CATEGORY: **SULFUR BURNER**

BACT Size: Minor Source BACT **SULFUR BURNER**

BACT Determination Number: 221	**BACT Determination Date:** 8/15/2019

Equipment Information

Permit Number: 25908

Equipment Description: SULFUR BURNER

EXPIRED

Unit Size/Rating/Capacity: < 1200°F and < 69 MMBtu/hr

Equipment Location: THATCHER COMPANY OF CALIFORNIA
8625 UNSWORTH AVE
SACRAMENTO, CA

BACT Determination Information

ROCs	**Standard:**	
	Technology Description:	Natural gas fuel or equivalent, Good combustion practices, Scrubber (using soda ash) with demister
	Basis:	Achieved in Practice
NOx	**Standard:**	30 ppmvd @ 3% O2 <1200°F
	Technology Description:	During Startup/Shutdown (NG Combustion), For units ≥ 325,000 BTU/hr: 30 ppmvd @ 3% O2 <1200°F, Normal Operation (Sulfur Combustion): 15 ppmvd @ 3% O2
	Basis:	Achieved in Practice
SOx	**Standard:**	300 ppmvd @ 3% O2
	Technology Description:	Natural gas fuel or equivalent, Good combustion practices, Scrubber (using soda ash) with demister
	Basis:	Achieved in Practice
PM10	**Standard:**	
	Technology Description:	Natural gas fuel or equivalent, Good combustion practices, Scrubber (using soda ash) with demister
	Basis:	Achieved in Practice
PM2.5	**Standard:**	
	Technology Description:	Natural gas fuel or equivalent, Good combustion practices, Scrubber (using soda ash) with demister
	Basis:	Achieved in Practice
CO	**Standard:**	1.400 ppmvd @ 3% O2 or 0.3 lb/MMBtu
	Technology Description:	Natural gas fuel or equivalent, Good combustion practices
	Basis:	Achieved in Practice
LEAD	**Standard:**	
	Technology Description:	
	Basis:	

Comments: T-BACT is natural gas fuel or equivalent, good combustion practices, scrubber (using soda ash) with demister

District Contact: Jeff Quok Phone No.: (916) 874-4863 email: jquok@airquality.org

777 12th Street, Third Floor

SACRAMENTO METROPOLITAN AIR QUALITY MANAGEMENT DISTRICT

Sacramento, CA 95814

BEST AVAILABLE CONTROL TECHNOLOGY DETERMINATION

EXPIRED

DETERMINATION NO.:	221
DATE:	August 15, 2019
ENGINEER:	Jeffrey Quok

Category/General Equip Description:	Sulfur Furnace with Start-up Burner
Equipment Specific Description:	Sulfur Furnace with Start-up Burner < 1200°F
Equipment Size/Rating:	< 69 MMBtu/hr
Previous BACT Det. No.:	N/A

This BACT determination was determined under the project A/C 25908 (Thatcher Company of California) for a Sulfur Furnace with Start-up Burner, which is a natural gas fueled burner used to heat molten sulfur to its auto-ignition temperature of approximately 500°F. After start-up the sulfur reaches auto-ignition temperature and no natural gas fuel is burned. The start-up burner is also operated during shutdown to burn off any excess sulfur in the furnace.

BACT/T-BACT ANALYSIS

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

The following control technologies are currently employed as BACT/T-BACT for sulfur dioxide production process by the following air pollution control districts:

US EPA

BACT

Source: EPA RACT/BACT/LAER Clearinghouse

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

T-BACT

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

RULE REQUIREMENTS:

40 CFR Part 60 – New Source Performance Standards (NSPS):

There are currently no 40 CFR, Part 60 NSPS sections that apply to this source category.

40 CFR Part 61 – National Emission Standards for Hazardous Air Pollutants (NESHAPS):

There are currently no 40 CFR, Part 61 NESHAPs that apply to this source category.

