Control Strategy Tool (CoST)

Cost Equations Documentation

Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Contacts: David Misenheimer and Larry Sorrels

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Contents

Tables

Figures

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1 Introduction

The purpose of EPA's Control Strategy Tool (CoST) is to model the emission reductions and costs associated with control strategies applied to sources of air pollution. It was developed as a replacement to EPA's AirControlNET (ACN) software. CoST overlays a detailed database of control measure information on EPA emissions inventories to compute source- and pollutant-specific emission reductions and associated costs at various geographic levels (national, regional, local). The Control Measures Database (CMDB) contained in CoST is composed of control measure and cost information for reducing the emissions of criteria pollutants (e.g., NO_x, SO_2, VOC, PM_{10}, $PM_{2.5}$, and NH_3) as well as CO and Hg from:

- Point sources in the U.S. electric power sector, as reflected in EPA's application of the Integrated Planning Model or "IPM" (ptipm emissions inventory sector)
- Point sources other than those contained in IPM (ptnonipm)
- Nonpoint sources (nonpt)
- Mobile sources (onroad and nonroad)[1].

CoST estimates the costs of emission control technologies in 2 ways:

1) Cost equations are used to determine engineering costs that take into account several variables for the source when data are available for those variables.
2) A simple cost factor in terms of dollars per ton of pollutant reduced is used to calculate the annual cost of the control measure.

Cost equations are used for some point sources (ptipm and ptnonipm sources); they are not used for nonpoint (nonpt) sources. This document describes the cost equations used in CoST.

This document provides a list of equations and associated variables assigned to specific control measures in CoST. The application of these equations is based on the individual emissions inventory records to which they are applied and the specific characteristics of those records. For example, Equation Type 1 calculates capital cost largely on a unit's generating capacity in megawatts (MW) and is scaled based on the original control cost calculations. It is applicable to NO_x and SO_2 emissions at ptipm electric generating unit (EGU) sources. For this equation type, variable and fixed operating and maintenance (O&M) costs are estimated.

Typically, each equation type is applied either to a pollutant-source combination or to a more general grouping of pollutants and sources. The scaling factors, additional variables, and cross-references by control measure and equation type are detailed in this document.

The remainder of this document is divided into chapters by the primary pollutant to be controlled. Chapters 2, 3, and 4 focus on NO_x, SO_2, and PM, respectively. Each chapter is further divided into two major sections; the first focuses on IPM equation types and the second focuses

[1] Emissions inventory definitions obtained from "Technical Support Document: Preparation of Emissions Inventories for the Version 4, 2005-based Platform". Available at : http://www3.epa.gov/airtransport/pdfs/2005_emissions_tsd_07jul2010.pdf

on the non-IPM types. Table 1-1 presents the equipment types and pollutants for each equation type. The description of each type of control equipment is listed in Table 1-2. The source code in CoST and the control parameters are provided in the appendices.

Table 1-1. Equipment Types and Primary Pollutants for each Equation Type.

Equation Type	Equipment Type	Primary Pollutants	Section
1	NO_x: LNB, LNBO, LNC1, LNC2, LNC3, NGR, SCR, SNCR SO_2: FGD	NO_x, SO_2	2.1.1, 3.1.1
2	LNB, SCR, SCR+LNB, SCR+steam injection, SCR+water injection, SNCR, SNCR-Urea, SNCR-Ammonia, Steam Injection, Water Injection	NO_x	2.2.1
3	FGD, sulfuric acid plant	SO_2	3.2.1
4	increase conversion rate, dual absorption	SO_2	3.2.2
5	amine scrubbing	SO_2	3.2.3
6	coke oven gas desulfurization	SO_2	3.2.4
7	[not currently supported by CoST]		
8	fabric filters, ESP, watering, catalytic oxidizers, venture scrubbers, substitute land-filling or chipping for burning	PM	4.1.1, 4.2.1
9	fabric filter - mechanical shaker	PM	4.1.2
10	ESP upgrade	PM	4.1.3
11	IDIS, SDA, wet FGD, low sulfur fuel, wet gas scrubber, sulfur recovery, tail gas treatment, catalyst additives, chemical additions to waste	SO_2	3.2.5
12	SCR, SCR-95%, ULNB, Excess O2 Control	NO_x	2.2.2
13	FGR, LNB, SCR, SNCR	NO_x	2.2.3
14	fabric filters	PM	4.2.2
15	ESP	PM	4.2.3
16	wet scrubber	SO_2	3.2.6
17	DIFF system	PM	4.2.4
18	increased caustic injection rate for existing dry injection control	SO_2	3.2.7
19	spray dryer absorber	SO_2	3.2.8
cost per ton	episodic ban, seasonal ban, LNB, AF Ratio, AF + IR, Mid-Kiln Firing, SCR, SNCR, ULNB, LEA, low emission combustion, and many others	NO_x	2.2.1.3

Table 1-2. Control Equipment Abbreviations in CoST

Equipment Abbreviation	Equipment Description
AF Ratio	Air/Fuel ratio controls
DIFF System	dry injection & fabric filter system
ESP	electrostatic precipitator
Excess O_2 Control	excess oxygen control to combustor
FGD	flue gas desulfurization
FGDW	FGU wet scrubber
FGR	flue gas recirculation
IDIS	
IR	Ignition timing retard (for internal combustion engines)
LEA	low excess air
LNB	low NO_x burner
LNBO	low NO_x burner technology with overfire air
LNC1	low NO_x burner technology w/ closed-coupled OFA
LNC2	low NO_x burner technology w/ separated OFA
LNC3	low NO_x burner technology w/ close coupled/separated OFA
LSD	lime spray dryer
LSFO	limestone forced oxidation
NGR	natural gas reburning
OFA	overfire air
SCR	selective catalytic reduction
SCR-95%	selective catalytic reduction with over 95% NO_x efficiency
SCR+LNB	both selective catalytic reduction and low NO_x burner technology
SCR+steam injection	selective catalytic reduction with steam injection
SCR+water injection	selective catalytic reduction with water injection
SDA	spray dryer absorber
SNCR	selective noncatalytic reduction
SNCR-Urea	selective noncatalytic reduction – urea
SNCR-Ammonia	selective noncatalytic reduction – ammonia
ULNB	ultra-low NO_x burner

2 NOx Control Cost Equations

This chapter is divided into two main sections – IPM and non-IPM sources. The types of cost equations for point source NO_x controls are described in their appropriate sections.

- Equation type 1 for IPM sector external combustion boilers
- Equation type 2 for non-IPM boiler and gas turbine point sources
- Equation type 12 for gas-fired process heaters at petroleum refineries
- Default cost per ton equations for non-IPM point sources

Each equation type is discussed, the relevant parameters are presented, and example calculations are provided. Appendix A includes the SQL queries that implement each CoST equation type. Appendix B provides tables of parameters and values used with each equation type.

2.1 IPM Sector (ptipm) NO_x Control Cost Equations

Equation Type 1 is the only cost equation belonging to this category of IPM sector (ptipm) point sources requiring NO_x emission reductions. These sources are electric generating units. All of the cost data for ptipm sources are originally from the Integrated Planning Model (IPM) v3.0, which is a model used by EPA's Clean Air Markets Division to estimate the costs of control strategies applied to electric utilities. NOx control technologies for Equation Type 1 are:

- Low NOx Burner (LNB)
- Low NOx Burner and Over Fire Air
- Low NOx Coal-and-Air Nozzles with Cross-Coupled and Separated Overfire Air
- Low NOx Coal-and-Air Nozzles with Cross-Coupled Overfire Air
- Low NOx Coal-and-Air Nozzles with Separated Overfire Air
- Natural Gas Reburn (NGR)
- Selective Catalytic Reduction (SCR)
- Selective Non-Catalytic Reduction (SNCR)

2.1.1 Equation Type 1 for NO_x - IPM Boilers

The data for this equation type were developed based on a series of model plants. The capacities of these model plants are used along with scaling factors and the emission inventory's unit-specific boiler characteristics (e.g., boiler capacity, stack parameters) to generate a control cost for an applied technology. Default cost per ton-reduced is not considered in the application of NO_x control measures to ptipm point sources. Table 2-1 lists all of the Source Classification Codes (SCCs) for the sources associated with Equation Type 1 in the CoST CMDB.

Table 2-1. NO_x Source Categories Associated with Equation Type 1

SCC	Description
10100201	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Wet Bottom (Bituminous Coal)
10100202	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Bituminous Coal)
10100203	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Cyclone Furnace (Bituminous Coal)
10100212	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Tangential) (Bituminous Coal)
10100217	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Bubbling Bed (Bituminous Coal)
10100222	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Subbituminous Coal)
10100226	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom Tangential (Subbituminous Coal)
10100301	External Combustion Boilers; Electric Generation; Lignite; Pulverized Coal: Dry Bottom, Wall Fired
10100302	External Combustion Boilers; Electric Generation; Lignite; Pulverized Coal: Dry Bottom, Tangential Fired
10100317	External Combustion Boilers; Electric Generation; Lignite; Atmospheric Fluidized Bed Combustion - Bubbling Bed
10100601	External Combustion Boilers; Electric Generation; Natural Gas; Boilers > 100 Million Btu/hr except Tangential
10100604	External Combustion Boilers; Electric Generation; Natural Gas; Tangentially Fired Units

2.1.1.1 Cost Equations

Capital Cost Equations

The purpose of a capital cost analysis is to put potential uses of capital (e.g., money, equipment) on the same economic basis. This allows a direct comparison to be made between these potential uses. The capital cost equations in CoST provide an estimate of the annualized capital cost of multiple technologies for their direct economic comparison.

When developing Equation Type 1 multiple model plants were designed and the economic calculations were then simplified. CoST calculates the capital cost associated with a control measure by applying a scaling factor to the calculations for an appropriate model plant; the scaling factor is calculated based on the ratio of the model plant's capacity to the capacity of a boiler measured in megawatts (MW). Tables B-1 and B-2 document the scaling factor associated with a model plant size and a scaling factor exponent.

$$Scaling\ Factor = \left(\frac{Scaling\ Factor\ Model\ Size}{Capacity}\right)^{Scaling\ Factor\ Exponent}$$

Where:
Scaling Factor Model Size = boiler capacity of the model plant (MW) (see values in Table B-2)
Scaling Factor Exponent = an empirical value based on the specific control measure (see values in Table B-2)
Capacity = capacity of the boiler (MW) (from the emissions inventory)

The capital cost associated with these NO_x control measures is a straightforward calculation of the capital cost multiplier (see Table B-2), the unit's boiler capacity (MW) (from emissions inventory), and the scaling factor that was calculated in the prior equation.

$$Capital\ Cost = Capital\ Cost\ Multiplier\ \times Capacity\ \times Scaling\ Factor\ \times 1{,}000$$

Where:
Capital Cost Multiplier = an empirical value based on the specific control measure
Capacity = capacity of the boiler (MW) from the inventory being processed
1,000 = unit conversion factor

The following equation provides the Capital Recovery Factor for the case of discrete interest compounding (i.e., not continuous compounding).

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{(1 + Interest\ Rate)^{Equipment\ Life}\ - 1}$$

Where:
Interest Rate = annual interest rate (see Table B-2)
Equipment Life = expected economic life of the control equipment (see Table B-2)

Finally, the following equation calculates the annualized capital cost. This is the cost of capital only; it does not include costs due to operations and maintenance. Those are discussed next.

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$

Where the *Capital Cost* and the *Capital Recovery Factor* have been calculated previously.

Operation and Maintenance Cost Equations

Operation and maintenance (O&M) costs, which are also calculated on an annual basis, are in addition to the capital cost of equipment. These O&M costs are divided into fixed costs and variable costs. Fixed costs are incurred because the equipment exists whether or not it is in operation. Examples of fixed costs are property taxes, insurance, and administrative charges. The fixed Operation and Maintenance (O&M) component is also based on the unit's capacity.

$$Fixed\ O\&M = Fixed\ O\&M\ Cost\ Multiplier\ \times Capacity\ \times 1{,}000$$

Where:
Fixed O&M Cost Multiplier = an empirical value based on the control measure (see Table B-2)
Capacity = capacity of the boiler (MW) (from the emissions inventory)
1,000 = unit conversion factor

The variable portion of the O&M costs includes an additional estimate for the unit's capacity factor. This factor is the unit's efficiency rating based on existing utilization and operation. A value of 1.00 would represent a completely efficient operation with no losses of production due to heat loss or other factors. A precalculated capacity utilization factor of 85% is used for the following utility boiler control measures; LNB, LNBO, LNC1, LNC2, and LNC3. A precalculated capacity utilization factor of 85% is used for the following utility boiler control measures; SCR, SNCR, and NGR.

$$Variable\ O\&M = Variable\ O\&M\ Cost\ Multiplier\ \times Capacity \times Capacity\ Factor\ \times\ 8{,}760$$

Where:
Variable O&M Cost Multiplier = an empirical value based on the specific control measure
Capacity Factor = an empirical value based on the specific control measure
8,760 = assumed number of hours of operation per year

The total annual operations and maintenance cost is then the sum of the annual fixed and variable O&M costs.

$$O\&M\ Cost = Fixed\ O\&M + Variable\ O\&M$$

Total Annualized Cost Equation

The annualized cost is then estimated using the unit's capital cost times the CRF (derived with the equipment specific interest rate and lifetime expectancy) and the sum of the fixed and variable O&M costs.

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + O\&M\ Cost$$

2.1.1.2 Example Calculations

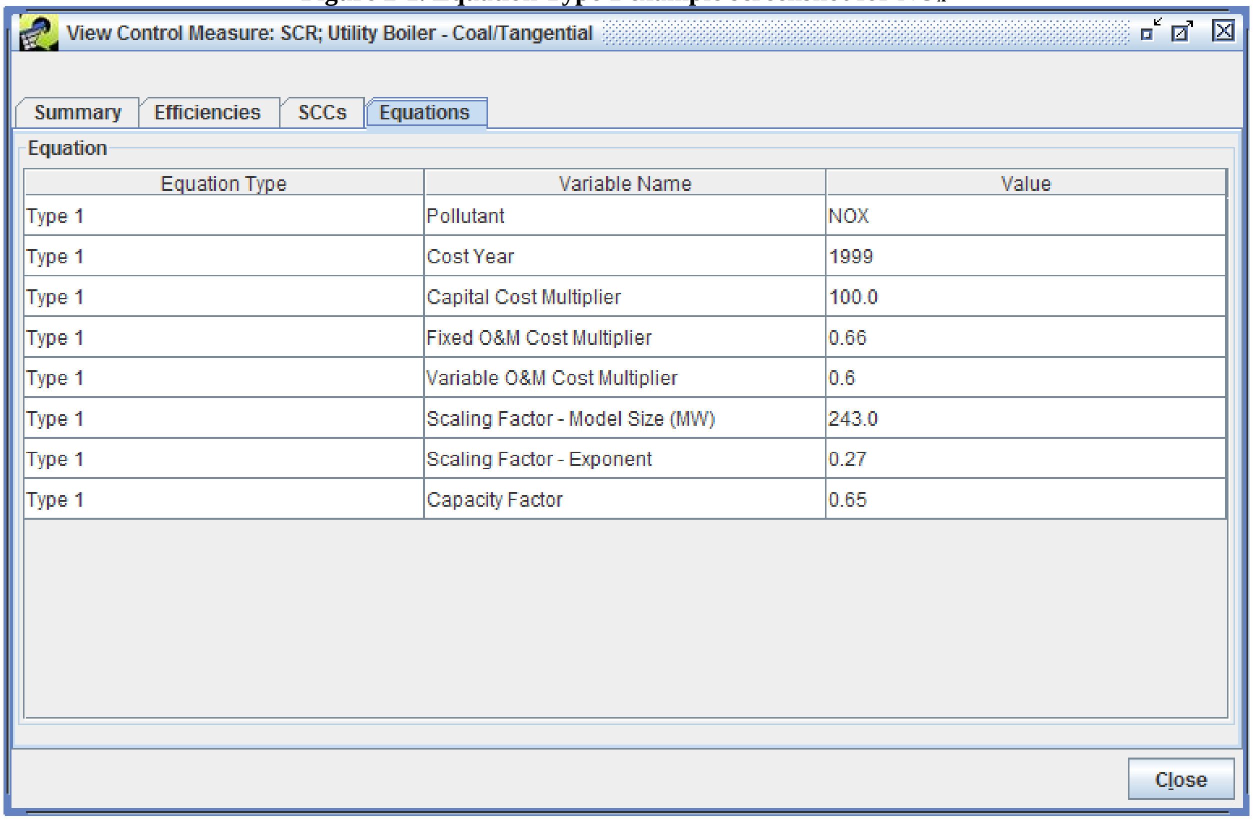
This section provides example calculations for an application of Equation Type 1. The example scenario is a utility boiler – coal/tangential that requires NO_x control. Using Table B-1 the CoST code is NSCR_UBCT, the control measure is SCR and the control efficiency is 90%. The remaining parameters required by Equation Type 1 are read from Table B-2.

Example Equation Type 1 Variables

The following values are read from Table B-2 and are shown in Figure 2-1.

Interest Rate = 7%
Equipment Life = 20 years
Capacity (MW) = 182.298
Capital Cost Multiplier ($/kW) = 100
Fixed O&M Cost Multiplier = 0.66
Variable O&M Cost Multiplier = 0.6
Scaling Factor Model Size (MW) = 243
Scaling Factor Exponent = 0.27
Capacity Factor = 0.65
Year for Cost Basis = 1999

Figure 2-1. Equation Type 1 example screenshot for NO_x



Equation Type	Variable Name	Value
Type 1	Pollutant	NOX
Type 1	Cost Year	1999
Type 1	Capital Cost Multiplier	100.0
Type 1	Fixed O&M Cost Multiplier	0.66
Type 1	Variable O&M Cost Multiplier	0.6
Type 1	Scaling Factor - Model Size (MW)	243.0
Type 1	Scaling Factor - Exponent	0.27
Type 1	Capacity Factor	0.65

Annualized Capital Cost Equation

$$Scaling\ Factor = \left(\frac{Scaling\ Factor\ Model\ Size}{Capacity}\right)^{Scaling\ Factor\ Exponent}$$

$$Scaling\ Factor = \left(\frac{243.0}{182.298}\right)^{0.27}$$

$$Scaling\ Factor = 1.081$$

$$Capital\ Cost = Capital\ Cost\ Multiplier\ \times Capacity\ \times Scaling\ Factor\ \times 1{,}000$$

$$Capital\ Cost = 100\frac{\$}{kW} \times 182.298\ MW \times 1.081 \times 1{,}000\frac{kW}{MW}$$

$$Capital\ Cost = \$19{,}700{,}828\ (1999\$)$$

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{(1 + Interest\ Rate)^{Equipment\ Life} - 1}$$

$$Capital\ Recovery\ Factor = \frac{0.07\ \times (1 + 0.07)^{20}}{(1 + 0.07)^{20} - 1}$$

$$Capital\ Recovery\ Factor = 0.094393$$

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$
$$Annualized\ Capital\ Cost = \$19{,}700{,}828 \times 0.094393$$
$$Annualized\ Capital\ Cost = \$1{,}859{,}620\ (1999\$)$$

Operation and Maintenance Cost Equation

$$Fixed\ O\&M = Fixed\ O\&M\ Cost\ Multiplier\ \times Capacity\ \times 1{,}000$$
$$Fixed\ O\&M = 0.66\frac{\$}{kW} \times 182.298\ MW \times 1{,}000\frac{kW}{MW}$$
$$Fixed\ O\&M = \$120{,}317$$

$$Variable\ O\&M$$
$$= Variable\ O\&M\ Cost\ Multiplier\ \left(\frac{\$}{MWh}\right) \times Capacity\ (MW) \times Capacity\ Factor$$
$$\times\ 8{,}760\ (Hours\ Per\ Year)$$
$$Variable\ O\&M = 0.6\frac{\$}{MWh} \times 182.298\ MW \times 0.65 \times 8{,}760\ Hours$$
$$Variable\ O\&M = \$622{,}803$$

$$O\&M\ Cost = Fixed\ O\&M + Variable\ O\&M$$
$$O\&M\ Cost = \$120{,}317 + \$622{,}803$$
$$O\&M\ Cost = \$743{,}130\ (1999\$)$$

Total Annualized Cost Equation

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + O\&M\ Cost$$
$$Total\ Annualized\ Cost = \$1{,}859{,}620 + \$743{,}130\ (1999\$)$$
$$Total\ Annualized\ Cost = \$2{,}602{,}750\ (1999\$)$$

2.2 Non-IPM Sector (ptnonipm) NO_x Control Cost Equations

Control costs for some non-EGU point sources where NO_x is the primary pollutant to be controlled are discussed in this section. Equation Type 2 estimates costs of NO_x controls for natural gas-fired turbines. Equation Type 2 originally also covered Industrial/Commercial/ Institutional (ICI) Boilers but costs of NO_x controls for ICI Boilers are now estimated by Equation Type 13. Equation Type 12 estimates emission control measures for gas-fired process heaters at petroleum refineries. Finally, default cost per ton factors are used for some additional source types.

2.2.1 Equation Type 2 for NOx – Natural Gas-Fired Turbines

Costs for Low NO_x Burners applied to Natural Gas-Fired Turbines are estimated using Equation Type 2, as described in this section. Equation Type 2 was originally derived to estimate cost of controls for Natural Gas-Fired Industrial Boilers and Turbines. However, NO_x controls for Industrial Boilers are now covered by Equation Type 13. Equation Type 2 uses a design capacity variable from the input emissions inventory, as well as a scaling component that is based on the original Alternative Control Technology or Control Technology Guidelines (ACT/CTG) analyses used to derive these estimates. Table 2-2 lists the SCCs for the sources associated with Equation Type 2 in the CoST CMDB.

Table 2-2. NO_x Source Categories Associated with Equation Type 2

SCC	Description
20100201	Internal Combustion Engines; Electric Generation; Natural Gas; Turbine
20200201	Internal Combustion Engines; Industrial; Natural Gas; Turbine
20200203	Internal Combustion Engines; Industrial; Natural Gas; Turbine: Cogeneration
20300202	Internal Combustion Engines; Commercial/Institutional; Natural Gas; Turbine
20300203	Internal Combustion Engines; Commercial/Institutional; Natural Gas; Turbine: Cogeneration

Equation Type 2 covers costs of NO_x controls for Gas Turbines. Table B-6 lists more information about this control measure.

Equation Type 2-based costs are estimated for units that have a design capacity not exceeding 2,000 million Btu per hour (mmBtu/hr). For those sources above the capacity threshold, default costs per ton are used (see Section 2.2.1.3). Furthermore, a size classification is applied for some ptnonipm sources based on the ozone season daily emissions value. Following the definition included in the NO_x SIP call program, a daily emissions value of less than one ton NO_x per day designates the source as small and applies control cost parameters consistent with this classification. Sources that emit one or more tons per day are considered large, and the appropriate parameters for large sources are applied.

2.2.1.1 Cost Equations

Capital Cost Equation

Tables B-6 and B-7 provide a list of the control cost parameters and variables as assigned during the application of Cost Equation Type 2 to NO_x controls. The O&M costs are calculated by subtracting the product of *capital costs* × *capital recovery factor* (CRF) from the *annualized costs*. The CRF is included in the current Control Measures Database (CMDB). This value is recalculated in CoST using the equipment life and interest rate of the specific measure, when available. If equipment life is unavailable for the measure then the CRF provided in the CMDB is used.

$$Capital\ Cost = Capital\ Cost\ Multiplier \times DESIGN\_CAPACITY^{\ Capital\ Cost\ Exponent}$$

Where:
Capital Cost Multiplier = an empirical value based on the specific control measure
Capital Cost Exponent = an empirical value based on the specific control measure
DESIGN_CAPACITY = the capacity in mmBTU/hr obtained from the emissions inventory

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{(1 + Interest\ Rate)^{Equipment\ Life}\ - 1}$$

Where:
Interest Rate = annual interest rate

Equipment Life = expected economic life of the control equipment

$$Annualized\ Capital\ Cost = Capital\ Cost \times Capital\ Recovery\ Factor$$

Where the *Capital Cost* and the *Capital Recovery Factor* have been calculated previously.

Total Annualized Cost Equation

$$Total\ Annualized\ Cost = Annual\ Cost\ Multiplier\ \times DESIGN\_CAPACITY^{Annual\ Cost\ Exponent}$$

Where:
Annual Cost Multiplier = an empirical value based on the specific control measure
Annual Cost Exponent = an empirical value based on the specific control measure
DESIGN_CAPACITY = the capacity in mmBTU/hr obtained from the emissions inventory

Operation and Maintenance Equation

$$O\&M\ Cost = Total\ Annualized\ Cost - Annualized\ Capital\ Cost$$

Where the *Total Annualized Cost* and the *Annualized Capital Cost* were calculated previously.

2.2.1.2 Example Calculations

This section provides example calculations for an application of Equation Type 2. The example scenario is an ICI boiler – coal/wall that requires NO_x control. Using Table B-6 the CoST code is NSCRIBCW, the control measure is SCR and the control efficiency is 90%. The remaining parameters required by Equation Type 2 are read from Table B-7.

Example Equation Type 2 Variables

The following values are read from Table B-7 and are shown in Figure 2-2. Also, this example uses the values for the Default Application, not the Incremental Application (i.e., no NO_x control is already being used).

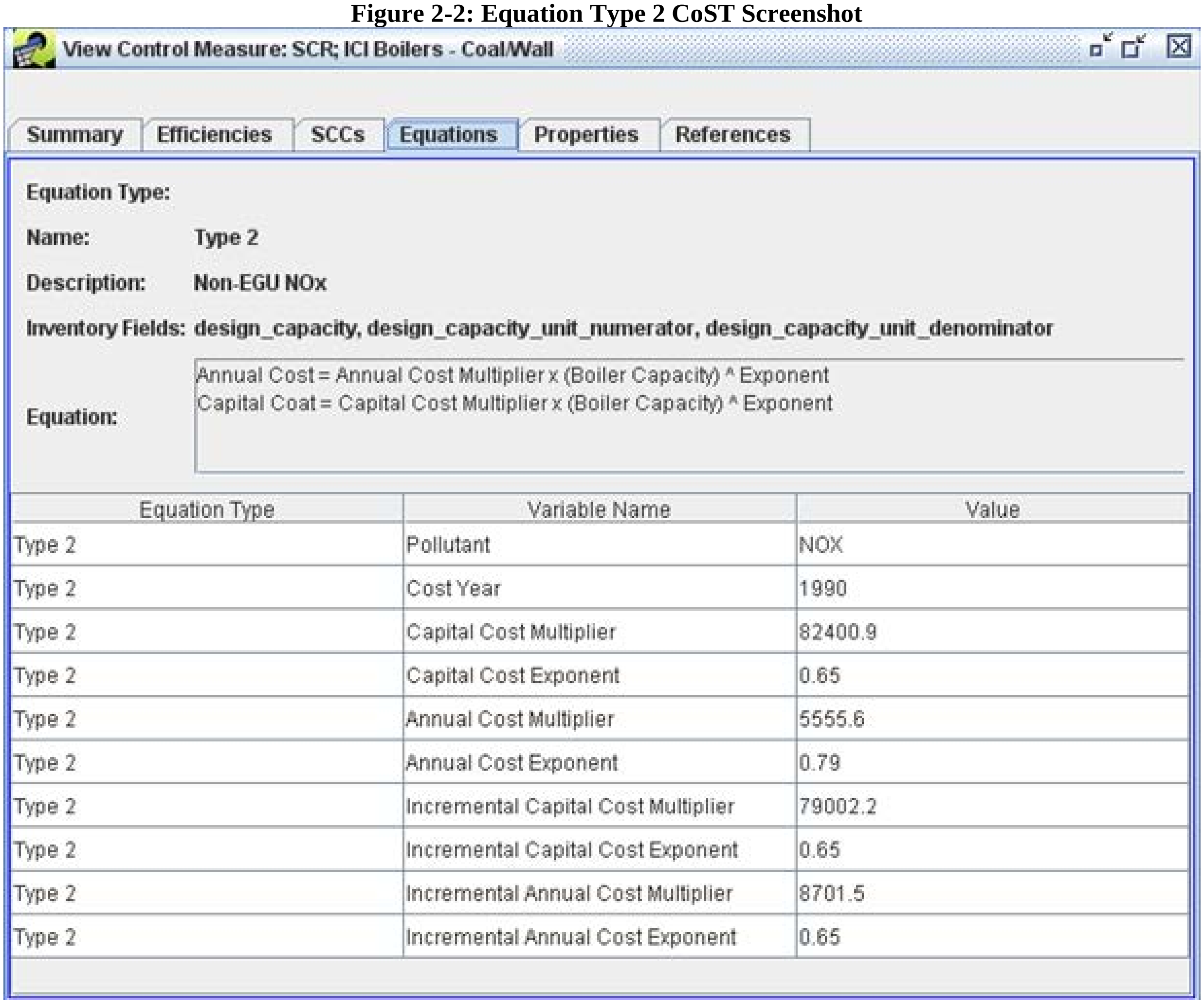
Interest Rate = 7%
Equipment Life = 20 years
DESIGN_CAPACITY = 301.0 mmBTU/hr (from emissions inventory)
Capital Cost Multiplier = 82400.9
Capital Cost Exponent = 0.65
Annual Cost Multiplier = 5555.6
Annual Cost Exponent = 0.79
Year for Cost Basis = 1990

The following values are for the Incremental Application shown in Section 0.

Interest Rate = 7%
Equipment Life = 20 years
DESIGN_CAPACITY = 301.0 mmBTU/hr (from emissions inventory)

Capital Cost Multiplier = 79002.2
Capital Cost Exponent = 0.65
Annual Cost Multiplier = 8701.5
Annual Cost Exponent = 0.65
Year for Cost Basis = 1990

Figure 2-2: Equation Type 2 CoST Screenshot



Equation Type	Variable Name	Value
Type 2	Pollutant	NOX
Type 2	Cost Year	1990
Type 2	Capital Cost Multiplier	82400.9
Type 2	Capital Cost Exponent	0.65
Type 2	Annual Cost Multiplier	5555.6
Type 2	Annual Cost Exponent	0.79
Type 2	Incremental Capital Cost Multiplier	79002.2
Type 2	Incremental Capital Cost Exponent	0.65
Type 2	Incremental Annual Cost Multiplier	8701.5
Type 2	Incremental Annual Cost Exponent	0.65

Equation Type 2 Example: When No Control is Currently in Place for the Source

All costs are in 1990 U.S. Dollars because that is the base year for the references for these equations and for the capital-to-annual ratios.

Capital Cost Equation

$$Capital\ Cost = Capital\ Cost\ Multiplier \times DESIGN\_CAPACITY^{\ Capital\ Cost\ Exponent}$$
$$Capital\ Cost = \$82{,}400 \times 301.0^{0.65}$$
$$Capital\ Cost = \$3{,}365{,}117\ (1990\$)$$

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{(1 + Interest\ Rate)^{Equipment\ Life}\ - 1}$$

$$Capital\ Recovery\ Factor = \frac{0.07\ \times (1 + 0.07)^{20}}{(1 + 0.07)^{20} - 1}$$
$$Capital\ Recovery\ Factor = 0.094393$$

$$Annualized\ Capital\ Cost = Capital\ Cost \times Capital\ Recovery\ Factor$$
$$Annualized\ Capital\ Cost = \$3{,}365{,}117 \times 0.0944$$
$$Annualized\ Capital\ Cost = \$317{,}643\ (1990\$)$$

Total Annualized Cost Equation

$$Total\ Annualized\ Cost = Annual\ Cost\ Multiplier\ \times DESIGN\_CAPACITY^{Annual\ Cost\ Exponent}$$
$$Total\ Annualized\ Cost = \$5{,}555.60 \times 301.0^{\ 0.79}$$
$$Total\ Annualized\ Cost = \$504{,}427\ (1990\$)$$

Operation and Maintenance Equation

$$O\&M\ Cost = Total\ Annualized\ Cost - Annualized\ Capital\ Cost$$
$$O\&M\ Cost = \$504{,}427 - \$317{,}643$$
$$O\&M\ Cost = \$186{,}784\ (1990\$)$$

Equation Type 2 Example: When Control is Applied Incrementally to the Source

Capital Cost Equation

$$Capital\ Cost$$
$$= Incremental\ Capital\ Cost\ Multiplier \times DESIGN\_CAPACITY^{\ Incremental\ Capital\ Cost\ Exponent}$$
$$Capital\ Cost = \$79{,}002.20 \times 301.0^{0.65}$$
$$Capital\ Cost = \$3{,}226{,}319\ (1990\$)$$

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{(1 + Interest\ Rate)^{Equipment\ Life} - 1}$$
$$Capital\ Recovery\ Factor = \frac{0.07\ \times (1 + 0.07)^{20}}{(1 + 0.07)^{20} - 1}$$
$$Capital\ Recovery\ Factor = 0.094393$$

$$Annualized\ Capital\ Cost = Capital\ Cost \times Capital\ Recovery\ Factor$$
$$Annualized\ Capital\ Cost = \$3{,}226{,}319 \times 0.0944$$
$$Annualized\ Capital\ Cost = \$304{,}564\ (1990\$)$$

Total Annualized Cost Equation

$$Total\ Annualized\ Cost$$
$$= Incremental\ Annual\ Cost\ Multiplier$$
$$\times DESIGN\_CAPACITY^{Incremental\ Annual\ Cost\ Exponent}$$

$$Total\ Annualized\ Cost = \$8{,}701.50\ \times 301.0^{0.65}$$
$$Total\ Annualized\ Cost = \$355{,}354\ (1990\$)$$

Operation and Maintenance Equation

$$O\&M\ Cost = Total\ Annualized\ Cost - Annualized\ Capital\ Cost$$
$$O\&M\ Cost = \ \$355{,}354 - \ \$304{,}564$$

$O\&M\ Cost = \$50{,}791\ (1990\$)$

2.2.1.3 Non-IPM Sector (ptnonipm) NOx Control Cost per Ton Calculations

When a source qualifies for Equation Type 2 except for the boiler capacity, default cost per ton values are assigned and applied to the annual emissions reduction achieved by the applied control measure. In these applications, a capital-to-annual cost ratio is applied to estimate the capital cost associated with the control. The O&M costs are calculated by subtracting the product of capital cost × CRF from the annualized costs. The variables used in the default cost per ton equations are provided in Tables B-20 and B-21.

Note that the calculations for this cost per ton method are performed in a different order than for the Equation Type 2 calculations.

Total Annualized Cost Equation

When no control is currently in place for the source:

$$Total\ Annualized\ Cost = Emission\ Reduction \times Default\ Cost\ Per\ Ton$$

Where:
Emission Reduction = calculated by CoST
Default Cost per Ton = an empirical value based on the specific control measure

When a control is applied incrementally to the source:

$$Total\ Annualized\ Cost = Emission\ Reduction \times Incremental\ Cost\ Per\ Ton$$

Where:
Emission Reduction = calculated by CoST
Incremental Cost per Ton = an empirical value based on the specific control measure

Capital Cost Equation

$$Capital\ Cost = Total\ Annualized\ Cost \times Capital\ to\ Annual\ Ratio$$

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{[(1 + Interest\ Rate)^{Equipment\ Life}\ - 1]}$$

Where:
Interest Rate = annual interest rate
Equipment Life = expected economic life of the control equipment

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$

Where the *Capital Cost* and the *Capital Recovery Factor* were calculated previously.

Operation and Maintenance Cost Equation

$$Total\ O\&M = Total\ Annualized\ Cost - Annualized\ Capital\ Cost$$

Where the *Total Annualized Cost* and the *Annualized Capital Cost* were calculated previously.

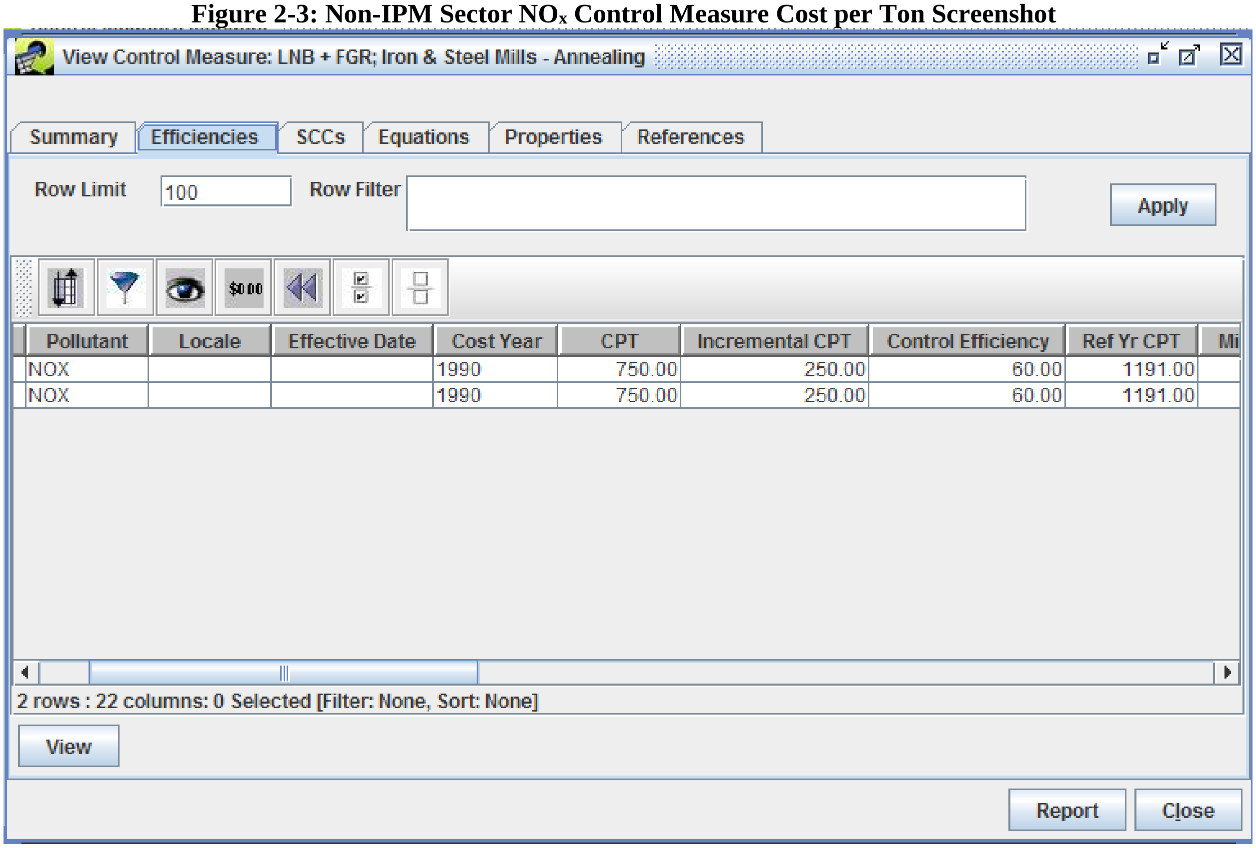
2.2.1.4 Non-IPM Sector (ptnonipm) NO_x Control Cost per Ton Example

This section provides example calculations for an application of this cost per ton method for NO_x control on a source in the non-IPM sector. Use Tables B-20 and B-21 with the CoST CM Abbreviation NLNBFCSRS to obtain the values in this example.

Example Equation Type 2 Variables

Interest Rate = 7%
NO_x Emission Reduction = 125 tons/yr
Equipment Life = 10 years (from Summary Tab)
Capital to Annual Ratio = 7.0 (from Efficiencies Tab)
Default Cost per Ton Reduced = 750 (1990$)
Incremental Cost per Ton Reduced = 250 (1990$)
Year for Cost Basis = 1990

Figure 2-3: Non-IPM Sector NO_x Control Measure Cost per Ton Screenshot



No Control Measure is Currently in Place for the Source

Total Annualized Cost Equation

$Total\ Annualized\ Cost = Emission\ Reduction \times Default\ Cost\ Per\ Ton$
$Total\ Annualized\ Cost = 125 \times \$750$
$Total\ Annualized\ Cost = \$93{,}750\ (1990\$)$

Capital Cost Equation

When no control measure is currently in place for the source:
$Capital\ Cost = Total\ Annualized\ Cost \times Capital\ to\ Annual\ Ratio$
$Capital\ Cost = \$93{,}750 \times 7.0$
$Capital\ Cost = \$656{,}250\ (1990\$)$

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{[(1 + Interest\ Rate)^{Equipment\ Life}\ - 1]}$$

$$Capital\ Recovery\ Factor = \frac{0.07\ \times (1 + 0.07)^{10}}{[(1 + 0.07)^{10}\ - 1]}$$
$$Capital\ Recovery\ Factor = 0.1424$$

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$
$Annualized\ Capital\ Cost = \$656{,}250 \times 0.1424$
$Annualized\ Capital\ Cost = \$93{,}435\ (1990\$)$

Operation and Maintenance Cost Equation

$Total\ O\&M\ Cost = Total\ Annualized\ Cost - Annualized\ Capital\ Cost$
$Total\ O\&M\ Cost = \$93{,}750 - \$93{,}435$
$Total\ O\&M\ Cost = \$315\ (1990\$)$

Control Measure is Applied Incrementally to the Source

Total Annualized Cost Equation

$Total\ Annualized\ Cost = Emission\ Reduction \times Incremental\ Cost\ Per\ Ton$
$Total\ Annualized\ Cost = 125 \times \$250$
$Total\ Annualized\ Cost = \$31{,}250\ (1990\$)$

Capital Cost Equation

When the control measure is added to one that is already in place at the source:
$Capital\ Cost = Total\ Annualized\ Cost \times Capital\ to\ Annual\ Ratio$
$Capital\ Cost = \$31{,}250 \times 7.0$
$Capital\ Cost = \$218{,}750\ (1990\$)$

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{[(1 + Interest\ Rate)^{Equipment\ Life}\ - 1]}$$

$$Capital\ Recovery\ Factor = \frac{0.07\ \times (1 + 0.07)^{10}}{[(1 + 0.07)^{10}\ - 1]}$$

$$Capital\ Recovery\ Factor = 0.14$$

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$
$$Annualized\ Capital\ Cost = \$218{,}750 \times 0.14$$
$$Annualized\ Capital\ Cost = \$30{,}625\ (1990\$)$$

Operation and Maintenance Cost Equation

$$Total\ O\&M\ Cost = Total\ Annualized\ Cost - Annualized\ Capital\ Cost$$
$$Total\ O\&M\ Cost = \$31{,}250 - \$30{,}625$$
$$Total\ O\&M\ Cost = \$625\ (1990\$)$$

2.2.2 Equation Type 12 for NO_x

For a select set of gas-fired process heaters at petroleum refineries, control costs are estimated using stack flowrate and temperature represented by Equation Type 12. Control technologies for Equation Type 12 are as follows:

- Excess O3 Control - 80 ppmv NOx outlet concentration
- Ultra-Low NOx Burner (ULNB) - 40 ppmv NOx outlet concentration
- Selective Catalytic Reduction (SCR) - 20 ppmv NOx outlet concentration
- SCR-95% - 10 ppmv NOx outlet concentration

Control costs are estimated for units that have a positive stack flowrate and temperature value. For those sources with missing stack flowrate or temperature, no costs are calculated. No default cost estimates are currently available for these sources. Table 2-3 lists all of the SCCs for the sources associated with Equation Type 12 in the CoST CMDB.

