SMAQMD BACT CLEARINGHOUSE

ACTIVE

CATEGORY Type:	**CREMATORY**
BACT Category:	Minor Source BACT

BACT Determination Number:	388	**BACT Determination Date:**	01/21/2025

Equipment Information

Permit Number:	N/A - Generic BACT Determination
Equipment Description:	Crematory, LPG Fired
Unit Size/Rating/Capacity:	Limited to a total charge weight of 749 tons/year
Equipment Location:	N/A - Generic BACT Determination

BACT Determination Information

District Contact:	Venk Reddy	**Phone No.:**	279-207-1146	**Email:**	vreddy@airquailty.org

ROCs	**Standard:**	LPG and a secondary combustion chamber (afterburner) ≥ 1,600 °F
	Technology Description:	
	Basis:	Achieved in Practice
NOx	**Standard:**	60 ppmv corrected to 3% O2 or 0.073 lb/MMBTU, measured as emissions from the fuel burning, not with the charge
	Technology Description:	
	Basis:	
SOx	**Standard:**	No standard
	Technology Description:	
	Basis:	
PM10	**Standard:**	LPG-fired with secondary chamber operating at ≥ 1,600 °F
	Technology Description:	
	Basis:	
PM2.5	**Standard:**	No standard
	Technology Description:	
	Basis:	
CO	**Standard:**	Not addressed
	Technology	

		Description:	
		Basis:	
	LEAD	**Standard:**	Not addressed
		Technology Description:	
		Basis:	

Comments:	This is a generic BACT determination based on BACT determinations made, and published, by other air agencies in California and/or other States.

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777 12th Street, Ste. 300 SACRAMENTO METROPOLITAN AIR QUALITY MANAGEMENT DISTRICT Sacramento, CA 95814

BEST AVAILABLE CONTROL TECHNOLOGY DETERMINATION

DETERMINATION NOS.:	388
DATE:	10/21/2024
ENGINEER:	Venk Reddy

Category/General Equip Description:	Crematory
Equipment Specific Description:	Crematory – LPG fired
Equipment Size/Rating:	749 ton per year charge limit
Previous BACT Det. No.:	N/A

This BACT determination is for crematories (Human and Pet) that will operate on LPG otherwise known as propane.

This determination will also include Best Available Control Technology for Toxics (T-BACT) for the hazardous air pollutants (HAP) associated with the process.

From the Cremation Association of North America, "Flame-based cremation uses flame and heat to reduce the human remains to bone fragments or cremated remains. This is completed within a machine called a cremator."

Pet crematories work in a similar fashion.

The BACT for CO will be addressed at a later date, when a project exceeds the threshold requiring limitations. It is not expected that this type of equipment will be large enough to trigger BACT requirements for CO, since the District CO BACT trigger level is 550 lbs/day.

BACT/T-BACT ANALYSIS

A. ACHIEVED IN PRACTICE (Rule 202, §205.1a):

The following control technologies are currently employed as BACT/T-BACT for crematories by the following agencies and air pollution control districts:

US EPA

BACT
Source: EPA RACT/BACT/LAER Clearinghouse

Pollutant	Crematory	
	Standard	Source
VOC	No standard	N/A
NOx	No standard	N/A
SOx	No standard	N/A
PM10	No standard	N/A
PM2.5	No standard	N/A
CO	No standard	N/A

No determinations were identified.

T-BACT
Source: EPA RACT/BACT/LAER Clearinghouse

No determinations were found.

RULE REQUIREMENTS:
None

California Air Resource Board (CARB)

BACT
Source: CARB BACT Clearinghouse

Pollutant	Crematory	
	Standard	Source
VOC	No standard	N/A
NOx	No standard	N/A
SOx	No standard	N/A
PM10	No standard	N/A
PM2.5	No standard	N/A
CO	No standard	N/A

No determinations were identified.

CARB BACT Guidelines Search

This search for crematory BACT determination yields results from BAAQMD, SMAQMD, SJVAPCD and SCAQMD. BAAQMD, SMAQMD, and SJVAPCD have reference to the use of natural gas, so they will not be considered. SCAQMD reference for a crematory from 2-1-2019 references natural gas for SOx and PM10. The pollutants VOC and NOx have a standard or control with no reference of fuel and referencing the SCAQMD rule for misc. NOx from 2-1-2019 that has since been revised. This BACT will be further discussed in the SCAQMD section. The BACT from SJVAPCD has been revised as well and will be further discussed in the respective section.