40 CFR Part 63 – NESHAPS for Source Categories (MACT Standards):
There are currently no 40 CFR, Part 63 NESHAPs that apply to this source category

Air Resources Board (ARB)

BACT
Source: CARB BACT Clearinghouse
There are no BACT standards published in the clearinghouse for this category.

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

RULE REQUIREMENTS:
ARB Airborne Toxic Control Measures (ATCM):
There are currently no ATCMs that apply to this source category.

Sacramento Metropolitan AQMD

BACT
Source: SMAQMD BACT Clearinghouse
There are no BACT standards published in the clearinghouse for this category.

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

RULE REQUIREMENTS:

Rule 419 – NOx from Miscellaneous Combustion Units (Amended 10/25/2018)
This rule applies to any miscellaneous combustion unit or cooking unit with a total rated heat input capacity of 2 MMBtu/hr located at a major stationary source of NOx and to any miscellaneous combustion unit or cooking unit with a total rated heat input capacity of 5 MMBtu/hr or greater that is not located at a major stationary source of NOx.

The NOx and CO emission limits for miscellaneous combustion units are summarized in the following table.

TABLE 1: Miscellaneous Combustion Units
Emission Limits Expressed As PPMV, corrected to 3% O_2

Equipment Category	**NOx Limit ppmv, corrected to 3% O_2 (lb/MMBtu)**		**CO Limit ppmv, corrected to 3% O_2 (lb/MMBtu)**
	Effective (see Section 401)		
Gaseous Fuel-Fired Equipment	**Process Temperature**		**All Temperatures**
	< 1200 °F	≥ 1200 °F	

TABLE 1: Miscellaneous Combustion Units Emission Limits Expressed As PPMV, corrected to 3% O_2			
Equipment Category	**NOx Limit ppmv, corrected to 3% O_2 (lb/MMBtu)**		**CO Limit ppmv, corrected to 3% O_2 (lb/MMBtu)**
	Effective (see Section 401)		
Gaseous Fuel-Fired Equipment	**Process Temperature**		**All Temperatures**
	< 1200 °F	≥ 1200 °F	
Other miscellaneous combustion unit not listed above	30 (0.036)	60 (0.073)	400 (0.30)

Rule 406 – Specific Contaminants (Amended 12/6/1978)
This rule limits the emission of sulfur compounds and combustion contaminants.

A person shall not discharge into the atmosphere from any single source of emission equipment whatsoever:
1. Sulfur compounds in any state or combination thereof exceeding in concentration at the point of discharge: sulfur compounds, calculated as sulfur dioxide: 0.2% volume.
2. Combustion contaminants in any state or combination thereof exceeding in concentration at the point of discharge: 0.23 grams per dry standard cubic meter (0.1 grains per dry standard cubic foot) of gas calculated to 12% carbon dioxide at standard conditions.

South Coast AQMD

BACT
Source: SCAQMD BACT Guidelines for Non-Major Polluting Facilities.
(Last Revised 2/2/2018)

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

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

RULE REQUIREMENTS:
Reg IV, Rule 407 – Liquid and Gaseous Air contaminants (Last amended 4/2/1982)
A person shall not discharge into the atmosphere from any equipment:
1. Carbon Monoxide (CO) exceeding 2,000 ppm by volume measured on a dry basis, averaged over 15 consecutive minutes
2. Sulfur compounds which would exist as liquid or gas at standard conditions exceeding 500 ppm, calculated as sulfur dioxide (SO2) and averaged over 15 consecutive minutes

Reg IV, Rule 1147 – NOx Reductions from Miscellaneous Sources
(Last amended 7/7/2017)
This rule is to reduce NOx emissions from gaseous and liquid fuel fired combustion equipment as defined in this rule.

The NOx and CO emission limits for miscellaneous combustion units are summarized in the following table.

