000	6,099,700
Total Annualized Cost	4,875,800	6,458,100	9,557,800

[a]0.02 gr/dscf corrected to 12 percent CO_2 and 90 and 70 percent reduction of HCl and SO_2, respectively.

[b]Assumes 50 percent of maintenance cost for labor.