T-BACT
There are no T-BACT standards published in the clearinghouse for this category.

RULE REQUIREMENTS:
No rules have been identified.

Sacramento Metropolitan AQMD

BACT

There are no BACT standards for this source category.

RULE REQUIREMENTS:
Rule 419 - NOx from Miscellaneous Combustion Units (10-25-2018)

New crematories fired at greater than 1,200 °F that are rated at 2 MMBTU/hr or greater located at a major source or greater than or equal to 5 MMBTU/hr located at an area source, must meet a standard of 60 ppmv corrected to 3% O_2 for NOx and 400 ppmv corrected to 3% O_2 for CO. There is no distinction of fuel type and this standard would be applicable to propane if the unit is rated over 5 MMBTU/hr.

South Coast AQMD

BACT
Source: SCAQMD BACT Guidelines for Non-Major Polluting Facilities, Pg 35

SCAQMD BACT Guidelines for Crematory Rev 1 Date: 2-1-2019	
Pollutant	**Standard**
VOC	LPG, Secondary Chamber ≥ 1,500 °F
NOx	60 ppm and compliance with Rule 1147 (2-1-2019)[(A)]
SOx	Natural gas

SCAQMD BACT Guidelines for Crematory Rev 1 Date: 2-1-2019	
PM10	Natural gas, Secondary Chamber ≥ 1,500 °F
PM2.5	No Standard
CO	No Standard

(A) Rule 1147 was updated on 5/6/22 with a lower standard of 30 ppmv for units fueled by 100% natural gas. See further discussion below.

SOx and PM10 will not be considered for the use of LPG.

T-BACT
There are no T-BACT standards published in the clearinghouse for this category.

RULE REQUIREMENTS:

Rule 1147 - NOx Reductions from Miscellaneous Sources (5/6/22)

Although the rule does not specifically state if propane is included in this rule, the NOx and CO emission standards are only measured "in Unit fueled by 100% natural gas" In situ testing and verification would not be possible if natural gas is not available. Therefore, the requirements of this rule are not considered achieved in practice for propane applications.

San Joaquin Valley APCD

BACT
Source: SJVAPCD BACT Guideline 1.9.3 (6/9/22)

SJVAPCD BACT Guideline 1.9.3	
Pollutant	**Standard**
VOC	LPG and a secondary combustion chamber (afterburner) ≥ 1,600 °F
NOx	60 ppmv @ 3% O_2 (0.073 lb/MMBTU) without charge
SOx	LPG Fuel
PM10	LPG fuel and a secondary combustion chamber (afterburner) ≥ 1,600 °F
PM2.5	No Standard
CO	No Standard

T-BACT
There are no T-BACT standards published in the clearinghouse for this category.

RULE REQUIREMENTS:

Rule 4302 Incinerator Burning (12/16/93)
The rule states that a person shall not burn in any incinerator within the District except in a multi-chamber incinerator as defined in Rule 1020 (Definitions). Section 3.27 of Rule 1020 defines a multi chamber incinerator as that used to dispose of combustible refuse by burning. Since human or pet remains are not considered refuse, this definition and thus Rule 4302 is not applicable to this source category.

San Diego County APCD

BACT
Source: NSR Requirements for BACT (June 2011)

SDCAPCD NSR Requirements for BACT	
Pollutant	**Standard**
VOC	No Standard
NOx	No Standard
SOx	No Standard
PM10	No Standard
PM2.5	No Standard
CO	No Standard

T-BACT
There are no T-BACT standards published in the clearinghouse for this category.

RULE REQUIREMENTS:
None.

Bay Area AQMD

BACT
Source: BAAQMD BACT Guideline Document # 53.1 (9.12.2007)

From BAAQMD BACT Guideline – Crematory (Revision 1 Date: 9/12/2007)	
Pollutant	**Standard**
VOC	Secondary Combustion ≥ 1,500 °F
NOx	Natural gas fired

From BAAQMD BACT Guideline – Crematory (Revision 1 Date: 9/12/2007)	
SOx	Natural gas fired
PM10	Natural gas firing with secondary combustion ≥ 1,600 °F
PM2.5	No Standard
CO	Secondary Chamber ≥ 1,500 °F

NOx, SOx and PM10 are not considered for the use of LPG.

T-BACT
There are no T-BACT standards published in the clearinghouse for this category.

RULE REQUIREMENTS:
None.