Table 2-3. NO_x Source Categories Associated with Equation Type 12

SCC	Description
30600102	Industrial Processes; Petroleum Industry; Process Heaters; Gas-fired
30600104	Industrial Processes; Petroleum Industry; Process Heaters; Gas-fired
30600105	Industrial Processes; Petroleum Industry; Process Heaters; Natural Gas-fired
30600106	Industrial Processes; Petroleum Industry; Process Heaters; Process Gas-fired
30600107	Industrial Processes; Petroleum Industry; Process Heaters; LPG-fired
30600108	Industrial Processes; Petroleum Industry; Process Heaters; Landfill Gas-fired

Table B-15 provides a list of the control cost parameters and variables as assigned during the application of Cost Equation Type 12 to NO_x controls applied to ptnonipm sources.

2.2.2.1 Cost Equations

Capital Cost Equations

The conditions in the stack are determined from the inventory being processed. Calculate the standard flowrate in standard cubic feet per minute (scfm):

$$Stack\ Flowrate\ (scfm) = Stack\ Flowrate\ (acfm) \times \left(\frac{Standard\ Temperature\ (Rankine)}{Stack\ Temperature\ (F) + 460}\right)$$

$$Stack\ Flowrate\ (scfm) = Stack\ Flowrate\ (acfm) \times \left(\frac{520}{Stack\ Temperature\ (F) + 460}\right)$$

Where:
Stack Flowrate (acfm) = flow rate of gas in the stack in actual cubic feet per minute (i.e., at the actual conditions of the stack, acfm)
Stack Flowrate (scfm) = flow rate of gas in the stack in standard cubic feet per minute (i.e., at 60˚F and ambient pressure, scfm)
Stack Temperature (˚F) = actual temperature in the stack

$$Capital\ Cost = (Fixed\ Capital\ Cost\ Multiplier + Variable\ Capital\ Cost\ Multiplier) \times \left(\frac{Stack\ Flowrate\ (scfm)}{150{,}000}\right)^{0.6}$$

Where:
Fixed Capital Cost Multiplier = an empirical value based on the specific control measure
Variable Capital Cost Multiplier = an empirical value based on the specific control measure[2]

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate \times (1 + Interest\ Rate)^{Equipment\ Life}}{(1 + Interest\ Rate)^{Equipment\ Life} - 1}$$

Where:
Interest Rate = annual interest rate
Equipment Life = expected economic life of the control equipment

$$Annualized\ Capital\ Cost = Capital\ Cost \times Capital\ Recovery\ Factor$$

Where the *Capital Cost* and the *Capital Recovery Factor* have been calculated previously.

Operation and Maintenance Cost Equations

$$Fixed\ O\&M = Fixed\ O\&M\ Cost\ Multiplier \times \left(\frac{Stack\ Flow\ Rate\ (scfm)}{150{,}000}\right)$$

[2] Fixed and variable cost multipliers for Equation Type 12 are from the reference "MACTEC Engineering and Consulting, Inc., 2005, “Petroleum Refinery Best Available Retrofit Technology (BART) Engineering Analysis”.

Where:
Fixed O&M Cost Multiplier = an empirical value based on the specific control measure
Stack Flow Rate = expected flow rate out of the stack in standard cubic feet per minute (scfm)

$$Variable\ O\&M = Variable\ O\&M\ Cost\ Multiplier\ \times \left(\frac{Stack\ Flow\ Rate\ (scfm)}{150{,}000}\right)$$

Where:
Variable O&M Cost Multiplier = an empirical value based on the specific control measure
Stack Flow Rate = expected flow rate out of the stack in standard cubic feet per minute (scfm)

$$Annualized\ O\&M\ Cost = Fixed\ O\&M + Variable\ O\&M$$

Where the *Fixed O&M* and the *Variable O&M* have been calculated previously.

Total Annualized Cost Equation

$$Total\ Annualized\ Cost = Annualized\ O\&M\ Cost + Annualized\ Capital\ Cost$$

Where the *Annualized O&M Cost* and the *Annualized Capital Cost* were calculated previously.

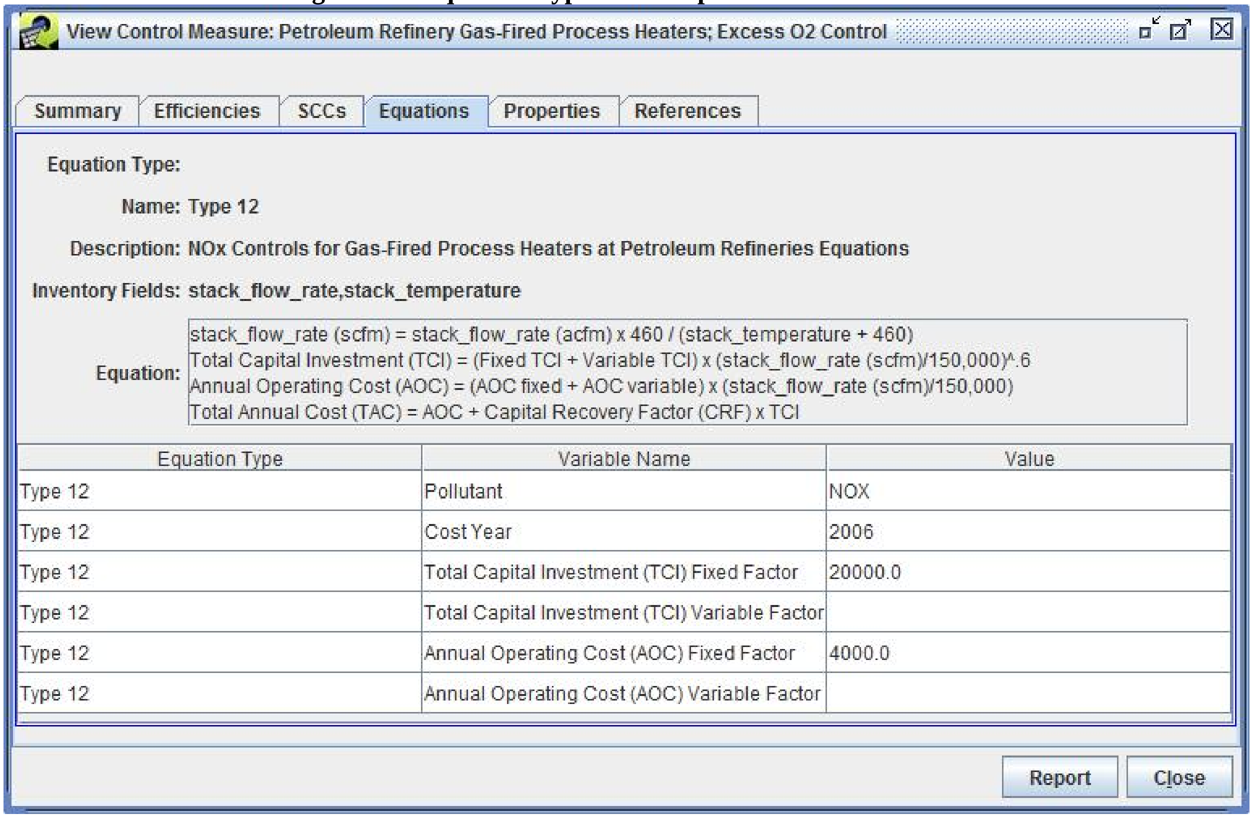
2.2.2.2 Example Calculations

This section provides example calculations for an application of Equation Type 12. The example scenario is a gas-fired process heater at a petroleum refinery. The NO_x control mechanism is excess oxygen control (PRGFPREO2C). The remaining parameters required by Equation Type 12 are read from Table B-15 and are shown in Figure 2-4.

Example Equation Type 12 Variables

Interest Rate = 7%
Equipment Life = 20 years (from summary tab of control measure data)
Stack Flowrate (acfm) = 43,055 ft^3/min
Stack Temperature (˚F) = 650 ˚F
Fixed Capital Cost Multiplier = $20,000
Variable Capital Cost Multiplier = $0
Fixed O&M Cost Multiplier = $4,000
Variable O&M Cost Multiplier = $0
Capital Recovery Factor = 0.243890694
Year for Cost Basis = 2006

Figure 2-4: Equation Type 12 Example Screenshot for NO_x



Annualized Capital Cost Equation

$$Stack\ Flow\ Rate\ (scfm) = Stack\ Flow\ Rate\ (acfm) \times \left(\frac{Standard\ Temperature\ (Rankine)}{Stack\ Temperature\ (F) + 460}\right)$$

$$Stack\ Flow\ Rate\ (scfm) = 43{,}055 \times \left(\frac{520}{650 + 460}\right)$$

$$Stack\ Flow\ Rate\ (scfm) = 20{,}170$$

$$Capital\ Cost = (Fixed\ Capital\ Cost\ Multiplier + Variable\ Capital\ Cost\ Multiplier) \times \left(\frac{Stack\ Flow\ Rate\ (scfm)}{150{,}000}\right)^{0.6}$$

$$Capital\ Cost = (20{,}000 + 0.0) \times \left(\frac{20{,}170}{150{,}000}\right)^{0.6}$$

$$Capital\ Cost = \$6{,}001\ (2006\$)$$

Note that for Equation Type 12 the *Capital Recovery Factor* is read from the table instead of being calculated from the discount rate and equipment life.

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$

$$Annualized\ Capital\ Cost = \$6{,}001 \times 0.243890694$$

$$Annualized\ Capital\ Cost = \$1{,}464\ (2006\$)$$

Operation and Maintenance Cost Equation

$$Fixed\ O\&M = Fixed\ O\&M\ Cost\ Multiplier\ \times \left(\frac{Stack\ Flow\ Rate\ (scfm)}{150{,}000}\right)$$

$$Fixed\ O\&M = 4{,}000 \times \left(\frac{20{,}170}{150{,}000}\right)$$

$$Fixed\ O\&M = \$538$$

$$Variable\ O\&M = Variable\ O\&M\ Cost\ Multiplier \times \left(\frac{Stack\ Flow\ Rate\ (scfm)}{150{,}000}\right)$$

$$Variable\ O\&M = 0 \times \left(\frac{20{,}170}{150{,}000}\right)$$

$$Variable\ O\&M = \$0$$

$$Annualized\ O\&M\ Cost = Fixed\ O\&M + Variable\ O\&M$$

$$O\&M\ Cost = \$538 + \$0$$

$$O\&M\ Cost = \$538\ (2006\$)$$

Total Annualized Cost Equation

$$Total\ Annualized\ Cost = Annualized\ O\&M\ Cost + Annualized\ Capital\ Cost$$

$$Total\ Annualized\ Cost = \$538 + \$1464\ (2006\$)$$

$$Total\ Annualized\ Cost = \$2{,}002\ (2006\$)$$

2.2.3 Equation Type 13 for NO_x

Equation Type 13 is used to calculate NOx control costs for a range of sizes of Industrial Commercial Institutional (ICI) boilers. NOx control technologies for Equation Type 13 are:

- Flue Gas Recirculation (FGR)
- Low NOx Burner (LNB)
- Low NOx Burner and Flue Gas Recirculation
- Selective Non-Catalytic Reduction (SNCR)
- Selective Catalytic Reduction (SCR)
- Low NOx Burner and Selective Non-Catalytic Reduction
- Low NOx Burner and Selective Catalytic Reduction

Eastern Research Group (ERG) derived Equation Type 13 based on a review of previous ICI Boiler control costs calculations and outputs from the EPA Coal Utility Environmental Cost (CUECost) model[3]. ERG generated costs for control devices on five boiler sizes (i.e., 100, 200, 300, 400, and 500 MMBtu/hr). Although control device costs do not rise in strict proportion to size, ERG demonstrated that plotted results of control costs versus boiler size showed a power-law relationship and used this relationship to derive Equation Type 13. Table 2-4 lists all of the SCCs for the sources associated with Equation Type 13 in the CoST CMDB.

[3] ERG (2010) MEMORANDUM: Evaluation and Develoment of NOx Control Technologies Cost Equations for ICI Boilers. From C. Burklin and B. Lange (ERG) to D. Misenheimer (US EPA). November 30, 2010.

Table 2-4. NOx Source Categories Associated with Equation Type 13

SCC	Description
10200101	External Combustion Boilers; Industrial; Anthracite Coal; Pulverized Coal
10200104	External Combustion Boilers; Industrial; Anthracite Coal; Traveling Grate (Overfeed) Stoker
10200201	External Combustion Boilers; Industrial; Bituminous Coal; Pulverized Coal: Wet Bottom
10200202	External Combustion Boilers; Industrial; Bituminous Coal; Pulverized Coal: Dry Bottom
10200203	External Combustion Boilers; Industrial; Bituminous Coal; Cyclone Furnace
10200204	External Combustion Boilers; Industrial; Bituminous Coal; Spreader Stoker
10200205	External Combustion Boilers; Industrial; Bituminous Coal; Overfeed Stoker
10200206	External Combustion Boilers; Industrial; Bituminous Coal; Underfeed Stoker
10200210	External Combustion Boilers; Industrial; Bituminous Coal; Overfeed Stoker **
10200212	External Combustion Boilers; Industrial; Bituminous Coal; Pulverized Coal: Dry Bottom (Tangential)
10200213	External Combustion Boilers; Industrial; Bituminous Coal; Wet Slurry
10200217	External Combustion Boilers; Industrial; Bituminous Coal; Atmospheric Fluidized Bed Combustion: Bubbling Bed
10200219	External Combustion Boilers; Industrial; Bituminous Coal; Cogeneration
10200222	External Combustion Boilers; Industrial; Subbituminous Coal; Pulverized Coal: Dry Bottom
10200224	External Combustion Boilers; Industrial; Subbituminous Coal; Spreader Stoker
10200225	External Combustion Boilers; Industrial; Subbituminous Coal; Traveling Grate (Overfeed) Stoker
10200229	External Combustion Boilers; Industrial; Subbituminous Coal; Cogeneration
10200301	External Combustion Boilers; Industrial; Lignite; Pulverized Coal: Dry Bottom
10200306	External Combustion Boilers; Industrial; Lignite; Spreader Stoker
10200401	External Combustion Boilers; Industrial; Residual Oil; Grade 6 oil
10200402	External Combustion Boilers; Industrial; Residual Oil; 10-100 Million BTU/hr
10200403	External Combustion Boilers; Industrial; Residual Oil; < 10 Million BTU/hr
10200404	External Combustion Boilers; Industrial; Residual Oil; Grade 5 Oil
10200405	External Combustion Boilers; Industrial; Residual Oil; Cogeneration
10200501	External Combustion Boilers; Industrial; Distillate Oil - Grades 1 and 2; Boiler
10200502	External Combustion Boilers; Industrial; Distillate Oil; 10-100 Million BTU/hr **
10200503	External Combustion Boilers; Industrial; Distillate Oil; < 10 Million BTU/hr **
10200504	External Combustion Boilers; Industrial; Distillate Oil; Grade 4 Oil
10200505	External Combustion Boilers; Industrial; Distillate Oil; Cogeneration
10200601	External Combustion Boilers; Industrial; Natural Gas; > 100 Million BTU/hr
10200602	External Combustion Boilers; Industrial; Natural Gas; 10-100 Million BTU/hr
10200603	External Combustion Boilers; Industrial; Natural Gas; < 10 Million BTU/hr
10200604	External Combustion Boilers; Industrial; Natural Gas; Cogeneration
10200701	External Combustion Boilers; Industrial; Process Gas; Petroleum Refinery Gas
10200704	External Combustion Boilers; Industrial; Process Gas; Blast Furnace Gas
10200707	External Combustion Boilers; Industrial; Process Gas; Coke Oven Gas
10200710	External Combustion Boilers; Industrial; Process Gas; Cogeneration
10200799	External Combustion Boilers; Industrial; Process Gas; Other: Specify in Comments
10201001	External Combustion Boilers; Industrial; Liquified Petroleum Gas (LPG); Butane
10201002	External Combustion Boilers; Industrial; Liquified Petroleum Gas (LPG); Propane
10201401	External Combustion Boilers; Industrial; CO Boiler; Natural Gas
10201402	External Combustion Boilers; Industrial; CO Boiler; Process Gas
10201403	External Combustion Boilers; Industrial; CO Boiler; Distillate Oil
10201404	External Combustion Boilers; Industrial; CO Boiler; Residual Oil
10300101	External Combustion Boilers; Commercial/Institutional; Anthracite Coal; Pulverized Coal
10300102	External Combustion Boilers; Commercial/Institutional; Anthracite Coal; Traveling Grate (Overfeed) Stoker
10300103	External Combustion Boilers; Commercial/Institutional; Anthracite Coal; Hand-fired
10300205	External Combustion Boilers; Commercial/Institutional; Bituminous Coal; Pulverized Coal: Wet Bottom

10300206	External Combustion Boilers; Commercial/Institutional; Bituminous Coal; Pulverized Coal: Dry Bottom
10300207	External Combustion Boilers; Commercial/Institutional; Bituminous Coal; Overfeed Stoker
10300208	External Combustion Boilers; Commercial/Institutional; Bituminous Coal; Underfeed Stoker
10300209	External Combustion Boilers; Commercial/Institutional; Bituminous Coal; Spreader Stoker
10300211	External Combustion Boilers; Commercial/Institutional; Bituminous Coal; Overfeed Stoker **
10300216	External Combustion Boilers; Commercial/Institutional; Bituminous Coal; Pulverized Coal: Dry Bottom (Tangential)
10300221	External Combustion Boilers; Commercial/Institutional; Subbituminous Coal; Pulverized Coal: Wet Bottom
10300222	External Combustion Boilers; Commercial/Institutional; Subbituminous Coal; Pulverized Coal: Dry Bottom
10300223	External Combustion Boilers; Commercial/Institutional; Subbituminous Coal; Cyclone Furnace
10300224	External Combustion Boilers; Commercial/Institutional; Subbituminous Coal; Spreader Stoker
10300225	External Combustion Boilers; Commercial/Institutional; Subbituminous Coal; Traveling Grate (Overfeed) Stoker
10300309	External Combustion Boilers; Commercial/Institutional; Lignite; Spreader Stoker
10300401	External Combustion Boilers; Commercial/Institutional; Residual Oil - Grade 6; Boiler
10300402	External Combustion Boilers; Commercial/Institutional; Residual Oil; 10-100 Million BTU/hr **
10300404	External Combustion Boilers; Commercial/Institutional; Residual Oil; Grade 5 Oil
10300501	External Combustion Boilers; Commercial/Institutional; Distillate Oil - Grades 1 and 2; Boiler
10300502	External Combustion Boilers; Commercial/Institutional; Distillate Oil; 10-100 Million BTU/hr **
10300503	External Combustion Boilers; Commercial/Institutional; Distillate Oil; < 10 Million BTU/hr **
10300504	External Combustion Boilers; Commercial/Institutional; Distillate Oil; Grade 4 Oil
10300601	External Combustion Boilers; Commercial/Institutional; Natural Gas; > 100 Million BTU/hr
10300602	External Combustion Boilers; Commercial/Institutional; Natural Gas; 10-100 Million BTU/hr
10300603	External Combustion Boilers; Commercial/Institutional; Natural Gas; < 10 Million BTU/hr
10300701	External Combustion Boilers; Commercial/Institutional; Process Gas; POTW Digester Gas-fired Boiler
10300799	External Combustion Boilers; Commercial/Institutional; Process Gas; Other Not Classified
10301001	External Combustion Boilers; Commercial/Institutional; Liquified Petroleum Gas (LPG); Butane
10301002	External Combustion Boilers; Commercial/Institutional; Liquified Petroleum Gas (LPG); Propane
30190001	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30190002	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Residual Oil: Process Heaters
30490001	Industrial Processes; Secondary Metal Production; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30490002	Industrial Processes; Secondary Metal Production; Fuel Fired Equipment; Residual Oil: Process Heaters
30590001	Industrial Processes; Mineral Products; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30590002	Industrial Processes; Mineral Products; Fuel Fired Equipment; Residual Oil: Process Heaters
30600101	Industrial Processes; Petroleum Industry; Process Heaters; Oil-fired **
30600103	Industrial Processes; Petroleum Industry; Process Heaters; Oil-fired
30600111	Industrial Processes; Petroleum Industry; Process Heaters; Oil-fired (No. 6 Oil) : 100 Million Btu Capacity
30790001	Industrial Processes; Pulp and Paper and Wood Products; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30790002	Industrial Processes; Pulp and Paper and Wood Products; Fuel Fired Equipment; Residual Oil: Process Heaters
31000401	Industrial Processes; Oil and Gas Production; Process Heaters; Distillate Oil (No. 2)
31000403	Industrial Processes; Oil and Gas Production; Process Heaters; Crude Oil
39990001	Industrial Processes; Miscellaneous Manufacturing Industries; Miscellaneous Manufacturing Industries; Distillate Oil (No. 2): Process Heaters
39990002	Industrial Processes; Miscellaneous Manufacturing Industries; Miscellaneous Manufacturing Industries; Residual Oil: Process Heaters

Table B-17 provides a list of the control cost parameters and variables as assigned by Cost Equation Type 13 to NO_x controls applied to ICI boiler sources. Table B-18 lists the assumptions used in constructing Equation Type 13.

2.2.3.1 Cost Equations

Capital Cost Equations

In finding that there are no cost savings from combining different ICI Boiler control technologies, ERG recommended that control costs for each technology be treated as additive when multiple control options are available. Calculate single control technology total capital costs with the following equation:

$$Capital\ Cost = Size\ Multiplier\ 1\ \times\ Boiler\ Size\ (\frac{MMBtu}{hr})^{Exponent\ 1}$$

Duel control technology total capital costs are calculated as an extension of the single control technology equation:

$$Captal\ Cost\ (Dual\ Control\ Technology)$$
$$= Size\ Multiplier\ 1\ \times\ Boiler\ Size\ (\frac{MMBtu}{hr})^{Exponent\ 1}$$
$$+\ Size\ Multiplier\ 2\ \times\ Boiler\ Size\ (\frac{MMBtu}{hr})^{Exponent\ 2}$$

Where:
Size Multiplier and Exponent = empirical values for each control technology that are based on a power law curve fitting of ICI boiler control costs versus boiler sizes
Boiler Size = ICI boiler hourly heat output

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{(1 + Interest\ Rate)^{Equipment\ Life}\ - 1}$$

Where:
Interest Rate = annual interest rate
Equipment Life = expected economic life of the control equipment

Operation and Maintenance Cost Equations

$$O\&M\ Cost$$
$$= Known\ Costs + Size\ Multiplier\ 1\ \times\ Boiler\ Size\ \left(\frac{MMBtu}{hr}\right)^{Exponent\ 1}$$
$$+\ Size\ Multiplier\ 2\ \times\ Boiler\ Size\ \left(\frac{MMBtu}{hr}\right)^{Exponent\ 2} + Flowrate\ Multiplier$$
$$\times\ Boiler\ Exhaust\ Flowrate\ \left(\frac{ft^3}{s}\right) +\ Emissions\ Multiplier\ \times\ Boiler\ Emissions\ (\frac{tons}{yr})$$

Where:
Size Multiplier and Exponent = empirical values for each control technology that are based on a power law curve fitting of ICI boiler control costs versus boiler sizes
Boiler Size = ICI boiler hourly heat output
Flowrate Multiplier = empirical value based on the specific control measure
Boiler Exhaust Flowrate = expected flowrate from the boiler in cubic feet per second
Emissions Multiplier = empirical value based on the specific control measure
Boiler Emissions = annual boiler emissions reate in tons per year

Total Annualized Cost Equation

$$Annualized\ Cost = Capital\ Cost\ \times\ Capital\ Recovery\ Factor + O\&M\ Cost$$

2.2.3.2 Example Calculations

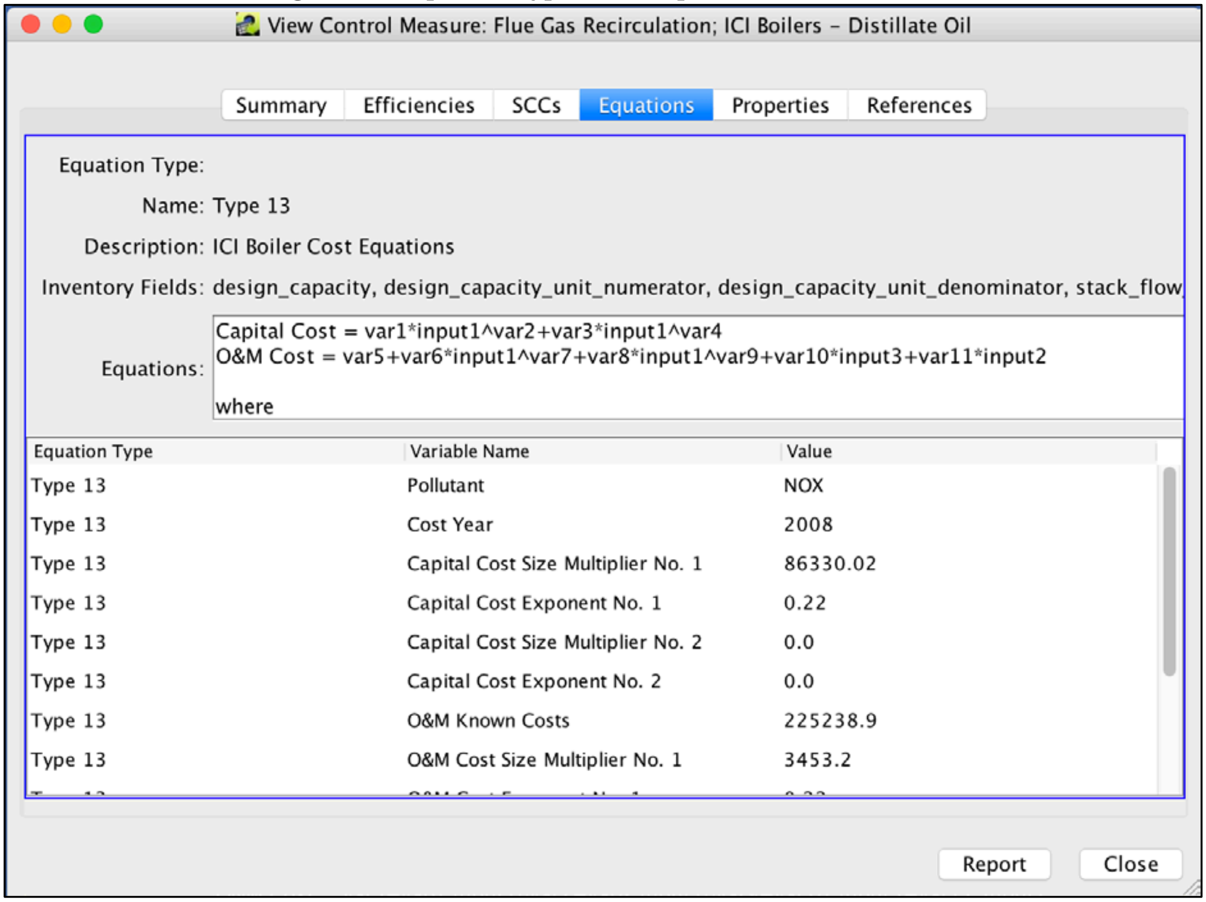
Equation Type 13 Example for NO_x

This section provides example calculations for an application of Equation Type 13. The example scenario is for a distillate oil ICI Boiler (NLNBFIBDO) with an output of 250 MMBtu/hr. The primary NO_x control mechanism is a low NOx burner (LNB) and the secondary device is flue gas recirculation (FGR). The remaining parameters required by Equation Type 13 are read from Table B-18 and are shown in Figure XX.

Example Equation Type 13 Variables

Control Device (Single) = LNB
Control Device (Dual) = LNB + FGR
Interest Rate = 7%
Equipment Life (years) = 15
Size (MMBtu) = 250
Capital Cost Size Multiplier 1 = \$5,460.27
Capital Cost Exponent 1 = 0.65
Capital Cost Size Multiplier 2 = \$86,330.02
Capital Cost Exponent 2 = 0.22
Known Costs = \$389,766.80
O&M Size Multiplier 1 = \$218.40
O&M Size Exponent 1 = 0.65
O&M Size Multiplier 2 = \$3,453.20
O&M Size Exponent 2 = 0.228
Flowrate Multiplier = 19.3
Boiler Exhaust Flowrate (ft^3/s) = 1,000
Emissions Multiplier = 0.0
Boiler Emissions (tons/year) = 3,500

Figure 2-5: Equation Type 13 Example Screenshot for NO_x



Capital Cost Equation (Single Device)

$$Capital\ Cost = Size\ Multiplier\ 1\ \times\ Boiler\ Size\ \left(\frac{MMBtu}{hr}\right)^{Exponent\ 1}$$

$$Capital\ Cost = 5{,}460.27\ \times\ 250^{0.65}$$

$$\boldsymbol{Capital\ Cost} = \$\mathbf{197{,}640.13}$$

Capital Cost Equation (Dual Device)

$$Captal\ Cost\ (Dual\ Control\ Technology)$$
$$= Size\ Multiplier\ 1\ \times\ Boiler\ Size\ \left(\frac{MMBtu}{hr}\right)^{Exponent\ 1}$$
$$+\ Size\ Multiplier\ 2\ \times\ Boiler\ Size\ \left(\frac{MMBtu}{hr}\right)^{Exponent\ 2}$$
$$Capital\ Cost = 5{,}460.27\ \times\ 250^{0.65} +\ 86{,}330.02\ \times\ 250^{0.22}$$

$$\boldsymbol{Capital\ Cost = \$488{,}516.63}$$

Capital Recovery Factor Equation

$$\boldsymbol{Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{(1 + Interest\ Rate)^{Equipment\ Life}\ - 1}}$$

$$\boldsymbol{Capital\ Recovery\ Factor = \frac{0.07\ \times (1 + 0.07)^{15}}{(1 + 0.07)^{15}\ - 1}}$$

$$\boldsymbol{Capital\ Recovery\ Factor = 0.1098}$$

Operation and Maintenance Cost Equation

$$O\&M\ Cost = Known\ Costs + Size\ Multiplier\ 1\ \times\ Boiler\ Size\ \left(\frac{MMBtu}{hr}\right)^{Exponent\ 1} + \ Size\ Multiplier\ 2\ \times\ Boiler\ Size\ \left(\frac{MMBtu}{hr}\right)^{Exponent\ 2} + 19.3\ \times\ 1{,}000 +\ 0.0\ \times\ Boiler\ Emissions\ (\frac{tons}{yr})$$

$$O\&M\ Cost = 389{,}766.80 + 218.4\ \times\ 250^{\ 0.65} +\ 3{,}453.20\ \times\ 250^{\ 0.228} + 19.3\ \times\ 1{,}000 +\ 0.0\ \times\ 3{,}500$$

$$O\&M\ Cost = \$429{,}132.53$$

Annual Cost Equation (Single Device)

$$Annual\ Cost = Capital\ Cost\ \times\ Captial\ Recovery\ Factor + O\&M\ Cost$$

$$Annual\ Cost = \$488{,}516.63\ \times\ 0.1098 + 429{,}132.53\ (2008\$)$$

$$Annual\ Cost = \$482{,}771.66\ (2008\$)$$

Annual Cost Equation (Dual Device)

$$Annual\ Cost = Capital\ Cost\ \times\ Captial\ Recovery\ Factor + O\&M\ Cost$$

$$Annual\ Cost = \$197{,}640.13\ \times\ 0.1098 + 429{,}132.53\ (2008\$)$$

$$Annual\ Cost = \$450{,}833.42\ (2008\$)$$

3 SO_2 Control Cost Equations

This section is divided into two main sections – IPM and non-IPM sources. The types of cost equations for point source SO_2 controls are described in their appropriate sections.

- Equation type 1 for IPM sector external combustion boilers
- Equation type 3 for non-IPM sector external combustion boilers, process heaters, primary metals, glassmaking furnace
- Equation type 4 for non-IPM sulfuric acid plants
- Equation type 5 for non-IPM elemental sulfur production
- Equation type 6 for non-IPM primary metal production related to by-product coke manufacturing
- Equation type 11 for non-IPM industrial external combustion boilers.
- Equation type 16 for non-IPM external combustion boilers and select industrial processes
- Equation type 18 for the same non-IPM sources as equation type 16
- Equation type 19 for the same non-IPM sources as equation type 16

Each equation type is discussed, the relevant parameters are presented, and example calculations are provided. Appendix A includes the SQL queries that implement each CoST equation type. Appendix B provides tables of parameters and values used with each equation type.

3.1 IPM Sector (ptipm) SO_2 Control Cost Equations

IPM sector (ptipm) point sources utilizing control cost equations for SO_2 emission reductions are limited to Equation Type 1 and to two low sulfur coal switching default cost per ton equation calculations. In Equation Type 1, model plant capacities are used along with scaling factors and the emission inventory's unit-specific boiler characteristics to generate a control cost for an applied technology.

Default cost per ton reduced values are not considered in the application of SO_2 control measures to ptipm point sources with the exception of two low sulfur coal switching options as presented in Table B-5.

These two low sulfur coal options are applied based on the sulfur content of the coal burned as provided in the emissions inventory. Three classifications of coal are assigned: (1) medium sulfur (<= 2% S by weight), (2) high sulfur (2-3% S by weight), and (3) very high sulfur (>3% S by weight).

3.1.1 Equation Type 1 for SO_2

Equation Type 1 involves the application of a scaling factor to adjust the capital cost associated with a control measure to the boiler size (MW) based on the original control technology's documentation. The applicable SCCs are listed in Table 3-1. As noted in Tables B-3 and B-4, a scaling factor model plant size and exponent are provided for this estimate.

For SO_2 controls applied to ptipm sources, a scaling factor is applied when the emission inventory source size is less than the scaling factor model size. If the unit's capacity is greater than or equal to the scaling factor model size, the scaling factor is set to unity (1.0).

Additional restrictions on source size are shown for other controls that use equation type 1. In Table B-4, when the Application Restriction lists a minimum and maximum capacity, the control is not applied unless the capacity of the source in the inventory falls within that range.

Table 3-1. SO_2 Source Categories Associated with Equation Type 1

SCC	Description
10100201	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Wet Bottom (Bituminous Coal)
10100202	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Bituminous Coal)
10100203	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Cyclone Furnace (Bituminous Coal)
10100204	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Spreader Stoker (Bituminous Coal)
10100205	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Traveling Grate (Overfeed) Stoker (Bituminous Coal)
10100211	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Wet Bottom (Tangential) (Bituminous Coal)
10100212	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Tangential) (Bituminous Coal)
10100215	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Cell Burner (Bituminous Coal)
10100217	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Bubbling Bed (Bituminous Coal)
10100218	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Circulating Bed (Bitum. Coal)
10100221	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Wet Bottom (Subbituminous Coal)
10100222	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Subbituminous Coal)
10100223	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Cyclone Furnace (Subbituminous Coal)
10100224	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Spreader Stoker (Subbituminous Coal)
10100225	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Traveling Grate (Overfeed) Stoker (Subbituminous Coal)
10100226	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom Tangential (Subbituminous Coal)
10100235	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Cell Burner (Subbituminous Coal)
10100237	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Bubbling Bed (Subbitum Coal)
10100238	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion - Circulating Bed (Subbitum Coal)

3.1.1.1 Cost Equations

Capital Cost Equations

The capital cost associated with these ptipm SO_2 control measures is a straightforward calculation of the capital cost multiplier, the unit's boiler capacity (in MW), and the scaling factor exponent.

$$Scaling\ Factor = \left(\frac{Scaling\ Factor\ Model\ Size}{Capacity}\right)^{Scaling\ Factor\ Exponent}$$

Where:
Scaling Factor Model Size = the boiler capacity (MW) of the model plant
Scaling Factor Exponent = an empirical value based on the specific control measure
Capacity = the boiler capacity (MW) obtained from the emissions inventory

$$Capital\ Cost = Capital\ Cost\ Multiplier\ \times Capacity\ \times Scaling\ Factor\ \times 1{,}000$$

Where:
Capital Cost Multiplier ($/kW) = an empirical value based on the specific control measure
Capacity (MW) = obtained from the emissions inventory
1000 = conversion factor to convert the *Capital Cost Multiplier* from $/kW to $/MW.

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{(1 + Interest\ Rate)^{Equipment\ Life} - 1}$$

Where:
Interest Rate = annual interest rate
Equipment Life = expected economic life of the control equipment

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$

Where the *Capital Cost* and the *Capital Recovery Factor* have been calculated previously.

Operation and Maintenance Cost Equations

The fixed O&M component is based on the unit's capacity. The variable O&M includes an estimate for the unit's capacity factor. This factor is the unit's efficiency rating based on existing utilization and operation. A value of 1.00 would represent a completely efficient operation with no losses of production due to heat loss or other factors. Where appropriate, CoST provides a list of precalculated capacity factor calculations ranging from 65% to 85% (0.65 to 0.85).

The annualized cost is then estimated using the unit's capital cost times the CRF (derived with the equipment specific interest rate and lifetime expectancy) and the sum of the fixed and variable O&M costs.

$$Fixed\ O\&M = Fixed\ O\&M\ Cost\ Multiplier\ \times Capacity\ \times 1{,}000$$

Where:
Fixed O&M Cost Multiplier = an empirical value based on the specific control measure
Capacity = obtained from the emissions inventory
1000 = a conversion factor to convert the Fixed O&M Cost Multiplier from \$/kW to \$/MW

$$Variable\ O\&M = Variable\ O\&M\ Cost\ Multiplier\ \times Capacity \times Capacity\ Factor\ \times\ 8{,}760$$

Where:
Variable O&M Cost Multiplier (\$/MW-h) = an empirical value based on the specific control measure
Capacity Factor = an empirical value based on the specific control measure
Capacity (MW) = obtained from the emissions inventory
8760 = the number of hours the equipment is assumed to operate a year

$$O\&M\ Cost = Fixed\ O\&M + Variable\ O\&M$$

Total Annualized Cost Equation

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + O\&M\ Cost$$

Where the *Annualized Capital Cost* and the *O&M Cost* were calculated previously.