Equipment Categories	**NOx Emission Limit for Unit Heating Ratings ≥ 325,000 BTU/hr PPM @ 3% O2, dry or lb/mmBtu heat input**		
Gaseous fuel-fired equipment	**Process Temperature**		
	≤ 800°F	**> 800°F and <1200°F**	**≥1200°F**
Other Unit or Process Temperature	30 ppm or 0.036 lb/mmBtu	30 ppm or 0.036 lb/mmBtu	60 ppm or 0.073 lb/mmBtu

San Diego County APCD

BACT
Source: NSR Requirements for BACT (June 2011)
There are no BACT standards published in the clearinghouse for this category

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

RULE REQUIREMENTS:
Regulation 4, Rule 68 – Fuel-Burning Equipment – Oxides of Nitrogen (9/20/1994)
This rule does not apply to fuel burning equipment which has a maximum input rating of < 50 mmBTU/hr.

Emissions of nitrogen oxides, from any non-vehicular fuel burning equipment subject to this rule, calculated as nitrogen dioxide at three percent oxygen on a dry basis, shall not exceed the following levels:

Type of Fuel	Nitrogen Oxides, Concentration	
	Volume (ppm)	Mass (mg/m3, at 20°C)
Gaseous	125	240
Liquid or Solid	225	430

When more than one type of fuel is used, the allowable NOx concentration shall be determined by proportioning the gross heat input for each fuel to its respective allowable concentration.

Regulation 4, Rule 53 – Specific Air Contaminants – (1/22/1997)
A person shall not discharge into the atmosphere from any single source of emission equipment whatsoever:
1. Sulfur compounds calculated as sulfur dioxide: 0.05 percent, by volume, on a dry basis.
2. Combustion particulates: 0.1 grains per dry standard cubic foot of gas which is standardized to 12% of carbon dioxide by volume (0.23 grams dscm).

Bay Area AQMD

BACT
Source: BAAQMD BACT Guideline (5/22/2015)
There are no BACT standards published in the clearinghouse for this category.

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

RULE REQUIREMENTS:
Reg 6, Rule 1 – General Requirements
No person shall emit total suspended particulate (TSP) from any source in excess of 343 mg per dscm (0.15 gr per dscf) of exhaust gas volume.

Reg 9, Rule 1 – Sulfur Dioxide
This rule establishes emission limits for sulfur dioxide from all sources.

General emission limitation: A person shall not emit from any source, other than a ship, a gas stream containing sulfur dioxide in excess of 300 ppm (dry).

Reg 9, Rule 3 – Inorganic Gaseous Pollutants; NOx from Heat Transfer Operations §9-3-301
This rule does not apply to any new or modified heat transfer operation designed for a maximum heat input of less than 264 GJ (250 million BTU).

San Joaquin Valley Unified APCD

BACT
Source: SJVAPCD BACT Guideline 1.9.2 (8/18/2013)

Sulfuric Acid or Potassium Thiosulfate Manufacturing Plant Start-up Heater	
VOC	No standard
NOx	Natural gas fuel (0.06 lb/MMBtu) with LPG backup
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:
Rule 4201 – Particulate Matter Concentration (Amended December 12, 1992)
A person shall not release or discharge into the atmosphere from any single source operation,

dust, fumes, or total suspended particulate matter emissions in excess of 0.1 grain per cubic foot of gas at dry standard conditions (0.23 grams per dry standard cubic meter).

Rule 4801 – Sulfur Compounds (Amended 12/17/1992)
A person shall not discharge into the atmosphere sulfur compounds, which would exist as a liquid or gas at standard conditions, exceeding in the concentration at the point of discharge: two-tenths (0.2) percent by volume calculated as sulfur dioxide, on a dry basis averaged over 15 consecutive minutes.