Summary of Achieved in Practice Control Technologies

The following control technologies have been identified and are ranked based on stringency:

SUMMARY OF ACHIEVED IN PRACTICE CONTROL TECHNOLOGIES	
Pollutant	**Standard**
VOC	1) Secondary combustion chamber (afterburner) ≥ 1,600 °F, when fired on LPG [SJVAPCD] 2) Secondary combustion chamber (afterburner) ≥ 1,500 °F, when fired on LPG [SCAQMD, BAAQMD] 3) No standard [US EPA, CARB, SMAQMD, SDCAPCD]
NOx	1) 60 ppmv corrected to 3% O_2 or 0.073 lb/MMBTU measurement of the fuel burned only [SJVAPCD, SCAQMD] 2) No standard [US EPA, CARB, SMAQMD, SDCAPCD, BAAQMD]
SOx	No standard [All]
PM10	1) LPG fired with secondary chamber operating at ≥ 1,600 °F [SJVAPCD] 2) No standard [US EPA, CARB, SMAQMD, SDCAPCD, SCAQMD, BAAQMD]
PM2.5	No Standard
CO	1) 400 ppmv @ 3% O_2 [SMAQMD] 2) Secondary chamber operating at ≥ 1,500 °F [BAAQMD] 3) No standard [US EPA, CARB, SMAQMD, SCAQMD, SJVAPCD, SCAQMD]

CO
The 400 ppmv corrected to 3% O_2 CO requirement listed in the table above was taken from SMAQMD Rule 419. Since there are currently no crematory units that operate at a major

source nor any rated at greater than 5 MMBTU/hr operating at area sources, this standard will not be considered achieved in practice for this application.

The following control technologies have been identified as the most stringent, achieved in practice control technologies:

BEST CONTROL TECHNOLOGIES ACHIEVED IN PRACTICE		
Pollutant	**Standard**	**Source**
VOC	Natural gas fuel and a secondary combustion chamber (afterburner) ≥ 1,600 °F	SJVAPCD
NOx	60 ppmv correct to 3% O_2 or 0.073 lb/MMBTU	SCAQMD, SJVAPCD
SOx	Natural gas fired	SCAQMD, SMAQMD, BAAQMD, SJVAPCD
PM10	Natural gas fired with secondary chamber operating at ≥ 1,600 °F	SJVAPCD,
PM2.5	No standard	
CO	Secondary chamber operating at ≥ 1,500 °F (natural gas) & 1,000 ppmv correct to 3% O_2 (natural gas)	BAAQMD

B. TECHNOLOGICALLY FEASIBLE AND COST EFFECTIVE (Rule 202, §205.1.b.):

<u>Technologically Feasible Alternatives:</u>
Any alternative basic equipment, fuel, process, emission control device or technique, singly or in combination, determined to be technologically feasible by the Air Pollution Control Officer.

The table below shows the technologically feasible alternatives identified as capable of reducing emissions beyond the levels determined to be "Achieved in Practice" as per Rule 202, §205.1.a.

Pollutant	**Technologically Feasible Alternatives**
VOC	No other technologically feasible option identified
NOx	1. Burner technology that can meet 30 PPM 2. Selective Catalytic Reduction (SCR)
SOx	1. Wet Scrubber 2. Dry Scrubber
PM10	1. Baghouse 2. Wet Scrubber 3. Dry Scrubber 4. Venturi Scrubber

Pollutant	Technologically Feasible Alternatives
PM2.5	1. Baghouse 2. Wet Scrubber 3. Dry Scrubber 4. Venturi Scrubber
CO	No other technologically feasible option identified

Updated in 2005, the SJVAPCD lists the use of a baghouse with a dry scrubber or a wet scrubber as technologically feasible for the control of SOx, the use of a baghouse and venturi scrubber for the control of PM10 and the use of an SCR or a low NOx burner for the control of NOx. The control strategies appear to be carryovers from other natural gas combustion operations and do not appear to be fully evaluated for a crematory. The BAAQMD evaluated the same source category in 2007 and does not list a baghouse, venturi scrubber, the use of an SCR or a low NOx burner as technologically feasible options. No other district lists these options as technologically feasible either. Additionally, SMAQMD contacted SJVAPCD (Manuel Salinas, Air Quality Engineer, 559-230-5833) and verified that an SCR, low NOx burner, baghouse or scrubber have not been installed on any crematories to date. Irrespective of the discussion above that questions San Joaquin's intent for listing add on controls as being technologically feasible for a crematory application, the following analysis will assume that add on controls are technologically feasible and a cost effectiveness determination needs to be conducted to determine if add on controls are in fact considered cost effective.