3.1.1.2 Example Calculations

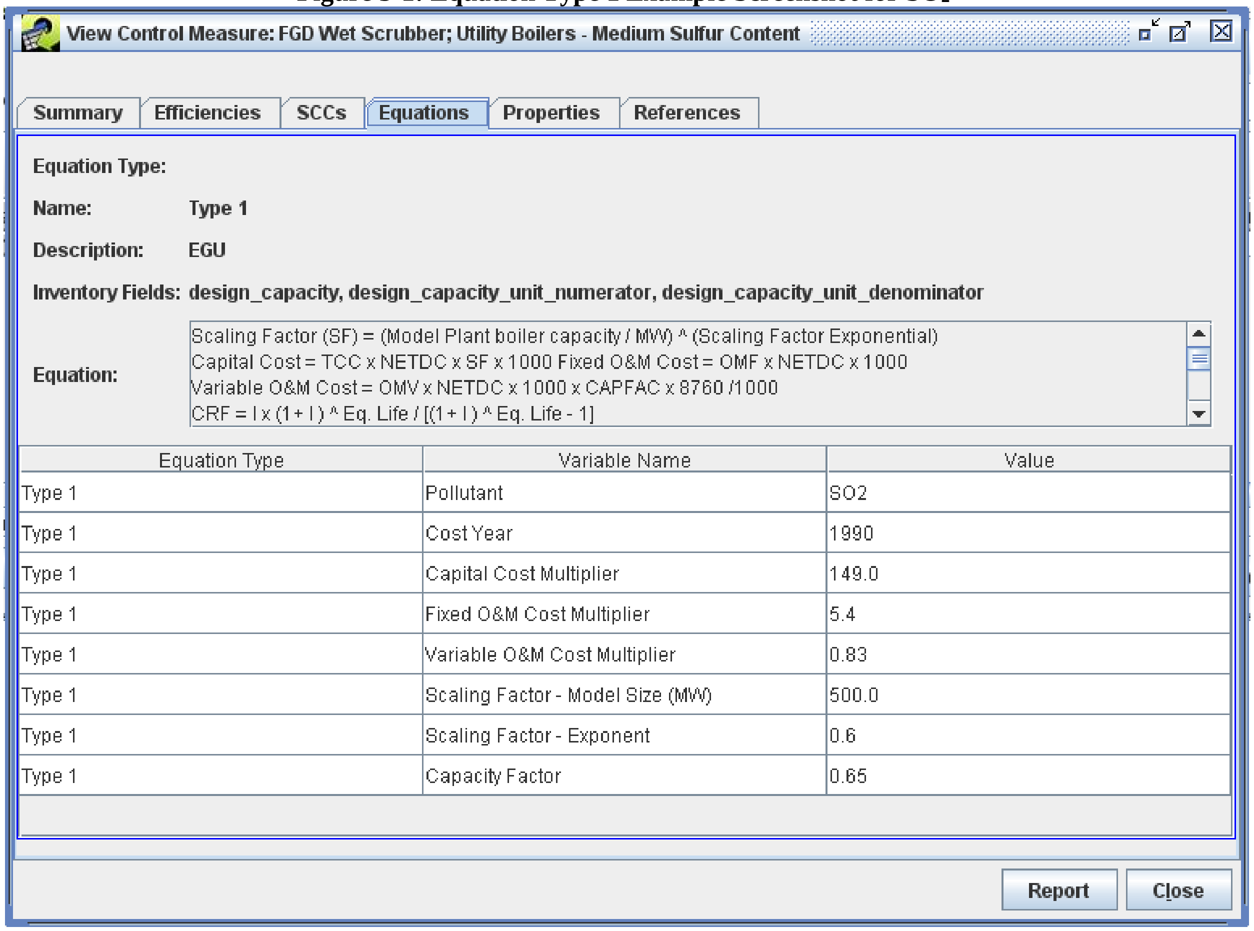
Equation Type 1 Example for SO_2

This section provides example calculations for an application of Equation Type 1 where SO_2 is the primary pollutant for this control technology. The example is for a utility boiler with medium sulfur content in its feedstock (i.e., %S<=2%), and a flue gas desulfurization wet scrubber for its control equipment.

Example Equation Variables
The following values are read from Tables B-3 and B-4 and are shown in Figure 3-1.

Interest Rate = 7%
Equipment Life = 15 years (from summary tab of control measure data)
Capacity = 160.6 MW
Scaling Factor Model Size = 500
Scaling Factor Exponent = 0.6
Capital Cost Multiplier = 149 \$/kW
Fixed O&M Cost Multiplier = 5.40 \$/kW
Variable O&M Cost Multiplier = 0.83 \$/MWh
Capacity Factor = 0.65
Year for Cost Basis = 1990

Figure 3-1: Equation Type 1 Example Screenshot for SO_2



Annualized Capital Cost

$$Scaling\ Factor = \left(\frac{Scaling\ Factor\ Model\ Size}{Capacity}\right)^{Scaling\ Factor\ Exponent}$$

$$Scaling\ Factor = \left(\frac{500.0}{160.6}\right)^{0.6}$$

$$Scaling\ Factor = 1.977$$

$$Capital\ Cost = Capital\ Cost\ Multiplier \times Capacity \times Scaling\ Factor \times 1{,}000$$

$$Capital\ Cost = 149\,\frac{\$}{kW} \times 160.6\ MW \times 1.977 \times 1{,}000\,\frac{kW}{MW}$$

$$Capital\ Cost = \$47{,}300{,}582\ (1990\$)$$

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate \times (1 + Interest\ Rate)^{Equipment\ Life}}{(1 + Interest\ Rate)^{Equipment\ Life} - 1}$$

$$Capital\ Recovery\ Factor = \frac{0.07 \times (1 + 0.07)^{15}}{(1 + 0.07)^{15} - 1}$$

$$Capital\ Recovery\ Factor = 0.109795$$

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$
$$Annualized\ Capital\ Cost = \$47{,}300{,}582 \times 0.109795$$
$$Annualized\ Capital\ Cost = \$5{,}193{,}367 (1990\$)$$

Operation and Maintenance Cost

$$Fixed\ O\&M = Fixed\ O\&M\ Cost\ Multiplier\ \left(\frac{\$}{kW}\right) \times Capacity(MW) \times 1{,}000$$
$$Fixed\ O\&M = 5.40 \frac{\$}{kW} \times 160.6\ MW \times 1{,}000 \frac{kW}{MW}$$
$$Fixed\ O\&M = \$867{,}240$$

$$Variable\ O\&M = Variable\ O\&M\ Cost\ Multiplier\ \left(\frac{\$}{MWh}\right) \times Capacity\ (MW) \times Capacity\ Factor\ \times 8{,}760\ (Hours\ Per\ Year)$$
$$Variable\ O\&M = 0.83 \frac{\$}{MWh} \times 160.6\ MW \times 0.65 \times 8{,}760\ Hours$$
$$Variable\ O\&M = \$758{,}998$$

$$O\&M\ Cost = Fixed\ O\&M + Variable\ O\&M$$
$$O\&M\ Cost = \$867{,}240 + \$758{,}998$$
$$O\&M\ Cost = \$1{,}626{,}238 (1990\$)$$

Total Annualized Cost

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + O\&M\ Cost$$
$$Total\ Annualized\ Cost = \$5{,}193{,}367 + \$1{,}626{,}238$$
$$Total\ Annualized\ Cost = \$6{,}819{,}605\ (1990\$)$$

3.2 Non-IPM Sector (ptnonipm) SO_2 Control Cost Equations

Ptnonipm point sources utilizing control cost equations for SO_2 emission reductions are represented by Equation Types 3 through 6, 11, 16, and 18 through 19. The equation types vary by control measure. Each equation uses the source's stack flowrate (in ft^3/min) as the primary variable to estimate cost. For a select set of SO_2 controls, boiler capacity (in mmBTU/hr) is used to assign a default cost per ton reduced which is used to derive the unit's control cost. Cost equations and default cost per ton reduced are taken from the original Alternative Control Technology, Control Technology Guidelines (ACT/CTG), or other EPA analyses used to derive these estimates. Table B-8 provides a list of the control cost equations assigned to various ptnonipm control measures.

If the unit already has some SO_2 control measure applied in the input inventory, incremental controls are applied only if their control efficiency value exceeds that of the input control. Control costs do not differ in these cases and the costs associated with incremental controls are the same as those applied on uncontrolled sources.

An additional list of control measures are assigned to SO_2 reductions but involve the application of default cost per ton measures to estimate the costs assigned with each control measure. These measures and their cost per ton reduced values (some based on boiler capacity size bins) are presented in Table B-8. The controls that have cost per ton reduced values based on boiler capacity size bins use Equation Type 11 to estimate costs (see Table B-14**).** A ratio of capital to annual costs is applied to estimate the capital cost associated with the control. The O&M costs are calculated by subtracting the capital cost × CRF from the total annualized cost.

Equations 16 and 18 were developed for the industrial, commercial, and institutional boilers and processes heater NESHAP for major sources (Boiler MACT). Equation 19 was developed for the commercial and industrial solid waste incinerator NESHAP (CISWI). The equations to calculate flowrates for Equation Types 14 through 18 are provided in section 3.2.6. Table B-19 lists the assumptions that are included in multiple Equation Types; assumptions that are for one specific control are listed in its respective section.

3.2.1 Equation Type 3 for SO_2

Table 3-2 lists all of the Source Classification Codes (SCCs) for the sources associated with Equation Type 3 and SO_2 in the CoST CMDB.

Table 3-2. SO_2 Source Categories Associated with Equation Type 3

SCC	Description
10200101	External Combustion Boilers; Industrial; Anthracite Coal; Pulverized Coal
10200104	External Combustion Boilers; Industrial; Anthracite Coal; Traveling Grate (Overfeed) Stoker
10200107	External Combustion Boilers; Industrial; Anthracite Coal; Hand-fired
10200201	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Pulverized Coal: Wet Bottom
10200202	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom
10200203	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Cyclone Furnace
10200204	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Spreader Stoker
10200205	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Overfeed Stoker
10200206	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Underfeed Stoker
10200210	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Overfeed Stoker
10200212	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Tangential)
10200213	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Wet Slurry
10200219	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Cogeneration (Bituminous Coal)
10200221	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Pulverized Coal: Wet Bottom (Subbituminous Coal)
10200222	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Subbituminous Coal)
10200223	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Cyclone Furnace (Subbituminous Coal)
10200224	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Spreader Stoker (Subbituminous Coal)
10200225	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Traveling Grate (Overfeed) Stoker (Subbituminous Coal)
10200226	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom Tangential (Subbituminous Coal)
10200229	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Cogeneration (Subbituminous Coal)
10200300	External Combustion Boilers; Industrial; Lignite; Pulverized Coal: Wet Bottom
10200301	External Combustion Boilers; Industrial; Lignite; Pulverized Coal: Dry Bottom, Wall Fired
10200302	External Combustion Boilers; Industrial; Lignite; Pulverized Coal: Dry Bottom, Tangential Fired
10200303	External Combustion Boilers; Industrial; Lignite; Cyclone Furnace
10200304	External Combustion Boilers; Industrial; Lignite; Traveling Grate (Overfeed) Stoker
10200306	External Combustion Boilers; Industrial; Lignite; Spreader Stoker

SCC	Description
10200307	External Combustion Boilers; Industrial; Lignite; Cogeneration
10200400	External Combustion Boilers; Industrial; Residual Oil; undefined
10200401	External Combustion Boilers; Industrial; Residual Oil; Grade 6 Oil
10200402	External Combustion Boilers; Industrial; Residual Oil; 10-100 Million Btu/hr
10200403	External Combustion Boilers; Industrial; Residual Oil; < 10 Million Btu/hr
10200404	External Combustion Boilers; Industrial; Residual Oil; Grade 5 Oil
10200405	External Combustion Boilers; Industrial; Residual Oil; Cogeneration
10201403	External Combustion Boilers; Industrial; CO Boiler; Distillate Oil
10201404	External Combustion Boilers; Industrial; CO Boiler; Residual Oil
10300101	External Combustion Boilers; Commercial/Institutional; Anthracite Coal; Pulverized Coal
10300102	External Combustion Boilers; Commercial/Institutional; Anthracite Coal; Traveling Grate (Overfeed) Stoker
10300103	External Combustion Boilers; Commercial/Institutional; Anthracite Coal; Hand-fired
10300205	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Pulverized Coal: Wet Bottom (Bituminous Coal)
10300206	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Bituminous Coal)
10300207	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Overfeed Stoker (Bituminous Coal)
10300208	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Underfeed Stoker (Bituminous Coal)
10300209	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Spreader Stoker (Bituminous Coal)
10300211	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Overfeed Stoker
10300214	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Hand-fired (Bituminous Coal)
10300216	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Tangential) (Bituminous Coal)
10300221	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Pulverized Coal: Wet Bottom (Subbituminous Coal)
10300222	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Subbituminous Coal)
10300223	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Cyclone Furnace (Subbituminous Coal)
10300224	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Spreader Stoker (Subbituminous Coal)
10300225	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Traveling Grate (Overfeed) Stoker (Subbituminous Coal)
10300226	External Combustion Boilers; Commercial/Institutional;Bituminous/Subbituminous Coal;Pulverized Coal: Dry Bottom Tangential (Subbituminous Coal)
10300305	External Combustion Boilers; Commercial/Institutional; Lignite; Pulverized Coal: Dry Bottom, Wall Fired
10300306	External Combustion Boilers; Commercial/Institutional; Lignite; Pulverized Coal: Dry Bottom, Tangential Fired
10300307	External Combustion Boilers; Commercial/Institutional; Lignite; Traveling Grate (Overfeed) Stoker
10300309	External Combustion Boilers; Commercial/Institutional; Lignite; Spreader Stoker
10300400	External Combustion Boilers; Commercial/Institutional; Residual Oil; undefined
10300401	External Combustion Boilers; Commercial/Institutional; Residual Oil; Grade 6 Oil
10300402	External Combustion Boilers; Commercial/Institutional; Residual Oil; 10-100 Million Btu/hr
10300404	External Combustion Boilers; Commercial/Institutional; Residual Oil; Grade 5 Oil
30300101	Industrial Processes; Primary Metal Production; Aluminum Ore (Electro-reduction); Prebaked Reduction Cell
30300102	Industrial Processes; Primary Metal Production; Aluminum Ore (Electro-reduction); Horizontal Stud Soderberg Cell
30300103	Industrial Processes; Primary Metal Production; Aluminum Ore (Electro-reduction); Vertical Stud Soderberg Cell
30300105	Industrial Processes; Primary Metal Production; Aluminum Ore (Electro-reduction); Anode Baking Furnace
30300199	Industrial Processes; Primary Metal Production; Aluminum Ore (Electro-reduction); Not Classified
30300201	Industrial Processes; Primary Metal Production; Aluminum Hydroxide Calcining; Overall Process
30300306	Industrial Processes; Primary Metal Production; By-product Coke Manufacturing; Oven Underfiring
30300813	Industrial Processes; Primary Metal Production; Iron Production (See 3-03-015 for Integrated Iron & Steel MACT); Windbox
30300817	Industrial Processes; Primary Metal Production; Iron Production (See 3-03-015 for Integrated Iron & Steel MACT); Cooler

SCC	Description
30300824	Industrial Processes; Primary Metal Production; Iron Production (See 3-03-015 for Integrated Iron & Steel MACT); Blast Heating Stoves
30300825	Industrial Processes; Primary Metal Production; Iron Production (See 3-03-015 for Integrated Iron & Steel MACT); Cast House
30300901	Industrial Processes; Primary Metal Production; Steel Manufacturing (See 3-03-015 for Integrated Iron & Steel MACT); Open Hearth Furnace: Stack
30300908	Industrial Processes; Primary Metal Production; Steel Manufacturing (See 3-03-015 for Integrated Iron & Steel MACT); Electric Arc Furnace: Carbon Steel (Stack)
30300911	Industrial Processes; Primary Metal Production; Steel Manufacturing (See 3-03-015 for Integrated Iron & Steel MACT); Soaking Pits
30300931	Industrial Processes; Primary Metal Production; Steel Manufacturing (See 3-03-015 for Integrated Iron & Steel MACT); Hot Rolling
30300933	Industrial Processes; Primary Metal Production; Steel Manufacturing (See 3-03-015 for Integrated Iron & Steel MACT); Reheat Furnaces
30300999	Industrial Processes; Primary Metal Production; Steel Manufacturing (See 3-03-015 for Integrated Iron & Steel MACT); Other Not Classified
30301001	Industrial Processes; Primary Metal Production; Lead Production; Sintering: Single Stream
30301002	Industrial Processes; Primary Metal Production; Lead Production; Blast Furnace Operation
30301101	Industrial Processes; Primary Metal Production; Molybdenum; Mining: General
30301199	Industrial Processes; Primary Metal Production; Molybdenum; Other Not Classified
30301201	Industrial Processes; Primary Metal Production; Titanium; Chlorination
30303003	Industrial Processes; Primary Metal Production; Zinc Production; Sinter Strand
30399999	Industrial Processes; Primary Metal Production; Other Not Classified; Other Not Classified
30500606	Industrial Processes; Mineral Products; Cement Manufacturing (Dry Process); Kilns
30500622	Industrial Processes; Mineral Products; Cement Manufacturing (Dry Process); Preheater Kiln
30500706	Industrial Processes; Mineral Products; Cement Manufacturing (Wet Process); Kilns
30500801	Industrial Processes; Mineral Products; Ceramic Clay/Tile Manufacture; Drying (use SCC 3-05-008-13)
30501001	Industrial Processes; Mineral Products; Coal Mining, Cleaning, and Material Handling (See 305310); Fluidized Bed
30501037	Industrial Processes; Mineral Products; Coal Mining, Cleaning, and Material Handling (See 305310); Truck Loading: Overburden
30501201	Industrial Processes; Mineral Products; Fiberglass Manufacturing; Regenerative Furnace (Wool-type Fiber)
30501211	Industrial Processes; Mineral Products; Fiberglass Manufacturing; Regenerative Furnace (Textile-type Fiber)
30501401	Industrial Processes; Mineral Products; Glass Manufacture; Furnace/General
30501402	Industrial Processes; Mineral Products; Glass Manufacture; Container Glass: Melting Furnace
30501403	Industrial Processes; Mineral Products; Glass Manufacture; Flat Glass: Melting Furnace
30501404	Industrial Processes; Mineral Products; Glass Manufacture; Pressed and Blown Glass: Melting Furnace
30501410	Industrial Processes; Mineral Products; Glass Manufacture; Raw Material Handling (All Types of Glass)
30501499	Industrial Processes; Mineral Products; Glass Manufacture; See Comment
30501602	Industrial Processes; Mineral Products; Lime Manufacture; Secondary Crushing/Screening
30501604	Industrial Processes; Mineral Products; Lime Manufacture; Calcining: Rotary Kiln ** (See SCC Codes 3-05-016-18,-19,-20,-21)
30501905	Industrial Processes; Mineral Products; Phosphate Rock; Calcining
30502201	Industrial Processes; Mineral Products; Potash Production; Mine: Grinding/Drying
30502509	Industrial Processes; Mineral Products; Construction Sand and Gravel; Cooler ** (See 3-05-027-30 for Industrial Sand Coolers)
30600201	Industrial Processes; Petroleum Industry; Catalytic Cracking Units; Fluid Catalytic Cracking Unit
30600402	Industrial Processes; Petroleum Industry; Blowdown Systems; Blowdown System w/o Controls
30600503	Industrial Processes; Petroleum Industry; Wastewater Treatment; Process Drains and Wastewater Separators
30600902	Industrial Processes; Petroleum Industry; Flares; Residual Oil
30601201	Industrial Processes; Petroleum Industry; Fluid Coking Units; General
30700104	Industrial Processes; Pulp and Paper and Wood Products; Sulfate (Kraft) Pulping; Recovery Furnace/Direct Contact Evaporator
30700110	Industrial Processes; Pulp and Paper and Wood Products; Sulfate (Kraft) Pulping; Recovery Furnace/Indirect Contact Evaporator
31000401	Industrial Processes; Oil and Gas Production; Process Heaters; Distillate Oil (No. 2)
31000402	Industrial Processes; Oil and Gas Production; Process Heaters; Residual Oil
31000403	Industrial Processes; Oil and Gas Production; Process Heaters; Crude Oil
31000405	Industrial Processes; Oil and Gas Production; Process Heaters; Process Gas

SCC	Description
31000411	Industrial Processes; Oil and Gas Production; Process Heaters; Distillate Oil (No. 2): Steam Generators
31000412	Industrial Processes; Oil and Gas Production; Process Heaters; Residual Oil: Steam Generators
31000413	Industrial Processes; Oil and Gas Production; Process Heaters; Crude Oil: Steam Generators

3.2.1.1 Cost Equations

Annualized Capital Costs for Flowrate ≥ 1,028,000 acfm

$$Capital\ Cost = Retrofit\ Factor \times Gas\ Flowrate\ Factor \times Capital\ Cost\ Factor \times STKFLOW \times 60$$

Where:
Gas Flowrate Factor = 0.486 kW/acfm
Capital Cost Factor = \$192/kW
STKFLOW = stack gas flowrate (ft^3/s) from the emissions inventory
60 = conversion factor to convert acfs to acfm

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate \times (1 + Interest\ Rate)^{Equipment\ Life}}{[(1 + Interest\ Rate)^{Equipment\ Life} - 1]}$$

Where:
Interest Rate = annual interest rate
Equipment Life = expected economic life of the control equipment

$$Annualized\ Capital\ Cost = Capital\ Cost \times Capital\ Recovery\ Factor$$

Where *Capital Cost* and *Capital Recovery Factor* were calculated previously.

Annualized Capital Costs for Flowrate < 1,028,000 acfm

$$Capital\ Cost = \left(\frac{1{,}028{,}000}{Flowrate}\right)^{0.6} \times Retrofit\ Factor \times Gas\ Flowrate\ Factor \times Capital\ Cost\ Factor \times STKFLOW \times 60$$

Where:
Gas Flowrate Factor = 0.486 kW/acfm
Capital Cost Factor = \$192/kW
STKFLOW = stack gas flowrate (ft^3/s) from the emissions inventory
60 = conversion factor to convert acfs to acfm

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate \times (1 + Interest\ Rate)^{Equipment\ Life}}{[(1 + Interest\ Rate)^{Equipment\ Life} - 1]}$$

Where:
Interest Rate = annual interest rate
Equipment Life = expected economic life of the control equipment

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$

Where *Capital Cost* and *Capital Recovery Factor* were calculated previously.

Operation and Maintenance Cost

$$Fixed\ O\&M = Gas\ Flow\ Rate\ Factor\ \times Fixed\ O\&M\ Rate$$

Where:
Gas Flowrate Factor = 0.486 kW/acfm
Fixed O&M Rate = \$6.9/kW-yr

$$Variable\ O\&M = Gas\ Flow\ Rate\ Factor \times Variable\ O\&M\ Cost\ Multiplier \times Hours\ per\ Year \times STKFLOW$$

Where:
Gas Flowrate Factor = 0.486 kW/acfs
Variable O&M Cost Multiplier = \$0.0015/kWh
Hours per Year = 8,736 hours
STKFLOW = stack gas flowrate (ft^3/s) from the emissions inventory

$$O\&M\ Cost = Fixed\ O\&M + Variable\ O\&M$$

Where *Fixed O&M* and *Variable O&M* were calculated previously.

Total Annualized Cost

The following equation applies whether the annualized capital cost is calculated based on the standard (≤1,028,000 acfm) or large (>1,028,000 acfm) size:

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + O\&M\ Cost$$

Where *Annualized Capital Cost* and *O&M Cost* were calculated previously.

3.2.1.2 Example Calculation

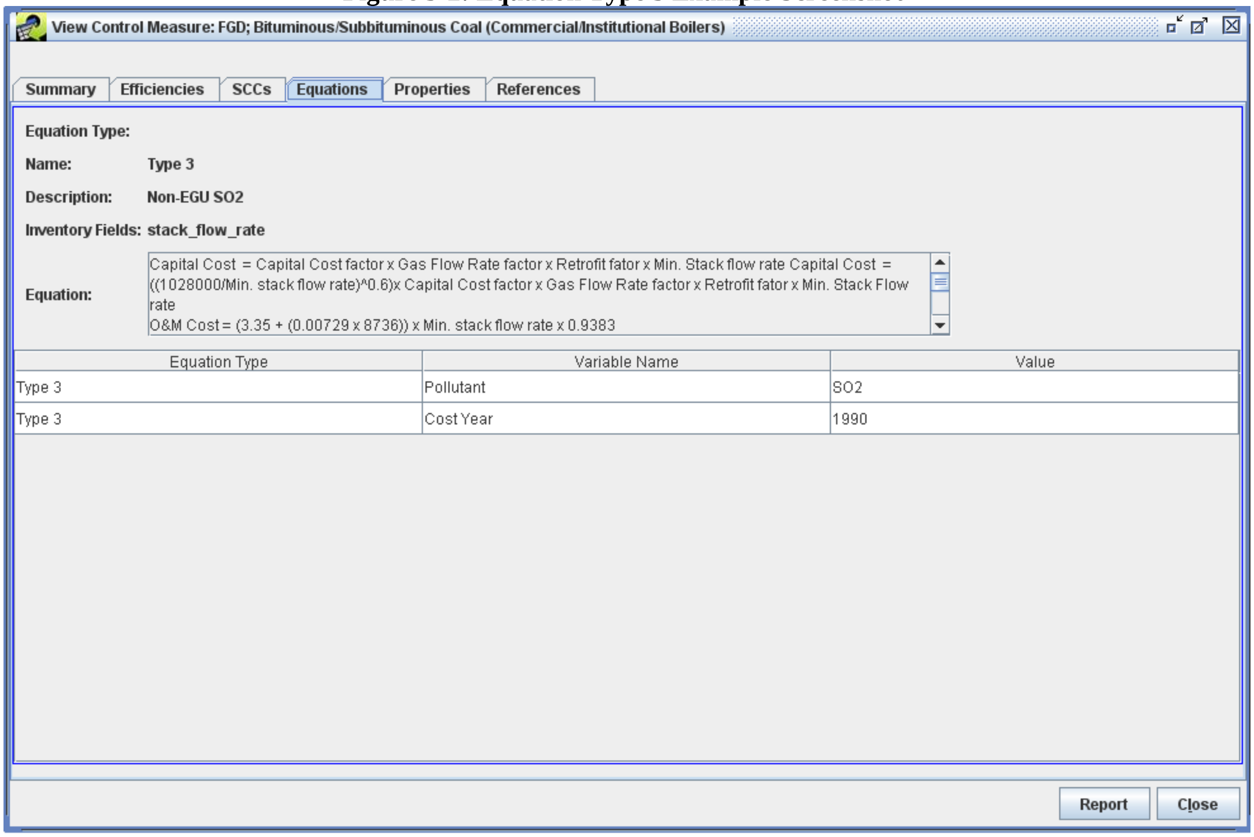
This section provides example calculations for an application of Equation Type 3. The example scenario is an industrial plant using FGD as the primary control technology for SO_2. Information for the equations in CoST is shown in Figure 3-2.

Example Equation Variables

Interest Rate = 7% per year
Equipment Life = 15 years
$STKFLOW\ = 1682.7 \frac{ft^3}{sec}$
Retrofit Factor = 1.1
Gas Flow Rate Factor = 0.486 kW/acfm

Capital Cost Factor = $192/kW
Fixed O&M Rate = $6.90/kW-yr
Variable O&M Rate = $0.0015/kWh
Year for Cost Basis = 1995

Figure 3-2: Equation Type 3 Example Screenshot



Annualized Capital Costs for Flowrate < 1,028,000 acfm

$$Capital\ Cost = \left(\frac{1{,}028{,}000}{Flowrate}\right)^{0.6} \times Retrofit\ Factor \times Gas\ Flow\ Rate\ Factor \times Capital\ Cost\ Factor \times STKFLOW \times 60$$

$$Capital\ Cost = \left(\frac{1{,}028{,}000}{1682.7\frac{ft^3}{sec} \times 60\frac{sec}{min}}\right)^{0.6} \times 1.1 \times 0.486\frac{\text{kW}}{\text{acfm}} \times \frac{\$192}{kW} \times 1682.7\frac{ft^3}{sec} \times 60\frac{sec}{min}$$

$$Capital\ Cost = \$41{,}705{,}106\ (1995\$)$$

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate \times (1 + Interest\ Rate)^{Equipment\ Life}}{[(1 + Interest\ Rate)^{Equipment\ Life} - 1]}$$

$$Capital\ Recovery\ Factor = \frac{flow\ rate.07\ \times (1+.07)^{15}}{[(1+.07)^{15}\ -1]}$$
$$Capital\ Recovery\ Factor = 0.1098$$

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$
$$Annualized\ Capital\ Cost = \$41{,}705{,}106\ \times 0.1098$$
$$Annualized\ Capital\ Cost = \$4{,}578{,}996\ (1990\$)$$

Operation and Maintenance Cost

$$Fixed\ O\&M = Gas\ Flow\ Rate\ Factor\ \times Fixed\ O\&M\ Rate$$
$$Fixed\ O\&M = 0.486\ \mathrm{kW/acfm}\ \ \times \$6.9/\mathrm{kW-yr}$$
$$Fixed\ O\&M = \$3.354$$

$$Variable\ O\&M$$
$$= Gas\ Flow\ Rate\ Factor \times Variable\ O\&M\ Cost\ Multiplier \times Hours\ per\ Year$$
$$\times STKFLOW$$

$$Variable\ O\&M = 0.486\frac{\mathrm{kW}}{\mathrm{acf}} \times \frac{\$0.0015}{\mathrm{kWh}} \times 8{,}736\ \mathrm{hours} \times 1682.7\frac{ft^3}{sec}\ \times 60\frac{sec}{min}$$

$$Variable\ O\&M = \$642{,}980$$

$$O\&M\ Cost = Fixed\ O\&M + Variable\ O\&M$$
$$O\&M\ Cost = \$3.354 + \$642{,}980$$
$$O\&M\ Cost = \$642{,}984\ (1990\$)$$

Total Annualized Cost

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + O\&M\ Cost$$
$$Total\ Annualized\ Cost = \$4{,}578{,}803\ + \$642{,}983$$
$$Total\ Annualized\ Cost = \$5{,}221{,}787\ (1990\$)$$

3.2.2 Equation Type 4 for SO_2

Equation Type 4 is applied to sulfuric acid plants. As shown in Table B-8 the sole control technology is to increase the percent conversion to meet a predefined target. The SCCs for the sources belonging to this type are listed in Table 3-3.

Table 3-3. SO_2 Source Categories Associated with Equation Type 4

SCC	Description
30102306	Industrial Processes; Chemical Manufacturing; Sulfuric Acid (Contact Process); Absorber/@ 99.0% Conversion
30102308	Industrial Processes; Chemical Manufacturing; Sulfuric Acid (Contact Process); Absorber/@ 98.0% Conversion
30102310	Industrial Processes; Chemical Manufacturing; Sulfuric Acid (Contact Process); Absorber/@ 97.0% Conversion
30102318	Industrial Processes; Chemical Manufacturing; Sulfuric Acid (Contact Process); Absorber/@ 93.0% Conversion
30301001	Industrial Processes; Primary Metal Production; Lead Production; Sintering: Single Stream
30301006	Industrial Processes; Primary Metal Production; Lead Production; Sintering: Dual Stream Feed End
30301007	Industrial Processes; Primary Metal Production; Lead Production; Sintering: Dual Stream Discharge End

SCC	Description
30301014	Industrial Processes; Primary Metal Production; Lead Production; Sintering Charge Mixing
30303002	Industrial Processes; Primary Metal Production; Zinc Production; Multiple Hearth Roaster
30303007	Industrial Processes; Primary Metal Production; Zinc Production; Flash Roaster
30303008	Industrial Processes; Primary Metal Production; Zinc Production; Fluid Bed Roaster

3.2.2.1 Cost Equations

Annualized Capital Cost

$$Capital\ Cost = \$990{,}000 + \$9.836 \times STKFLOW \times 60$$

Where:
Fixed Capital Cost = \$990,000
Scaled Capital Cost = \$9.836
STKFLOW = stack gas flowrate (ft^3/s) from the emissions inventory
60 = conversion factor to convert acfs to acfm

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{[(1 + Interest\ Rate)^{Equipment\ Life}\ - 1]}$$

Where:
Interest Rate = annual interest rate
Equipment Life = expected economic life of control equipment

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$

Operation and Maintenance Cost

$$Fixed\ O\&M = \$75{,}800$$

Where:
Fixed O&M Cost = \$75,800 based on model plant data

$$Variable\ O\&M = \$12.82 \times STKFLOW \times 60$$

Where:
Variable O&M Cost Multiplier = \$12.82 based on model plant data
STKFLOW = stack gas flowrate (ft^3/s) from the emissions inventory
60 = conversion factor to convert acfs to acfm

$$Total\ O\&M = Fixed\ O\&M + Variable\ O\&M$$

Total Annualized Cost

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + O\&M\ Cost$$

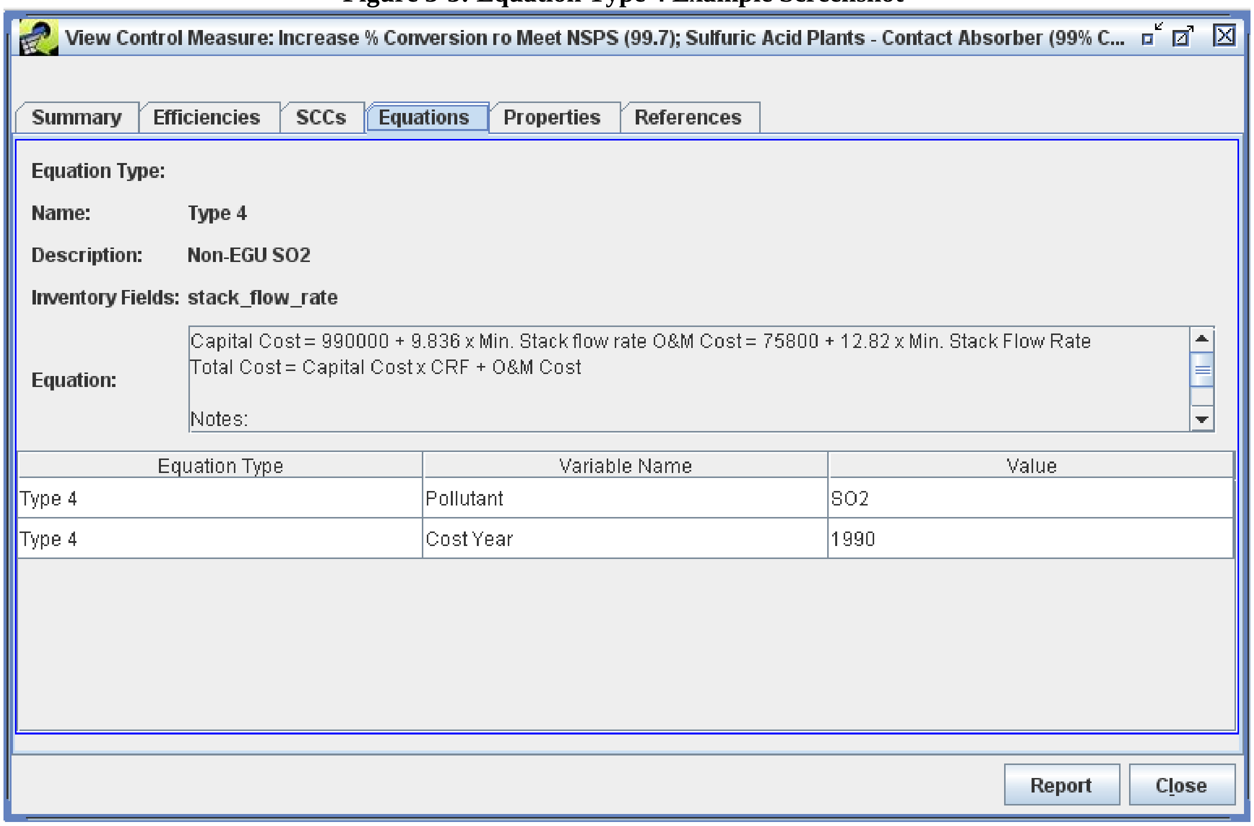
3.2.2.2 Example Calculations

The CoST screenshot related to the Equation Type 4 example is shown in Figure 3-3.

Example Equation Variables

$Interest\ Rate = 7\%$
$Equipment\ Life = 15$ years (from summary tab of control measure data)
$STKFLOW = 956.7\frac{ft^3}{sec}$
$Year\ for\ Cost\ Basis = 1990$

Figure 3-3: Equation Type 4 Example Screenshot



Annualized Capital Cost

$$Capital\ Cost = \$990{,}000 + \$9.836 \times STKFLOW \times 60$$
$$Capital\ Cost = \$990{,}000 + \$9.836/acfm \times 956.7\frac{ft^3}{sec} \times 60\frac{sec}{min}$$
$$Capital\ Cost = \$1{,}554{,}606\ (1990\$)$$

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate \times (1 + Interest\ Rate)^{Equipment\ Life}}{[(1 + Interest\ Rate)^{Equipment\ Life} - 1]}$$

$$Capital\ Recovery\ Factor = \frac{0.07\ \times (1 + 0.07)^{15}}{[(1 + 0.07)^{15}\ - 1]}$$

$$Capital\ Recovery\ Factor = 0.1098$$

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$
$$Annualized\ Capital\ Cost = \$1{,}554{,}606\ \times 0.1098$$
$$Annualized\ Capital\ Cost = \$170{,}687\ (1990\$)$$

Operation and Maintenance Cost

$$Fixed\ O\&M = \$75{,}800$$
$$Variable\ O\&M = \$12.82 \times STKFLOW \times 60$$
$$Variable\ O\&M = \$12.82/acfm \times 956.7 \frac{ft^3}{sec} \times 60 \frac{sec}{min}$$
$$Variable\ O\&M = \$735{,}893$$

$$Total\ O\&M = Fixed\ O\&M + Variable\ O\&M$$
$$Total\ O\&M = \$75{,}800 + \$735{,}894$$
$$Total\ O\&M = \$811{,}694\ (1990\$)$$

Total Annualized Cost

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + O\&M\ Cost$$
$$Total\ Annualized\ Cost = \$170{,}687 + \$811{,}694$$
$$Total\ Annualized\ Cost = \$982{,}381 (1990\$)$$

3.2.3 Equation Type 5 for SO_2

Equation Type 5 is applied to chemical manufacturing related to elemental sulfur production. As shown in Table B-8 the sole control technology is amine scrubbing. The SCCs for the sources belonging to this type are listed in Table 3-4.

Table 3-4. SO_2 Source Categories Associated with Equation Type 5

SCC	Description
30103201	Industrial Processes; Chemical Manufacturing; Elemental Sulfur Production; Mod. Claus: 2 Stage w/o Control (92-95% Removal)
30103202	Industrial Processes; Chemical Manufacturing; Elemental Sulfur Production; Mod. Claus: 3 Stage w/o Control (95-96% Removal)
30103203	Industrial Processes; Chemical Manufacturing; Elemental Sulfur Production; Mod. Claus: 4 Stage w/o Control (96-97% Removal)

3.2.3.1 Cost Equations

Annualized Capital Cost

$$Capital\ Cost = Fixed\ Capital\ Cost + Scaled\ Capital\ Cost\ \times STKFLOW \times 60$$

$$Capital\ Cost = \$2{,}882{,}540 + \$244.74 \times STKFLOW \times 60$$

Where:
$Fixed\ Capital\ Cost$ = \$2,882,540
$Scaled\ Capital\ Cost$ = \$244.74
$STKFLOW$ = stack gas flowrate (ft^3/s) from the emissions inventory
60 = conversion factor to convert acfs to acfm

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{[(1 + Interest\ Rate)^{Equipment\ Life} - 1]}$$

Where:
$Interest\ Rate$ = annual interest rate
$Equipment\ Life$ = expected economic life of the control equipment

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$

Where the *Capital Cost* and the *Capital Recovery Factor* were calculated previously.

Operation and Maintenance Cost

$$Fixed\ O\&M = \$749{,}170$$

Where:
\$749,170 is the fixed O&M cost based on model plant data

$$Variable\ O\&M = \$148.4 \times STKFLOW \times 60$$

Where:
Variable O&M Cost Multiplier = \$148.4 based on model plant data and credit for recovered product
$STKFLOW$ = stack gas flowrate (ft^3/s) from the emissions inventory
60 = conversion factor to convert acfs to acfm

$$Total\ O\&M = Fixed\ O\&M + Variable\ O\&M$$

Where the *Fixed O&M* and the *Variable O&M* were calculated previously.

Total Annualized Cost

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + Total\ O\&M$$

Where the *Annualized Capital Cost* and the *Total O&M* were calculated previously.

3.2.3.2 Example Calculations

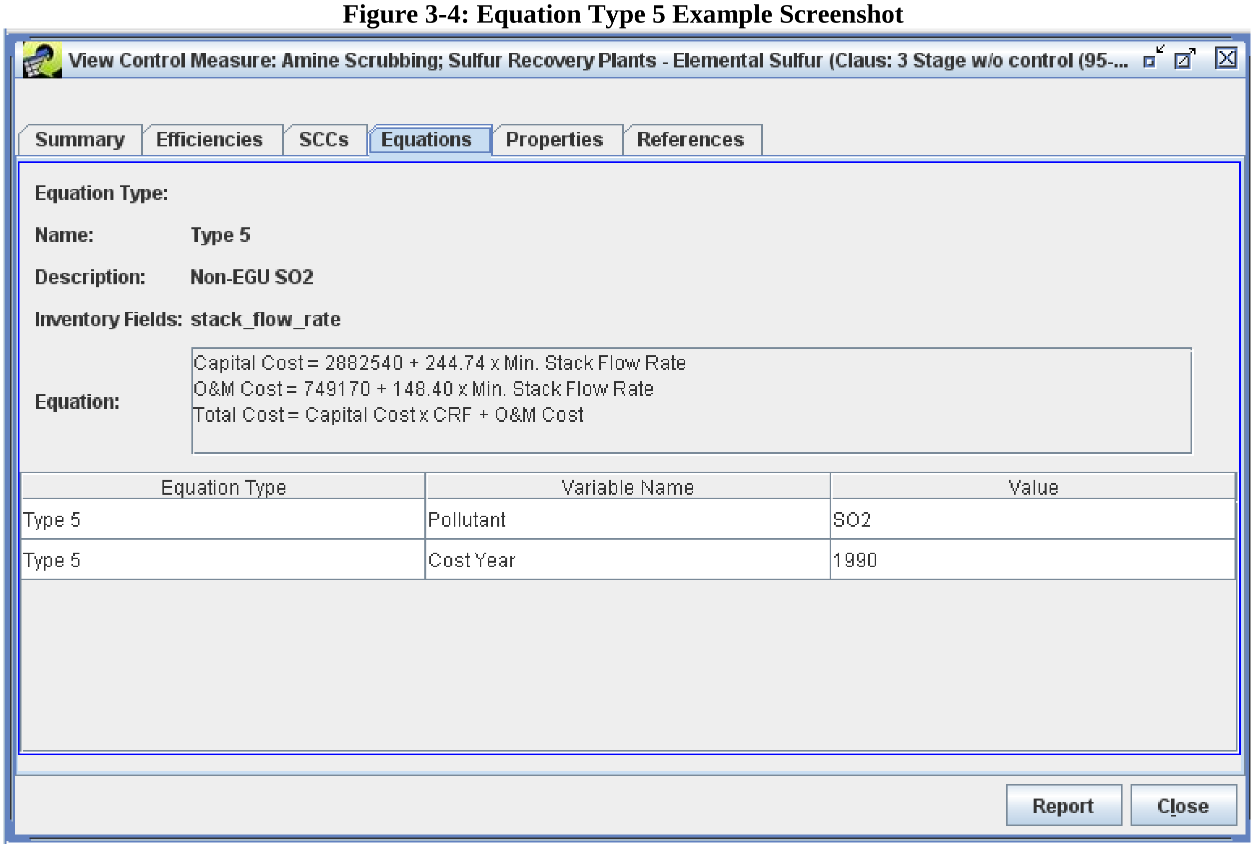
This section provides example calculations for an application of Equation Type 5. The example is an industrial process that produces elemental sulfur and requires SO_2 control. Using Table B-8 the CoST code is SAMSCSRP95 and the control type being implemented is amine scrubbing.