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

SUMMARY OF ACHIEVED IN PRACTICE CONTROL TECHNOLOGIES	
VOC	No Standard – [EPA, ARB, SMAQMD, SCAQMD, SDCAPCD, BAAQMD, SJVAPCD]
NOx	1. For units ≥ 325,000 BTU/hr: 30 ppmvd @ 3% O_2 <1200°F, 60 ppmvd @ 3% O_2 ≥1200°F [SMAQMD, SCAQMD] 2. Natural gas with optional LPG as backup fuel (0.6 lb/MMBtu or 50 ppmd @ 3% O2) [SJVAPCD] 3. Gaseous fuel: 125 ppm and 240 mg/m3 at 20°C, Liquid or Solid fuel: 225 ppm and 430 mg/m3 at 20°C. [SDAPCD] 4. No Standard [EPA, ARB, SMAQMD, SDCAPCD, BAAQMD]
SOx	1. 300 ppmvd [BAAQMD] 2. 500 ppmvd [SCAQMD] 3. 0.5% by volume [SDAPCD] 4. 0.2% by volume [SMAQMD, BAAQMD] 5. No Standard [EPA, ARB, SDCAPCD, SJVAPCD]
PM10	1. 0.1 grains per dry standard cubic foot at 12% carbon dioxide by volume [SMAQMD, SDAPCD, SJVAPCD] 2. 0.15 grains per dscf [BAAQMD] 3. No Standard [EPA, ARB]
PM2.5	No Standard – [EPA, ARB, SMAQMD, SCAQMD, SDCAPCD, BAAQMD, SJVAPCD]
CO	1. 400 ppm @ 3% O_2 or 0.3 lb/MMBtu [SMAQMD] 2. 800 ppm @ 3% O_2 [SCAQMD] 3. No Standard [EPA, ARB, SMAQMD, SDCAPCD, BAAQMD, SJVAPCD]

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

BEST CONTROL TECHNOLOGIES ACHIEVED		
Pollutant	**Standard**	**Source**
VOC	No Standard	EPA, ARB, SMAQMD, SCAQMD, SDCAPCD, BAAQMD, SJVAPCD
NOx	For units ≥ 325,000 BTU/hr: 30 ppmvd @ 3% O_2 <1200°F, 60 ppmvd @ 3% O_2 ≥1200°F	SMAQMD, SCAQMD
SOx	300 ppmvd	BAAQMD
PM10	0.1 grains per dry standard cubic foot at 12% carbon dioxide by volume	SMAQMD, SDAPCD, SJVAPCD
PM2.5	No Standard	EPA, ARB, SMAQMD, SCAQMD, SDCAPCD, BAAQMD, SJVAPCD
CO	400 ppm @ 3% O_2 or 0.3 lb/MMBtu	SMAQMD

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

Technologically Feasible Alternatives:
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	1. Natural gas fuel or equivalent during start-up/shutdown 2. Good combustion practices 3. Scrubber (using soda ash) with demister
NOx	During Start-up/Shutdown (Natural Gas Combustion) 1. SCR During Normal Operations (Sulfur Combustion) 1. 15 ppm @ 3% O2
SOx	Scrubber (using soda ash) with demister – 18 ppm SOx as SO2 @ 3% O2
PM10	1. Natural gas fuel or equivalent during start-up/shutdown 2. Good combustion practices 3. Scrubber (using soda ash) with demister
PM2.5	1. Natural gas fuel or equivalent during start-up/shutdown 2. Good combustion practices 3. Scrubber (using soda ash) with demister
CO	1. Natural gas fuel or equivalent during start-up/shutdown 2. Good combustion practices

Pollutant	Technologically Feasible Alternatives
Organic HAP/VHAP (T-BACT)	1. Natural gas fuel or equivalent during start-up/shutdown 2. Good combustion practices. 3. Scrubber (using soda ash) with demister

NSCR is not a technologically feasible option during start-up. NSCR system operating temperatures range from approximately 700°F to 1500°F per EPA's CAM Technical Guidance Document. Since the auto-ignition temperature of molten sulfur is approximately 500°F, the burner will cease firing before the NSCR catalyst achieves operating temperature.

Thatcher Company of California is proposing to use natural gas to fire their sulfur start-up burner, good combustion practices, and exhaust gas venting to a scrubber (using soda ash) with a demister. Therefore, natural gas or an equivalent fuel and good combustion practices will be considered technologically feasible for VOC, SOx, PM10, PM2.5, CO, and Organic HAP/VHAP. A scrubber (using soda ash) with demister will be considered technologically feasible for VOC, SOx, PM10, PM2.5, and Organic HAP/VHAP. For SOx the applicant is proposed a limit of 18 ppm SOx as SO2 @ 3% O2.