Cost Effective Determination:

After identifying the technologically feasible control options, a cost analysis is performed to take into consideration economic impacts for all technologically feasible controls identified. All the controls were updated to 2023 cost values.

Maximum Cost per Ton of Air Pollutants Controlled

1. A control technology is considered to be cost-effective if the cost of controlling one ton of that air pollutant is less than the limits specified below:

Pollutant	Maximum Cost ($/ton) (Amended 6/25/24)
VOC	26,300
NO_X	36,700
PM10	11,400
SO_X	18,300
CO	300

Cost Effectiveness Analysis Summary

This BACT determination will perform a cost effectiveness analysis in accordance with the updated EPA OAQPS Air Pollution Control Cost Manual. The interest rate was based on the previous 6-month average interest rate on United States Treasury Securities (based on the life of the equipment) and addition of two percentage points and rounding up to the next higher integer rate.

NOx:

Burner Technology that will meet 30 PPM:
SCAQMD has passed a rule that shows that the 30 PPM NOx from a burner is possible for this source category. However, there are no known burners used for crematories that will meet this standard at this time. Therefore it is not considered achieved in practice or technologically feasible.

SCR System:
A cost effectiveness analysis was done to determine if an SCR system could be considered cost effective to control the NOx from a crematory and is calculated in Appendix A of this document. The crematory is estimated to have a burner that when fired with no body will emit NOx at less than 60 ppmv when fired on natural gas or lpg. To estimate the NOx emissions attributed to the burning of the charge, AP-42 Chapter 2.3 - Medical Waste Incineration Table 2.3-1(7/93) was used. This value for NOx is 3.56 lb of NOx per ton of charge. As a worst-case assumption, and consistent with the crematory permitting manual of the BAAQMD, the NOx emission factor that is used in this analysis will be the combined emission factor of 5.23 lbs of NOx/ton of charge which includes the emission factor of combustion added to the emission factor from burning of the charge. Calculations are based on a crematory rated at 4.95 MMBTU/hr.

The original cost analysis was done based on 1998 cost values. The estimate has been updated to 2023 values. The current permitting methodology is to permit based on yearly throughput and modern cremator operators are wanting greater throughputs beyond the operating hours originally estimated. Therefore, the burn rate and resultant TPY were raised until the cost effectiveness was reached. The interest rate used was calculated to be 7%, based on SMAQMD BACT policy using the twenty year treasury rate averaged over 6 months plus 2 percent then rounded up.

The below rates were used in the calculation represent the twenty year treasury interest rate on the listed date.

10/1/24 – 4.14%
9/3/24 – 4.21%
8/1/24 – 4.35%
7/1/24 – 4.76%
6/2/24 – 4.63%
5/1/24 – 4.85%

The total charge would be 749 tons per year. This would be maximum operation of 12 hrs/day 6 days/week 52 weeks/yr. With an SCR NOx control efficiency of 90%, the NOx emissions from the crematory are calculated to be 0.2 tons per year (749 TPY*5.2 lb/ton * (1 - 0.9) / 2000 lb/ton = 0.2 tons/year).

The cost for an SCR system was estimated using EPA's Cost Control Manual, 6th Edition. The SCR sizing criteria for which the costs are based are primarily determined from the exhaust flow rate and temperature. The spreadsheet that was used determines the flow rate from the burner rating.

The total annualized cost for the SCR system is estimated to be $101,712.56. The total NOx controlled would be 1.75 tons/year at 60 ppmv (749 tpy * 5.2 lb/ton * 0.9/2000 lb/ton = 1.75

tpy NOx controlled). The analysis shows the cost effectiveness calculation to be $58.071.09 per ton of NOx reduced. Since the District's cost effectiveness threshold for NOx is $36,700 per ton, the addition of the SCR would not be considered cost effective at this and lower throughputs.

Total Annualized Cost of SCR	Quantity of NOx Controlled (TPY)	Cost of SCR per ton removed	SMAQMD cost effective threshold for NOx	Cost effective
$101,712.56	1.75 @ 60 ppmv	$ 58,071.09 @ 60 ppmv of NOx	$36,700	No

The 4.9 MMBtu/hr value used in the SCR calculation is a conglomerate number used to estimate the sizing of the SCR to take into account the NOx from the body as well as combustion and does not represent the sizing of the crematory unit. The crematory used for calculation purposes was 4.5 MMbtu/hr. Based on this there will be no limitation on BTU/yr.