Example Equation Variables

$Interest\ Rate = 7\%$
$Equipment\ Life = 15$ years
$STKFLOW\ = 541.6\frac{ft^3}{sec}$

$Year\ for\ Cost\ Basis = 1990$

Figure 3-4: Equation Type 5 Example Screenshot



Annualized Capital Cost

$$Capital\ Cost\ = \$2{,}882{,}540 + \$244.74 \times STKFLOW \times 60$$
$$Capital\ Cost\ = \$2{,}882{,}540 + \$244.74/acfm \times 541.6\frac{ft^3}{sec} \times 60\frac{sec}{min}$$
$$Capital\ Cost\ = \$10{,}835{,}611\ (1990\$)$$

$$Capital\ Recovery\ Factor\ = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{[(1 + Interest\ Rate)^{Equipment\ Life}\ - 1]}$$

$$Capital\ Recovery\ Factor\ = \frac{0.07\ \times (1 + 0.07)^{15}}{[(1 + 0.07)^{15}\ - 1]}$$

$Capital\ Recovery\ Factor\ = 0.1098$

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$
$$Annualized\ Capital\ Cost = \$10{,}835{,}611\ \times 0.1098$$
$$Annualized\ Capital\ Cost = \$1{,}189{,}750\ (1990\$)$$

Operation and Maintenance Cost

$$Fixed\ O\&M = \$749{,}170$$
$$Variable\ O\&M = \$148.4 \times STKFLOW \times 60$$
$$Variable\ O\&M = \$148.4/acfm \times 541.6 \frac{ft^3}{sec} \times 60 \frac{sec}{min}$$
$$Variable\ O\&M = \$4{,}822{,}406$$

$$Total\ O\&M = Fixed\ O\&M + Variable\ O\&M$$
$$Total\ O\&M = \$749{,}170 + \$4{,}822{,}406$$
$$Total\ O\&M = \$5{,}571{,}576\ (1990\$)$$

Total Annualized Cost

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + Total\ O\&M$$
$$Total\ Annualized\ Cost = \$1{,}189{,}750 + \$5{,}571{,}576$$
$$Total\ Annualized\ Cost = \$6{,}761{,}326\ (1990\$)$$

3.2.4 Equation Type 6 for SO_2

Equation Type 6 is applied to primary metal production related to by-product coke manufacturing. As shown in Table B-8 the sole control technology is coke oven gas desulfurization. The sole SCC for sources belonging to this type is listed in Table 3-5.

Table 3-5. SO_2 Source Categories Associated with Equation Type 6

SCC	Description
30300306	Industrial Processes; Primary Metal Production; By-product Coke Manufacturing; Oven Underfiring

3.2.4.1 Cost Equations

Annualized Capital Cost

$$Capital\ Cost = \$3{,}449{,}803 + \$135.86 \times STKFLOW \times 60$$

Where:
Fixed Capital Cost = \$3,449,803
Scaled Capital Cost = \$135.86 per acfm (developed from model plant data)
STKFLOW = stack gas flowrate (ft^3/s) from the emissions inventory
60 = conversion factor to convert acfs to acfm

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{[(1 + Interest\ Rate)^{Equipment\ Life}\ - 1]}$$

Where:
Interest Rate = annual interest rate
Equipment Life = expected economic life of the control equipment

$$Annualized\ Capital\ Cost = Capital\ Cost \times Capital\ Recovery\ Factor$$

Where the *Capital Cost* and the *Capital Recovery Factor* were calculated previously.

Operation and Maintenance Cost

$$Fixed\ O\&M = \$797{,}667$$

Where:
Fixed O&M = $797,667 derived from model plant data

$$Variable\ O\&M = \$58.84 \times STKFLOW$$

Where:
Variable O&M Cost Multiplier = $58.84 derived from model plant data
STKFLOW = stack gas flowrate (ft3/s) from the emissions inventory

$$Total\ O\&M = Fixed\ O\&M + Variable\ O\&M$$

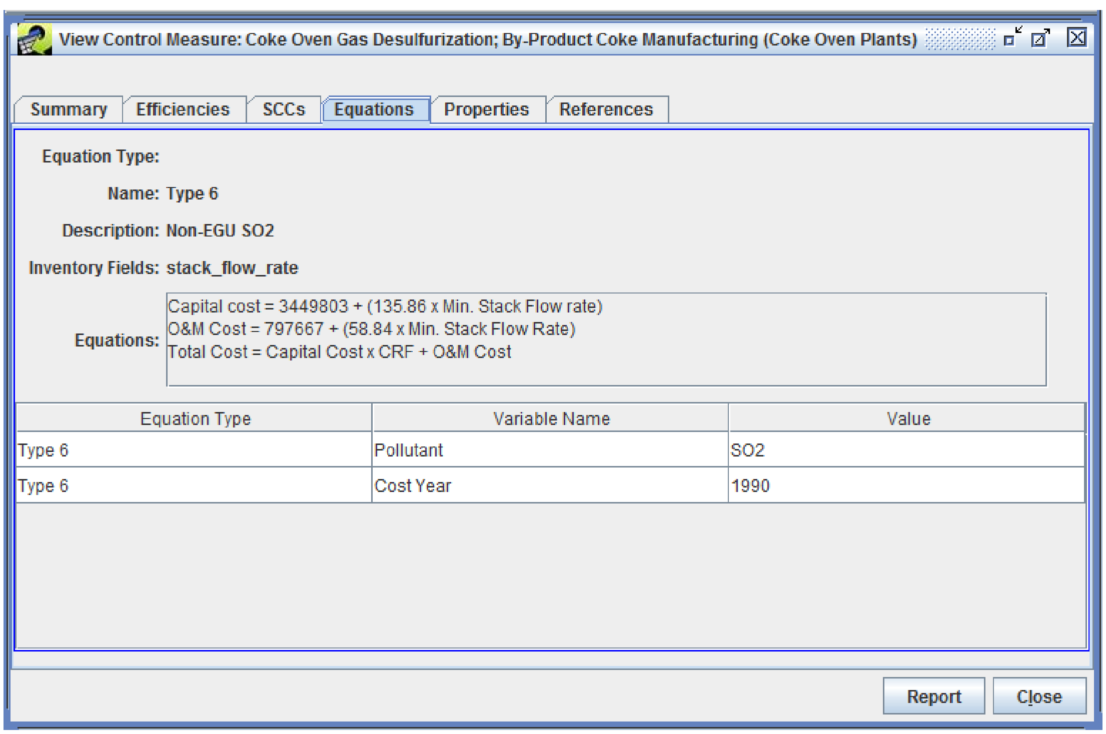
Total Annualized Cost

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + O\&M\ Cost$$

3.2.4.2 Example Calculations

The CoST screenshot related to the Equation Type 6 example is shown in Figure 2-5. Relevant data are found in Table B-8 for CoST abbreviation SCOGDCOP.

Figure 2-5. Equation Type 6 Example Screenshot



Example Equation Variables

$Interest\ Rate = 7\%$
$Equipment\ Life = 15$ years (from summary tab of control measure data)
$STKFLOW = 5327.45 \frac{ft^3}{sec}$
Year for Cost Basis = 1990

Annualized Capital Cost
$Capital\ Cost = \$3{,}449{,}803 + \$135.86 \times STKFLOW$
$Capital\ Cost = \$3{,}449{,}803 + \$135.86 \times 5327.45 \frac{ft^3}{sec} \times 60 \frac{sec}{min}$
$Capital\ Cost = \$46{,}877{,}044$ (1990\$)

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{[(1 + Interest\ Rate)^{Equipment\ Life}\ - 1]}$$

$$Capital\ Recovery\ Factor = \frac{0.07\ \times (1 + 0.07)^{15}}{[(1 + 0.07)^{15}\ - 1]}$$

$Capital\ Recovery\ Factor = 0.1098$

$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$
$Annualized\ Capital\ Cost = \$46{,}877{,}044\ \times 0.1098$
$Annualized\ Capital\ Cost = \$5{,}147{,}099$ (1990\$)

Operation and Maintenance Cost

$Fixed\ O\&M = \$797{,}667$

$Variable\ O\&M = \$58.84 \times STKFLOW$
$Variable\ O\&M = \$58.84 \times 5327.45 \frac{ft^3}{sec} \times 60 \frac{sec}{min}$
$Variable\ O\&M = \$18{,}808{,}029$

$Total\ O\&M = Fixed\ O\&M + Variable\ O\&M$
$Total\ O\&M = \$797{,}667 + \$18{,}808{,}029$
$Total\ O\&M = \$19{,}605{,}696$ (1990\$)

Total Annualized Cost

$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + O\&M\ Cost$
$Total\ Annualized\ Cost = \$5{,}147{,}099 + \$19{,}605{,}696$
$Total\ Annualized\ Cost = \$24{,}752{,}705$ (1990\$)

3.2.5 Equation Type 11 for SO_2

The primary sources associated with Equation Type 11 are industrial external combustion boilers. The list of source categories is provided in Table 3-6. Data on relevant SO_2 controls are listed in Table B-14.

Table 3-6. SO_2 Source Categories Associated with Equation Type 11

SCC	Description
10200201	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Pulverized Coal: Wet Bottom
10200202	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom
10200203	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Cyclone Furnace
10200204	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Spreader Stoker
10200205	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Overfeed Stoker
10200206	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Underfeed Stoker
10200210	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Overfeed Stoker
10200212	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Tangential)
10200213	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Wet Slurry
10200217	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Bubbling Bed (Bituminous Coal)
10200218	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Circulating Bed (Bitum. Coal)
10200219	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Cogeneration (Bituminous Coal)
10200221	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Pulverized Coal: Wet Bottom (Subbituminous Coal)
10200222	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Subbituminous Coal)
10200223	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Cyclone Furnace (Subbituminous Coal)
10200224	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Spreader Stoker (Subbituminous Coal)
10200225	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Traveling Grate (Overfeed) Stoker (Subbituminous Coal)
10200226	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom Tangential (Subbituminous Coal)
10200229	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Cogeneration (Subbituminous Coal)
10200301	External Combustion Boilers; Industrial; Lignite;Pulverized Coal: Dry Bottom, Wall Fired
10200302	External Combustion Boilers; Industrial; Lignite;Pulverized Coal: Dry Bottom, Tangential Fired
10200303	External Combustion Boilers; Industrial; Lignite; Cyclone Furnace
10200304	External Combustion Boilers; Industrial; Lignite; Traveling Grate (Overfeed) Stoker
10200306	External Combustion Boilers; Industrial; Lignite; Spreader Stoker
10200307	External Combustion Boilers; Industrial; Lignite; Cogeneration
10200400	External Combustion Boilers; Industrial; Residual Oil; undefined
10200401	External Combustion Boilers; Industrial; Residual Oil; Grade 6 Oil
10200402	External Combustion Boilers; Industrial; Residual Oil;10-100 Million Btu/hr
10200403	External Combustion Boilers; Industrial; Residual Oil; < 10 Million Btu/hr
10200404	External Combustion Boilers; Industrial; Residual Oil; Grade 5 Oil
10200405	External Combustion Boilers; Industrial; Residual Oil; Cogeneration
10201404	External Combustion Boilers; Industrial; CO Boiler; Residual Oil

3.2.5.1 Cost Equations

Total Annualized Cost

$$Total\ Annualized\ Cost = Emissions\ Reduction\ \times Default\ Cost\ Per\ Ton$$

Where:
Emissions Reduction = calculated from emissions inventory and control efficiency
Default Cost per Ton = based on the specific control measure

Total Capital Cost

$$Capital\ Cost = Total\ Annualized\ Cost \times Capital\ to\ Annual\ Ratio$$

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{[(1 + Interest\ Rate)^{Equipment\ Life}\ - 1]}$$

Where:
Interest Rate = annual interest rate
Equipment Life = expected economic life of the control equipment

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$

Where the *Capital Cost* and the *Capital Recovery Factor* were calculated previously.

Operation and Maintenance Cost

$$Total\ O\&M = Total\ Annualized\ Cost - Annualized\ Capital\ Cost$$

Where the *Total Annualized Cost* and the Annualized *Capital Cost* were calculated previously.

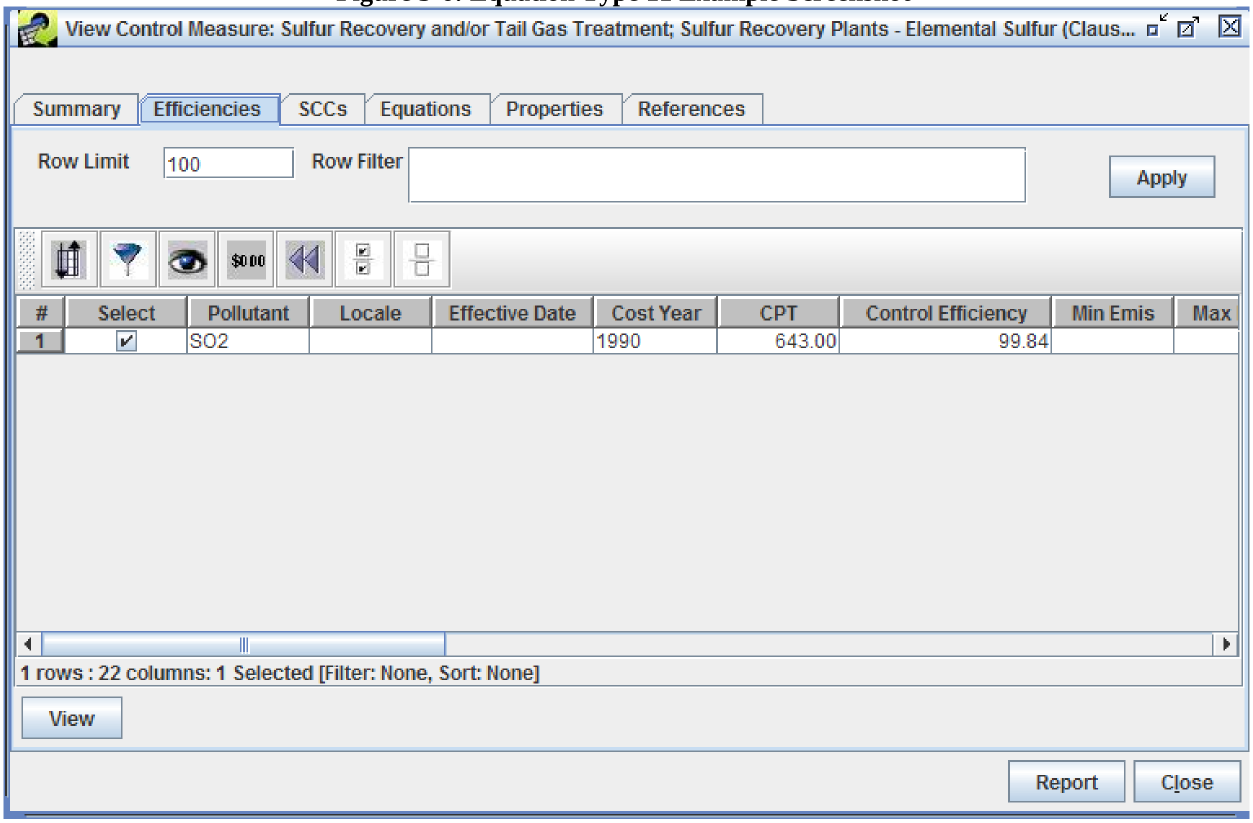
3.2.5.2 Example Calculations

The CoST screenshot related to the Equation Type 11 example is shown in Figure 3-6. Relevant data are found in Table B-14 for CoST abbreviation SSRTGSRP95.

Example Equation Variables

Interest Rate = 7%
Equipment Life = 30 years (from summary tab of control measure data)
$SO_2\ Emissions\ Reductions = 68.7$ tons
Default Cost per Ton = 643 ($/ton)
Total Annualized Cost = 44,174
Capital to Annual Ratio = 0
Year for Cost Basis = 1990

Figure 3-6: Equation Type 11 Example Screenshot



Total Annualized Cost

$$Total\ Annualized\ Cost = Emissions\ Reduction\ \times Default\ Cost\ Per\ Ton$$
$$Total\ Annualized\ Cost = 68.7\ Tons\ SO_2\ \times 643\frac{\$}{Ton}$$
$$Total\ Annualized\ Cost = \$44{,}174\ (1990\$)$$

Total Capital Cost

$$Capital\ Cost = Total\ Annualized\ Cost \times Capital\ to\ Annual\ Ratio$$
$$Capital\ Cost = \$44{,}174 \times 0$$
$$Capital\ Cost = \$0$$

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$
$$Annualized\ Capital\ Cost = \$0\ \times Capital\ Recovery\ Factor$$
$$Annualized\ Capital\ Cost = \$0$$

Operation and Maintenance Cost

$$Total\ O\&M\ Cost = Total\ Annualized\ Cost - Annualized\ Capital\ Cost$$
$$Total\ O\&M\ Cost = \$44{,}174 - \$0$$
$$Total\ O\&M\ Cost = \$44{,}174\ (1990\$)$$

3.2.6 Equation Type 16 for SO_2

These equations are used for wet scrubbers. This control technology provides extensive SO_2 control (95%) and minimal PM reduction (50% to 94%).

The list of source categories is provided in Table 3-7.

Table 3-7. SO_2 Source Categories Associated with Equation Type 16

SCC	Description
10100201	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Wet Bottom (Bituminous Coal)
10100202	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Bituminous Coal)
10100204	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Spreader Stoker (Bituminous Coal)
10100205	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Traveling Grate (Overfeed) Stoker (Bituminous Coal)
10100212	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Tangential) (Bituminous Coal)
10100217	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Bubbling Bed (Bituminous Coal)
10100218	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Circulating Bed (Bitum. Coal)
10100222	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Subbituminous Coal)
10100224	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Spreader Stoker (Subbituminous Coal)
10100226	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom Tangential (Subbituminous Coal)
10100401	External Combustion Boilers; Electric Generation; Residual Oil; Grade 6 Oil: Normal Firing
10100404	External Combustion Boilers; Electric Generation; Residual Oil; Grade 6 Oil: Tangential Firing
10100501	External Combustion Boilers; Electric Generation; Distillate Oil; Grades 1 and 2 Oil
10100601	External Combustion Boilers; Electric Generation; Natural Gas; Boilers > 100 Million Btu/hr except Tangential
10100602	External Combustion Boilers; Electric Generation; Natural Gas; Boilers < 100 Million Btu/hr except Tangential
10100604	External Combustion Boilers; Electric Generation; Natural Gas; Tangentially Fired Units
10100701	External Combustion Boilers; Electric Generation; Process Gas; Boilers > 100 Million Btu/hr
10100702	External Combustion Boilers; Electric Generation; Process Gas; Boilers < 100 Million Btu/hr
10100703	External Combustion Boilers; Electric Generation; Process Gas; Petroleum Refinery Gas
10100801	External Combustion Boilers; Electric Generation; Petroleum Coke; All Boiler Sizes
10100902	External Combustion Boilers; Electric Generation; Wood/Bark Waste; Wood/Bark Fired Boiler
10100903	External Combustion Boilers; Electric Generation; Wood/Bark Waste; Wood-fired Boiler - Wet Wood (>=20% moisture)
10100911	External Combustion Boilers; Electric Generation; Wood/Bark Waste; Stoker boilers
10101002	External Combustion Boilers; Electric Generation; Liquified Petroleum Gas (LPG); Propane
10101101	External Combustion Boilers; Electric Generation; Bagasse; All Boiler Sizes
10101201	External Combustion Boilers; Electric Generation; Solid Waste; Specify Waste Material in Comments
10101202	External Combustion Boilers; Electric Generation; Solid Waste; Refuse Derived Fuel
10101204	External Combustion Boilers; Electric Generation; Solid Waste; Tire Derived Fuel : Shredded
10101301	External Combustion Boilers; Electric Generation; Liquid Waste; Specify Waste Material in Comments
10101302	External Combustion Boilers; Electric Generation; Liquid Waste; Waste Oil
10200101	External Combustion Boilers; Industrial; Anthracite Coal; Pulverized Coal
10200202	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom
10200204	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Spreader Stoker
10200205	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Overfeed Stoker
10200218	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Circulating Bed (Bitum. Coal)
10200224	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Spreader Stoker (Subbituminous Coal)

SCC	Description
10200225	External Combustion Boilers; Industrial; Bituminous/Subbituminous Coal; Traveling Grate (Overfeed) Stoker (Subbituminous Coal)
10200401	External Combustion Boilers; Industrial; Residual Oil; Grade 6 Oil
10200402	External Combustion Boilers; Industrial; Residual Oil; 10-100 Million Btu/hr
10200404	External Combustion Boilers; Industrial; Residual Oil; Grade 5 Oil
10200501	External Combustion Boilers; Industrial; Distillate Oil; Grades 1 and 2 Oil
10200502	External Combustion Boilers; Industrial; Distillate Oil; 10-100 Million Btu/hr
10200503	External Combustion Boilers; Industrial; Distillate Oil; < 10 Million Btu/hr
10200504	External Combustion Boilers; Industrial; Distillate Oil; Grade 4 Oil
10200505	External Combustion Boilers; Industrial; Distillate Oil; Cogeneration
10200601	External Combustion Boilers; Industrial; Natural Gas; > 100 Million Btu/hr
10200602	External Combustion Boilers; Industrial; Natural Gas; 10-100 Million Btu/hr
10200603	External Combustion Boilers; Industrial; Natural Gas; < 10 Million Btu/hr
10200604	External Combustion Boilers; Industrial; Natural Gas; Cogeneration
10200701	External Combustion Boilers; Industrial; Process Gas; Petroleum Refinery Gas
10200704	External Combustion Boilers; Industrial; Process Gas; Blast Furnace Gas
10200707	External Combustion Boilers; Industrial; Process Gas; Coke Oven Gas
10200710	External Combustion Boilers; Industrial; Process Gas; Cogeneration
10200711	External Combustion Boilers; Industrial; Process Gas; Landfill Gas
10200799	External Combustion Boilers; Industrial; Process Gas; Other: Specify in Comments
10200901	External Combustion Boilers; Industrial; Wood/Bark Waste; Bark-fired Boiler
10200902	External Combustion Boilers; Industrial; Wood/Bark Waste; Wood/Bark-fired Boiler
10200903	External Combustion Boilers; Industrial; Wood/Bark Waste; Wood-fired Boiler - Wet Wood (>=20% moisture)
10200905	External Combustion Boilers; Industrial; Wood/Bark Waste; Wood/Bark-fired Boiler (< 50,000 Lb Steam)
10200906	External Combustion Boilers; Industrial; Wood/Bark Waste; Wood-fired Boiler (< 50,000 Lb Steam)
10200907	External Combustion Boilers; Industrial; Wood/Bark Waste; Wood Cogeneration
10200908	External Combustion Boilers; Industrial; Wood/Bark Waste; Wood-fired Boiler - Dry Wood (<20% moisture)
10200910	External Combustion Boilers; Industrial; Wood/Bark Waste; Fuel cell/Dutch oven boilers
10200911	External Combustion Boilers; Industrial; Wood/Bark Waste; Stoker boilers
10201001	External Combustion Boilers; Industrial; Liquified Petroleum Gas (LPG); Butane
10201002	External Combustion Boilers; Industrial; Liquified Petroleum Gas (LPG); Propane
10201201	External Combustion Boilers; Industrial; Solid Waste; Specify Waste Material in Comments
10201301	External Combustion Boilers; Industrial; Liquid Waste; Specify Waste Material in Comments
10201302	External Combustion Boilers; Industrial; Liquid Waste; Waste Oil
10201303	External Combustion Boilers; Industrial; Liquid Waste; Salable Animal Fat
10201401	External Combustion Boilers; Industrial; CO Boiler; Natural Gas
10201403	External Combustion Boilers; Industrial; CO Boiler; Distillate Oil
10300206	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Bituminous Coal)
10300208	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Underfeed Stoker (Bituminous Coal)
10300209	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Spreader Stoker (Bituminous Coal)
10300214	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Hand-fired (Bituminous Coal)
10300217	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Bubbling Bed (Bituminous Coal)
10300218	External Combustion Boilers; Commercial/Institutional; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Circulating Bed (Bitum. Coal)
10300401	External Combustion Boilers; Commercial/Institutional; Residual Oil; Grade 6 Oil
10300402	External Combustion Boilers; Commercial/Institutional; Residual Oil; 10-100 Million Btu/hr
10300404	External Combustion Boilers; Commercial/Institutional; Residual Oil; Grade 5 Oil
10300501	External Combustion Boilers; Commercial/Institutional; Distillate Oil; Grades 1 and 2 Oil
10300502	External Combustion Boilers; Commercial/Institutional; Distillate Oil; 10-100 Million Btu/hr
10300503	External Combustion Boilers; Commercial/Institutional; Distillate Oil; < 10 Million Btu/hr
10300504	External Combustion Boilers; Commercial/Institutional; Distillate Oil; Grade 4 Oil
10300601	External Combustion Boilers; Commercial/Institutional; Natural Gas; > 100 Million Btu/hr

SCC	Description
10300602	External Combustion Boilers; Commercial/Institutional; Natural Gas; 10-100 Million Btu/hr
10300603	External Combustion Boilers; Commercial/Institutional; Natural Gas; < 10 Million Btu/hr
10300701	External Combustion Boilers; Commercial/Institutional; Process Gas; POTW Digester Gas-fired Boiler
10300799	External Combustion Boilers; Commercial/Institutional; Process Gas; Other Not Classified
10300811	External Combustion Boilers; Commercial/Institutional; Landfill Gas; Landfill Gas
10300902	External Combustion Boilers; Commercial/Institutional; Wood/Bark Waste; Wood/Bark-fired Boiler
10300903	External Combustion Boilers; Commercial/Institutional; Wood/Bark Waste; Wood-fired Boiler - Wet Wood (>=20% moisture)
10300911	External Combustion Boilers; Commercial/Institutional; Wood/Bark Waste; Stoker boilers
10300912	External Combustion Boilers; Commercial/Institutional; Wood/Bark Waste; Fluidized bed combustion boilers
10301001	External Combustion Boilers; Commercial/Institutional; Liquified Petroleum Gas (LPG); Butane
10301002	External Combustion Boilers; Commercial/Institutional; Liquified Petroleum Gas (LPG); Propane
10301003	External Combustion Boilers; Commercial/Institutional; Liquified Petroleum Gas (LPG); Butane/Propane Mixture: Specify Percent Butane in Comments
10301201	External Combustion Boilers; Commercial/Institutional; Solid Waste; Specify Waste Material in Comments
10301202	External Combustion Boilers; Commercial/Institutional; Solid Waste; Refuse Derived Fuel
10500105	External Combustion Boilers; Space Heaters; Industrial; Distillate Oil
10500106	External Combustion Boilers; Space Heaters; Industrial; Natural Gas
10500205	External Combustion Boilers; Space Heaters; Commercial/Institutional; Distillate Oil
10500206	External Combustion Boilers; Space Heaters; Commercial/Institutional; Natural Gas
30130201	Industrial Processes; Chemical Manufacturing; Carbon Tetrachloride; General
30290001	Industrial Processes; Food and Agriculture; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30290003	Industrial Processes; Food and Agriculture; Fuel Fired Equipment; Natural Gas: Process Heaters
30500105	Industrial Processes; Mineral Products; Asphalt Roofing Manufacture; General
30500199	Industrial Processes; Mineral Products; Asphalt Roofing Manufacture; See Comment
30501021	Industrial Processes; Mineral Products; Coal Mining, Cleaning, and Material Handling (See 305310); Overburden Removal
30699999	Industrial Processes; Petroleum Industry; Petroleum Products - Not Classified; Not Classified
31000203	Industrial Processes; Oil and Gas Production; Natural Gas Production; Compressors
31000414	Industrial Processes; Oil and Gas Production; Process Heaters; Natural Gas: Steam Generators
31100199	Industrial Processes; Building Construction; Construction: Building Contractors; Other Not Classified
39999999	Industrial Processes; Miscellaneous Manufacturing Industries; Miscellaneous Industrial Processes; Other Not Classified

The equations that are used to calculate flowrates for Equation Types 14 through 18 are provided here. The two equations calculate flowrate in actual cubic feet per minute (acfm) and dry standard cubic feet per minute (dscfm), respectively.

$$F_a = \frac{(V_{Exhaust})(DC)}{60}$$

Where:

F_a = Exhaust flowrate (acfm)
$V_{Exhaust}$ = Relative exhaust volume (ACF/MMBtu)
DC = Design capacity of unit (MMBtu/hr)
60 = Conversion factor hour to minutes

$$F_d = (F_a)\left(\frac{460 + 68}{460 + T}\right)\left(1 - \frac{\%Moist}{100}\right)$$

Where:

F_d = Exhaust flowrate (dscfm)

F_a = Exhaust flowrate (acfm)
T = Assumed stack gas temperature (˚F)
%Moist = Assumed stack gas moisture content (%)

Table B-19 lists the assumptions that were used in constructing more than one of the cost equations for Equation Types 14 – 19. Assumptions that are specifically for Equations Type 16 are listed in Table B-20.

3.2.6.1 Cost Equations

Total Capital Investment

$$TCI = [(2.88)(\#Scrub)(F_a)] + \left[(1076.54)(\#Scrub)\sqrt{F_a}\right] + [(9.759)(F_a)] + \left[(360.463)\sqrt{F_a}\right]$$

Where:
#Scrub = if $F_a < 149602$, then #Scrub = 1
if $149602 \leq F_a < 224403$, then #Scrub = 2
if $244403 \leq F_a < 299204$, then #Scrub = 3
if $299204 \leq F_a < 374005$, then #Scrub = 4
if $F_a \geq 374005$, then #Scrub = 5
F_a = Exhaust flowrate (acfm)

Total Annualized Costs

$$TAC = \left[(\#Scrub)(TCI)\left(\frac{(i)(1+i)^{Eq_{Life}}}{(1+i)^{Eq_{Life}}-1}\right)\right] + [(0.04)(TCI)] + \left\{(20.014)(\#Scrub)(F_a)(Op_{Hrs})\left[C_{SO2} - (C_{SO2})\left(\frac{100-98}{100-(98)(C_{SO2})}\right)\right]\right\} + [(16.147)(\#Scrub)(Op_{Hrs})] + \left\{(1.17E-5)(F_a)(Op_{Hrs})(\#Scrub)\left[\left((479.85)\left(\frac{1}{\sqrt{F_a}}\right)^{1.18}\right) + (6.895)\right]\right\} + [(1.33E-5)(Op_{Hrs})(\#Scrub)(F_a)]$$

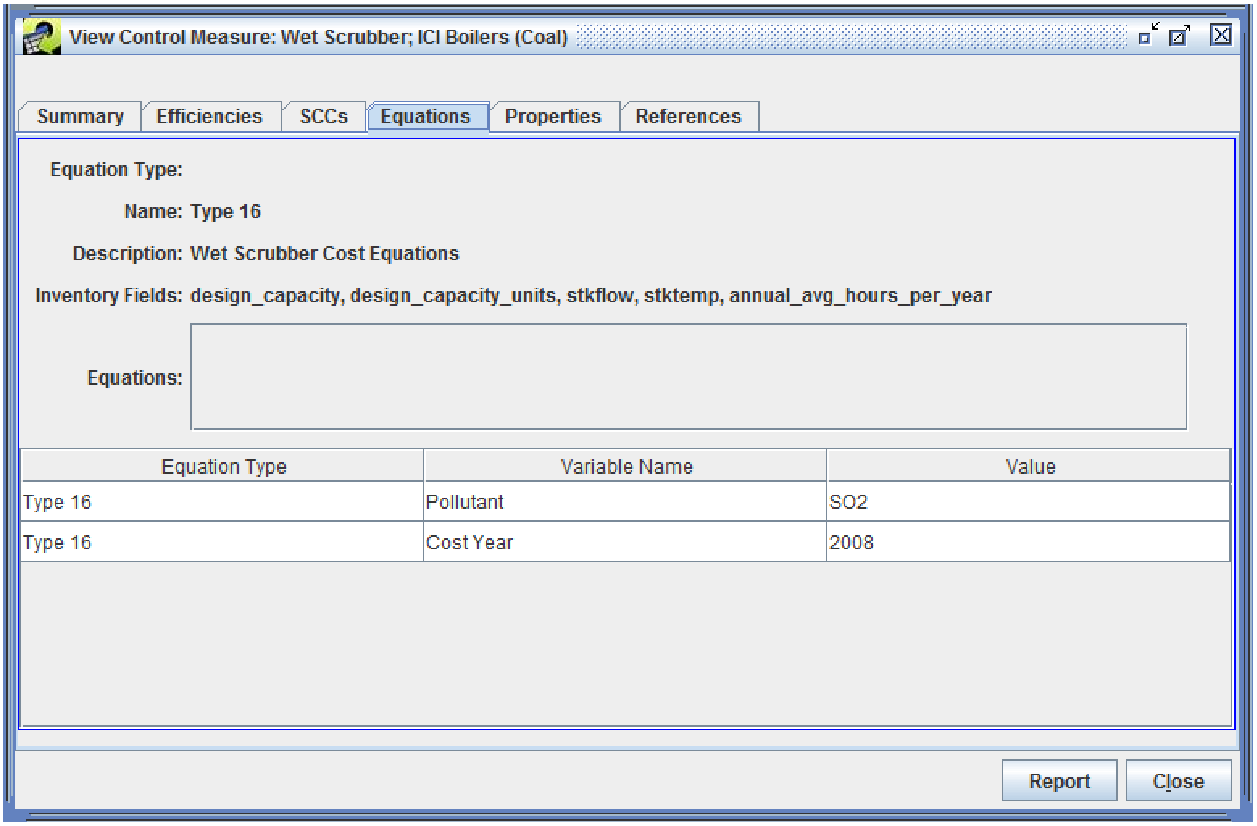
Where:
#Scrub = if $F_a < 149602$, then #Scrub = 1
if $149602 \leq F_a < 224403$, then #Scrub = 2
if $244403 \leq F_a < 299204$, then #Scrub = 3
if $299204 \leq F_a < 374005$, then #Scrub = 4
if $F_a \geq 374005$, then #Scrub = 5
TCI = Total Capital Investment ($)
i = Annual interest rate expressed as a fraction (i.e., percentage divided by 100)
Eq_{Life} = Estimated equipment life (years)
F_a = Exhaust flowrate (acfm)
C_{SO2} = Mole fraction of SO_2 in exhaust gas
Op_{Hrs} = Annual operating hours of unit (hours per year)

3.2.6.2 Example Calculations

This section provides example calculations for an application of Equation Type 16. The example is a coal-fired ICI boiler with a wet scrubber for SO_2 control. The values for some of the parameters used in this equation type are shown in Tables B-19 and B-20.

Figure 2-7 illustrates the Equations tab of the View Control Measure screen for the Wet Scrubber: ICI Boilers (Coal) emissions control device for SO_2.

Figure 2-7: Equation Type 16 Example Screenshot



Example Equation Variables

#Scrub = 1
i = 0.07 (interest rate 7%)
Eq_{Life} = 15 years
F_a = 55493 actual cubic feet per minute
C_{SO2} = 1.15E-3 mole fraction SO_2 in exhaust gas
Op_{Hrs} = 2688 operating hours per year
Year for Cost Basis = 2008

Total Capital Investment

$$TCI = [(2.88)(\#Scrub)(F_a)] + \left[(1076.54)(\#Scrub)\sqrt{F_a}\right] + [(9.759)(F_a)] + \left[(360.463)\sqrt{F_a}\right]$$
$$= [(2.88)(1)(55493)] + \left[(1076.54)(1)\sqrt{55493}\right] + [(9.759)(55493)] + \left[(360.463)\sqrt{55493}\right]$$
$$= \$1{,}039{,}890$$

Total Annualized Costs

$$TAC$$
$$= \left[(\#Scrub)(TCI)\left(\frac{(i)(1+i)^{Eq_{Life}}}{(1+i)^{Eq_{Life}}-1}\right)\right] + [(0.04)(TCI)]$$
$$+ \left\{(20.014)(\#Scrub)(F_a)(Op_{Hrs})\left[C_{SO2} - (C_{SO2})\left(\frac{100-98}{100-\ (98)(C_{SO2})}\right)\right]\right\}$$
$$+ [(16.147)(\#Scrub)(Op_{Hrs})]$$
$$+ \left\{(1.17E-5)(F_a)(Op_{Hrs})(\#Scrub)\left[\left((479.85)\left(\frac{1}{\sqrt{F_a}}\right)^{1.18}\right) + (6.895)\right]\right\}$$
$$+ [(1.33E-5)(Op_{Hrs})(\#Scrub)(F_a)]$$
$$= \left[(1)(\$1{,}309{,}890)\left(\frac{(0.07)(1+0.07)^{15}}{(1+0.07)^{15}-1}\right)\right] + [(0.04)(\$1{,}309{,}890)]$$
$$+ \left\{(20.014)(1)(55493)(2688)\left[(1.15E-3) - (1.15E-3)\left(\frac{100-98}{100-(98)(1.15E-3)}\right)\right]\right\}$$
$$+ [(16.147)(1)(2688)]$$
$$+ \left\{(1.17E-5)(55493)(2688)(1)\left[\left((479.85)\left(\frac{1}{\sqrt{55493}}\right)^{1.18}\right) + (6.895)\right]\right\}$$
$$+ [(1.33E-5)(2688)(1)(55493)]$$
$$= \$217{,}891$$

3.2.7 Equation Type 18 for SO_2

These equations are used for increased caustic injection rate for existing dry injection control. Therefore, no new capital investment is required. Two assumptions specific to increased caustic injection systems were included when constructing these equations (Table B-22). The list of source categories is provided in Table 3-7.

3.2.7.1 Cost Equations

Total Capital Investment

$$TCI = 0$$

No variables are used in this calculation.

Total Annualized Costs

$$TAC = (3.87E - 6)(C_{SO2})(F_d)(Op_{Hrs})$$

Where:

C_{SO2} = Concentration of SO_2 in stack gas, dry parts per million by volume (ppmvd)
F_d = Exhaust flowrate (dscfm)
Op_{Hrs} = Annual operating hours of the unit (hrs/yr)

3.2.7.2 Example Calculations

This section provides example calculations for an application of Equation Type 18. The example is an ICI boiler burning residual oil with an increased caustic injection rate for SO_2 control. The values for some of the parameters used in this equation type are shown in Tables B-19 and B-22.

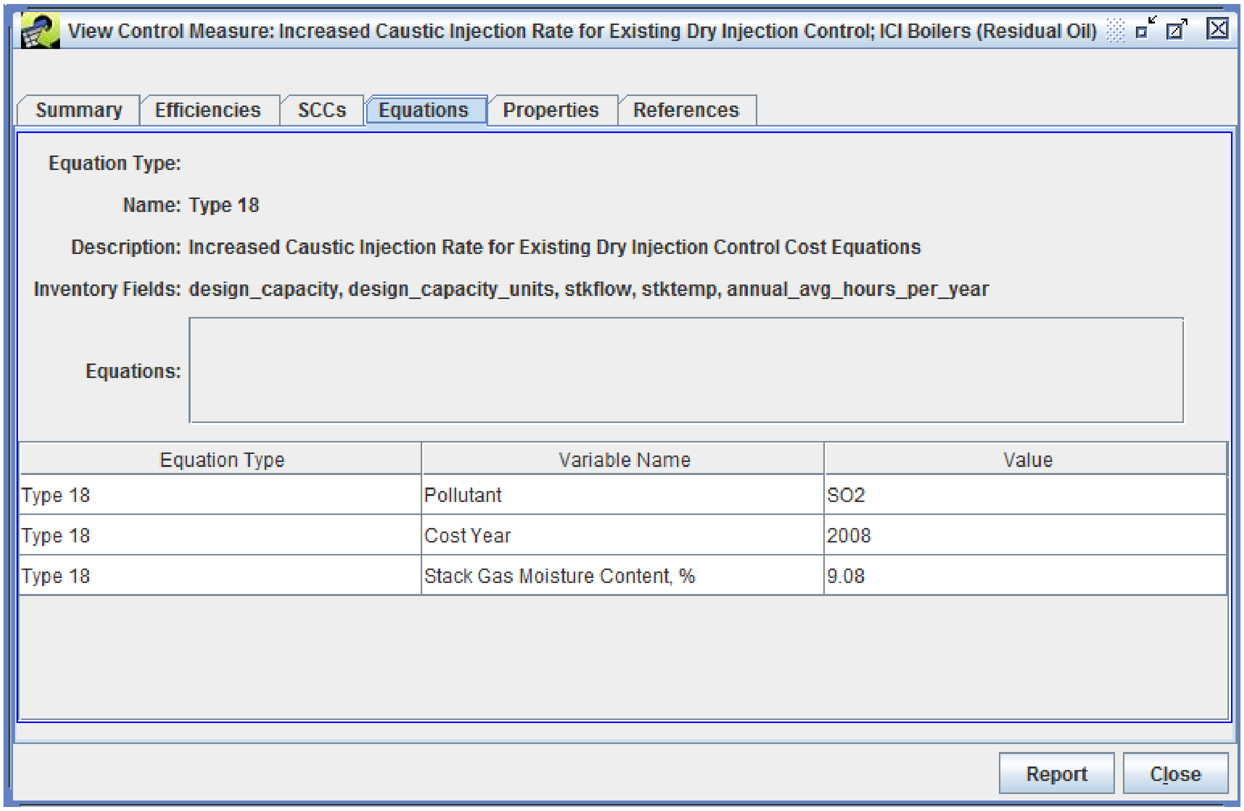
Example Equation Variables

C_{SO2} = dry parts per million by volume (ppmvd)
F_d = dry standard cubic feet per minute (dscfm)
Op_{Hrs} = 8424 operating hours per year
Year for Cost Basis = 2008

Note that for the Boiler MACT rulemaking, sources that responded to the survey reported average annual operating hours for the relevant combustion units. For facilities that did not report annual operating hours, it was assumed that the unit was in operation for 8424 hours per year, reflecting two weeks of boiler down time per year.