After the start-up phase the molten sulfur begins auto-ignition and no natural gas fuel is burned. During this normal operational phase Thatcher Company is proposing a NOx limit of 15 ppm @ 3% O2. This NOx limit is based on source test from a similar Thatcher facility located in Utah. A similar sulfur burning process was permitted in SJVAPCD and was also permitted with a NOx limit of 15 ppm @ 3% O2 (https://www.valleyair.org/notices/Docs/2014/03-14-14_(C-1132059)/Preliminary-C-1132059.pdf). Therefore, this NOx limit will be considered technologically feasible.

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.

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 (except coating operations):

Pollutant	Maximum Cost ($/ton)
VOC	17,500
NO_X	24,500
PM10	11,400
SO_X	18,300
CO	TBD if BACT triggered

Cost Effectiveness Analysis Summary

Selective Catalytic Reduction (SCR):
The sulfur start-up burner will operate at approximately 500 ^{0}F, the NOx removal efficiency is around 50% because the SCR would be operating below the optimum temperature range of 700 to 750^{0}F per EPA's SCR Cost manual. A cost effective analysis for SCRs was performed below assuming the burner operates 8,760 hours per year. A NOx baseline level of 30 ppm was

chosen since the applicant proposes that their 1 MMBtu/hr burner can meet a NOx level of 30 ppm and SMAQMD Rule 419 – NOx from Miscellaneous Combustion Units would require sulfur burners to meet 30 ppm NOx for burners rating 5 MMBtu/hr or greater.

As shown in Attachment B, the cost effectiveness for the add on SCR system to control NOx to 15 ppm (50% control) was calculated to be **$83,866/ton** for a 1 MMBtu/hr burner. An additional cost analysis was done to determine at what burner rating SCR becomes cost effective. As shown below, SCR is cost effective for burners greater or equal to 69 MMBtu/hr (see Attachment B).

A. For a 1 MMBtu/hr burner:

NOx Control Level = 15 ppmv (50% Control)

NOx Baseline Level = 30 ppmv

Burner Rating = 1 MMBtu/hr

Equipment Life = 20 years

Direct Cost = $46,078

Direct Annual Cost = $1,480 per year

Indirect Annual Cost = $5,205 per year

Total Annual Cost = $6,685 per year

NOx Removed = 0.08 tons per year

Cost of NOx Removal = $83,866 per ton reduced

Therefore, add on SCR system is considered not cost effective and is eliminated.

B. For a 69 MMBtu/hr burner

NOx Control Level = 15 ppmv (50% Control)

NOx Baseline Level = 30 ppmv

Burner Rating = 69 MMBtu/hr

Equipment Life = 20 years

Direct Cost = $739,874

Direct Annual Cost = $50,437 per year

Indirect Annual Cost = $86,627 per year

Total Annual Cost = $134,064 per year

NOx Removed = 5.47 tons per year

Cost of NOx Removal = $24,500 per ton reduced

Therefore, add on SCR system is considered cost effective for burners greater than, or equal to 69 MMBtu/hr and not cost effective for burners rated at less than 69 MMBtu/hr.

C. SELECTION OF BACT/T-BACT:

Based on the review of EPA, ARB, SMAQMD, SCAQMD, SDCAPCD, BAAQMD, and SJVAPCD BACT Clearinghouses and cost effectiveness determinations for Technologically Feasible Controls, BACT for VOC, NOx, SOx, PM10, and PM2.5 will be the following:

BACT For Sulfur Start-up Burner < 1200°F and < 69 MMBtu/hr		
Pollutant	**Standard**	**Source**
VOC	1. Natural gas fuel or equivalent 2. Good combustion practices 3. Scrubber (using soda ash) with demister	Technologically feasible
NOx	During Startup/Shutdown (Natural Gas Combustion) For units ≥ 325,000 BTU/hr: 30 ppmvd @ 3% O_2 <1200°F During Normal Operation (Sulfur Combustion) 15 ppmvd @ 3% O_2	SMAQMD, SCAQMD Technologically feasible
SOx	1. 300 ppmvd @ 3% O_2 2. Natural Gas fuel or equivalent 3. Good combustion practices 4. Scrubber (using soda ash) with demister	BAAQMD, Technologically feasible
PM10	1. Natural gas fuel or equivalent 2. Good combustion practices 3. Scrubber (using soda ash) with demister	Technologically feasible
PM2.5	1. Natural gas fuel or equivalent 2. Good combustion practices 3. Scrubber (using soda ash) with demister	Technologically feasible
CO	1. 400 ppmvd @ 3% O_2 or 0.3 lb/MMBtu 2. Good combustion practices 3. Natural gas fuel or equivalent	SMAQMD, Technologically feasible

T-BACT For Sulfur Start-up Burner < 1200°F and < 69 MMBtu/hr		
Pollutant	**Standard**	**Source**
Organic HAP/VHAP (T-BACT)	1. Natural gas fuel or equivalent 2. Good combustion practices 3. Scrubber (using soda ash) with demister	Technologically feasible

APPROVED BY: [signature] **DATE:** 8-13-19

Attachment A

BACT Determinations Published by SJVAPCD

San Joaquin Valley Unified Air Pollution Control District

Best Available Control Technology (BACT) Guideline 1.9.2

Emission Unit:	Sulfuric Acid or Potassium Thiosulfate Manufacturing Plant Start-up Heater	**Industry Type:**	All
		Last Update:	August 18, 2013

Equipment Rating: None

Pollutant	Achieved in Practice or contained in SIP	Technologically Feasible	Alternate Basic Equipment
NOx	Natural gas fuel (0.06 lb/MMBtu) with LPG backup	1. Non-Selective catalytic reduction 2. Selective catalytic reduction 3. Natural gas fuel with LPG backup, Low-NOx burner (30 ppmv @ 3% O2)	

Attachment B

Cost Effectiveness Determination for SCR

1 MMBtu/hr BURNER 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 = $ 83,866.02 $/ton

Equipment

Oven rating	1	mmBTU/hr
Oven Operating hours	8760	hours
Oven capacity factor	1	
SCR Operating Days	365	days
Total Capacity Factor	1	
Baseline NOx (30 ppm)	0.0364	lb/mmBTU
SCR NOx (50 % Control)	0.0182	lb/mmBTU
Ammonia Slip	10	ppm
Ammonia Stoichiometric Ratio	1.05	
Stored Ammonia Conc	29	%
Ammonia Storage days	90	days
Sulfur Content	0.005	%
Pressure drop for SCR Ductwork	3	inches W.G.
Pressure drop for each Catalyst Layer	1	inches W.G.
Temperature at SCR Inlet	650	degrees F
Equipment Life	20	years
Annual interest Rate	5	%
Catalyst cost, Initial	240	$/ft2
Catalyst cost, replacement	290	$/ft2
Electrical Power cost	0.138	$/KWh
Ammonia Cost	0.101	$/lb
Catalyst Life	24000	hr
Catalyst Layers	2 full, 1 empty	

Boiler Calculations

Q_B	1	mmBTU/hr
$q_{flue\ gas}$	356.3273976	acfm
N_{NOx}	0.5	

SCR Reactor Calculations

$Vol_{Catalyst}$	1.56781886	ft3
$A_{Catalyst}$	0.371174372	ft2
A_{SCR}	0.426850528	ft2
l=w=	0.653337989	ft
n_{layer}	1	
h_{layer}	5.223941565	
n_{total}	2	
h_{SCR}	33.44788313	ft

Reagent Calculations

$m_{reagent}$	0.014146633	lb/hr
m_{sol}	0.048781494	lb/hr
q_{sol}	0.006516685	gph
Tank Volume	14.07603955	gal