PM:

Baghouse:
A screening cost effectiveness analysis was done to determine if a baghouse could be considered cost effective to control the particulate from a crematory. Based on source testing of a crematory unit (P/O 24785 North Sacramento Funeral home Inc. source test) only about 32% of the total particulate collected is filterable. However, this analysis will assume that the baghouse will collect 100% of the filterable emissions which would be approximately 0.152 tons/yr, based on 12 hrs/day, 6 days/week, and 52 weeks/yr. With the District's particulate cost effectiveness threshold of $11,400/ton, interest rate of 7% and an equipment life of 10 years, the capital cost for the control would have to be less than $12,170.46 to be considered cost effective.

Based on EPA's Cost Control Manual, 6th Edition, the capital cost of a baghouse needed to control the flow characteristics of a crematory is estimated to be approximately $44,048.25 (2023) (refer to Attachment A). Since the capital costs of a baghouse alone are higher than the capital costs needed to be considered cost effective, the baghouse will not be considered cost effective. The analysis above only considers the amortized capital costs of the control device and no other annualized costs (such as maintenance, energy, etc.) were included. Inclusion of these other annualized costs would only drive the cost effectiveness higher.

Therefore, the conclusion is that a baghouse used to control particulate matter for a crematory is not considered cost effective and as such will not be considered BACT. See Appendix A for cost analysis.

Total Annualized Cost of a Baghouse	Quantity of PM10 Controlled (TPY)	Cost of a Baghouse per ton Removed	SMAQMD cost effective Threshold for PM10	Cost Effective
$6,271.48	0.152	$41,259.74	$11,400	No

Venturi Scrubber:
A screening cost effective analysis was done for a venturi scrubber using the EPA Cost Control Manual, 6th Edition. Unlike the baghouse discussion above, the entire PM quantity (filterable and condensable) was used for cost effectiveness determination, as opposed to only the filterable fraction of PM for the baghouse. The lowest cost option was considered when making the determination of costs. A venturi scrubber system sized to control 3,337 cfm of exhaust gas is estimated to cost $169,172.41 (refer to Attachment A) which only takes into account the equipment costs. The cost effectiveness for this system would then be $158,462.79 per ton of PM controlled. Since the system costs are greater than the District's cost effectiveness criteria, a venturi scrubber is not considered cost effective.

Total Annualized Cost of Venturi Scrubber	Quantity of PM10 Controlled (TPY)	Cost of Venturi per ton removed	SMAQMD cost effective threshold for PM10	Cost effective
$24,086.34	0.152	$158,462.79	$11,400	No

SOx:

Wet Scrubber:
A cost effectiveness analysis was done for the control of SOx with the use of a wet scrubber. Based on the information presented in the EPA Cost Control Manual, 6th Edition, the cost of the capital equipment was selected by using the lowest surface area and subsequent cost information available in this section of the manual. For SOx, the District's cost effectiveness threshold is $18,300 per ton. The cost of the wet scrubber was estimated to have a total annual cost of $58,293.87 (refer to Attachment A) and control efficiency was assumed to be 100%. The cost of the electricity, or caustic was not considered. The total SOx emissions controlled is 0.46 tons/year. The cost per ton removed for this control was calculated to be $58,807.49 and therefore is not considered to be cost effective.

Total Annualized Cost of Wet Scrubber	Quantity of SOx Controlled (TPY)	Cost of wet scrubber per ton removed	SMAQMD cost effective threshold for SOx	Cost effective
$58.293.87	0.46	$126,725.80	$18,300	No

Dry Scrubber:
The EPA Cost Control Manual, 6th Edition does not have a chapter on dry scrubbers. A dry scrubber consists of a dry reactant or powder injection system and a baghouse. Costs for a dry scrubber are estimated using the equipment costs of a baghouse plus the annual operating costs of a wet scrubber. Since the reference manual does not have cost information for the powder injection system, the cost of electricity, powder reactant and the powder injection system were not considered in this analysis. The total annualized costs are estimated to be $49,295.24 (refer to Attachment A). The cost per ton of SOx removed is calculated to be $107,163.57 and therefore is not considered to be cost effective.