Figure 2-8 illustrates the Equations tab of the View Control Measure screen for the Increased Caustic Injection Rate emissions control method for SO_2.

Figure 2-8: Equation Type 18 Example Screenshot



Total Capital Investment

TCI = $0

Total Annualized Costs

$$TAC = (3.87E-6)(C_{SO2})(F_d)(Op_{Hrs})$$
$$= (3.87E-6)(C_{SO2})(F_d)(8424)$$
$$= (3.26E-2)(C_{SO2})(F_d)$$

3.2.8 Equation Type 19 for SO_2

These equations are for spray dryer absorbers. This control technology, which provides less-than-extensive SO_2 control (80%) and no reduction in PM, was used for the CISWI rule. The list of source categories is provided in Table 3-7.

3.2.8.1 Cost Equations

Total Capital Investment

$$TCI = [(143.76)(F_d)] + \left[(0.610)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)^2\right] + \left[(17412.26)e^{(0.017)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right] + \left[(53.973)e^{(0.014)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right] + (931911.04)$$

Where:

F_d	=	Exhaust flowrate (dscfm)
F_a	=	Exhaust flowrate (acfm)
#Ducts	=	if $F_d \leq 154042$, then #Ducts = 1
		if $F_d > 154042$, then #Ducts = F_d/154042

Total Annualized Costs

$$TAC = (Op_{Hrs})\{[(1.62E-3)(F_d)] + [(6.84E-7)(C_{SO2})(F_d)] + [(3.72E-5)(F_a)] + (21.157)\} + \left\{\left[7.2E-2 + \left(\frac{(i)(1+i)^{Eq_{Life}}}{(1+i)^{Eq_{Life}}-1}\right)\right](TCI)\right\}$$

Where:

F_d	=	Exhaust flowrate (dscfm)
F_a	=	Exhaust flowrate (acfm)
Op_{Hrs}	=	Annual operating hours of unit (hrs/yr)
C_{SO2}	=	Concentration of SO_2 in stack gas (dry parts per million by volume [ppmvd])
TCI	=	Total Capital Investment ($)
i	=	annual interest rate
Eq_{Life}	=	Estimated equipment life (yrs)

3.2.8.2 Example Calculations

This example is for addition of a spray dryer absorber onto one of the source categories listed in Table 3-7.

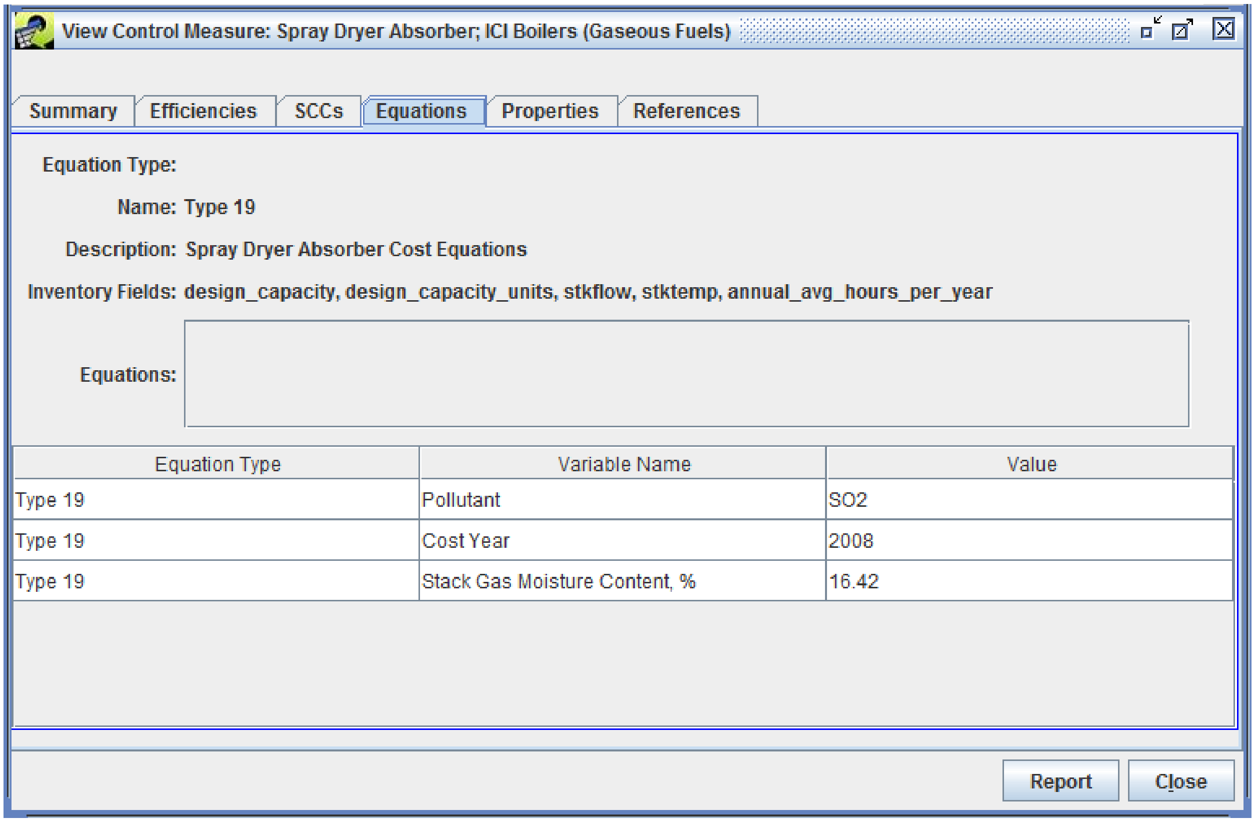
Example Equation Variables

F_d = 32138 dry standard cubic feet per minute (dscfm)
F_a = 55493 actual cubic feet per minute (cfm)
#Ducts = 1

C_{SO2} = 1.15 dry parts per million by volume (ppmvd)
Op_{Hrs} = 2688 operating hours per year
i = 0.07 annual interest rate
Eq_{Life} = 15 years
Year for Cost Basis = 2008

Figure 2-9 illustrates the View Control Measure screen for the Spray Dryer Absorber emissions control method for SO_2.

Figure 2-9: Equation Type 19 Example Screenshot



Total Capital Investment

$$TCI = [(143.76)(F_d)] + \left[(0.610)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)^2\right] + \left[(17412.26)e^{(0.017)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right] + \left[(53.973)e^{(0.014)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right] + (931911.04)$$

$$= [(143.76)(32138)] + \left[(0.610)\left(\frac{\sqrt{55493}}{1}\right)^2\right] + \left[(17412.26)e^{(0.017)\left(\frac{\sqrt{55493}}{1}\right)}\right]$$
$$+ \left[(53.973)e^{(0.014)\left(\frac{\sqrt{55493}}{1}\right)}\right] + (931911.04)$$
$$= \$6,542,689$$

Total Annualized Costs

$$TAC$$
$$= (Op_{Hrs})\{[(1.62E-3)(F_d)] + [(6.84E-7)(C_{SO2})(F_d)] + [(3.72E-5)(F_a)] + (21.157)\}$$
$$+ \left\{\left[(7.2E-2) + \left(\frac{(i)(1+i)^{Eq_{Life}}}{(1+i)^{Eq_{Life}}-1}\right)\right](TCI)\right\}$$
$$= (2688)\{[(1.62E-3)(32138)] + [(6.84E-7)(1.15)(32138)] + [(3.72E-5)(55493)]$$
$$+ (21.157)\} + \left\{\left[(7.2E-2) + \left(\frac{(0.07)(1+0.07)^{15}}{(1+0.07)^{15}-1}\right)\right](\$6,542,689)\right\}$$
$$= \$1,391,860$$

4 PM Control Cost Equations

This section is divided into two main sections – IPM and non-IPM sources. The types of cost equations for point source PM controls are described in their appropriate sections.

- Equation type 8 for IPM fabric filter (mechanical shaker, pulse jet, reverse air), ESP (wire plate type)
- Equation type 9 for IPM fabric filter (mechanical shaker)
- Equation type 10 for IPM upgrades to ESPs
- Equation type 8 for non-IPM watering, substitute for burning, ESP, catalytic oxidizers, fabric filter, venture scrubber
- Equation type 14 for non-IPM fabric filter
- Equation type 15 for non-IPM ESP
- Equation type 17 for non-IPM dry injection and fabric filter (DIFF)

Each equation type is discussed, the relevant parameters are presented, and example calculations are provided. Appendix A includes the SQL queries that implement each CoST equation type. Appendix B provides tables of parameters and values used with each equation type.

4.1 IPM Sector (ptipm) PM Control Cost Equations

Three types of equations are utilized in the control cost calculation for IPM sector PM controls. Equation Type 8 uses the unit's stack flowrate (in acfm) as the primary variable for control cost calculation. If a unit's stack flow is outside of a range of values (15,000 <= stack flowrate (cfm) <= 1,400,000), then the control measure is not applied to the specific unit; instead a default cost per ton value calculation is used. The second equation, Equation Type 9, is referenced in a report prepared by EPA's Office of Research and Development (ORD). This equation also uses a unit's stack flowrate (acfm) with capital and O&M cost factors. The third equation, Equation Type 10, is used for control measures that are upgrades to existing ESPs.

If the unit already has PM controls applied in the emissions inventory, incremental controls are applied only if their control efficiency value exceeds that of the input control. Control costs do not differ in these cases and the costs associated with incremental controls are the same as those applied on uncontrolled sources.

4.1.1 Equation Type 8 for PM

Equation Type 8 is applicable to many SCCs in the electric generation category (Table 4-1). Table B-9 provides a list of the control cost equations assigned to various ptipm PM control measures. The control efficiencies for both PM_{10} and $PM_{2.5}$ are provided in this table. Values are representative of typical cost values and, although not provided as options in the CoST output, low and high cost values are also available in the source tables.

Table B-9 also presents the default cost per ton values used when a unit's stack flowrate is outside the recommended range of 15,000 – 1,400,000 cfm. Three variables are available for this calculation; a capital cost multiplier, an O&M cost multiplier, and an annualized cost multiplier. Equations for the cost method using the default cost per ton factors are not provided in this document.

Table 4-1. PM Electric Generation Categories Associated with Equation Type 8

SCC	Description
10100201	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Wet Bottom (Bituminous Coal)
10100202	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Bituminous Coal)
10100203	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Cyclone Furnace (Bituminous Coal)
10100204	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Spreader Stoker (Bituminous Coal)
10100205	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Traveling Grate (Overfeed) Stoker (Bituminous Coal)
10100211	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Wet Bottom (Tangential) (Bituminous Coal)
10100212	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Tangential) (Bituminous Coal)
10100215	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Cell Burner (Bituminous Coal)
10100217	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Bubbling Bed (Bituminous Coal)
10100218	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Circulating Bed (Bitum. Coal)
10100221	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Wet Bottom (Subbituminous Coal)
10100222	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Subbituminous Coal)
10100223	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Cyclone Furnace (Subbituminous Coal)
10100224	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Spreader Stoker (Subbituminous Coal)
10100225	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Traveling Grate (Overfeed) Stoker (Subbituminous Coal)
10100226	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom Tangential (Subbituminous Coal)
10100235	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Cell Burner (Subbituminous Coal)
10100237	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Bubbling Bed (Subbitum Coal)
10100238	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion - Circulating Bed (Subbitum Coal)
10100300	External Combustion Boilers; Electric Generation; Lignite; Pulverized Coal: Wet Bottom
10100301	External Combustion Boilers; Electric Generation; Lignite; Pulverized Coal: Dry Bottom, Wall Fired
10100302	External Combustion Boilers; Electric Generation; Lignite; Pulverized Coal: Dry Bottom, Tangential Fired
10100303	External Combustion Boilers; Electric Generation; Lignite; Cyclone Furnace
10100304	External Combustion Boilers; Electric Generation; Lignite; Traveling Grate (Overfeed) Stoker
10100306	External Combustion Boilers; Electric Generation; Lignite; Spreader Stoker
10100316	External Combustion Boilers; Electric Generation; Lignite; Atmospheric Fluidized Bed
10100317	External Combustion Boilers; Electric Generation; Lignite; Atmospheric Fluidized Bed Combustion - Bubbling Bed
10100318	External Combustion Boilers; Electric Generation; Lignite; Atmospheric Fluidized Bed Combustion - Circulating Bed
10100401	External Combustion Boilers; Electric Generation; Residual Oil; Grade 6 Oil: Normal Firing
10100404	External Combustion Boilers; Electric Generation; Residual Oil; Grade 6 Oil: Tangential Firing
10100405	External Combustion Boilers; Electric Generation; Residual Oil; Grade 5 Oil: Normal Firing
10100406	External Combustion Boilers; Electric Generation; Residual Oil; Grade 5 Oil: Tangential Firing

4.1.1.1 Cost Equations

Capital Cost Equations

$$Capital\ Cost = Typical\ Capital\ Cost\ \times STKFLOW \times 60$$

Where:
Typical Capital Cost = cost in $/acfm
STKFLOW = stack gas flowrate (ft3/s) from the emissions inventory
60 = unit conversion factor between seconds and minutes

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{(1 + Interest\ Rate)^{Equipment\ Life}\ - 1}$$

Where:
Interest Rate = annual interest rate
Equipment Life = expected economic life of the control equipment

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$

Where the *Capital Cost* and the *Capital Recovery Factor* were calculated previously.

Operation and Maintenance Cost Equation

$$O\&M\ Cost = Typical\ O\&M\ Cost\ \times STKFLOW \times 60$$

Where:
Typical O&M Cost = cost in $/acfm
STKFLOW = stack gas flowrate (ft3/s) from the emissions inventory
60 = unit conversion factor between seconds and minutes

Total Annualized Cost Equation

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + 0.04 \times Capital\ Cost + O\&M\ Cost$$

Where the *Annualized Capital Cost*, the *Capital Cost*, and the *O&M Cost* were calculated previously.

4.1.1.2 Example Calculations

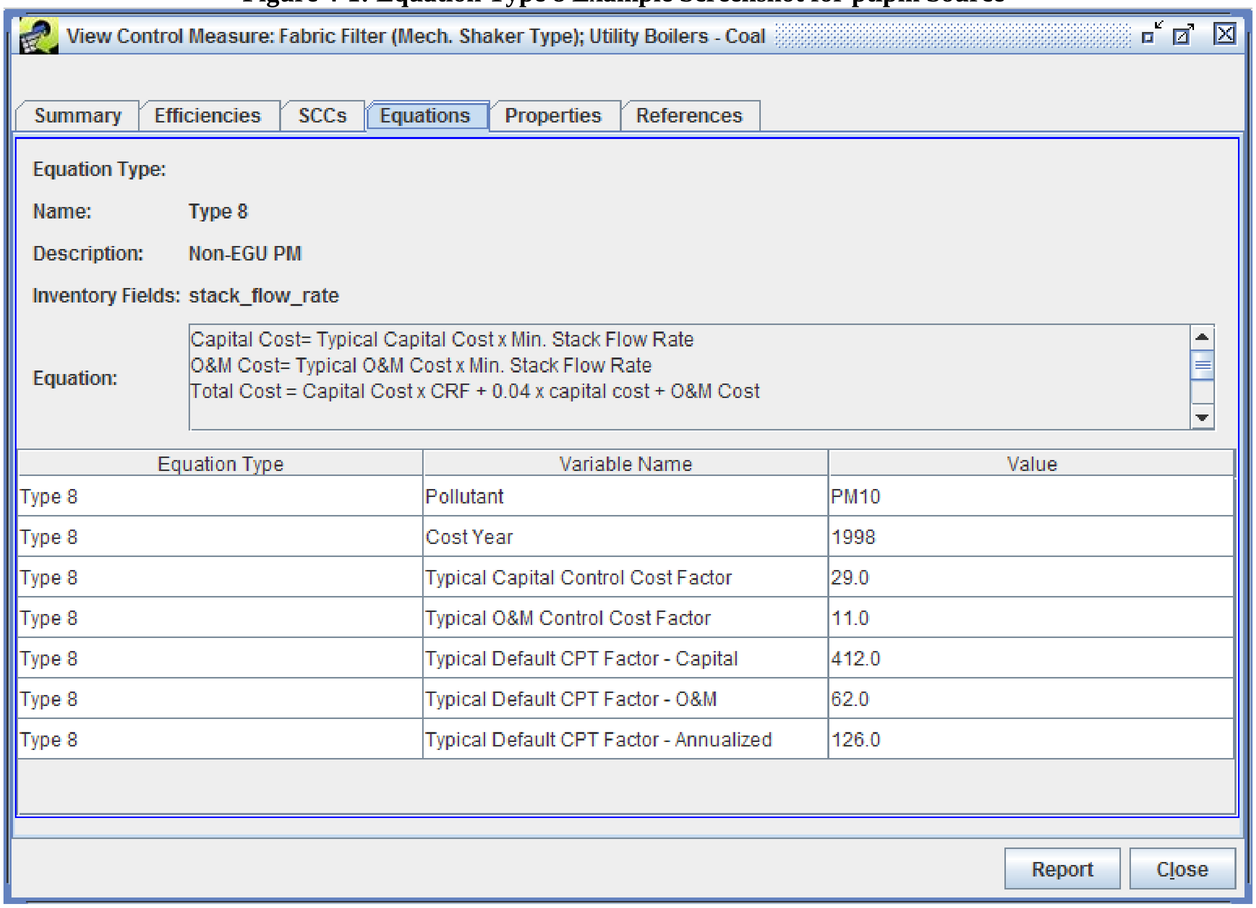
This section provides example calculations for a “typical” application (i.e., not a “default” application) of Equation Type 8 to an EGU. The example scenario is a coal-burning utility boiler using a fabric filter (mechanical shaker type) for PM control. Using Table B-9 the CoST code is PFFMSUBC.

Variables for Example Equation Type 8 (ptipm)

Typical Capital Cost = $29/acfm

Typical O&M Cost = \$11/acfm
Interest Rate = 7%
Equipment Life = 20 years (from summary tab of control measure data)
PM_{10} *Emissions Reductions* = 135 tons
$STKFLOW = 283.69\ \text{ft}^3/\text{sec}$
Year for Cost Basis = 1998

Figure 4-1: Equation Type 8 Example Screenshot for ptipm Source



View Control Measure: Fabric Filter (Mech. Shaker Type); Utility Boilers - Coal

Summary | Efficiencies | SCCs | Equations | Properties | References

Equation Type:
Name: Type 8
Description: Non-EGU PM
Inventory Fields: stack_flow_rate
Equation:
Capital Cost= Typical Capital Cost x Min. Stack Flow Rate
O&M Cost= Typical O&M Cost x Min. Stack Flow Rate
Total Cost = Capital Cost x CRF + 0.04 x capital cost + O&M Cost

Equation Type	Variable Name	Value
Type 8	Pollutant	PM10
Type 8	Cost Year	1998
Type 8	Typical Capital Control Cost Factor	29.0
Type 8	Typical O&M Control Cost Factor	11.0
Type 8	Typical Default CPT Factor - Capital	412.0
Type 8	Typical Default CPT Factor - O&M	62.0
Type 8	Typical Default CPT Factor - Annualized	126.0

Report | Close

Capital Cost Equations

$$Capital\ Cost = Typical\ Capital\ Cost \times STKFLOW \times 60$$

$$Capital\ Cost = \$29/acfm \times 283.69\frac{ft^3}{sec} \times 60\frac{sec}{min}$$

$$Capital\ Cost = \$493{,}621\ (1998\$)$$

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate \times (1 + Interest\ Rate)^{Equipment\ Life}}{(1 + Interest\ Rate)^{Equipment\ Life} - 1}$$

$$Capital\ Recovery\ Factor = \frac{0.07 \times (1 + 0.07)^{20}}{(1 + 0.07)^{20} - 1}$$

$$Capital\ Recovery\ Factor = 0.094393$$

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$
$$Annualized\ Capital\ Cost = \$493{,}621\ \times 0.094393$$
$$Annualized\ Capital\ Cost = \$46{,}594\ (1998\$)$$

Operation and Maintenance Cost Equation

$$O\&M\ Cost = Typical\ O\&M\ Cost\ \times STKFLOW \times 60$$
$$O\&M\ Cost = \$11/acfm\ \times 283.69 \frac{ft^3}{sec} \times 60 \frac{sec}{min}$$
$$O\&M\ Cost = \$187{,}235\ (\$1998)$$

Total Annualized Cost Equation

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + 0.04 \times Capital\ Cost + O\&M\ Cost$$
$$Total\ Annualized\ Cost = \$46{,}594 + 0.04 \times \$493{,}621 + \$187{,}235$$
$$Total\ Annualized\ Cost = \$253{,}575\ (1998\$)$$

4.1.2 Equation Type 9 for PM

Equation Type 9 applies to select SCCs in the electric generation category (Table 4-2). Table B-12 supplies the capital and O&M factors associated with Equation Type 9. This equation type does not appear to include any default cost per ton backup calculation in the event of stack flowrates being outside of the acceptable range; however, note that a description of the control measures utilizing this equation (Fabric Filter – Mechanical Shaker) is also represented in the ptipm Equation Type 8 control measure list.

Table 4-2. Electric Generation Categories Associated with Equation Type 9

SCC	Description
10100201	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Wet Bottom (Bituminous Coal)
10100202	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Bituminous Coal)
10100203	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Cyclone Furnace (Bituminous Coal)
10100212	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Tangential) (Bituminous Coal)
10100217	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Bubbling Bed (Bituminous Coal)
10100601	External Combustion Boilers; Electric Generation; Natural Gas; Boilers > 100 Million Btu/hr except Tangential
10100604	External Combustion Boilers; Electric Generation; Natural Gas; Tangentially Fired Units

This section includes descriptions of parameters that include abbreviations listed in Table B-12. The complete parameter names were too long to fit in the table’s header.

4.1.2.1 Cost Equations

Capital Cost Equations

$$Capital\ Cost = [(Total\ Equipment\ Cost\ Factor\ \times STKFLOW) + Total\ Equipment\ Cost\ Constant\ ] \times\ Equipment\ to\ Capital\ Cost\ Multiplier$$

Where:
Total Equipment Cost Factor (tecs) = based on the specific control measure
Total Equipment Cost Constant (teci) = based on the specific control measure
Capital Cost Multiplier (ec to cc) = based on the specific control measure
STKFLOW = stack gas flowrate (ft3/s) from the emissions inventory

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{(1 + Interest\ Rate)^{Equipment\ Life}\ - 1}$$

Where:
Interest Rate = annual interest rate
Equipment Life = expected economic life of the control equipment

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$

Where *Capital Cost* and *Capital Recovery Factor* were calculated previously.

Operation and Maintenance Cost Equation

$$O\&M\ Cost = \left(Electricity\ Factor\ \times STKFLOW\left(\frac{ft^3}{min}\right) + Electricity\ Constant\right) + \left(Dust\ Disposal\ Factor \times STKFLOW\left(\frac{ft^3}{min}\right) + Dust\ Disposal\ Constant\right) + \left(Bag\ Replacement\ Factor \times STKFLOW\left(\frac{ft^3}{min}\right) + Bag\ Replacement\ Constant\right)$$

Where:
Electricity Factor (els) = based on the specific control measure
Electricity Constant (eli) = based on the specific control measure
Dust Disposal Factor (dds) = based on the specific control measure
Dust Disposal Constant (ddi) = based on the specific control measure
Bag Replacement Factor (brs) = based on the specific control measure
Bag Replacement Constant (bri) = are control measure specific
STKFLOW = stack gas flowrate (ft3/s) from the emissions inventory

Total Annualized Cost Equation

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + O\&M\ Cost$$

Where the *Annualized Capital Cost* and the *O&M Cost* were calculated previously.

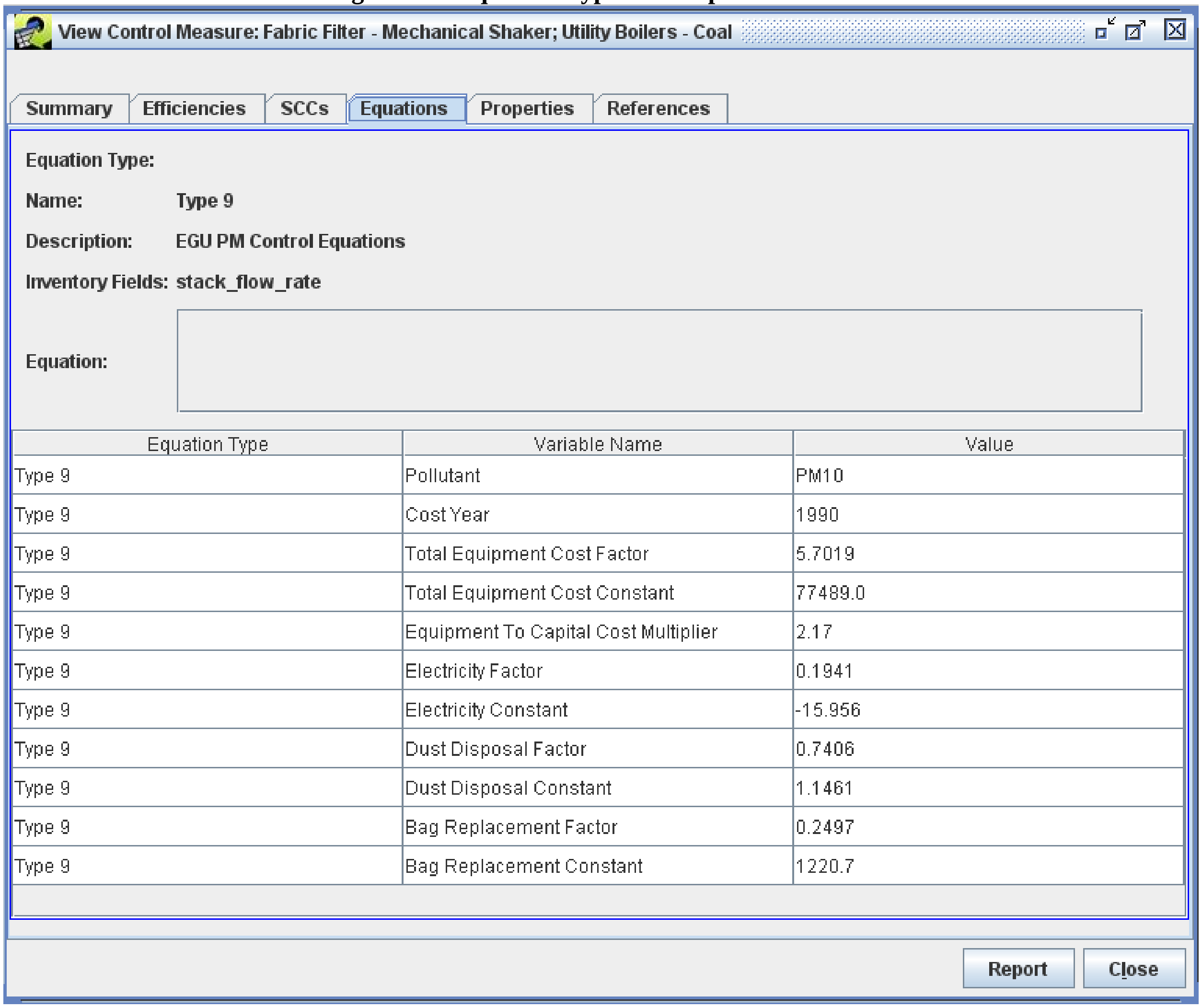
4.1.2.2 Example Calculations

This section provides example calculations for an application of Equation Type 9. The example scenario is a coal-fired, utility boiler that requires PM control. The control technology is a fabric filter with a mechanical shaker. Using Table B-12 the code is PFFMSUBC2 and the control efficiency is 99% for both PM_{10} and $PM_{2.5}$. The values are shown in Figure 4-2.

Example Equation Variables

Total Equipment Cost Factor (tecs) = 5.7019
Total Equipment Cost Constant (teci) = 77489
Equipment to Capital Cost Multiplier (ec to cc) = 2.17
Electricity Factor (els) = 0.1941
Electricity Constant (eli) = -14.956
Dust Disposal Factor (dds) = 0.7406
Dust Disposal Constant (ddi) = 1.1461
Bag Replacement Factor (brs) = 0.2497
Bag Replacement Constant (bri) = 1220.7
Interest Rate = 7%
Equipment Life = 20 years (from summary tab of control measure data)
STKFLOW =16,354 ft^3/min
Year for Cost Basis = 1990

Figure 4-2: Equation Type 9 Example Screenshot



Equation Type	Variable Name	Value
Type 9	Pollutant	PM10
Type 9	Cost Year	1990
Type 9	Total Equipment Cost Factor	5.7019
Type 9	Total Equipment Cost Constant	77489.0
Type 9	Equipment To Capital Cost Multiplier	2.17
Type 9	Electricity Factor	0.1941
Type 9	Electricity Constant	-15.956
Type 9	Dust Disposal Factor	0.7406
Type 9	Dust Disposal Constant	1.1461
Type 9	Bag Replacement Factor	0.2497
Type 9	Bag Replacement Constant	1220.7

Annualized Capital Cost

$$Capital\ Cost = ((Total\ Equipment\ Cost\ Factor\ \times STKFLOW\left(\frac{\text{ft}^3}{\text{min}}\right) + Total\ Equipment\ Cost\ Constant\ ) \times\ Equipment\ to\ Capital\ Cost\ Multiplier$$

$$Capital\ Cost = \left(\frac{\$5.7019}{acfm} \times 16{,}354\left(\frac{\text{ft}^3}{\text{min}}\right) + \$77{,}489\right) \times 2.17$$

$$Capital\ Cost = \$370{,}501\ (1990\$)$$

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{(1 + Interest\ Rate)^{Equipment\ Life}\ - 1}$$

$$Capital\ Recovery\ Factor = \frac{0.07\ \times (1+0.07)^{20}}{(1+0.07)^{20}-1}$$

$$Capital\ Recovery\ Factor = 0.094393$$

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$
$$Annualized\ Capital\ Cost = \$370{,}504 \times 0.094393$$
$$Annualized\ Capital\ Cost = \$34{,}973\ (1990\$)$$

Operation and Maintenance Cost

$$\begin{aligned} &O\&M\ Cost \\ &= \left(Electricity\ Factor\ \times STKFLOW\left(\frac{\mathrm{ft}^3}{\mathrm{min}}\right) + Electricity\ Constant\right) \\ &+ \left(Dust\ Disposal\ Factor \times STKFLOW\left(\frac{\mathrm{ft}^3}{\mathrm{min}}\right) + Dust\ Disposal\ Constant\right) \\ &+ \left(Bag\ Replacement\ Factor \times STKFLOW\left(\frac{\mathrm{ft}^3}{\mathrm{min}}\right) + Bag\ Replacement\ Constant\right) \end{aligned}$$

$$\begin{aligned} &O\&M\ Cost \\ &= \left(\frac{\$0.1941}{acfm} \times 16{,}354\left(\frac{\mathrm{ft}^3}{\mathrm{min}}\right) - \$15.956\right) + \left(\$0.7406/acfm \times 16{,}354\left(\frac{\mathrm{ft}^3}{\mathrm{min}}\right) + \$1.1461\right) \\ &+ \left(\$0.2497/acfm \times 16{,}354\left(\frac{\mathrm{ft}^3}{\mathrm{min}}\right) + \$1220.7\right) \end{aligned}$$
$$O\&M\ Cost = \$20{,}576\ (1990\$)$$

Total Annualized Cost

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + O\&M\ Cost$$
$$Total\ Annualized\ Cost = \$34{,}973 + \$20{,}576$$
$$Total\ Annualized\ Cost = \$55{,}549\ (1990\$)$$

4.1.3 Equation Type 10 for PM

In addition to add-on control measures, there are control measures included in CoST that are upgrades to control measures already in operation on a unit. CoST includes control measures that are upgrades to ESPs on ptipm sources. These control measures are costed using Equation Type 10 and the variable values are presented in Table B-13. The SCCs using Equation Type 10 are listed in Table 4-3. Also, note that Equation Type 10 is specifically for $PM_{2.5}$.

Table 4-3. Electric Generation Categories Associated with Equation Type 10

SCC	Description
10100201	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Wet Bottom (Bituminous Coal)
10100202	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Bituminous Coal)
10100203	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Cyclone Furnace (Bituminous Coal)
10100204	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Spreader Stoker (Bituminous Coal)
10100205	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Traveling Grate (Overfeed) Stoker (Bituminous Coal)
10100211	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Wet Bottom (Tangential) (Bituminous Coal)
10100212	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Tangential) (Bituminous Coal)
10100215	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Cell Burner (Bituminous Coal)
10100217	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Bubbling Bed (Bituminous Coal)
10100218	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Circulating Bed (Bitum. Coal)
10100221	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Wet Bottom (Subbituminous Coal)
10100222	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom (Subbituminous Coal)
10100223	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Cyclone Furnace (Subbituminous Coal)
10100224	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Spreader Stoker (Subbituminous Coal)
10100225	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Traveling Grate (Overfeed) Stoker (Subbituminous Coal)
10100226	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Dry Bottom Tangential (Subbituminous Coal)
10100235	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Cell Burner (Subbituminous Coal)
10100237	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion: Bubbling Bed (Subbitum Coal)
10100238	External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Atmospheric Fluidized Bed Combustion - Circulating Bed (Subbitum Coal)
10100300	External Combustion Boilers; Electric Generation; Lignite; Pulverized Coal: Wet Bottom
10100301	External Combustion Boilers; Electric Generation; Lignite; Pulverized Coal: Dry Bottom, Wall Fired
10100302	External Combustion Boilers; Electric Generation; Lignite; Pulverized Coal: Dry Bottom, Tangential Fired
10100303	External Combustion Boilers; Electric Generation; Lignite; Cyclone Furnace
10100304	External Combustion Boilers; Electric Generation; Lignite; Traveling Grate (Overfeed) Stoker
10100306	External Combustion Boilers; Electric Generation; Lignite; Spreader Stoker
10100316	External Combustion Boilers; Electric Generation; Lignite; Atmospheric Fluidized Bed
10100317	External Combustion Boilers; Electric Generation; Lignite; Atmospheric Fluidized Bed Combustion - Bubbling Bed
10100318	External Combustion Boilers; Electric Generation; Lignite; Atmospheric Fluidized Bed Combustion - Circulating Bed
10100401	External Combustion Boilers; Electric Generation; Residual Oil; Grade 6 Oil: Normal Firing
10100404	External Combustion Boilers; Electric Generation; Residual Oil; Grade 6 Oil: Tangential Firing
10100405	External Combustion Boilers; Electric Generation; Residual Oil; Grade 5 Oil: Normal Firing
10100406	External Combustion Boilers; Electric Generation; Residual Oil; Grade 5 Oil: Tangential Firing

4.1.3.1 Cost Equations

Capital Cost Equations

$$Capital\ Cost\ Scaling\ Factor = \left(\frac{250\ MW}{Capacity}\right)^{Capital\ Scaling\ Factor\ Exponent}$$

Where:
Capital Scaling Factor Exponent = based on the specific control measure
Capacity = the boiler capacity (MW) obtained from the emissions inventory

$$Capital\ Cost = Capital\ Cost\ Multiplier\ \times Capacity\ \times Capital\ Cost\ Scaling\ Factor\ \times 1{,}000$$

Where:
Capital Cost Multiplier =based on the specific control measure
Capacity = obtained from the emissions inventory
1000 = conversion factor between kW and MW

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{(1 + Interest\ Rate)^{Equipment\ Life} - 1}$$

Where:
Interest Rate = annual interest rate
Equipment Life = expected economic life of the control equipment

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$

Where the *Capital Cost* and the *Capital Recovery Factor* were calculated previously.

Operation and Maintenance Cost Equations

$$Fixed\ O\&M\ Cost\ Scaling\ Factor = \left(\frac{250\ MW}{Capacity}\right)^{Fixed\ O\&M\ Scaling\ Factor\ Exponent}$$

Where:
Fixed O&M Scaling Factor Exponent = based on the specific control measure
Capacity (MW) = boiler capacity obtained from the emissions inventory

$$Fixed\ O\&M = Fixed\ O\&M\ Cost\ Scaling\ Factor \times Fixed\ O\&M\ Cost\ Multiplier\ \times Capacity\ \times 1{,}000$$

Where:
Fixed O&M Cost Multiplier = based on the specific control measure
Capacity (MW) = obtained from the emissions inventory
1000 = conversion factor between kW and MW

$$Variable\ O\&M = Variable\ O\&M\ Cost\ Multiplier\ \times Capacity \times Capacity\ Factor \times\ Annual\ Operating\ Hours$$

Where:
Variable O&M Cost Multiplier = based on the specific control measure
Capacity Factor = based on the specific control measure
Capacity = obtained from the emissions inventory
Annual Operating Hours = obtained from the emissions inventory

$$O\&M\ Cost = Fixed\ O\&M + Variable\ O\&M$$

Where the *Fixed O&M* and the $Variable\ O\&M$ costs were calculated previously.

Total Annualized Cost Equation

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + .04\ \times Total\ Capital\ Cost + O\&M\ Cost$$

Where:
0.04 (4%) = portion of the Total Capital Cost that is the fixed annual charge for taxes, insurance and administrative costs

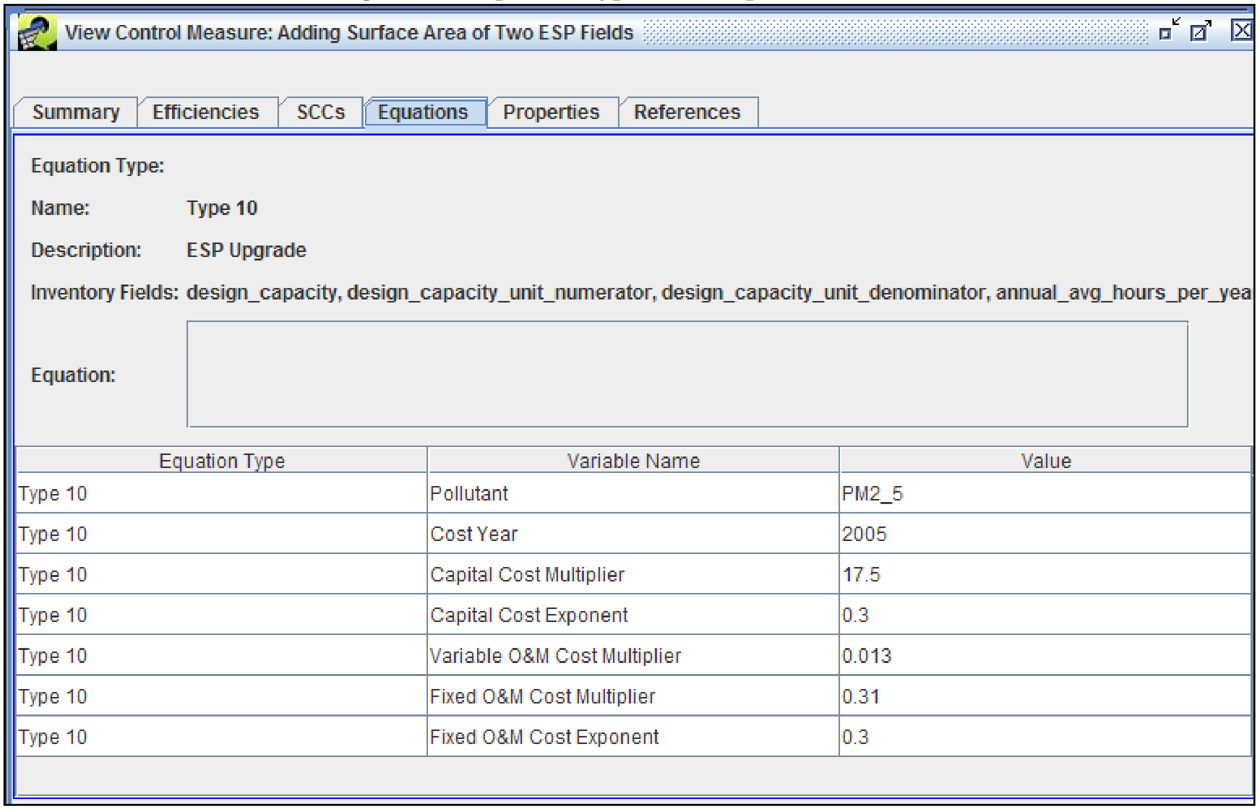
4.1.3.2 Example Calculations

This section provides example calculations for an application of Equation Type 10. The example scenario is a coal-fired utility boiler that requires $PM_{2.5}$ control. Using Table B-13 the control technology is adding surface area of two ESP fields and the CoST code is PDESPM2FLD.