Cost Estimation

Direct Costs

DC	$46,078.36

Indirect Costs

General Facilities	$2,303.92
Engineering and home office fees	$4,607.84
Process Contingency	$2,303.92
Total Indirect Installation Costs	$9,215.67
Project Contingency	$8,294.11
Total Plant Cost	$63,588.14
Preproduction Cost	$1,271.76
Inventory Capital	$10.64
Total Capital Investment	$64,870.54

Direct Annual Costs

Maintenance Costs	$973.06	per yr
Power	0.264411	KW
Annual Electricity	$319.64	per yr
Reagent Solution Cost	$43.16	per yr

Catalyst Replacement

FWF	0.317208565	
Annual Catalyst Replacement	$144.22	per yr

Total Variable Direct Cost	$507.03	per yr
Total Direct Annual Cost	$1,480.08	per yr
CRF	0.080242587	
Indirect Annual Cost	$5,205.38	per yr
Total annual Cost	$6,685.46	per yr
NOx Removed	0.08	tons
Cost of NOx removal	$83,866.02	per ton

69 MMBtu/hr BURNER 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 = $ 24,500.00 $/ton

Equipment

Oven rating	69	mmBTU/hr
Oven Operating hours	8760	hours
Oven capacity factor	1	
SCR Operating Days	365	days
Total Capacity Factor	1	
Baseline NOx (30 ppm)	0.0364	lb/mmBTU
SCR NOx (50% Control)	0.0182	lb/mmBTU
Ammonia Slip	10	ppm
Ammonia Stoichiometric Ratio	1.05	
Stored Ammonia Conc	29	%
Ammonia Storage days	90	days
Sulfur Content	0.005	%
Pressure drop for SCR Ductwork	3	inches W.G.
Pressure drop for each Catalyst Layer	1	inches W.G.
Temperature at SCR Inlet	650	degrees F
Equipment Life	20	years
Annual interest Rate	5	%
Catalyst cost, Initial	240	$/ft2
Catalyst cost, replacement	290	$/ft2
Electrical Power cost	0.138	$/KWh
Ammonia Cost	0.101	$/lb
Catalyst Life	24000	hr
Catalyst Layers	2 full, 1 empty	

Boiler Calculations

Q_B	68.6435416	mmBTU/hr
$q_{flue\ gas}$	24459.57454	acfm
N_{NOx}	0.5	

SCR Reactor Calculations

$Vol_{Catalyst}$	107.6206391	ft3
$A_{Catalyst}$	25.47872348	ft2
A_{SCR}	29.300532	ft2
l=w=	5.412996582	ft
n_{layer}	1	
h_{layer}	5.223941565	
n_{total}	2	
h_{SCR}	33.44788313	ft

Reagent Calculations

$m_{reagent}$	0.971075014	lb/hr
m_{sol}	3.348534532	lb/hr
q_{sol}	0.447328336	gph
Tank Volume	966.2292064	gal

Cost Estimation

Direct Costs

DC	$739,874.32

Indirect Costs

General Facilities	$36,993.72
Engineering and home office fees	$73,987.43
Process Contingency	$36,993.72
Total Indirect Installation Costs	$147,974.86
Project Contingency	$133,177.38
Total Plant Cost	$1,021,026.56
Preproduction Cost	$20,420.53
Inventory Capital	$730.52
Total Capital Investment	$1,042,177.61

Direct Annual Costs

Maintenance Costs	$15,632.66	per yr
Power	18.15010748	KW
Annual Electricity	$21,941.30	per yr
Reagent Solution Cost	$2,962.65	per yr

Catalyst Replacement

FWF	0.317208565

Annual Catalyst Replacement	$9,900.07	per yr
Total Variable Direct Cost	$34,804.03	per yr
Total Direct Annual Cost	$50,436.69	per yr
CRF	0.080242587	
Indirect Annual Cost	$83,627.03	per yr
Total annual Cost	$134,063.72	per yr
NOx Removed	5.47	tons
Cost of NOx removal	$24,500.00	per ton