Total Annualized Cost of Dry Scrubber	Quantity of SOx Controlled (TPY)	Cost of Dry Scrubber per ton Removed	SMAQMD Cost Effective Threshold for SOx	Cost Effective
$49,295.24	0.46	$107,163.57	$18,300	No

PM + SOx:

Per the SMAQMD *Procedures for Making Best Available Control Technology (BACT) and Best Available Control Technology for Toxic (T-BACT) Determinations for New and Modified Emission Units (10/15)*, when a control technology is expected to control multiple forms of criteria pollutants both shall be assessed for cost effectiveness. In the case of a wet scrubber, the control of SOx, and PM10 should be considered. Per the calculation method found in the document, and assuming that 100% of PM10 and SOx is removed by the wet scrubber:

$$\text{Max Cost} = \sum^{P} (\text{Emissions Reduced} * \text{Cost Effectiveness Value})$$

P = Each pollutant subject to BACT

Max Cost = (0.152 ton PM10/yr X $11,400/ton PM) + (0.46 ton SOx/yr X $18,300/ ton SOx)
= $10,150.80/year

Since the annualized costs of a wet scrubber or a dry scrubber with baghouse is $58,293.87 and/or $49,295.24, respectively and since either is greater than the Max Cost value calculated above the use of a wet scrubber or dry scrubber with baghouse is not considered cost effective.

APC Device	Total Annualized Cost	Quantity of SOx & PM10 Controlled per Yr	Aggregate Max Cost Threshold for SOx & PM10	Cost Effective
Wet Scrubber	$58,293.87	0.46 tons SOx 0.156 tons PM10	$10,150.80	No
Dry Scrubber with Baghouse	$49,295.24	0.46 tons SOx 0.156 tons PM10	$10,150.80	No

C. SELECTION OF BACT:

No technologically feasible control technologies were found to be cost effective and therefore not selected. BACT will be standards that have been achieved in practice.

BACT #388 for a crematory with operation restrictions of 863 ton per year charge limit		
Pollutant	**Standard**	**Source**
VOC	LPG and a secondary combustion chamber (afterburner) ≥ 1,600 °F	SJVAPCD
NOx	60 ppmv corrected to 3% O_2 or 0.073 lb/MMBTU, measured as emissions from the fuel burning, not with the charge	SJVACPD, SCAQMD
SOx	No standard	SCAQMD, SMAQMD, BAAQMD, SJVAPCD
PM10	LPG-fired with secondary chamber operating at ≥ 1,600 °F	SJVAPCD
PM2.5	No standard	
CO	Not addressed	

D. SELECTION OF T-BACT:

There are no Federal NSPSs, NESHAPs nor State ATCMs for this source category. None of the sources surveyed have any toxic T-BACT determinations published. The District contacted the SCAQMD, the BAAQMD, and the SJVAPCD to inquire about any T-BACT determinations that may not have been published for this source category. In all cases, the T-BACT determinations were essentially the crematory's operational parameters that have been required as BACT. Therefore, T-BACT standards will be considered as meeting the BACT standards identified above.

APPROVED BY: Brian F Krebs **DATE:** 01-21-2025

Attachment A

Crematory – Control Equipment Cost Analysis

PM10 Baghouse Cost Effective Requirements

PM Cost effective Number	11400	$/ton				
			Total PM =			
PM emission from Crematory 23% of PM is filterable	0.152	tons/yer	0.152 ton/year			
Cost needed to be cost effective	$ 1,732.80	$				
CRF (7% interest and 10 year life)	0.142377503					
P (Cost of control need to be cost effective)	**$ 12,170.46**					

Particulate Matter Control (Bag House) Cost Analysis

Gas to cloth ratio for shaker or reverse air bag house	1.8					
A	9					
B	0.8					
L	0.1					
D (mass mean diameter of particle, 7 um guess)	7					
V	4.958928378	equation 1.11				
acfm of system	3337	acfm				
Bag Size	672.927646	ft^2				
Cost of Bag house common housing design	$ 7,127.18	$				
Cost of insulation	$ 2,541.63	$				
Cost of BAG Nextel, bottom bag removal	$ 11,217.70	high Temp Bags				
Bag house cages	$ 50.14					
cage cost	$ 12.23	$/cage				
Total cage costs	$ 613.23	$				
Purchase equipment costs (1998)	**$ 21,499.74**	CEPCI 2023		798	CEPCI 1998	389.5
Purchase equipment costs (2023)	$ 44,048.25					
Purchased equipment costs	**$ 44,048.25**	$				
Annualized Cost	$ 6,271.48					
Cost effectiveness	$ 41,259.74	$/Ton controlled				

PM10 Venturi Cost Effecive Analysis

Total PM	0.152	Tons/year				
PM Cost effectiveness	11400	$/tons controlled				
CRF (7% interest and 10 year life)	0.142377503					

From Table 2.8 Direct and Indirect Installation Costs for Venturi Scrubbers, EPA Control Cost Manual 6th edition, 1-02