Example Equation Variables

Capital Cost Multiplier = 17.5
Capital Scaling Factor Exponent = 0.3
Fixed O&M Cost Multiplier = 0.31
Fixed O&M Scaling Factor Exponent = 0.3
Variable O&M Cost Multiplier = 0.013
Capacity = 58.068 MW
Interest Rate = 7%
Equipment Life = 5 years (from summary tab of control measure data)
Year for Cost Basis = 2005

Figure 4-3: Equation Type 10 Example Screenshot



Capital Cost Equations

$$Capital\ Cost\ Scaling\ Factor = \left(\frac{250\ MW}{Capacity}\right)^{Capital\ Scaling\ Factor\ Exponent}$$

$$Capital\ Cost\ Scaling\ Factor = \left(\frac{250\ MW}{58.068\ MW}\right)^{0.3}$$

$$Capital\ Cost\ Scaling\ Factor = 1.55$$

$$Capital\ Cost = Capital\ Cost\ Multiplier\ \times Capacity\ \times Capital\ Cost\ Scaling\ Factor\ \times 1{,}000$$

$$Capital\ Cost = \frac{\$17.50}{kW} \times 58.068\ MW\ \times 1.55\ \times 1{,}000\ \frac{kW}{MW}$$

$$Capital\ Cost = \$1{,}575{,}095$$

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{(1 + Interest\ Rate)^{Equipment\ Life}\ - 1}$$

$$Capital\ Recovery\ Factor = \frac{0.07\ \times (1 + 0.07)^5}{(1 + 0.07)^5\ - 1}$$

$$Capital\ Recovery\ Factor = 0.2439$$

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$
$$Annualized\ Capital\ Cost = \$1{,}575{,}095\ \times 0.2439$$
$$Annualized\ Capital\ Cost = \$384{,}166\ (2005\$)$$

Operation and Maintenance Cost Equations

$$Fixed\ O\&M\ Cost\ Scaling\ Factor = \left(\frac{250\ MW}{Capacity}\right)^{Fixed\ O\&M\ Scaling\ Factor\ Exponent}$$

$$Fixed\ O\&M\ Cost\ Scaling\ Factor = \left(\frac{250\ MW}{58.068\ MW}\right)^{0.3}$$

$$Fixed\ O\&M\ Cost\ Scaling\ Factor = 1.55$$

$$Fixed\ O\&M = Fixed\ O\&M\ Cost\ Scaling\ Factor \times Fixed\ O\&M\ Cost\ Multiplier\ \times Capacity\ \times 1{,}000$$

$$Fixed\ O\&M = 1.55 \times \$0.31\frac{\$}{kW\text{-}year}\ \times 58.068\ MW\ \times 1{,}000\frac{kW}{MW}$$

$$Fixed\ O\&M = \$27{,}901$$

$$Variable\ O\&M = Variable\ O\&M\ Cost\ Multiplier\ \times Capacity \times Capacity\ Factor \times\ Annual\ Operating\ Hours$$

$$Variable\ O\&M = \$0.013\frac{\$}{kWh}\ \times 58.068\ MW \times 0.85\ \times\ 8{,}760\frac{Hours}{Year}$$

$$Variable\ O\&M = \$5{,}620$$

$$O\&M\ Cost = Fixed\ O\&M + Variable\ O\&M$$
$$O\&M\ Cost = \$27{,}901 + \$5{,}620$$
$$O\&M\ Cost = \$33{,}522\ (2005\$)$$

Total Annualized Cost Equation

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + .04\ \times Total\ Capital\ Cost + O\&M\ Cost$$
$$Total\ Annualized\ Cost = \$384{,}166 + .04\ \times \$1{,}575{,}095 + \$33{,}522$$
$$Total\ Annualized\ Cost = \$480{,}692\ (2005\$)$$

4.2 Non-IPM Sector (ptnonipm) PM Control Cost Equations

Non-IPM point sources utilizing control cost equations for PM emission reductions are Equation Types 8, 14, 15, and 17. Equation Type 8 uses the unit's stack flowrate (in scfm) as the primary variable for control cost calculation. If a unit's stack flow is less than 5 cubic feet per minute (cfm), then the control cost equation is not applied to the specific unit and instead a default cost per ton calculation is used.

Equations 14, 15 and 18 were developed for the industrial, commercial, and institutional boilers and processes heater NESHAP for major sources (Boiler MACT). The equations to calculate flowrates for Equation Types 14 through 18 are provided in section 3.2.6 (above). Also, the costs are based on the calendar year 2008.

Although applicability and control costs are based on PM_{10} emissions, $PM_{2.5}$ reductions also occur when the above limits are met. A revision is scheduled to change the primary pollutant for all PM control measures from PM_{10} to $PM_{2.5}$ and recalculate all the control costs. This will be available in a future version of the Control Measures Database (CMDB).

If the unit already has PM controls applied in the input inventory, incremental controls are applied only if their control efficiency value exceeds that of the input control. Control costs do not differ in these cases and the costs associated with incremental controls are the same as those applied on uncontrolled sources.

Table B-10 provides a list of the control cost equations assigned to various PM control measures. Both the control efficiencies for PM_{10} and $PM_{2.5}$ are provided in this table. Values are representative of typical cost values and low and high cost values are also available in the source tables. These typical costs are presented in terms of $/acfm. Table B-11 presents the default cost per ton values used when a unit's stack flowrate is outside of the recommended range. Three variables are available for this calculation: a capital cost multiplier, an O&M cost multiplier, and an annualized cost multiplier. These are expressed in terms of $/ton PM_{10} reduced.

4.2.1 Equation Type 8 for PM

There are 2915 SCCs in the CoST CMDB database for this category. Listing all of the SCCs in a table would be too large for this document, so the major categories of SCCs are listed in Table 4-4. Parameters for the cost control equations are from Table B-10.

Table 4-4. PM ptnonipm Categories Associated with Equation Type 8

Primary SCC	Secondary SCC
External Combustion Boilers	Industrial
External Combustion Boilers	Commercial/Institutional
Industrial Processes	Chemical Manufacturing
Industrial Processes	Food & Agriculture: Grain Milling
Industrial Processes	Primary Metal Production
Industrial Processes	Secondary Metal Production
Industrial Processes	Mineral Products
Industrial Processes	Pulp and Paper and Wood Products
Industrial Processes	Fabricated Metal Products
Waste Disposal	Municipal Incineration

4.2.1.1 Cost Equations

Capital Cost Equation

$$Total\ Capital\ Cost = Typical\ Capital\ Cost\ \times STKFLOW$$

Where:
Typical Capital Cost = based on the specific control measure
STKFLOW = stack gas flowrate (ft3/s) from the emissions inventory

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate\ \times (1 + Interest\ Rate)^{Equipment\ Life}}{[(1 + Interest\ Rate)^{Equipment\ Life}\ - 1]}$$

Where:
Interest Rate = annual interest rate
Equipment Life = expected economic life of the control equipment

$$Annualized\ Capital\ Cost = Capital\ Cost\ \times Capital\ Recovery\ Factor$$

Where the *Capital Cost* and the *Capital Recovery Factor* were calculated previously.

Operation and Maintenance Cost Equation

$$O\&M\ Cost = Typical\ O\&M\ Cost\ \times STKFLOW$$

Where:
Typical O&M Cost = based on the specific control measure
STKFLOW = stack gas flowrate (ft3/s) from the emissions inventory

Total Annualized Cost Equation

When stackflow is available and in range,

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + 0.04 \times Capital\ Cost + O\&M\ Cost$$

Where:
0.04 = 4% of the Capital Cost; fixed annual charge for taxes, insurance, and administrative cost

Annualized Capital Cost and *O&M Cost* were calculated previously.

When stackflow is unavailable in the inventory,

$$Total\ Annualized\ Cost = Emission\ Reduction \times Default\ Cost\ Per\ Ton$$

Where:
Emission Reduction = calculated by CoST
Default Cost per Ton = based on the specific control measure

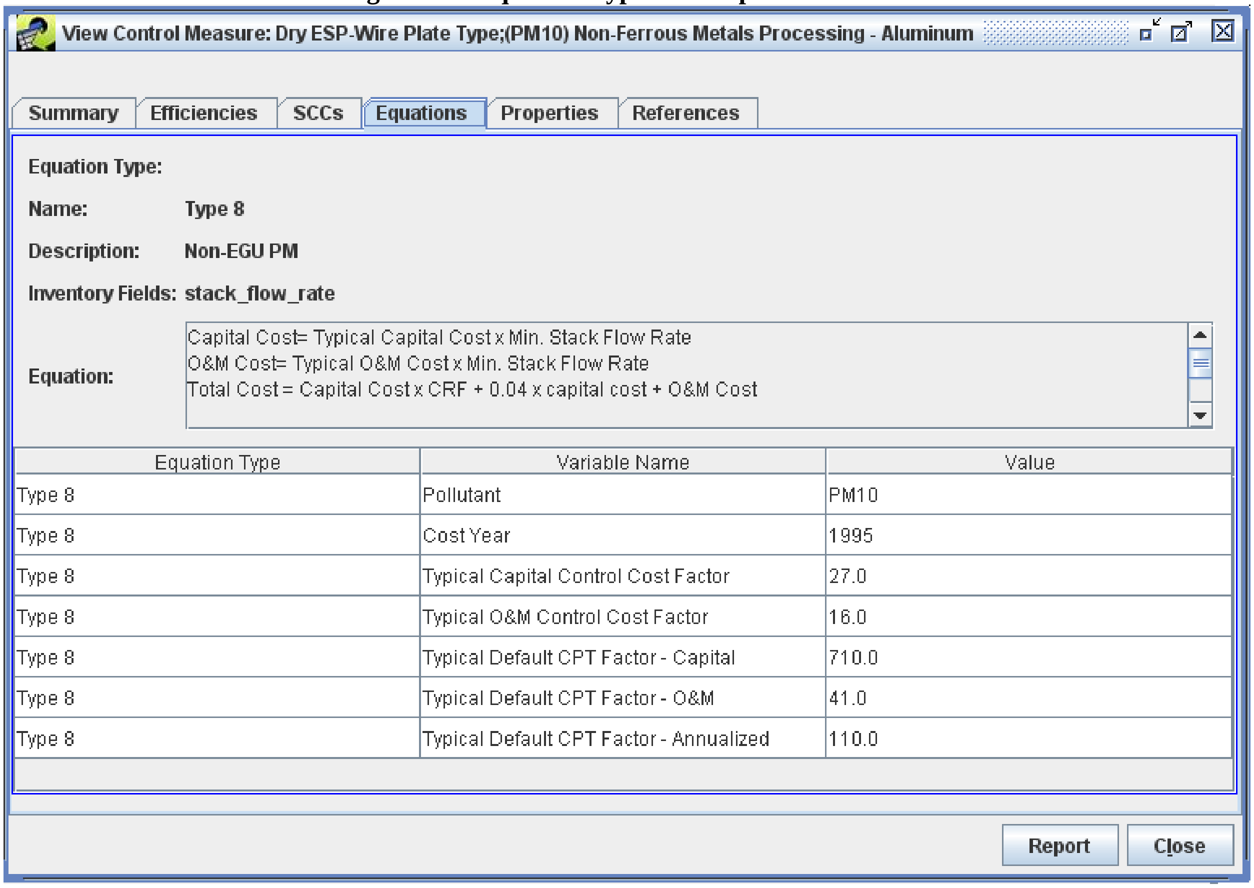
4.2.1.2 Equation Type 8 Example with Inventory Stackflow

This section provides example calculations for a “typical” application of Equation Type 8 to a non-EGU plant; see Section 4.2.1.3 for an example of a “default” application. The example scenario is non-ferrous metal processor of aluminum using a dry ESP – plate type for PM control. Using Table B-10 the CoST code is PDESPMPAM.

Example Equation Variables

Typical Capital Cost = 27.0 $/acfm
Typical O&M Cost = $16.0/acfm
Interest Rate = 7%
Equipment Life = 20 years
PM_{10} *Emissions Reductions* = 162.78 tons
$STKFLOW = 283.69\ \text{ft}^3/\text{sec}$
Year for Cost Basis = 1995

Figure 4-4: Equation Type 8 Example Screenshot


View Control Measure: Dry ESP-Wire Plate Type;(PM10) Non-Ferrous Metals Processing - Aluminum

Summary | Efficiencies | SCCs | Equations | Properties | References

Equation Type:

Name: Type 8

Description: Non-EGU PM

Inventory Fields: stack_flow_rate

Equation:
Capital Cost= Typical Capital Cost x Min. Stack Flow Rate
O&M Cost= Typical O&M Cost x Min. Stack Flow Rate
Total Cost = Capital Cost x CRF + 0.04 x capital cost + O&M Cost

Equation Type	Variable Name	Value
Type 8	Pollutant	PM10
Type 8	Cost Year	1995
Type 8	Typical Capital Control Cost Factor	27.0
Type 8	Typical O&M Control Cost Factor	16.0
Type 8	Typical Default CPT Factor - Capital	710.0
Type 8	Typical Default CPT Factor - O&M	41.0
Type 8	Typical Default CPT Factor - Annualized	110.0

Report | Close

Capital Cost Equation

$$Capital\ Cost = Typical\ Capital\ Cost \times STKFLOW \times 60$$

$$Capital\ Cost = \$27/acfm \times 283.69 \frac{ft^3}{sec} \times 60 \frac{sec}{min}$$

$$Capital\ Cost = \$459{,}578\ (1995\$)$$

$$Capital\ Recovery\ Factor = \frac{Interest\ Rate \times (1 + Interest\ Rate)^{Equipment\ Life}}{(1 + Interest\ Rate)^{Equipment\ Life} - 1}$$

$$Capital\ Recovery\ Factor = \frac{0.07 \times (1 + 0.07)^{20}}{(1 + 0.07)^{20} - 1}$$

$$Capital\ Recovery\ Factor = 0.094393$$

$$Annualized\ Capital\ Cost = Capital\ Cost \times Capital\ Recovery\ Factor$$

$$Annualized\ Capital\ Cost = \$459{,}578 \times 0.094393$$

$$Annualized\ Capital\ Cost = \$43{,}381\ (1995\$)$$

Operation and Maintenance Cost Equation

$$O\&M\ Cost = Typical\ O\&M\ Cost\ \times STKFLOW \times 60$$
$$O\&M\ Cost = \$16/acfm\ \times 283.69\frac{ft^3}{sec} \times 60\frac{sec}{min}$$
$$O\&M\ Cost = \$272{,}342\ (\$1995)$$

Total Annualized Cost Equation

$$Total\ Annualized\ Cost = Annualized\ Capital\ Cost + 0.04 \times Capital\ Cost + O\&M\ Cost$$
$$Total\ Annualized\ Cost = \$43{,}381 + 0.04 \times \$459{,}578 + \$272{,}342$$
$$Total\ Annualized\ Cost = \$637{,}851\ (1995\$)$$

4.2.1.3 Equation Type 8 Example without Inventory Stackflow

This example gets its values for a coal-burning utility boiler with a Dry ESP – Wire Plate Type control from Table B-9. This is an example of using ptipm values for the same type of control equipment when needing default values. The CoST code is PDESPWPUBC.

Example Equation Variables

Default Cost per Ton – Capital =710 $/ton
Default Cost per Ton – O&M = 41 $/ton
Default Cost per Ton Annualized = 110 $/ton
Uncontrolled PM_{10} = 15 tons (from inventory record without stack parameters)
PM_{10} *control efficiency* = 98%
PM_{10} *reduction* = 14.7 tons
Year for Cost Basis = 1995

Capital Cost

$$Total\ Capital\ Cost = Emission\ Reduction \times Default\ Cost\ Per\ Ton - Capital$$
$$Total\ Capital\ Cost = 14.7\ tons \times 710\frac{\$}{ton}$$
$$Total\ Capital\ Cost = \$10{,}437\ (1995\$)$$

Operating and Maintenance Cost

$$Total\ O\&M\ Cost = Emission\ Reduction \times Default\ Cost\ Per\ Ton - O\&M$$
$$Total\ O\&M\ Cost = 14.7\ tons \times 41\frac{\$}{ton}$$
$$Total\ O\&M\ Cost = \$603\ (1995\$)$$

Total Annualized Cost Equation

$$Total\ Annualized\ Cost = Emission\ Reduction \times Default\ Cost\ Per\ Ton - Annualized$$
$$Total\ Annualized\ Cost = 14.7\ tons \times 110\frac{\$}{ton}$$
$$Total\ Annualized\ Cost = \$1{,}617\ (1995\$)$$

4.2.2 ICI Boiler Control Equations Type 14 for PM

These equations are used for fabric filters when PM control on the order of 99% is required and no SO_2 reduction is needed. The applicable SCCs for this equation type are the same as those listed in Table 3-7.

4.2.2.1 Cost Equations

Total Capital Investment

$$TCI = (105.91)(F_d) + 699754.7 + \left[(0.560)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)^2\right] + \left[(1096.141)e^{(0.017)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right] + \left[(33.977)e^{(0.014)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right]$$

Where:

F_d = Exhaust flowrate (dscfm)
F_a = Exhaust flowrate (acfm)
#Ducts = if $F_d \leq 154042$, then #Ducts = 1
if $F_d > 154042$, then #Ducts = F_d / 154042

Total Annualized Costs

$$TAC = [(17.44)(Op_{Hrs})] + \left\{(TCI)\left[(0.072) + \left(\frac{(i)(1+i)^{Eq_{Life}}}{(1+i)^{Eq_{Life}} - 1}\right)\right]\right\} + \left\{(F_a)\left[(4.507) + (1.24E-5)(Op_{Hrs}) - (4.184)\left(\frac{(i)(1+i)^{Eq_{Life}}}{(1+i)^{Eq_{Life}} - 1}\right)\right]\right\} + \{(F_d)(Op_{Hrs})[(3.76E-3) + (1.81E-3)(C_{PM})]\}$$

Where:

F_d = Exhaust flowrate (dscfm)
Op_{Hrs} = Annual operating hours of unit (hrs/yr)
TCI = Total Capital Investment ($)
F_a = Exhaust flowrate (acfm)
C_{PM} = Concentration of PM in stack gas (grains per dry standard cubic foot [gr/dscf])
i = Interest rate expressed as a fraction (i.e., percentage divided by 100)
Eq_{Life} = Estimated equipment life (yrs)

4.2.2.2 Example Calculations

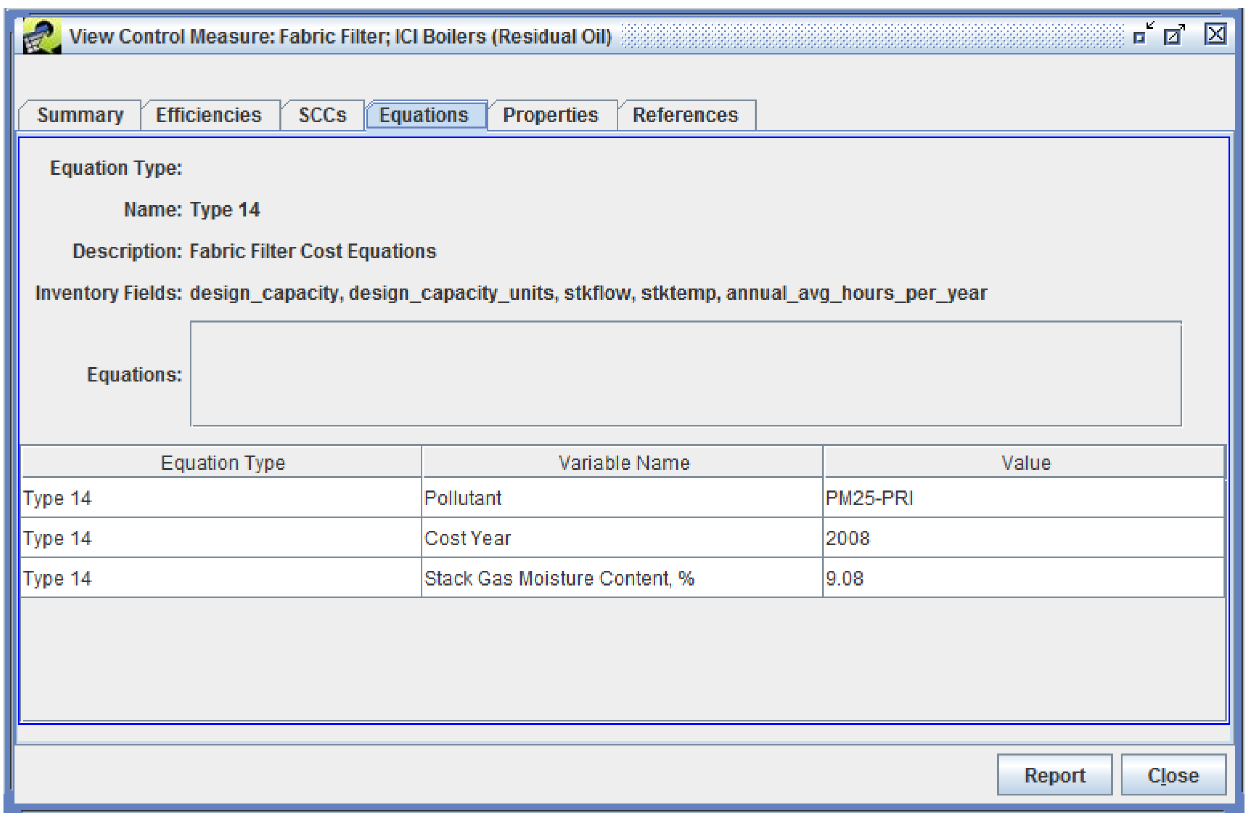
The example scenario for Equation Type 14 is for an ICI boiler that is burning residual oil. It needs to use a fabric filter as its emissions control equipment for PM. Assumptions that were used in constructing Equations Type 14 are listed in Table B-16.

Example Equation Variables

#Ducts = 1
i = 0.07 (annual interest rate 7%)
Eq_{Life} = 15 years
F_a = 55493 acfm
F_d = 32138 dscfm
Op_{Hrs} = 2688 operating hours per year
C_{PM} = 2.68E-3 gr/dscf
Year for Cost Basis = 2008

Figure 3-5 illustrates the View Control Measure screen for the Fabric Filter emissions control method for ICI Boilers (Residual Oil) emitting PM.

Figure 3-5: Equation Type 14 Example Screenshot



Total Capital Investment

$$TCI = (105.91)(F_d) + 699754.7 + \left[(0.560)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)^2\right] + \left[(1096.141)e^{(0.017)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right] + \left[(33.977)e^{(0.014)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right]$$

$$= (105.91)(32138) + (699754.7) + \left[(0.560)\left(\frac{\sqrt{55493}}{1}\right)^2\right] + \left[(1096.141)e^{(0.017)\left(\frac{\sqrt{55493}}{1}\right)}\right] + \left[(33.977)e^{(0.014)\left(\frac{\sqrt{55493}}{1}\right)}\right] = \$4{,}195{,}619$$

Total Annualized Costs

$$TAC = [(17.44)(Op_{Hrs})] + \left\{(TCI)\left[(0.072) + \left(\frac{(i)(1+i)^{Eq_{Life}}}{(1+i)^{Eq_{Life}} - 1}\right)\right]\right\} + \left\{(F_a)\left[(4.507) + (1.24E-5)(Op_{Hrs}) - (4.184)\left(\frac{(i)(1+i)^{Eq_{Life}}}{(1+i)^{Eq_{Life}} - 1}\right)\right]\right\} + \{(F_d)(Op_{Hrs})[(3.76E-3) + (1.81E-3)(C_{PM})]\}$$

$$= [(17.44)(2688)] + \left\{(4195619)\left[(0.072) + \left(\frac{(0.07)(1+0.07)^{15}}{(1+0.07)^{15} - 1}\right)\right]\right\} + \left\{(55493)\left[(4.507) + (1.24E-5)(2688) - (4.184)\left(\frac{(0.07)(1+0.07)^{15}}{(1+0.07)^{15} - 1}\right)\right]\right\} + \{(32138)(2688)[(3.76E-3) + (1.81E-3)(2.68E-3)]\} = \$1{,}361{,}318$$

4.2.3 ICI Boiler Control Equations Type 15 for PM

These equations are used for electrostatic precipitators when PM control on the order of 98% is required and no SO_2 reduction is needed. Note that one assumption specific to an electrostatic precipitator was included in constructing these equations. That assumption was that the pressure drop through the control device is 0.38 inches of water (in H_2O). The applicable SCCs for this equation type are the same as those listed in Table 3-7.

4.2.3.1 Cost Equations

Total Capital Investment

$$TCI = \{(12.265)(EC_1)[(5.266)(F_a)]^{EC_2}\} + \left[(0.784)\left(\frac{F_a}{\#Ducts}\right)\right] + (\#Ducts)\left\{\left[(2237.13)\left(e^{(0.017)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right)\right] + \left[(69.345)\left(e^{(0.014)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right)\right] + (17588.69)\right\}$$

Where:

EC_1	=	First equipment cost factor for ESP if $F_a \geq 9495$, $EC_1 = 57.87$ if $Fa < 9495$, $EC_1 = 614.55$
F_a	=	Exhaust flowrate (acfm)
EC_2	=	Second equipment cost factor for ESP if $F_a \geq 9495$, $EC_2 = 0.8431$ if $Fa < 9495$, $EC_2 = 0.6276$
#Ducts	=	if $F_a < 308084$, #Ducts = 1 if $308084 \leq F_a < 462126$, #Ducts = 2 if $462126 \leq F_a < 616168$, #Ducts = 3 if $F_a \geq 616168$, #Ducts = 4

Total Annualized Costs

$$TAC = [(10.074)(Op_{Hrs})] + [(0.052)(F_a)] + \left\{(6.56E-3)\left(1.04 + \left(\frac{(i)(1+i)^{Eq_{Life}}}{(1+i)^{Eq_{Life}}-1}\right)\right)\left((EC_1)[(5.266)(F_a)]^{EC_2}\right)\right\} + [(0.021)(Op_{Hrs})(E_{PM})(DC)] + \left\{(1.17E-5)(F_a)(Op_{Hrs})\left[(1.895) + \left((479.85)\left(\frac{1}{\sqrt{F_a}}\right)^{1.18}\right)\right]\right\} + [(7.15E-4)(Op_{Hrs})(F_a)] + \left\{\left(0.04 + \left(\frac{(i)(1+i)^{Eq_{Life}}}{(1+i)^{Eq_{Life}}-1}\right)\right)(\#Ducts)\left[(0.783)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)^2 + (2237.44)\left(e^{(0.0165)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right) + (69.355)\left(e^{(0.0140)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right) + (17591.15)\right]\right\}$$

Where:

Op_{Hrs}	=	Annual operating hours of unit (hrs/yr)
F_a	=	Exhaust flowrate (acfm)
i	=	Interest rate expressed as a fraction of 1 (percentage divided by 100)
Eq_{Life}	=	Estimated equipment life, years

EC_1 = First equipment cost factor for ESP
If $F_a \geq 9495$, $EC_1 = 57.87$
If $F_a < 9495$, $EC_1 = 614.55$
EC_2 = Second equipment cost factor for ESP
If $F_a \geq 9495$, $EC_2 = 0.8431$
If $F_a < 9495$, $EC_2 = 0.6276$
E_{PM} = PM emission rate, pounds per million British thermal units (lb/MMBtu)
DC = Design capacity of boiler, (MMBtu/hr)
#Ducts = If $F_a < 308084$, #Ducts = 1
If $308084 \leq F_a < 462126$, #Ducts = 2
If $462126 \leq F_a < 616168$, #Ducts = 3
If $F_a \geq 616168$, #Ducts = 4

4.2.3.2 Example Calculations

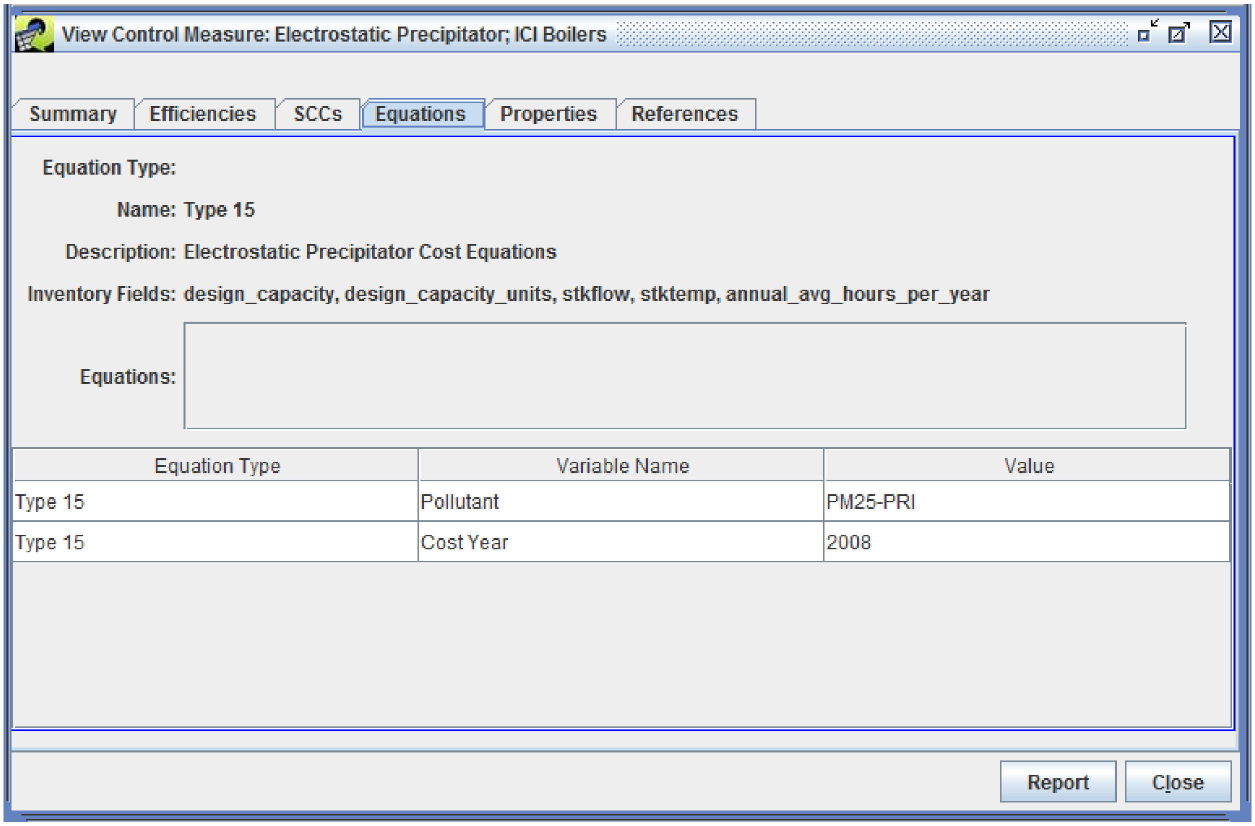
The example scenario for Equation Type 15 is for an ICI boiler. It needs to use an ESP as its emissions control equipment for PM. Assumptions that were used in constructing Equations Type 15 are listed in Table B-16.

Example Equation Variables

$EC_1 = 57.87$
$F_a = 55493$
$EC_2 = 0.8431$
#Ducts = 1
$Op_{Hrs} = 2688$
$Eq_{Life} = 15$
$E_{PM} = 4.10E\text{-}3$
$DC = 180$
Year for Cost Basis = 2008

Figure 3-6 illustrates information for the Electrostatic Precipitator control equipment for ICI Boilers controlling PM.

Figure 3-6: Equation Type 15 Example Screenshot



Total Capital Investment

$$TCI = \{(12.265)(EC_1)[(5.266)(F_a)]^{EC_2}\} + \left[(0.784)\left(\frac{F_a}{\#Ducts}\right)\right] + (\#Ducts)\left\{\left[(2237.13)\left(e^{(0.017)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right)\right] + \left[(69.345)\left(e^{(0.014)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right)\right] + (17588.69)\right\}$$

$$= \{(12.265)(57.87)[(5.266)(55493)]^{0.8431}\} + \left[(0.784)\left(\frac{55493}{1}\right)\right] + (1)\left\{\left[(2237.13)\left(e^{(0.017)\left(\frac{\sqrt{55493}}{1}\right)}\right)\right] + \left[(69.345)\left(e^{(0.014)\left(\frac{\sqrt{55493}}{1}\right)}\right)\right] + (17588.69)\right\}$$

$$= \$28{,}977{,}485$$

Total Annualized Costs

$$
\begin{aligned}
TAC &= [(10.074)(Op_{Hrs})] + [(0.052)(F_a)] \\
&+ \left\{(6.56E-3)\left(1.04 + \left(\frac{(i)(1+i)^{Eq_{Life}}}{(1+i)^{Eq_{Life}}-1}\right)\right)\left((EC_1)[(5.266)(F_a)]^{EC_2}\right)\right\} \\
&+ [(0.021)(Op_{Hrs})(E_{PM})(DC)] \\
&+ \left\{(1.17E-5)(F_a)(Op_{Hrs})\left[(1.895) + \left((479.85)\left(\frac{1}{\sqrt{F_a}}\right)^{1.18}\right)\right]\right\} \\
&+ [(7.15E-4)(Op_{Hrs})(F_a)] \\
&+ \left\{\left(0.04 + \left(\frac{(i)(1+i)^{Eq_{Life}}}{(1+i)^{Eq_{Life}}-1}\right)\right)(\#Ducts)\left[(0.783)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)^2\right.\right. \\
&\left.\left.+ (2237.44)\left(e^{(0.0165)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right) + (69.355)\left(e^{(0.0140)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right) + (17591.15)\right]\right\} \\
&= [(10.074)(2688)] + [(0.052)(55493)] \\
&+ \left\{(6.56E-3)\left(1.04 + \left(\frac{(0.07)(1+0.07)^{15}}{(1+0.07)^{15}-1}\right)\right)\left((57.87)[(5.266)(55493)]^{0.8431}\right)\right\} \\
&+ [(0.021)(2688)(4.10E-3)(180)] \\
&+ \left\{(1.17E-5)(55493)(2688)\left[(1.895) + \left((479.85)\left(\frac{1}{\sqrt{55493}}\right)^{1.18}\right)\right]\right\} \\
&+ [(7.15E-4)(2688)(55493)] \\
&+ \left\{\left(0.04 + \left(\frac{(0.07)(1+0.07)^{15}}{(1+0.07)^{15}-1}\right)\right)(1)\left[(0.783)\left(\frac{\sqrt{55493}}{1}\right)^2 + (2237.44)\left(e^{(0.0165)\left(\frac{\sqrt{55493}}{1}\right)}\right)\right.\right. \\
&\left.\left.+ (69.355)\left(e^{(0.0140)\left(\frac{\sqrt{55493}}{1}\right)}\right) + (17591.15)\right]\right\} = \$184,770
\end{aligned}
$$

4.2.4 ICI Boiler Control Equations Type 17 for PM

These equations are used for dry injection and fabric filter (DIFF) systems when both extensive PM control on the order of 99% and SO_2 reduction of approximately 70% are required. Equation Type 17 is presented in this section instead of section 3.2 because the primary reduction is achieved for PM. Two assumptions specific to DIFF systems were included when constructing these equations (Table B-18). Other assumptions in these equations are included in Table B-16.

The applicable SCCs for this equation type are the same as those listed in Table 3-7.

4.2.4.1 Equations

Total Capital Investment

$$TCI = [(143.76)(F_d)] + \left[(0.610)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)^2\right] + \left[(1757.65)\left(e^{(0.017)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right)\right] + \left[(59.973)\left(e^{(0.014)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right)\right] + (931911.04)$$

Where:

F_d = Exhaust flowrate (dscfm)

F_a = Exhaust flowrate (acfm)

#Ducts = if $F_d \leq 154042$, #Ducts = 1
if $F_d > 154042$, #Ducts = $F_d/154042$

Total Annualized Costs

$$TAC = [(1.62E-3)(Op_{Hrs})(F_d)] + [(17.314)(Op_{Hrs})] + [(1.05E-6)(C_{SO2})(F_d)(Op_{Hrs})] + [(3.72E-5)(Op_{Hrs})(F_a)] + [(1.81E-4)(Op_{Hrs})(C_{PM})(F_d)] + \left[(0.847)\left(1-\left(\frac{(i)(1+i)^{Eq_{Life}}}{(1+i)^{Eq_{Life}}-1}\right)\right)(F_a)\right] + \left[(0.04)+\left(\frac{(i)(1+i)^{Eq_{Life}}}{(1+i)^{Eq_{Life}}-1}\right)\right]\left\{[(0.032)(TCI)] + \left[(0.606)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)^2\right] + \left[(1757.65)\left(e^{(0.017)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right)\right] + \left[(53.973)\left(e^{(0.014)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right)\right] + (13689.81)\right\}$$

Where:

F_d = Exhaust flowrate (dscfm)

Op_{Hrs} = Annual operating hours of unit (hrs/yr)

C_{SO2} = Concentration of SO_2 in stack gas, dry ppm by volume (ppmvd)

F_a = Exhaust flowrate (acfm)

C_{PM} = Concentration of PM in the stack gas (gr/dscf)

i = Interest rate expressed as a fraction of 1 (percentage divided by 100)

Eq_{Life} = Estimated equipment life (yrs)

#Ducts = If $F_d \leq 154042$, #Ducts = 1
If $F_d > 154042$, #Ducts = $F_d/154042$

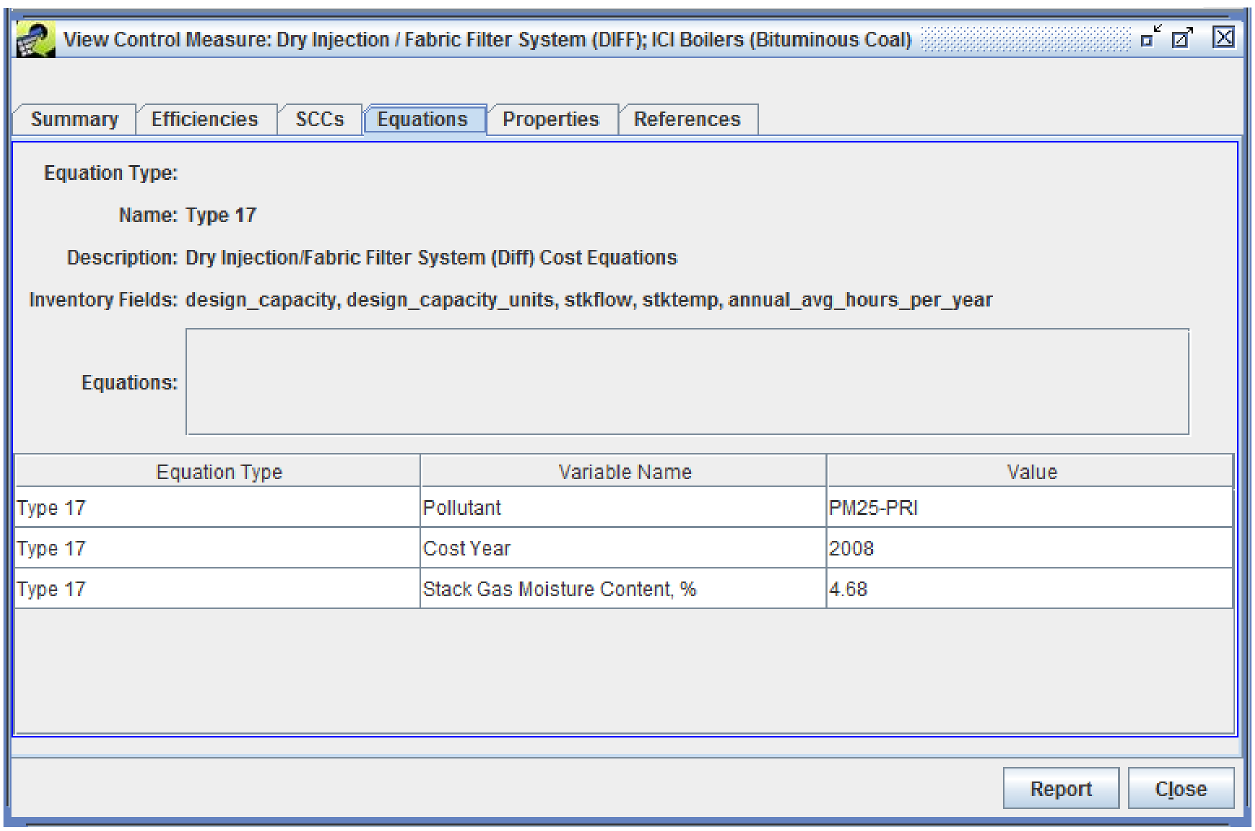
4.2.4.2 Example Calculations

Figure 3-7 illustrates information in the CoST View Control Measures tool showing the Dry Injection/Fabric Filter (DIFF) System for ICI Boilers (Bituminous Coal) for Equation Type 17.