Ventur Packaged Unit (A1)	$14,098.43	150*Q(sat)^0.56	3337	acfm	low energy cabon steel	
Additional Equipement (A2)	$11,278.74	80% of Unit				
Purchase Equipment Cost, PEC	$29,945.06	1.18*(A1+A2)				
Direct Installation Costs, DC	$16,769.24	0.56*PEC				
Total Indirect Costs, IC	$10,480.77	0.35*PEC				
Total(1998)	$82,572.25	CEPCI 2023	798	CEPCI 1998	389.5	
Total (2023)	$169,172.41					
Total	$169,172.41					
Total Annualized Cost	$24,086.34					
Cost Effectiveness	$158,462.79	$/Ton Controlled				

Cost Effective Requirements SOx Wet Scrubber

SOx Cost effective Number	18300	$/ton
SOx emissions	0.46	tons/yer
CRF (7% interest and 10 year life)	0.142377503	

SOx Control (Packed Tower) Cost Analysis

Total Capital Investment				Figure 1.4 pg 1-27, Setion 5.2 Post Combstion Controls, Chapter 1 Wet Scrubbers for Acid Gas	
Tower Cost	$ 7,935.00		69 ft^2	Equation 1.40 pg 1-24, Setion 5.2 Post Combstion Controls, Chapter 1 Wet Scrubbers for Acid Gas	
Packing Costs	$ 207.00				
AUX Eq (fan & Pump)	$ 4,071.00	1/2 the tower costs Guess			
PEC	$ 14,411.34				
DC	$ 22,594.05				
IC	$ 4,274.55				
TCI	$ 41,279.94				
Direct Annual Costs				Table 1.4, pg 1-28, Setion 5.2 Post Combstion Controls, Chapter 1 Wet Scrubbers for Acid Gas	
Operating Labor	$ 3,659.76	(.5 hr/shift) (1 shift/8 hrs)(3,744 hrs/yr)*$15.64			
Supervisor	$ 548.96	15% of operating Labor			
Solvent (water)	$ 690.00				
Caustic replacement					
Watewater disposal					
Maintenance Labor	$ 4,027.14	(.5 hr/shift) (1 shift/8 hrs)(3,744 hrs/yr)*$17.21			
Material	$ 4,027.14	100% of maintenance labor			
Electricity					
Indirect Annual costs					
Overhead	$ 7,357.80	60% of total labor and material costs			
Admin charges	$ 825.60				
Property Tax	$ 412.80				
Insurance	$ 412.80				
Total indirect annual costs	$ 21,962.00				
Total annual costs (1995)	$ 27,839.34	CEPCI 2023	798	CEPCI 1995	381.1
Total annual costs (2023)	$ 58,293.87				
TAC/Ton of Sox controlled	$ 126,725.80				

Cost Effective Requirements SOx Dry Scrubber

SOx Cost effective Number	18300	$/ton	
SOx emissions	0.46	tons/yer	0.46
CRF (7% interest and 10 year life)	0.142377503		

SOx Control (Bag House) Cost Analysis

Gas to cloth ratio for shaker or reverse air bag house	1.8	
A	9	
B	0.8	
L	0.1	
D (mass mean diameter of particle, 7 um guess)	7	
V	4.958928378	equation 1.11
acfm of system	3337	acfm
Bag Size	672.927646	ft^2
Cost of Bag house common housing design	7127.180728	$
Cost of insulation	2541.628651	$
Cost of BAG Nextel, bottom bag removal	11217.70386	high Temp Bags
Bag house cages	50.14363979	
cage cost	12.22944239	$/cage
Total cage costs	613.228754	$
Purchased equipment costs	**21499.74199**	$

DC					
Operating Labor	$ 3,659.76	(.5 hr/shift) (1 shift/8 hrs)(3,744 hrs/yr)*$15.64			
Supervisor	$ 548.96	15% of operating Labor			
Maintenance Labor	$ 4,027.14	(.5 hr/shift) (1 shift/8 hrs)(3,744 hrs/yr)*$17.21			
Material	$ 4,027.14	100% of maintenance labor			
Electricity					
IC					
Overhead	$ 7,357.80	60% of total labor and material			
Admin charges	$ 429.99				
Property Tax	$ 215.00				
Insurance	$ 215.00				
Total annualized costs (1995)	$ 23,541.88	CEPCI 2023	798	CEPCI 1995	381.1
Total annualized costs (2023)	$ 49,295.24				
TAC/tons controlled	$ 107,163.57				