Example Equation Variables

F_d = 32138
F_a = 55493
#Ducts = 1
Op_{Hrs} = 2688
Eq_{Life} = 15
i = 0.07
C_{PM} = 2.68E-3
C_{SO2} = 1.15
Year for Cost Basis = 2008

Figure 3-7: Equation Type 17 Example Screenshot



Total Capital Investment

$$TCI = [(143.76)(F_d)] + \left[(0.610)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)^2\right] + \left[(1757.65)\left(e^{(0.017)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right)\right] + \left[(59.973)\left(e^{(0.014)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right)\right] + (931911.04)$$

$$= [(143.76)(32138)] + \left[(0.610)\left(\frac{\sqrt{55493}}{1}\right)^2\right] + \left[(1757.65)\left(e^{(0.017)\left(\frac{\sqrt{55493}}{1}\right)}\right)\right] + \left[(59.973)\left(e^{(0.014)\left(\frac{\sqrt{55493}}{1}\right)}\right)\right] + (931911.04) = \$5,683,965$$

Total Annualized Costs

$$TAC = [(1.62E-3)(Op_{Hrs})(F_d)] + [(17.314)(Op_{Hrs})] + [(1.05E-6)(C_{SO2})(F_d)(Op_{Hrs})] + [(3.72E-5)(Op_{Hrs})(F_a)] + [(1.81E-4)(Op_{Hrs})(C_{PM})(F_d)] + \left[(0.847)\left(1-\left(\frac{(i)(1+i)^{Eq_{Life}}}{(1+i)^{Eq_{Life}}-1}\right)\right)(F_a)\right] + \left[(0.04)+\left(\frac{(i)(1+i)^{Eq_{Life}}}{(1+i)^{Eq_{Life}}-1}\right)\right]\left\{[(0.032)(TCI)] + \left[(0.606)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)^2\right] + \left[(1757.65)\left(e^{(0.017)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right)\right] + \left[(53.973)\left(e^{(0.014)\left(\frac{\sqrt{F_a}}{\#Ducts}\right)}\right)\right] + (13689.81)\right\}$$

$$= [(1.62E-3)(2688)(32138)] + [(17.314)(2688)] + [(1.05E-6)(1.15)(32138)(2688)] + [(3.72E-5)(2688)(55493)] + [(1.81E-4)(2688)(2.68E-3)(32138)] + \left[(0.847)\left(1-\left(\frac{(0.07)(1+0.07)^{15}}{(1+0.07)^{15}-1}\right)\right)(55493)\right] + \left[(0.04)+\left(\frac{(0.07)(1+0.07)^{15}}{(1+0.07)^{15}-1}\right)\right]\left\{[(0.032)(5683965)] + \left[(0.606)\left(\frac{\sqrt{55493}}{1}\right)^2\right] + \left[(1757.65)\left(e^{(0.017)\left(\frac{\sqrt{55493}}{1}\right)}\right)\right] + \left[(53.973)\left(e^{(0.014)\left(\frac{\sqrt{55493}}{1}\right)}\right)\right] + (13689.81)\right\}$$

$$= \$283,064$$

Appendix A. CoST Source Code

A.1 Equation Type 1 CoST Code for NO_x

```
-- Type 1
CREATE OR REPLACE FUNCTION public.get_type1_equation_costs(
   control_measure_id integer,
   measure_abbreviation character varying(10),
   discount_rate double precision,
   equipment_life double precision,
   capital_recovery_factor double precision,
   emis_reduction double precision,
   design_capacity double precision,
   capital_cost_multiplier double precision,
   fixed_om_cost_multiplier double precision,
   variable_om_cost_multiplier double precision,
   scaling_factor_model_size double precision,
   scaling_factor_exponent double precision,
   capacity_factor double precision,
   OUT annual_cost double precision,
   OUT capital_cost double precision,
   OUT operation_maintenance_cost double precision,
   OUT annualized_capital_cost double precision,
   OUT computed_cost_per_ton double precision)  AS $$
DECLARE
   cap_recovery_factor double precision := capital_recovery_factor;
   scaling_factor double precision;
   fixed_operation_maintenance_cost double precision;
   variable_operation_maintenance_cost double precision;
BEGIN
   -- NOTES:
   -- design capacity must in the units MW

   -- get capital recovery factor, calculate if it wasn't passed in...
        IF coalesce(discount_rate, 0) != 0 and coalesce(equipment_life, 0) != 0 THEN
             cap_recovery_factor :=
public.calculate_capital_recovery_factor(discount_rate, equipment_life);
        END IF;

   -- calculate scaling factor
   scaling_factor :=
      case
         when (measure_abbreviation = 'NSCR_UBCW' or measure_abbreviation =
'NSCR_UBCT') and design_capacity >= 600.0 then 1.0
         when design_capacity >= 500.0 then 1.0
         else scaling_factor_model_size ^ scaling_factor_exponent
      end;

   -- calculate capital cost
   capital_cost := capital_cost_multiplier * design_capacity * scaling_factor * 1000;

   -- calculate operation maintenance cost
   -- calculate fixed operation maintenance cost
   fixed_operation_maintenance_cost := fixed_om_cost_multiplier * design_capacity *
1000;
   -- calculate variable operation maintenance cost
   variable_operation_maintenance_cost := variable_om_cost_multiplier *
design_capacity * capacity_factor * 8760;
   -- calculate total operation maintenance cost
```

```
    operation_maintenance_cost := coalesce(fixed_operation_maintenance_cost, 0) +
coalesce(variable_operation_maintenance_cost, 0);

    -- calculate annualized capital cost
    annualized_capital_cost := capital_cost * cap_recovery_factor;

    -- calculate annual cost
    annual_cost := annualized_capital_cost + operation_maintenance_cost;

    -- calculate computed cost per ton
    computed_cost_per_ton :=
        case
            when coalesce(emis_reduction, 0) <> 0 then annual_cost / emis_reduction
            else null
        end;
END;
$$ LANGUAGE plpgsql IMMUTABLE;

-- Cost Equation Factory Method
CREATE OR REPLACE FUNCTION public.get_strategy_costs(
    use_cost_equations boolean,
    control_measure_id integer,
    measure_abbreviation character varying(10),
    discount_rate double precision,
    equipment_life double precision,
    capital_annualized_ratio double precision,
    capital_recovery_factor double precision,
    ref_yr_cost_per_ton double precision,
    emis_reduction double precision,
    ref_yr_chained_gdp_adjustment_factor double precision,
    equation_type character varying(255),
    variable_coefficient1 double precision,
    variable_coefficient2 double precision,
    variable_coefficient3 double precision,
    variable_coefficient4 double precision,
    variable_coefficient5 double precision,
    variable_coefficient6 double precision,
    variable_coefficient7 double precision,
    variable_coefficient8 double precision,
    variable_coefficient9 double precision,
    variable_coefficient10 double precision,
    stack_flow_rate double precision,
    design_capacity double precision,
    design_capacity_unit_numerator character varying,
    design_capacity_unit_denominator character varying,
    ceff double precision,
    ref_yr_incremental_cost_per_ton double precision,
    OUT annual_cost double precision,
    OUT capital_cost double precision,
    OUT operation_maintenance_cost double precision,
    OUT annualized_capital_cost double precision,
    OUT computed_cost_per_ton double precision,
    OUT actual_equation_type character varying(255)
--  ,OUT valid_cost boolean
    )  AS $$
DECLARE
    converted_design_capacity double precision;
    valid_cost boolean;
BEGIN
    -- at first, we can only assume that everything is right...
    valid_cost := true;
```

```
    -- Each Cost Equation Function will return costs in the cost year that is specified
in the emf.control_measure_equations table,
    -- after the costs are calculated we can adjust the costs to the reference cost
year.

    -- try cost equations first, then maybe use default approach, if needed
    IF use_cost_equations THEN
        IF equation_type is not null THEN
            -- Type 1
            IF equation_type = 'Type 1' THEN

                converted_design_capacity :=
public.convert_design_capacity_to_mw(design_capacity, design_capacity_unit_numerator,
design_capacity_unit_denominator);

                IF coalesce(design_capacity, 0) <> 0 THEN
                    select costs.annual_cost,
                        costs.capital_cost,
                        costs.operation_maintenance_cost,
                        costs.annualized_capital_cost,
                        costs.computed_cost_per_ton
                    from public.get_type1_equation_costs(control_measure_id,
                        measure_abbreviation,
                        discount_rate,
                        equipment_life,
                        capital_recovery_factor,
                        emis_reduction,
                        converted_design_capacity,
                        variable_coefficient1,
                        variable_coefficient2,
                        variable_coefficient3,
                        variable_coefficient4,
                        variable_coefficient5,
                        variable_coefficient6) as costs
                    into annual_cost,
                        capital_cost,
                        operation_maintenance_cost,
                        annualized_capital_cost,
                        computed_cost_per_ton;
                    IF annual_cost is not null THEN
                        valid_cost := true;
                        actual_equation_type := 'Type 1';
                    ELSE
                        valid_cost := false;
                        actual_equation_type := '-Type 1';
                    END IF;
                    -- adjust costs to the reference cost year
                    annual_cost := ref_yr_chained_gdp_adjustment_factor * annual_cost;
                    capital_cost := ref_yr_chained_gdp_adjustment_factor * capital_cost;
                    operation_maintenance_cost := ref_yr_chained_gdp_adjustment_factor *
operation_maintenance_cost;
                    annualized_capital_cost := ref_yr_chained_gdp_adjustment_factor *
annualized_capital_cost;
                    computed_cost_per_ton := ref_yr_chained_gdp_adjustment_factor *
computed_cost_per_ton;
                    return;
                END IF;
                valid_cost := false;
                actual_equation_type := '-Type 1';
            END IF;
```

A.2 Equation Type 2 CoST Code

```
-------------------------------------------------------------------------------------

-- plpgsql script code funneling to Type 2 cost equations…

converted_design_capacity := public.convert_design_capacity_to_mw(design_capacity,
design_capacity_unit_numerator, design_capacity_unit_denominator);
-- convert design capacity to mmBtu/hr
converted_design_capacity := 3.412 * converted_design_capacity;

IF coalesce(converted_design_capacity, 0) <> 0 THEN
-- design capacity must be less than or equal to 2000 MMBTU/hr (or 586.1665 MW/hr))
IF (converted_design_capacity <= 2000.0) THEN
       select costs.annual_cost,
          costs.capital_cost,
          costs.operation_maintenance_cost,
          costs.annualized_capital_cost,
          costs.computed_cost_per_ton
       from public.get_type2_equation_costs(control_measure_id,
          discount_rate,
          equipment_life,
          capital_recovery_factor,
          emis_reduction,
          converted_design_capacity,
          variable_coefficient1,
          variable_coefficient2,
          variable_coefficient3,
          variable_coefficient4) as costs
       into annual_cost,
          capital_cost,
          operation_maintenance_cost,
          annualized_capital_cost,
          computed_cost_per_ton;
       IF annual_cost is not null THEN
          valid_cost := true;
          actual_equation_type := 'Type 2';
       ELSE
          valid_cost := false;
          actual_equation_type := '-Type 2';
       END IF;
       -- adjust costs to the reference cost year
       annual_cost := ref_yr_chained_gdp_adjustment_factor * annual_cost;
       capital_cost := ref_yr_chained_gdp_adjustment_factor * capital_cost;
       operation_maintenance_cost := ref_yr_chained_gdp_adjustment_factor *
operation_maintenance_cost;
       annualized_capital_cost := ref_yr_chained_gdp_adjustment_factor *
annualized_capital_cost;
       computed_cost_per_ton := ref_yr_chained_gdp_adjustment_factor *
computed_cost_per_ton;
       return;
   END IF;
END IF;
valid_cost := false;
actual_equation_type := '-Type 2';

-- Next the code will call the default CPT approach

-------------------------------------------------------------------------------------
```

```
-- Type 2
CREATE OR REPLACE FUNCTION public.get_type2_equation_costs(
    control_measure_id integer,
    discount_rate double precision,
    equipment_life double precision,
    capital_recovery_factor double precision,
    emis_reduction double precision,
    design_capacity double precision,
    capital_cost_multiplier double precision,
    capital_cost_exponent double precision,
    annual_cost_multiplier double precision,
    annual_cost_exponent double precision,
    OUT annual_cost double precision,
    OUT capital_cost double precision,
    OUT operation_maintenance_cost double precision,
    OUT annualized_capital_cost double precision,
    OUT computed_cost_per_ton double precision)  AS $$
DECLARE
    cap_recovery_factor double precision := capital_recovery_factor;
BEGIN
    -- NOTES:
    -- design capacity must in the units mmBtu/hr

    -- get capital recovery factor, calculate if it wasn't passed in...
IF coalesce(discount_rate, 0) != 0 and coalesce(equipment_life, 0) != 0 THEN
cap_recovery_factor := public.calculate_capital_recovery_factor(discount_rate,
equipment_life);
END IF;

    -- calculate capital cost
    capital_cost := capital_cost_multiplier * (design_capacity ^
capital_cost_exponent);

    -- calculate annualized capital cost
    annualized_capital_cost := capital_cost * cap_recovery_factor;

    -- calculate annual cost
    annual_cost := annual_cost_multiplier * design_capacity ^ annual_cost_exponent;

    -- calculate operation maintenance cost
    operation_maintenance_cost := annual_cost - annualized_capital_cost;

    -- calculate computed cost per ton
    computed_cost_per_ton :=
        case
            when coalesce(emis_reduction, 0) <> 0 then annual_cost / emis_reduction
            else null
        end;
END;
$$ LANGUAGE plpgsql IMMUTABLE;

CREATE OR REPLACE FUNCTION public.convert_design_capacity_to_mw(design_capacity double
precision, design_capacity_unit_numerator character varying,
    design_capacity_unit_denominator character varying) returns double precision AS $$
DECLARE
    converted_design_capacity double precision;
    unit_numerator character varying;
    unit_denominator character varying;
BEGIN

--default if not known
unit_numerator := coalesce(trim(upper(design_capacity_unit_numerator)), '');
unit_denominator := coalesce(trim(upper(design_capacity_unit_denominator)), '');
```

```
 --if you don't know the units then you assume units are MW
   IF length(unit_numerator) = 0 THEN
      return converted_design_capacity;
   END IF;

/* FROM Larry Sorrels at the EPA
        1) E6BTU does mean mmBTU.

        2)  1 MW = 3.412 million BTU/hr (or mmBTU/hr).   And conversely, 1
        mmBTU/hr = 1/3.412 (or 0.2931) MW.

        3)  All of the units listed below are convertible, but some of the
        conversions will be more difficult than others.  The ft3, lb, and ton
        will require some additional conversions to translate mass or volume
        into an energy term such as MW or mmBTU/hr.  Applying some density
        measure (which is mass/volume) will likely be necessary.
*/

        --capacity is already in the right units...
        --no conversion is necessary, these are the expected units.
   IF (unit_numerator = 'MW' and unit_denominator = '') THEN
      return design_capacity;
   END IF;

        IF (unit_numerator = 'MMBTU'
            or unit_numerator = 'E6BTU'
            or unit_numerator = 'BTU'
            or unit_numerator = 'HP'
            or unit_numerator = 'BLRHP') THEN

      --convert numerator unit
      IF (unit_numerator = 'MMBTU'
          or unit_numerator = 'E6BTU') THEN
         converted_design_capacity := design_capacity / 3.412;
      END IF;
      IF (unit_numerator = 'BTU') THEN
         converted_design_capacity := design_capacity / 3.412 / 1000000.0;
      END IF;
      IF (unit_numerator = 'HP') THEN
         converted_design_capacity := design_capacity * 0.000746;
      END IF;
      IF (unit_numerator = 'BLRHP') THEN
         converted_design_capacity := design_capacity * 0.000981;
      END IF;

      --convert denominator unit, if missing ASSUME per hr
      IF (unit_denominator = '' or unit_denominator = 'HR'
          or unit_denominator = 'H') THEN
         return converted_design_capacity;
      END IF;
      IF (unit_denominator = 'D' or unit_denominator = 'DAY') THEN
         return converted_design_capacity * 24.0;
      END IF;
      IF (unit_denominator = 'M' or unit_denominator = 'MIN') THEN
         return converted_design_capacity / 60.0;
      END IF;
      IF (unit_denominator = 'S' or unit_denominator = 'SEC') THEN
         return converted_design_capacity / 3600.0;
      END IF;
   END IF;
   return null;
END;
```

```
$$ LANGUAGE plpgsql IMMUTABLE;
```

A.3 Equation Type 3 CoST Code

```
--------------------------------------------------------------------------------

-- Code that funnels the source to the correct control measure cost equations.

-- NOTES:
--  stack flowrate was converted from cfs to cfm prior to getting here.

-- Type 3
IF equation_type = 'Type 3' THEN
   IF coalesce(STKFLOW, 0) <> 0 THEN
      select costs.annual_cost,
         costs.capital_cost,
         costs.operation_maintenance_cost,
         costs.annualized_capital_cost,
         costs.computed_cost_per_ton
      from public.get_type3_equation_costs(control_measure_id,
         discount_rate,
         equipment_life,
         capital_recovery_factor,
         emis_reduction,
         STKFLOW) as costs
      into annual_cost,
         capital_cost,
         operation_maintenance_cost,
         annualized_capital_cost,
         computed_cost_per_ton;
      IF annual_cost is not null THEN
         valid_cost := true;
         actual_equation_type := 'Type 3';
      ELSE
         valid_cost := false;
         actual_equation_type := '-Type 3';
      END IF;
      -- adjust costs to the reference cost year
      annual_cost := ref_yr_chained_gdp_adjustment_factor * annual_cost;
      capital_cost := ref_yr_chained_gdp_adjustment_factor * capital_cost;
      operation_maintenance_cost := ref_yr_chained_gdp_adjustment_factor *
operation_maintenance_cost;
      annualized_capital_cost := ref_yr_chained_gdp_adjustment_factor *
annualized_capital_cost;
      computed_cost_per_ton := ref_yr_chained_gdp_adjustment_factor *
computed_cost_per_ton;
      return;
   END IF;
   valid_cost := false;
   actual_equation_type := '-Type 3';
END IF;

-- Next the code will call the default CPT approach

--------------------------------------------------------------------------------

-- Type 3
CREATE OR REPLACE FUNCTION public.get_type3_equation_costs(
   control_measure_id integer,
   discount_rate double precision,
   equipment_life double precision,
   capital_recovery_factor double precision,
```

```
    emis_reduction double precision,
    STKFLOW double precision,
    OUT annual_cost double precision,
    OUT capital_cost double precision,
    OUT operation_maintenance_cost double precision,
    OUT annualized_capital_cost double precision,
    OUT computed_cost_per_ton double precision)  AS $$
DECLARE
    cap_recovery_factor double precision := capital_recovery_factor;
    capital_cost_factor double precision := 192;
    gas_flow_rate_factor double precision := 0.486;
    retrofit_factor double precision := 1.1;
BEGIN
    -- get capital recovery factor, calculate if it wasn't passed in...
IF coalesce(discount_rate, 0) != 0 and coalesce(equipment_life, 0) != 0 THEN
                cap_recovery_factor :=
public.calculate_capital_recovery_factor(discount_rate, equipment_life);
          END IF;

    -- calculate capital cost
    capital_cost :=
        case
            when STKFLOW < 1028000 then
                (1028000/ STKFLOW) ^ 0.6 * capital_cost_factor * gas_flow_rate_factor *
retrofit_factor * STKFLOW
            else
                capital_cost_factor * gas_flow_rate_factor * retrofit_factor * STKFLOW
        end;

    -- calculate annualized capital cost
    annualized_capital_cost := capital_cost * cap_recovery_factor;

    -- calculate operation maintenance cost
    operation_maintenance_cost := (3.35 + (0.000729 * 8736)) * STKFLOW;

    -- calculate annual cost
    annual_cost := annualized_capital_cost + operation_maintenance_cost;

    -- calculate computed cost per ton
    computed_cost_per_ton :=
        case
            when coalesce(emis_reduction, 0) <> 0 then annual_cost / emis_reduction
            else null
        end;
END;
$$ LANGUAGE plpgsql IMMUTABLE;
```

A.4 Equation Type 4 CoST Code

```
---------------------------------------------------------------------------------

-- Code that funnels the source to the correct control measure cost equations.

-- NOTES:
--  stack flowrate was converted from cfs to cfm prior to getting here.

-- Type 4
IF equation_type = 'Type 4' THEN
   IF coalesce(STKFLOW, 0) <> 0 THEN
      select costs.annual_cost,
         costs.capital_cost,
         costs.operation_maintenance_cost,
         costs.annualized_capital_cost,
         costs.computed_cost_per_ton
      from public.get_type4_equation_costs(control_measure_id,
         discount_rate,
         equipment_life,
         capital_recovery_factor,
         emis_reduction,
         STKFLOW) as costs
      into annual_cost,
         capital_cost,
         operation_maintenance_cost,
         annualized_capital_cost,
         computed_cost_per_ton;
      IF annual_cost is not null THEN
         valid_cost := true;
         actual_equation_type := 'Type 4';
      ELSE
         valid_cost := false;
         actual_equation_type := '-Type 4';
      END IF;
      -- adjust costs to the reference cost year
      annual_cost := ref_yr_chained_gdp_adjustment_factor * annual_cost;
      capital_cost := ref_yr_chained_gdp_adjustment_factor * capital_cost;
      operation_maintenance_cost := ref_yr_chained_gdp_adjustment_factor *
operation_maintenance_cost;
      annualized_capital_cost := ref_yr_chained_gdp_adjustment_factor *
annualized_capital_cost;
      computed_cost_per_ton := ref_yr_chained_gdp_adjustment_factor *
computed_cost_per_ton;
      return;
   END IF;
   valid_cost := false;
   actual_equation_type := '-Type 4';
END IF;

-- Next the code will call the default CPT approach

-------------------------------------------------------------------------------------

-- Type 4
CREATE OR REPLACE FUNCTION public.get_type4_equation_costs(
   control_measure_id integer,
   discount_rate double precision,
   equipment_life double precision,
```

```
    capital_recovery_factor double precision,
    emis_reduction double precision,
    STKFLOW double precision,
    OUT annual_cost double precision,
    OUT capital_cost double precision,
    OUT operation_maintenance_cost double precision,
    OUT annualized_capital_cost double precision,
    OUT computed_cost_per_ton double precision)  AS $$
DECLARE
    cap_recovery_factor double precision := capital_recovery_factor;
BEGIN
    -- get capital recovery factor, calculate if it wasn't passed in...
         IF coalesce(discount_rate, 0) != 0 and coalesce(equipment_life, 0) != 0 THEN
              cap_recovery_factor :=
public.calculate_capital_recovery_factor(discount_rate, equipment_life);
         END IF;

    -- calculate capital cost
    capital_cost := (990000 + 9.836 * STKFLOW);

    -- calculate annualized capital cost
    annualized_capital_cost := capital_cost * cap_recovery_factor;

    -- calculate operation maintenance cost
    operation_maintenance_cost := (75800 + 12.82 * STKFLOW);

    -- calculate annual cost
    annual_cost := annualized_capital_cost + operation_maintenance_cost;

    -- calculate computed cost per ton
    computed_cost_per_ton :=
        case
            when coalesce(emis_reduction, 0) <> 0 then annual_cost / emis_reduction
            else null
        end;
END;
$$ LANGUAGE plpgsql IMMUTABLE;
```

A.5 Equation Type 5 CoST Code

```
----------------------------------------------------------------------------------

-- Code that funnels the source to the correct control measure cost equations.

-- NOTES:
--  stack flowrate was converted from cfs to cfm prior to getting here.

-- Type 5
IF equation_type = 'Type 5' THEN
    IF coalesce(STKFLOW, 0) <> 0 THEN
        select costs.annual_cost,
            costs.capital_cost,
            costs.operation_maintenance_cost,
            costs.annualized_capital_cost,
            costs.computed_cost_per_ton
        from public.get_type5_equation_costs(control_measure_id,
            discount_rate,
            equipment_life,
            capital_recovery_factor,
            emis_reduction,
```

```
          STKFLOW) as costs
       into annual_cost,
          capital_cost,
          operation_maintenance_cost,
          annualized_capital_cost,
          computed_cost_per_ton;
       IF annual_cost is not null THEN
          valid_cost := true;
          actual_equation_type := 'Type 5';
       ELSE
          valid_cost := false;
          actual_equation_type := '-Type 5';
       END IF;
       -- adjust costs to the reference cost year
       annual_cost := ref_yr_chained_gdp_adjustment_factor * annual_cost;
       capital_cost := ref_yr_chained_gdp_adjustment_factor * capital_cost;
       operation_maintenance_cost := ref_yr_chained_gdp_adjustment_factor *
operation_maintenance_cost;
       annualized_capital_cost := ref_yr_chained_gdp_adjustment_factor *
annualized_capital_cost;
       computed_cost_per_ton := ref_yr_chained_gdp_adjustment_factor *
computed_cost_per_ton;
       return;
   END IF;
   valid_cost := false;
   actual_equation_type := '-Type 5';
END IF;

-- Next the code will call the default CPT approach

----------------------------------------------------------------------------------

-- Type 5
CREATE OR REPLACE FUNCTION public.get_type5_equation_costs(
   control_measure_id integer,
   discount_rate double precision,
   equipment_life double precision,
   capital_recovery_factor double precision,
   emis_reduction double precision,
   STKFLOW double precision,
   OUT annual_cost double precision,
   OUT capital_cost double precision,
   OUT operation_maintenance_cost double precision,
   OUT annualized_capital_cost double precision,
   OUT computed_cost_per_ton double precision)  AS $$
DECLARE
   cap_recovery_factor double precision := capital_recovery_factor;
BEGIN
   -- get capital recovery factor, calculate if it wasn't passed in...
          IF coalesce(discount_rate, 0) != 0 and coalesce(equipment_life, 0) != 0 THEN
                 cap_recovery_factor :=
public.calculate_capital_recovery_factor(discount_rate, equipment_life);
       END IF;

   -- calculate capital cost
   capital_cost := (2882540 + 244.74 * STKFLOW);

   -- calculate annualized capital cost
   annualized_capital_cost := capital_cost * cap_recovery_factor;

   -- calculate operation maintenance cost
   operation_maintenance_cost := (749170 + 148.40 * STKFLOW);
```

```
    -- calculate annual cost
    annual_cost := annualized_capital_cost + operation_maintenance_cost;

    -- calculate computed cost per ton
    computed_cost_per_ton :=
        case
            when coalesce(emis_reduction, 0) <> 0 then annual_cost / emis_reduction
            else null
        end;
END;
$$ LANGUAGE plpgsql IMMUTABLE;
```

A.6 Equation Type 6 CoST Code

```
-------------------------------------------------------------------------------------

-- Code that funnels the source to the correct control measure cost equations.

-- NOTES:
--  stack flowrate was converted from cfs to cfm prior to getting here.

IF equation_type = 'Type 6' THEN
    IF coalesce(STKFLOW, 0) <> 0 THEN
        select costs.annual_cost,
            costs.capital_cost,
            costs.operation_maintenance_cost,
            costs.annualized_capital_cost,
            costs.computed_cost_per_ton
        from public.get_type6_equation_costs(control_measure_id,
            discount_rate,
            equipment_life,
            capital_recovery_factor,
            emis_reduction,
            STKFLOW) as costs
        into annual_cost,
            capital_cost,
            operation_maintenance_cost,
            annualized_capital_cost,
            computed_cost_per_ton;
        IF annual_cost is not null THEN
            valid_cost := true;
            actual_equation_type := 'Type 6';
        ELSE
            valid_cost := false;
            actual_equation_type := '-Type 6';
        END IF;
        -- adjust costs to the reference cost year
        annual_cost := ref_yr_chained_gdp_adjustment_factor * annual_cost;
        capital_cost := ref_yr_chained_gdp_adjustment_factor * capital_cost;
        operation_maintenance_cost := ref_yr_chained_gdp_adjustment_factor *
operation_maintenance_cost;
        annualized_capital_cost := ref_yr_chained_gdp_adjustment_factor *
annualized_capital_cost;
        computed_cost_per_ton := ref_yr_chained_gdp_adjustment_factor *
computed_cost_per_ton;
        return;
    END IF;
    valid_cost := false;
    actual_equation_type := '-Type 6';
END IF;
```

```
-- Next the code will call the default CPT approach

-------------------------------------------------------------------------------

-- Type 6
CREATE OR REPLACE FUNCTION public.get_type6_equation_costs(
   control_measure_id integer,
   discount_rate double precision,
   equipment_life double precision,
   capital_recovery_factor double precision,
   emis_reduction double precision,
   STKFLOW double precision,
   OUT annual_cost double precision,
   OUT capital_cost double precision,
   OUT operation_maintenance_cost double precision,
   OUT annualized_capital_cost double precision,
   OUT computed_cost_per_ton double precision)  AS $$
DECLARE
   cap_recovery_factor double precision := capital_recovery_factor;
BEGIN
   -- get capital recovery factor, calculate if it wasn't passed in...
          IF coalesce(discount_rate, 0) != 0 and coalesce(equipment_life, 0) != 0
THEN
                cap_recovery_factor :=
public.calculate_capital_recovery_factor(discount_rate, equipment_life);
          END IF;

   -- calculate capital cost
   capital_cost := (3449803 + 135.86 * STKFLOW);

   -- calculate annualized capital cost
   annualized_capital_cost := capital_cost * cap_recovery_factor;

   -- calculate operation maintenance cost
   operation_maintenance_cost := (797667 + 58.84 * STKFLOW);

   -- calculate annual cost
   annual_cost := annualized_capital_cost + operation_maintenance_cost;

   -- calculate computed cost per ton
   computed_cost_per_ton :=
      case
         when coalesce(emis_reduction, 0) <> 0 then annual_cost / emis_reduction
         else null
      end;
END;
$$ LANGUAGE plpgsql IMMUTABLE;
```

A.7 Equation Type 7 CoST Code

Equation Type 7 has not been implemented in CoST.

A.8 Equation Type 8 CoST Code

```
--------------------------------------------------------------------------------------

-- Code that funnels the source to the correct control measure cost equations.

-- NOTES:
--
-- Type 8
IF equation_type = 'Type 8' THEN
   IF coalesce(STKFLOW, 0) <> 0 THEN
      select costs.annual_cost,
         costs.capital_cost,
         costs.operation_maintenance_cost,
         costs.annualized_capital_cost,
         costs.computed_cost_per_ton
      from public.get_type8_equation_costs(control_measure_id,
         discount_rate,
         equipment_life,
         capital_recovery_factor,
         emis_reduction,
         STKFLOW,
         variable_coefficient1,
         variable_coefficient2,
         variable_coefficient3,
         variable_coefficient4,
         variable_coefficient5) as costs

      into annual_cost,
         capital_cost,
         operation_maintenance_cost,
         annualized_capital_cost,
         computed_cost_per_ton;
      IF annual_cost is not null THEN
         valid_cost := true;
         actual_equation_type := 'Type 8';
      ELSE
         valid_cost := false;
         actual_equation_type := '-Type 8';
      END IF;
      -- adjust costs to the reference cost year
      annual_cost := ref_yr_chained_gdp_adjustment_factor * annual_cost;
      capital_cost := ref_yr_chained_gdp_adjustment_factor * capital_cost;
      operation_maintenance_cost := ref_yr_chained_gdp_adjustment_factor *
operation_maintenance_cost;
      annualized_capital_cost := ref_yr_chained_gdp_adjustment_factor *
annualized_capital_cost;
      computed_cost_per_ton := ref_yr_chained_gdp_adjustment_factor *
computed_cost_per_ton;
      return;
   END IF;
   valid_cost := false;
   actual_equation_type := '-Type 8';
END IF;

-- Next the code will call the default CPT approach

--------------------------------------------------------------------------------------

-- Type 8
```

```
CREATE OR REPLACE FUNCTION public.get_type8_equation_costs(
   control_measure_id integer,
   discount_rate double precision,
   equipment_life double precision,
   capital_recovery_factor double precision,
   emis_reduction double precision,
   STKFLOW double precision,
   capital_control_cost_factor double precision,
   om_control_cost_factor double precision,
   default_capital_cpt_factor double precision,
   default_om_cpt_factor double precision,
   default_annualized_cpt_factor double precision,
   OUT annual_cost double precision,
   OUT capital_cost double precision,
   OUT operation_maintenance_cost double precision,
   OUT annualized_capital_cost double precision,
   OUT computed_cost_per_ton double precision)  AS $$
DECLARE
   cap_recovery_factor double precision := capital_recovery_factor;
BEGIN
   -- get capital recovery factor, calculate if it wasn't passed in...
          IF coalesce(discount_rate, 0) != 0 and coalesce(equipment_life, 0) != 0
THEN
                 cap_recovery_factor :=
public.calculate_capital_recovery_factor(discount_rate, equipment_life);
         END IF;

   -- calculate capital cost
   capital_cost :=
      case
         when coalesce(STKFLOW, 0) = 0 then null
         when STKFLOW >= 5.0 then capital_control_cost_factor * STKFLOW
         else default_capital_cpt_factor * emis_reduction
      end;

   -- calculate operation maintenance cost
   operation_maintenance_cost :=
      case
         when coalesce(STKFLOW, 0) = 0 then null
         when STKFLOW >= 5.0 then om_control_cost_factor * STKFLOW
         else default_om_cpt_factor * emis_reduction
      end;

   -- calculate annualized capital cost
   annualized_capital_cost := capital_cost * cap_recovery_factor;

   -- calculate annual cost
   annual_cost :=
      case
         when coalesce(STKFLOW, 0) = 0 then null
         when STKFLOW >= 5.0 then annualized_capital_cost + 0.04 * capital_cost +
operation_maintenance_cost
         else default_annualized_cpt_factor * emis_reduction
      end;

   -- calculate computed cost per ton
   computed_cost_per_ton :=
      case
         when coalesce(emis_reduction, 0) <> 0 then annual_cost / emis_reduction
         else null
      end;
END;
$$ LANGUAGE plpgsql IMMUTABLE;
```

A.9 Equation Type 9 CoST Code

```
-------------------------------------------------------------------------------------

-- Code that funnels the source to the correct control measure cost equations.

-- NOTES:
--

-- Type 9
IF equation_type = 'Type 9' THEN
   IF coalesce(STKFLOW, 0) <> 0 THEN
      select costs.annual_cost,
         costs.capital_cost,
         costs.operation_maintenance_cost,
         costs.annualized_capital_cost,
         costs.computed_cost_per_ton
      from public.get_type9_equation_costs(control_measure_id,
         discount_rate,
         equipment_life,
         capital_recovery_factor,
         emis_reduction,
         STKFLOW,
         variable_coefficient1,
         variable_coefficient2,
         variable_coefficient3,
         variable_coefficient4,
         variable_coefficient5,
         variable_coefficient6,
         variable_coefficient7,
         variable_coefficient8,
         variable_coefficient9) as costs
      into annual_cost,
         capital_cost,
         operation_maintenance_cost,
         annualized_capital_cost,
         computed_cost_per_ton;
      IF annual_cost is not null THEN
         valid_cost := true;
         actual_equation_type := 'Type 9';
      ELSE
         valid_cost := false;
         actual_equation_type := '-Type 9';
      END IF;
      -- adjust costs to the reference cost year
      annual_cost := ref_yr_chained_gdp_adjustment_factor * annual_cost;
      capital_cost := ref_yr_chained_gdp_adjustment_factor * capital_cost;
      operation_maintenance_cost := ref_yr_chained_gdp_adjustment_factor *
operation_maintenance_cost;
      annualized_capital_cost := ref_yr_chained_gdp_adjustment_factor *
annualized_capital_cost;
      computed_cost_per_ton := ref_yr_chained_gdp_adjustment_factor *
computed_cost_per_ton;
      return;
   END IF;
   valid_cost := false;
   actual_equation_type := '-Type 9';
END IF;

-- Next the code will call the default CPT approach
```

```
-------------------------------------------------------------------------------------

-- Type 9 - ptipm PM Control Equations
CREATE OR REPLACE FUNCTION public.get_type9_equation_costs(
   control_measure_id integer,
   discount_rate double precision,
   equipment_life double precision,
   capital_recovery_factor double precision,
   emis_reduction double precision,
   STKFLOW double precision, -- in cfm
   total_equipment_cost_factor double precision,
   total_equipment_cost_constant double precision,
   equipment_to_capital_cost_multiplier double precision,
   electricity_factor double precision,
   electricity_constant double precision,
   dust_disposal_factor double precision,
   dust_disposal_constant double precision,
   bag_replacement_factor double precision,
   bag_replacement_constant double precision,
   OUT annual_cost double precision,
   OUT capital_cost double precision,
   OUT operation_maintenance_cost double precision,
   OUT annualized_capital_cost double precision,
   OUT computed_cost_per_ton double precision)  AS $$
DECLARE
   cap_recovery_factor double precision := capital_recovery_factor;
BEGIN
   -- get capital recovery factor, calculate if it wasn't passed in...
         IF coalesce(cap_recovery_factor, 0) = 0 and coalesce(discount_rate, 0) != 0
and coalesce(equipment_life, 0) != 0 THEN
                 cap_recovery_factor :=
public.calculate_capital_recovery_factor(discount_rate, equipment_life);
         END IF;

   -- calculate capital cost
   capital_cost := ((total_equipment_cost_factor * STKFLOW) +
total_equipment_cost_constant) * equipment_to_capital_cost_multiplier;

   -- calculate operation maintenance cost
   operation_maintenance_cost :=
      ((electricity_factor * STKFLOW) + electricity_constant) +
((dust_disposal_factor * STKFLOW) + dust_disposal_constant) + ((bag_replacement_factor
* STKFLOW) + bag_replacement_constant);

   -- calculate annualized capital cost
   annualized_capital_cost := capital_cost * cap_recovery_factor;

   -- calculate annual cost
   annual_cost :=  annualized_capital_cost + operation_maintenance_cost;

   -- calculate computed cost per ton
   computed_cost_per_ton :=
      case
         when coalesce(emis_reduction, 0) <> 0 then annual_cost / emis_reduction
         else null
      end;
END;
$$ LANGUAGE plpgsql IMMUTABLE;
```

A.10 Equation Type 10 CoST Code

```
---------------------------------------------------------------------------------------
-- Code that funnels the source to the correct control measure cost equations.

-- Type 10
IF equation_type = 'Type 10' THEN
   --default units numerator to MW
   converted_design_capacity :=
      public.convert_design_capacity_to_mw(design_capacity,
      case
         when length(coalesce(design_capacity_unit_numerator, '')) = 0 then
   'MW'::character varying
         else
            design_capacity_unit_numerator
      end
      , design_capacity_unit_denominator);


   IF coalesce(design_capacity, 0) <> 0 THEN
      select costs.annual_cost,
         costs.capital_cost,
         costs.variable_operation_maintenance_cost,
         costs.fixed_operation_maintenance_cost,
         costs.operation_maintenance_cost,
         costs.annualized_capital_cost,
         costs.computed_cost_per_ton
      from public.get_type10_equation_costs(
         discount_rate,
         equipment_life,
         capital_recovery_factor,
         emis_reduction,
         converted_design_capacity,
         annual_avg_hours_per_year,
         variable_coefficient1,
         variable_coefficient2,
         variable_coefficient3,
         variable_coefficient4,
         variable_coefficient5) as costs
      into annual_cost,
         capital_cost,
         variable_operation_maintenance_cost,
         fixed_operation_maintenance_cost,
         operation_maintenance_cost,
         annualized_capital_cost,
         computed_cost_per_ton;
      IF annual_cost is not null THEN
         valid_cost := true;
         actual_equation_type := 'Type 10';
      ELSE
         valid_cost := false;
         actual_equation_type := '-Type 10';
      END IF;
      -- adjust costs to the reference cost year
      annual_cost := ref_yr_chained_gdp_adjustment_factor * annual_cost;
      capital_cost := ref_yr_chained_gdp_adjustment_factor * capital_cost;
      variable_operation_maintenance_cost := ref_yr_chained_gdp_adjustment_factor *
variable_operation_maintenance_cost;
      fixed_operation_maintenance_cost := ref_yr_chained_gdp_adjustment_factor *
fixed_operation_maintenance_cost;
```

```
        operation_maintenance_cost := ref_yr_chained_gdp_adjustment_factor * 
operation_maintenance_cost;
        annualized_capital_cost := ref_yr_chained_gdp_adjustment_factor * 
annualized_capital_cost;
        computed_cost_per_ton := ref_yr_chained_gdp_adjustment_factor * 
computed_cost_per_ton;
        return;
    END IF;
    valid_cost := false;
    actual_equation_type := '-Type 10';
END IF;

-- Next the code will call the default CPT approach
--------------------------------------------------------------------------------------

-- Type 10
CREATE OR REPLACE FUNCTION public.get_type10_equation_costs(
    discount_rate double precision, 
    equipment_life double precision, 
    capital_recovery_factor double precision, 
    emis_reduction double precision, 
    design_capacity double precision, 
    annual_avg_hours_per_year double precision, 
    capital_cost_multiplier double precision, 
    capital_cost_exponent double precision, 
    variable_operation_maintenance_cost_multiplier double precision, 
    fixed_operation_maintenance_cost_multiplier double precision, 
    fixed_operation_maintenance_cost_exponent double precision, 
    OUT annual_cost double precision, 
    OUT capital_cost double precision, 
    OUT variable_operation_maintenance_cost double precision, 
    OUT fixed_operation_maintenance_cost double precision, 
    OUT operation_maintenance_cost double precision, 
    OUT annualized_capital_cost double precision, 
    OUT computed_cost_per_ton double precision)  AS $$
DECLARE
    cap_recovery_factor double precision := capital_recovery_factor;
BEGIN
    -- NOTES:
    -- design capacity must be in the units, MW

    -- get capital recovery factor, calculate if it wasn't passed in...
           IF coalesce(cap_recovery_factor, 0) = 0 and coalesce(discount_rate, 0) != 0 
and coalesce(equipment_life, 0) != 0 THEN
                cap_recovery_factor := 
public.calculate_capital_recovery_factor(discount_rate, equipment_life);
          END IF;

    -- calculate capital cost
    capital_cost := design_capacity * capital_cost_multiplier * 1000 * (250.0 / 
design_capacity) ^ capital_cost_exponent;

    -- calculate annualized capital cost
    annualized_capital_cost := capital_cost * cap_recovery_factor;


    -- calculate variable_operation_maintenance_cost
    variable_operation_maintenance_cost := 
variable_operation_maintenance_cost_multiplier * design_capacity * 0.85 * 
annual_avg_hours_per_year;

    -- calculate fixed_operation_maintenance_cost
```

```
    fixed_operation_maintenance_cost := design_capacity * 1000 *
fixed_operation_maintenance_cost_multiplier * (250 / design_capacity) ^
fixed_operation_maintenance_cost_exponent;

    -- calculate operation maintenance cost
    operation_maintenance_cost := variable_operation_maintenance_cost +
fixed_operation_maintenance_cost;

    -- calculate annual cost
    annual_cost := annualized_capital_cost + operation_maintenance_cost;

    -- calculate computed cost per ton
    computed_cost_per_ton :=
        case
            when coalesce(emis_reduction, 0) <> 0 then annual_cost / emis_reduction
            else null
        end;
END;
$$ LANGUAGE plpgsql IMMUTABLE;
```