SCR COST EFFECTIVENESS CALCULATION

EPA AIR POLLUTION CONTROL COST MANUAL, Sixth Edition, EPA/452/B-02-001, January 2002
Section 4.2 - NOx Post-Combustion, Chapter 2 - Selective Catalytic Reduction

Cost Effectiveness = $ 58,071.09 $/ton

Equipment

Crematory rating	4.952057895	mmBTU/hr						
Crematory Operating hours	3744	hours	12 hrs a day 6 days a week 52 weeks a year					
Crematory capacity factor	1							
SCR Operating Days	312	days						
Total Capacity Factor	0.854794521							
Baseline Nox (400 lb/hr burn rate, 3.56 lb/ton of charge*, 4.5 MMBTU/hr) *Nox emission Rate from AP-42 Table 2.3-1 Medical waste incineration	1.58E-01	lb/mmBTU	=400*3.56/2000/4.5					
SCR Nox (90% control)	1.58E-02	lb/mmBTU						
Ammonia Slip	10	ppm						
Ammonia Stochiometric Ratio	1.05							
Stored Ammonia Conc	29	%						
Amonnia Storage days	90	days						
Sulfur Content	0.005	%						
Pressure drop for SCR Ductwork	3	inches W.G.		Rolling Acres Test Results				
Pressure drop for each Catalyst Layer	1	inche W.G.		3/20/2013				**AVE**
Temperature at SCR Inlet	1641.67	degrees F			1475	1675	1775	**1641.67**
Cost year	1998							
Equipment Life	20	years						
Annual interest Rate	7	%						
Catalyst cost, Initial	240	$/ft2						
Catalyst cost, replacement	290	$/ft2						
Electrical Power cost	0.1124	$/KWh						
Ammonia Cost	0.101	$/lb						
Catalyst Life	24000	hr						
Catalyst Layers	2 full, 1 empty							

Crematory Calculations

Q_B	4.952057895	mmBTU/hr				
$q_{flue\ gas}$	3341	acfm	3013	3736	3274	**3341**
N_{NOx}	0.9					

SCR Reactor Calculations

$Vol_{Catalyst}$	262.0873365	ft3
$A_{Catalyst}$	3.480208333	ft2
A_{SCR}	4.002239583	ft2
l=w=	2.000559817	ft
n_{layer}	24	
h_{layer}	4.137831026	
n_{total}	25	
h_{SCR}	287.4457757	ft

Reagent Calculations

$m_{reagent}$	0.304084661	lb/hr
m_{sol}	1.048567798	lb/hr
q_{sol}	0.140077423	gph
Tank Volume	302.5672341	gal

Cost Estimation

Direct Costs

DC	$	269,633.34

Indirect Costs

General Facilites	$	13,481.67
Engineering and home office fees	$	26,963.33
Process Contingency	$	13,481.67
Total Indirect Installation Costs	$	53,926.67
Project Contingency	$	48,534.00
Total Plant Cost	$	372,094.00
Preproduction Cost	$	7,441.88
Inventory Capital	$	228.76
Total Capital Investment	$	379,764.64

Direct Annual Costs

Maintenance Costs	$	5,696.47	per yr
Power		7.353464282	KW
Annual Electricity	$	6,189.05	per yr
Reagent Solution Cost	$	927.73	per yr

Catalyst Replacement

FWF		0.311051666	
Annual Catalyst Replacement	$	985.07	per yr

Total Variable Direct Cost	$	8,101.85	per yr		
Total Direct Annual Cost	$	13,798.32	per yr		
CRF		0.094392926			
Indirect Annual Cost	$	35,847.10	per yr		
Total annual Cost	$	49,645.41	per yr		
2023 costs	$	101,712.56	CEPCI 2023	798 CEPCI 199!	389.5
NOx Removed		1.75	tons per year		
Cost of NOx controlled per ton removal	$	58,071.09	per ton		

	3.56	NOx lb/ton(A)		400 lb/hr (B)
		(A) - Table 2.3-1 AP-42, 2.3 Medical Waste Incineration		(B) Burn rate of the crematory
	1.64	NOx lb/ton (C)		
		(C) - Natural gas combustion at 60 ppm		4.5 is baseline rating
	5.20	Combined NOx lb/ton		
tons of charge based on yearly limitation based on maximum usage.		lb of NOx based on 3.56 lb of NOx/ ton of charge	LB of NOx controlled based on 90%	
749 tons		1.95 tons	1.75 tons	