A.11 Equation Type 11 CoST Code

```
---------------------------------------------------------------------------------

-- Code that funnels the source to the correct control measure cost equations.

-- NOTES:
--  design_capacity must be in the correct units, MW/hr is assumed if no units are
specified

-- Type 11
IF equation_type = 'Type 11' THEN

    -- convert design capacity to mmBTU/hr
    converted_design_capacity := 3.412 *
public.convert_design_capacity_to_mw(design_capacity, design_capacity_unit_numerator,
design_capacity_unit_denominator);

    IF coalesce(converted_design_capacity, 0) <> 0 THEN
        select costs.annual_cost,
            costs.capital_cost,
            costs.operation_maintenance_cost,
            costs.annualized_capital_cost,
            costs.computed_cost_per_ton
        from public.get_type11_equation_costs(discount_rate,
            equipment_life,
            capital_recovery_factor,
            capital_annualized_ratio,
            emis_reduction,
            converted_design_capacity,
            variable_coefficient1,
            variable_coefficient2,
            variable_coefficient3,
            variable_coefficient4,
            variable_coefficient5) as costs
        into annual_cost,
            capital_cost,
            operation_maintenance_cost,
            annualized_capital_cost,
            computed_cost_per_ton;
        IF annual_cost is not null THEN
```

```
          valid_cost := true;
          actual_equation_type := 'Type 11';
       ELSE
          valid_cost := false;
          actual_equation_type := '-Type 11';
       END IF;
       -- adjust costs to the reference cost year
       annual_cost := ref_yr_chained_gdp_adjustment_factor * annual_cost;
       capital_cost := ref_yr_chained_gdp_adjustment_factor * capital_cost;
       operation_maintenance_cost := ref_yr_chained_gdp_adjustment_factor *
operation_maintenance_cost;
       annualized_capital_cost := ref_yr_chained_gdp_adjustment_factor *
annualized_capital_cost;
       computed_cost_per_ton := ref_yr_chained_gdp_adjustment_factor *
computed_cost_per_ton;
       return;
   END IF;
   valid_cost := false;
   actual_equation_type := '-Type 11';
END IF;

-- Next the code will call the default CPT approach

----------------------------------------------------------------------------------

-- Type 11 - SO2 Non-IPM Control Equations
CREATE OR REPLACE FUNCTION public.get_type11_equation_costs(
   discount_rate double precision,
   equipment_life double precision,
   capital_recovery_factor double precision,
   capital_annualized_ratio double precision,
   emis_reduction double precision,
   design_capacity double precision,    -- needs to be in units of mmBTU/hr
   low_default_cost_per_ton double precision,
   low_boiler_capacity_range double precision,
   medium_default_cost_per_ton double precision,
   medium_boiler_capacity_range double precision,
   high_default_cost_per_ton double precision,
   OUT annual_cost double precision,
   OUT capital_cost double precision,
   OUT operation_maintenance_cost double precision,
   OUT annualized_capital_cost double precision,
   OUT computed_cost_per_ton double precision)  AS $$
DECLARE
   cap_recovery_factor double precision := capital_recovery_factor;
BEGIN
   -- get capital recovery factor, calculate if it wasn't passed in...
           IF coalesce(cap_recovery_factor, 0) = 0 and coalesce(discount_rate, 0) != 0
and coalesce(equipment_life, 0) != 0 THEN
                cap_recovery_factor :=
public.calculate_capital_recovery_factor(discount_rate, equipment_life);
          END IF;

   -- figure out cost per ton
   computed_cost_per_ton :=
       case
when design_capacity <= low_boiler_capacity_range then low_default_cost_per_ton
          when design_capacity > low_boiler_capacity_range and design_capacity <
medium_boiler_capacity_range then medium_default_cost_per_ton
          when design_capacity >= medium_boiler_capacity_range then
high_default_cost_per_ton
       end;
```

```
   -- calculate annual cost
   annual_cost := emis_reduction * computed_cost_per_ton;
   -- calculate capital cost
   capital_cost := annual_cost  * capital_annualized_ratio;
   -- calculate annualized capital cost
   annualized_capital_cost := capital_cost * cap_recovery_factor;
   -- calculate operation maintenance cost
   operation_maintenance_cost := annual_cost - annualized_capital_cost;

END;
$$ LANGUAGE plpgsql IMMUTABLE;
```

A.12 Equation Type 12 CoST Code

```
-------------------------------------------------------------------------------------
-- Code that funnels the source to the correct control measure cost equations.

-- NOTES:
--  stack flowrate was converted from cfs to cfm prior to getting here.

IF equation_type = 'Type 12' THEN

IF coalesce(stack_flow_rate, 0) <> 0 and coalesce(stack_temperature, 0) <> 0 THEN
       select costs.annual_cost,
          costs.capital_cost,
          costs.variable_operation_maintenance_cost,
          costs.fixed_operation_maintenance_cost,
          costs.operation_maintenance_cost,
          costs.annualized_capital_cost,
          costs.computed_cost_per_ton
       from public.get_type12_equation_costs(
          emis_reduction,
          stack_flow_rate,
          stack_temperature,
          capital_recovery_factor,
          variable_coefficient1,
          variable_coefficient2,
          variable_coefficient3,
          variable_coefficient4) as costs
       into annual_cost,
          capital_cost,
          variable_operation_maintenance_cost,
          fixed_operation_maintenance_cost,
          operation_maintenance_cost,
          annualized_capital_cost,
          computed_cost_per_ton;
       IF annual_cost is not null THEN
          valid_cost := true;
          actual_equation_type := 'Type 12';
       ELSE
          valid_cost := false;
          actual_equation_type := '-Type 12';
       END IF;
       -- adjust costs to the reference cost year
       annual_cost := ref_yr_chained_gdp_adjustment_factor * annual_cost;
       capital_cost := ref_yr_chained_gdp_adjustment_factor * capital_cost;
       variable_operation_maintenance_cost := ref_yr_chained_gdp_adjustment_factor * 
variable_operation_maintenance_cost;
       fixed_operation_maintenance_cost := ref_yr_chained_gdp_adjustment_factor * 
fixed_operation_maintenance_cost;
```

```
      operation_maintenance_cost := ref_yr_chained_gdp_adjustment_factor *
operation_maintenance_cost;
      annualized_capital_cost := ref_yr_chained_gdp_adjustment_factor *
annualized_capital_cost;
      computed_cost_per_ton := ref_yr_chained_gdp_adjustment_factor *
computed_cost_per_ton;
      return;
   END IF;
   valid_cost := false;
   actual_equation_type := '-Type 12';
END IF;

-- Next the code will call the default CPT approach

--------------------------------------------------------------------------------------

-- Type 12
CREATE OR REPLACE FUNCTION public.get_type12_equation_costs(
   emis_reduction double precision,     -- ton/yr
   stack_flow_rate double precision,    -- cfm
   stack_temperature double precision,  -- F
   capital_recovery_factor double precision,
   total_capital_investment_fixed_factor double precision,
   total_capital_investment_variable_factor double precision,
   annual_operating_cost_fixed_factor double precision,
   annual_operating_cost_variable_factor double precision,
   OUT annual_cost double precision,
   OUT capital_cost double precision,
   OUT variable_operation_maintenance_cost double precision,
   OUT fixed_operation_maintenance_cost double precision,
   OUT operation_maintenance_cost double precision,
   OUT annualized_capital_cost double precision,
   OUT computed_cost_per_ton double precision)  AS $$
DECLARE
   cap_recovery_factor double precision := capital_recovery_factor;
BEGIN
   -- calculate capital cost
   capital_cost := (coalesce(total_capital_investment_fixed_factor, 0.0) +
coalesce(total_capital_investment_variable_factor, 0.0)) * ((stack_flow_rate * 520 /
(stack_temperature + 460.0)) / 150000) ^ 0.6;

   -- calculate fixed operation maintenance cost
   fixed_operation_maintenance_cost := (coalesce(annual_operating_cost_fixed_factor,
0.0)) * ((stack_flow_rate * 520 / (stack_temperature + 460.0)) / 150000);

   -- calculate variable operation maintenance cost
   variable_operation_maintenance_cost :=
(coalesce(annual_operating_cost_variable_factor,0.0)) * ((stack_flow_rate * 520 /
(stack_temperature + 460.0)) / 150000);

   -- calculate operation maintenance cost
   operation_maintenance_cost := fixed_operation_maintenance_cost +
variable_operation_maintenance_cost;

   -- calculate annualized capital cost
   annualized_capital_cost := capital_cost * cap_recovery_factor;

   -- calculate annual cost
   annual_cost := operation_maintenance_cost + annualized_capital_cost;

   -- calculate computed cost per ton
   computed_cost_per_ton :=
      case
```

```
          when coalesce(emis_reduction, 0) <> 0 then annual_cost / emis_reduction
          else null
       end;
END;
$$ LANGUAGE plpgsql IMMUTABLE;
```

A.13 Equation Type 13 CoST Code

This is the portion of the source code that is specific for Equation 13. The complete source code with overall logic is not included here.

```
annual_cost_expression := '(' ||
' || case when not has_design_capacity_columns then '' else '
              -- Equation Type 13
              when coalesce(' || equation_type_table_alias || '.name,'''') = ''Type 
13'' and coalesce(' || convert_design_capacity_expression || ', 0) <> 0 and coalesce(' 
|| stkflow_expression || ', 0) <> 0 then '
|| chained_gdp_adjustment_factor_expression || ' * 
                 (
                 (' || control_measure_equation_table_alias || '.value1 * 3.412 * ' || 
convert_design_capacity_expression || ' ^ ' || control_measure_equation_table_alias || 
'.value2 + ' || control_measure_equation_table_alias || '.value3 * 3.412 * ' || 
convert_design_capacity_expression || ' ^ ' || control_measure_equation_table_alias || 
'.value4)/*capital_cost*/ * (' || capital_recovery_factor_expression || ')
                 + (' || control_measure_equation_table_alias || '.value5 + ' || 
control_measure_equation_table_alias || '.value6 * 3.412 * ' || 
convert_design_capacity_expression || ' ^ ' || control_measure_equation_table_alias || 
'.value7 + ' || control_measure_equation_table_alias || '.value8 * 3.412 * ' || 
convert_design_capacity_expression || ' ^ ' || control_measure_equation_table_alias || 
'.value9 + ' || control_measure_equation_table_alias || '.value10 * (' || 
stkflow_expression || ' / 60.0) + ' || control_measure_equation_table_alias || 
'.value11 * ' || emis_reduction_sql || ')/*operation_maintenance_cost*/
                 )
' end || ')';

capital_cost_expression := '(' ||
' || case when not has_design_capacity_columns then '' else '
              -- Equation Type 13
              when coalesce(' || equation_type_table_alias || '.name,'''') = ''Type 
13'' and coalesce(' || convert_design_capacity_expression || ', 0) <> 0 and coalesce(' 
|| stkflow_expression || ', 0) <> 0 then '
|| chained_gdp_adjustment_factor_expression || ' * 
                 (' || control_measure_equation_table_alias || '.value1 * 3.412 * ' || 
convert_design_capacity_expression || ' ^ ' || control_measure_equation_table_alias || 
'.value2 + ' || control_measure_equation_table_alias || '.value3 * 3.412 * ' || 
convert_design_capacity_expression || ' ^ ' || control_measure_equation_table_alias || 
'.value4)
' end || ')';

operation_maintenance_cost_expression := '(' ||
' || case when not has_design_capacity_columns then '' else '
              -- Equation Type 13
              when coalesce(' || equation_type_table_alias || '.name,'''') = ''Type 
13'' and coalesce(' || convert_design_capacity_expression || ', 0) <> 0 and coalesce(' 
|| stkflow_expression || ', 0) <> 0 then '
|| chained_gdp_adjustment_factor_expression || ' * 
                 (' || control_measure_equation_table_alias || '.value5 + ' || 
control_measure_equation_table_alias || '.value6 * 3.412 * ' || 
convert_design_capacity_expression || ' ^ ' || control_measure_equation_table_alias || 
'.value7 + ' || control_measure_equation_table_alias || '.value8 * 3.412 * ' ||
```

```
convert_design_capacity_expression || ' ^ ' || control_measure_equation_table_alias ||
'.value9 + ' || control_measure_equation_table_alias || '.value10 * (' ||
stkflow_expression || ' / 60.0) + ' || control_measure_equation_table_alias ||
'.value11 * ' || emis_reduction_sql || ')
' end || ')';

annualized_capital_cost_expression := '(' ||
```

A.14 Equation Type 14 CoST Code

This is the portion of the source code that is specific for Equation Type 14. The complete source code with overall logic is not included here.

```
   --type 14 variables
   t14_use_equation text;
   t14_fa text;
   t14_fd text;
   t14_noducts text;
   t14_cpm text;
   t14_tci text;
   t14_tac text;

-- TYPE 14 definition Fabric Filter ---------------
/*

F_a=(V_Exhaust )(DC)/60    Equation 1

Where:
Fa = Exhaust flowrate, ACFM
VExhaust  = Relative Exhaust Volume, ACF/MMBtu --> ' ||
control_measure_equation_table_alias || '.value1
DC = Design Capacity of Unit, MMBtu/hr  --> convert_design_capacity_expression

t14_fa := '(' || control_measure_equation_table_alias || '.value5 * (' ||
convert_design_capacity_expression || ') / 60.0 || ')';

F_a = ' || control_measure_equation_table_alias || '.value5 * (' ||
convert_design_capacity_expression || ') / 60.0

F_d=F_a ((460+68)/(460+T))(1-%_Moist/100)      Equation 2

t14_fd := '((' || t14_fa || ') * ((460.0 + 68.0)/(460.0 + ' || inv_table_alias ||
'.stktemp)) * (1.0 - ' || control_measure_equation_table_alias || '.value2 / 100.0))';

F_d = (' || control_measure_equation_table_alias || '.value5 * (' ||
convert_design_capacity_expression || ') / 60.0) * ((460.0 + 68.0)/(460.0 + ' ||
inv_table_alias || '.stktemp)) * (1.0 - ' || control_measure_equation_table_alias ||
'.value2 / 100.0)

Where:
Fd = Exhaust flowrate, DSCFM
Fa = Exhaust flowrate, ACFM
T  = Assumed Stack Gas Temperature, Â°F --> ' || inv_table_alias || '.stktemp
%Moist = Assumed Stack Gas Moisture Content, % --> ' ||
control_measure_equation_table_alias || '.value1

t14_noducts := '(case when  ' || t14_fd || ' <= 154042.0 then 1 else ceiling(' ||
t14_fd || ' / 154042.0) end)';

TCI=(105.91)(F_d )+(699754.7)+[(0.560) (âˆš(F_a )/#_Ducts )^2 ]+[(1096.141)
e^(0.017)(âˆš(F_a )/#_Ducts )  ]+[(33.977) e^(0.014)(âˆš(F_a )/#_Ducts )  ]
```

```
t14_tci := '((105.91) * (' || t14_fd || ')+(699754.7)+((0.560) * (sqrt(' || t14_fa ||
')/' || t14_noducts || ' )^2) + ((1096.141) * exp((0.017) * (sqrt(' || t14_fa || ')/'
|| t14_noducts || ' ))) + ((33.977) * exp((0.014) * (sqrt(' || t14_fa || ')/' ||
t14_noducts || ' ))))';

Where:
Fd = Exhaust Flowrate, dry standard cubic feet per minute (DSCFM)
Fa = Exhaust Flowrate, actual cubic feet per minute (ACFM)
#Ducts = If Fd â‰¤ 154042, #Ducts = 1;
If Fd > 154042, #Ducts = Fd / 154042

select case when  154044.0 <= 154042.0 then 1 else ceiling(1540404.0 / 154042.0) end

B-1b:  TOTAL ANNUALIZED COSTS (TAC)

TAC=[(17.44)(ã€–Opã€—_Hrs )]+{(TCI)[(0.072)+(((i) (1+i)^(ã€–Eqã€—_Life ))/((1+i)^(ã€–
Eqã€—_Life )-1))]}+{(F_a )[(4.507)+(0.0000124)(ã€–Opã€—_Hrs )-(4.184)(((i) (1+i)^(ã€–
Eqã€—_Life ))/((1+i)^(ã€–Eqã€—_Life )-1))]}+{(F_d )(ã€–Opã€—_Hrs
)[(0.00376)+(0.00181)(C_PM )]}

t14_tac := '[(17.44)(' || inv_table_alias || '.annual_avg_hours_per_year || ')]+{(' ||
t14_tci || ')[(0.072)+(' || capital_recovery_factor_expression || ')]}+{(' || t14_fa
|| ')[(4.507)+(0.0000124)(' || inv_table_alias || '.annual_avg_hours_per_year || ')-
(4.184)(' || capital_recovery_factor_expression || ')]}+{(' || t14_fd || ')(' ||
inv_table_alias || '.annual_avg_hours_per_year || ')[(0.00376)+(0.00181)(C_PM )]}';

Where:
Fd = Exhaust Flowrate, dry standard cubic feet per minute (DSCFM)
OpHrs  = Annual operating hours of unit (hrs/yr)
TCI = Total Capital Investment ($)
Fa = Exhaust Flowrate, actual cubic feet per minute (ACFM)
CPM = Concentration of PM in stack gas, grains per dry standard cubic foot (gr/dscf)
i  = Interest rate expressed as a fraction of 1 (percentage divided by 100)
EqLife = Estimated equipment life, years

Equation Type Definition:

Measure Specific Equation Type Variable Inputs:  value1 --> % Moisture
Inventory Inputs:
   design capacity
   design capacity units
   stack temperature
   stack flow rate (in cfm)
   operating hours (in hrs/yr)
*/

t14_use_equation := 'coalesce(' || equation_type_table_alias || '.name,'''') = ''Type
14'' and coalesce(' || convert_design_capacity_expression || ', 0) <> 0 and coalesce('
|| inv_table_alias || '.stktemp, 0) <> 0 and coalesce(' || stkflow_expression || ', 0)
<> 0 and coalesce(' || inv_table_alias || '.annual_avg_hours_per_year, 0.0) <> 0.0';

--use brenda shines approach

t14_fa := '(' || stkflow_expression || ')';

t14_fd := '((' || t14_fa || ') * ((460.0 + 68.0)/(460.0 + ' || inv_table_alias ||
'.stktemp)) * (1.0 - ' || control_measure_equation_table_alias || '.value1 / 100.0))';

t14_noducts := '(case when  ' || t14_fd || ' <= 154042.0 then 1 else round(' || t14_fd
|| ' / 154042.0) end)';

t14_cpm := '(' || emis_sql || ') * 1.725 * 15.4323584 / (' || t14_fd || ')';
```

```
      /*1 ton/year = 1.725 grams/minute (from David)  1 gram = 15.4323584 grains */

t14_tci := '((105.91) * (' || t14_fd || ')+(699754.7)+((0.560) * (sqrt(' || t14_fa ||
')/' || t14_noducts || ' )^2) + ((1096.141) * exp((0.017) * (sqrt(' || t14_fa || ')/'
|| t14_noducts || ' ))) + ((33.977) * exp((0.014) * (sqrt(' || t14_fa || ')/' ||
t14_noducts || ' ))))';

t14_tac := '((17.44) * (' || inv_table_alias || '.annual_avg_hours_per_year))+((' ||
t14_tci || ') * ((0.072)+(' || capital_recovery_factor_expression || ')))+((' ||
t14_fa || ') * ((4.507)+(0.0000124) * (' || inv_table_alias ||
'.annual_avg_hours_per_year)-(4.184) * (' || capital_recovery_factor_expression ||
')))+((' || t14_fd || ') * (' || inv_table_alias || '.annual_avg_hours_per_year) *
((0.00376)+(0.00181) * (' || t14_cpm || ')))';
```

A.15 Equation Type 15 CoST Code

This is the portion of the source code that is specific for Equation Type 15. The complete source code with overall logic is not included here.

```
   --type 15 variables
   t15_use_equation text;
   t15_fa text;
   t15_noducts text;
   t15_ec1 text;
   t15_ec2 text;
   t15_pm_emis_rate text;
   t15_tci text;
   t15_tac text;

-- TYPE 15 definition Electrostatic Precipitator  ---------------
/*
TCI={(12.265)(ã€–ECã€—_1 ) [(5.266)(F_a )]^(ã€–ECã€—_2 ) }+[(0.784)(F_a/#_Ducts
)]+(#_Ducts ){[(2237.13)(e^(0.017)(âˆš(F_a )/#_Ducts )  )]+[(69.345)(e^(0.014)(âˆš(F_a
)/#_Ducts )  )]+(17588.69)}

Where:
EC1 = First equipment cost factor for ESP;
If Fa â‰¥ 9495, EC1 = 57.87;
If Fa < 9495, EC1 = 614.55
Fa  = Exhaust Flowrate, actual cubic feet per minute (ACFM)
EC2 = Second equipment cost factor for ESP;
If Fa â‰¥ 9495, EC2 = 0.8431;
If Fa < 9495, EC2 = 0.6276
#Ducts = If Fa < 308084, #Ducts = 1;
If 308084 â‰¤ Fa < 462126, #Ducts = 2;
If 462126 â‰¤ Fa < 616168, #Ducts = 3;
If Fa â‰¥ 616168, #Ducts = 4

B-2b:  TOTAL ANNUALIZED COSTS (TAC)

TAC=[(10.074)(ã€–Opã€—_Hrs )]+[(0.052)(F_a )]+{(0.00656)(1.04+(((i) (1+i)^(ã€–Eqã€—
_Life ))/((1+i)^(ã€–Eqã€—_Life )-1)))((ã€–ECã€—_1 ) [(5.266)(F_a )]^(ã€–ECã€—_2 )
)}+[(0.021)(ã€–Opã€—_Hrs )(E_PM )(DC)]+{(0.0000117)(F_a )(ã€–Opã€—_Hrs
)[(1.895)+((479.85) (1/âˆš(F_a ))^1.18 )]}+[(0.000715)(ã€–Opã€—_Hrs )(F_a
)]+{(0.04+(((i) (1+i)^(ã€–Eqã€—_Life ))/((1+i)^(ã€–Eqã€—_Life )-1)))(#_Ducts )[(0.783)
(âˆš(F_a )/#_Ducts )^2+(2237.44)(e^(0.0165)(âˆš(F_a )/#_Ducts )
)+(69.355)(e^(0.0140)(âˆš(F_a )/#_Ducts )  )+(17591.15)]}

Where:
OpHrs  = Annual operating hours of unit (hrs/yr)
```

```
Fa  = Exhaust Flowrate, actual cubic feet per minute (ACFM)
i   = Interest rate expressed as a fraction of 1 (percentage divided by 100)
EqLife = Estimated equipment life, years
EC1 = First equipment cost factor for ESP;
If Fa â‰¥ 9495, EC1 = 57.87;
If Fa < 9495, EC1 = 614.55
EC2 = Second equipment cost factor for ESP;
If Fa â‰¥ 9495, EC2 = 0.8431;
If Fa < 9495, EC2 = 0.6276
EPM = PM emission rate, pounds per million British thermal units (lb/MMBtu)
DC  = Design capacity of boiler, million British thermal units per hour (MMBtu/hr)
#Ducts = If Fa < 308084, #Ducts = 1;
If 308084 â‰¤ Fa < 462126, #Ducts = 2;
If 462126 â‰¤ Fa < 616168, #Ducts = 3;
If Fa â‰¥ 616168, #Ducts = 4

Equation Type Definition:

Measure Specific Equation Type Variable Inputs:  value1 --> % Moisture
Inventory Inputs:
   design capacity
   design capacity units
   stack temperature
   stack flow rate (in cfm)
   operating hours (in hrs/yr)
*/

t15_use_equation := 'coalesce(' || equation_type_table_alias || '.name,'''') = ''Type
15'' and coalesce(' || convert_design_capacity_expression || ', 0) <> 0 and coalesce('
|| inv_table_alias || '.stktemp, 0) <> 0 and coalesce(' || stkflow_expression || ', 0)
<> 0 and coalesce(' || inv_table_alias || '.annual_avg_hours_per_year, 0.0) <> 0.0';

--use brenda shines approach

t15_fa := '(' || stkflow_expression || ')';

t15_ec1 := '(case when  ' || t15_fa || ' < 9495.0 then 614.55 else 57.87 end)';

t15_ec2 := '(case when  ' || t15_fa || ' < 9495.0 then 0.6276 else 0.8431 end)';

t15_noducts := '(case when  ' || t15_fa || ' < 308084.0 then 1 when  ' || t15_fa || '
>= 308084.0 and ' || t15_fa || ' < 462126.0 then 2 when  ' || t15_fa || ' >= 462126.0
and ' || t15_fa || ' < 616168.0 then 3 else 4 end)';
t15_pm_emis_rate := '(' || emis_sql || ') * 2000.0 / 365.0 / 24.0 / (3.412 * ' ||
convert_design_capacity_expression || ')';

t15_tci := '((12.265) * (' || t15_ec1 || ') * ((5.266) * (' || t15_fa || ' ))^(' ||
t15_ec2 || ') )+((0.784) * (' || t15_fa || '/' || t15_noducts || '))+(' || t15_noducts
|| ') * (((2237.13) * (exp((0.017) * (sqrt(' || t15_fa || ')/' || t15_noducts ||
'))))+((69.345) * (exp((0.014) * (sqrt(' || t15_fa || ')/' || t15_noducts ||
'))))+(17588.69))';

t15_tac := '((10.074) * (' || inv_table_alias ||
'.annual_avg_hours_per_year))+((0.052) * (' || t15_fa || '))+((0.00656) * (1.04+((' ||
capital_recovery_factor_expression || '))) * ((' || t15_ec1 || ') * ((5.266) * (' ||
t15_fa || '))^(' || t15_ec2 || ') ))+((0.021) * (' || inv_table_alias ||
'.annual_avg_hours_per_year) * (' || t15_pm_emis_rate || ') * (3.412 * ' ||
convert_design_capacity_expression || '))+((0.0000117) * (' || t15_fa || ') * (' ||
inv_table_alias || '.annual_avg_hours_per_year) * ((1.895)+((479.85) * (1/sqrt(' ||
t15_fa || '))^1.18 )))+((0.000715) * (' || inv_table_alias ||
'.annual_avg_hours_per_year) * (' || t15_fa || '))+((0.04+((' ||
capital_recovery_factor_expression || '))) * (' || t15_noducts || ') * ((0.783) *
(sqrt(' || t15_fa || ')/(' || t15_noducts || '))^2+(2237.44) * (exp((0.0165) * (sqrt('
```

```
|| t15_fa || ')/(' || t15_noducts || '))))+(69.355) * (exp((0.0140) * (sqrt(' ||
t15_fa || ')/(' || t15_noducts || '))))+(17591.15)))';
```

A.16 Equation Type 16 CoST Code

This is the portion of the source code that is specific for Equation Type 16. The complete source code with overall logic is not included here.

```
   --type 16 variables
   t16_use_equation text;
   t16_fa text;
   t16_noscrubbers text;
   t16_so2_mole_conc text;
   t16_tci text;
   t16_tac text;

-- TYPE 16 definition WET SCRUBBER  ---------------
/*

APPENDIX B-3:  WET SCRUBBER COST EQUATIONS
________________________________________

B-3a:  TOTAL CAPITAL INVESTMENT (TCI)

TCI=[(2.88)(#_Scrub )(F_a )]+[(1076.54)(#_Scrub ) √((F_a ) )]+[(9.759)(F_a
)]+[(360.463) √((F_a ) )]

Where:
#Scrub = If Fa < 149602, #Scrub = 1;
If 149602 ≤ Fa < 224403, #Scrub = 2;
If 224403 ≤ Fa < 299204, #Scrub = 3;
If 299204 ≤ Fa < 374005, #Scrub = 4;
If Fa ≥ 374005, #Scrub = 5
Fa  = Exhaust Flowrate, actual cubic feet per minute (ACFM)

B-3b:  TOTAL ANNUALIZED COSTS (TAC)

TAC=[(#_Scrub )(TCI)(((i) (1+i)^( Eq_Life ))/((1+i)^( Eq_Life )-
1))]+[(0.04)(TCI)]+{(20.014)(#_Scrub )(F_a )( Op_Hrs )[C_SO2-(C_SO2 )((100-98)/(100-
(98)(C_SO2 ) ))]}+[(16.147)(#_Scrub )( Op_Hrs )]+{(0.0000117)(F_a )( Op_Hrs
)(#_Scrub )[((479.85) (1/√(F_a ))^1.18 )+(6.895)]}+[(0.0000133)( Op_Hrs )(#_Scrub
)(F_a )]

Where:
#Scrub = If Fa < 149602, #Scrub = 1;
If 149602 ≤ Fa < 224403, #Scrub = 2;
If 224403 ≤ Fa < 299204, #Scrub = 3;
If 299204 ≤ Fa < 374005, #Scrub = 4;
If Fa ≥ 374005, #Scrub = 5
TCI = Total Capital Investment ($)
i   = Interest rate expressed as a fraction of 1 (percentage divided by 100)
EqLife = Estimated equipment life, years
Fa  = Exhaust Flowrate, actual cubic feet per minute (ACFM)
CSO2   = Mole fraction of SO2 in exhaust gas
OpHrs  = Annual operating hours of unit (hrs/yr)

CSO2 calculation:

Calculate volume (ft3/lb-mole) of NOx in gaseous form under standard conditions (60 F,
1 atm) using Ideal Gas Law, pV = nRT or V/n = RT/p, where:
   V = volume in ft3
   n = molecular weight of SO2 (64.06 lb/lb-mole)
```

```
   R = gas constant (0.7302 atm-ft3/lb-mole R)
   T = absolute temperature in Rankin (F + 460) = 60 + 460 = (520 R)
   p = pressure in atmospheres (1 atm)
Ideal Gas Law approximates the volume of a gas under certain conditions.

V/n = (0.7302 x 520) / (1) = 379.7 ft3/lb-mole

Calculate SO2 emissions (lb-mole/yr):

   n = 53.33 tons/yr SO2  x  2000 lb/ton  x  1 lb-mole / 64.06 lbs SO2 = 1,665 lb-
mole/yr

Convert SO2 emissions (lb-mole/yr) to SO2 volumetric flowrate (ft3/min):

1,665 lb-mole/yr x 1 yr/8736 hrs x 1 hr/60 min x 379.7ft3/lb-mole = 1.206 ft3/min

   Calculate outlet concentration of SO2 (ppmv):

ppmv SO2 = ( SO2 emissions (ft3/min) / Stack vol flowrate scfm ) x 10^6

ppmv SO2 = ( 1.206 ft3/min / 20,170 ft3/min ) x 10^6  = 59.79 ppmv

mole fraction SO2 = 59.79 ppmv / 10^6 = 5.979e-5 mole fraction SO2

Equation Type Definition:

Measure Specific Equation Type Variable Inputs:  NONE
Inventory Inputs:
   stack flowrate (in cfm)
   operating hours (in hrs/yr)
*/

t16_use_equation := 'coalesce(' || equation_type_table_alias || '.name,'''') = ''Type
16'' and coalesce(' || stkflow_expression || ', 0) <> 0 and coalesce(' ||
inv_table_alias || '.annual_avg_hours_per_year, 0.0) <> 0.0';
t16_fa := '(' || stkflow_expression || ')';

t16_noscrubbers := '(case when  ' || t16_fa || ' < 149602.0 then 1 when  ' || t16_fa
|| ' >= 149602.0 and ' || t16_fa || ' < 224403.0 then 2 when  ' || t16_fa || ' >=
224403.0 and ' || t16_fa || ' < 299204.0 then 3 when  ' || t16_fa || ' >= 299204.0 and
' || t16_fa || ' < 374005.0 then 4 else 5 end)';

t16_so2_mole_conc := '((' || emis_sql || ') * 2000.0 / (64.06) / ' || inv_table_alias
|| '.annual_avg_hours_per_year / 60 * ((0.7302 * 520) / (1.0)) / ( (' || t16_fa || ')
* 520 / ((' || inv_table_alias || '.stktemp) + 460.0)))';

t16_tci := '((2.88) * (' || t16_noscrubbers || ') * (' || t16_fa || '))+((1076.54) *
(' || t16_noscrubbers || ') * sqrt(' || t16_fa || '))+((9.759) * (' || t16_fa ||
'))+((360.463) * sqrt(' || t16_fa || '))';

t16_tac := '((' || t16_noscrubbers || ') * (' || t16_tci || ') * (' ||
capital_recovery_factor_expression || '))+((0.04) * (' || t16_tci || '))+((20.014) *
(' || t16_noscrubbers || ') * (' || t16_fa || ') * (' || inv_table_alias ||
'.annual_avg_hours_per_year) * ((' || t16_so2_mole_conc || ')-(' || t16_so2_mole_conc
|| ') * ((100.0-98.0)/(100.0-(98.0) * (' || t16_so2_mole_conc || ') ))))+((16.147) *
(' || t16_noscrubbers || ') * (' || inv_table_alias ||
'.annual_avg_hours_per_year))+((0.0000117) * (' || t16_fa || ') * (' ||
inv_table_alias || '.annual_avg_hours_per_year) * (' || t16_noscrubbers || ') *
(((479.85) * (1/sqrt(' || t16_fa || '))^1.18 )+(6.895)))+((0.0000133) * (' ||
inv_table_alias || '.annual_avg_hours_per_year) * (' || t16_noscrubbers || ') * (' ||
t16_fa || '))';
```

A.17 Equation Type 17 CoST Code

This is the portion of the source code that is specific for Equation Type 17. The complete source code with overall logic is not included here.

```
   --type 17 variables
   t17_use_equation text;
   t17_fa text;
   t17_fd text;
   t17_noducts text;
   t17_pm_conc text;
   t17_so2_conc text;
   t17_tci text;
   t17_tac text;

-- TYPE 17 definition Dry Injection/fabric Filter System (DIFF)  ---------------
/*

APPENDIX B-4:  DRY INJECTION/FABRIC FILTER SYSTEM (DIFF) COST EQUATIONS
________________________________________

B-4a:  TOTAL CAPITAL INVESTMENT (TCI)

TCI=[(143.76)(F_d )]+[(0.610) (âˆš(F_a )/#_Ducts )^2 ]+[(1757.65) e^(0.017)(âˆš(F_a
)/#_Ducts )  ]+[(59.973) e^(0.014)(âˆš(F_a )/#_Ducts )  ]+(931911.04)

Where:
Fd = Exhaust Flowrate, dry standard cubic feet per minute (DSCFM)
Fa = Exhaust Flowrate, actual cubic feet per minute (ACFM)
#Ducts = If Fd â‰¤ 154042, #Ducts = 1;
If Fd > 154042, #Ducts = Fd / 154042

B-4b:  TOTAL ANNUALIZED COSTS (TAC)

TAC=[(0.00162)(ã€–Opã€—_Hrs )(F_d )]+[(17.314)(ã€–Opã€—_Hrs )]+[(0.00000105)(C_SO2
)(F_d )(ã€–Opã€—_Hrs )]+[(0.0000372)(ã€–Opã€—_Hrs )(F_a )]+[(0.000181)(ã€–Opã€—_Hrs
)(C_PM )(F_d )]+[(0.847)(1-(((i) (1+i)^(ã€–Eqã€—_Life ))/((1+i)^(ã€–Eqã€—_Life )-
1)))(F_a )]+[(0.04)+(((i) (1+i)^(ã€–Eqã€—_Life ))/((1+i)^(ã€–Eqã€—_Life )-
1))]{[(0.032)(TCI)]+[(0.606) (âˆš(F_a )/#_Ducts )^2 ]+[(1757.65) e^(0.017)(âˆš(F_a
)/#_Ducts )  ]+[(53.973) e^(0.014)(âˆš(F_a )/#_Ducts )  ]+(13689.81)}

Where:
Fd = Exhaust Flowrate, dry standard cubic feet per minute (DSCFM)
OpHrs  = Annual operating hours of unit (hrs/yr)
CSO2   = Concentration of SO2 in stack gas, dry parts per million by volume (ppmvd)
Fa = Exhaust Flowrate, actual cubic feet per minute (ACFM)
CPM = Concentration of PM in stack gas, grains per dry standard cubic foot (gr/dscf)
i  = Interest rate expressed as a fraction of 1 (percentage divided by 100)
EqLife = Estimated equipment life, years
#Ducts = If Fd â‰¤ 154042, #Ducts = 1;
If Fd > 154042, #Ducts = Fd / 154042

Equation Type Definition:

Measure Specific Equation Type Variable Inputs:  value1 --> % Moisture
Inventory Inputs:
   stack temperature
   stack flow rate (in cfm)
   operating hours (in hrs/yr)

*/
```

```
t17_use_equation := 'coalesce(' || equation_type_table_alias || '.name,'''') = ''Type
17'' and coalesce(' || inv_table_alias || '.stktemp, 0) <> 0 and coalesce(' ||
stkflow_expression || ', 0) <> 0 and coalesce(' || inv_table_alias ||
'.annual_avg_hours_per_year, 0.0) <> 0.0';

--use brenda shines approach

t17_fa := '(' || stkflow_expression || ')';

t17_fd := '((' || t17_fa || ') * ((460.0 + 68.0)/(460.0 + ' || inv_table_alias ||
'.stktemp)) * (1.0 - ' || control_measure_equation_table_alias || '.value1 / 100.0))';

t17_noducts := '(case when  ' || t17_fd || ' <= 154042.0 then 1 else round(' || t17_fd
|| ' / 154042.0) end)';

t17_pm_conc := '(' || emis_sql || ') * 1.725 * 15.4323584 / (' || t17_fd || ')'; /*1
ton/year = 1.725 grams/minute (from David)  1 gram = 15.4323584 grains */

t17_so2_conc := '((' || so2_emis_sql || ') * 2000.0 / (64.06) / ' || inv_table_alias
|| '.annual_avg_hours_per_year / 60 * ((0.7302 * 520) / (1.0)) / ( (' || t17_fa || ')
* 520 / ((' || inv_table_alias || '.stktemp) + 460.0))) * 10^6';

t17_tci := '((143.76) * (' || t17_fd || '))+((0.610) * (sqrt(' || t17_fa || ')/' ||
t17_noducts || ')^2 )+((1757.65) * exp((0.017) * (sqrt(' || t17_fa || ')/' ||
t17_noducts || ')))+((59.973) * exp((0.014) * (sqrt(' || t17_fa || ')/' || t17_noducts
|| ')))+(931911.04)';

t17_tac := '((0.00162) * (' || inv_table_alias || '.annual_avg_hours_per_year) * (' ||
t17_fd || '))+((17.314) * (' || inv_table_alias ||
'.annual_avg_hours_per_year))+((0.00000105) * (' || t17_so2_conc || ' ) * (' || t17_fd
|| ') * (' || inv_table_alias || '.annual_avg_hours_per_year))+((0.0000372) * (' ||
inv_table_alias || '.annual_avg_hours_per_year) * (' || t17_fa || '))+((0.000181) * ('
|| inv_table_alias || '.annual_avg_hours_per_year) * (' || t17_pm_conc || ') * (' ||
t17_fd || '))+((0.847) * (1-(' || capital_recovery_factor_expression || ')) * (' ||
t17_fa || '))+((0.04)+(' || capital_recovery_factor_expression || ')) * (((0.032) * ('
|| t17_tci || '))+((0.606) * (sqrt(' || t17_fa || ')/' || t17_noducts || ')^2
)+((1757.65) * exp((0.017) * (sqrt(' || t17_fa || ')/' || t17_noducts ||
')))+((53.973) * exp((0.014) * (sqrt(' || t17_fa || ')/' || t17_noducts ||
')))+(13689.81))';
```

A.18 Equation Type 18 CoST Code

This is the portion of the source code that is specific for Equation Type 18. The complete source code with overall logic is not included here.

```
   --type 18 variables
   t18_use_equation text;
   t18_fa text;
   t18_fd text;
   t18_so2_conc text;
   t18_tci text;
   t18_tac text;

-- TYPE 18 definition INCREASED CAUSTIC INJECTION RATE FOR EXISTING DRY INJECTION
CONTROL  ----------
/*
APPENDIX B-5:  INCREASED CAUSTIC INJECTION RATE FOR EXISTING DRY INJECTION CONTROL
COST EQUATIONS
```

```
B-5a:  TOTAL CAPITAL INVESTMENT (TCI)

TCI=0

Where:
N/A

B-5b:  TOTAL ANNUALIZED COSTS (TAC)

TAC=(0.00000387)(C_SO2 )(F_d )(ã€–Opã€—_Hrs )

Where:
CSO2   = Concentration of SO2 in stack gas, dry parts per million by volume (ppmvd)
Fd = Exhaust Flowrate, dry standard cubic feet per minute (DSCFM)
OpHrs  = Annual operating hours of unit (hrs/yr)

Equation Type Definition:

Measure Specific Equation Type Variable Inputs:  value1 --> % Moisture
Inventory Inputs:
   stack temperature
   stack flowrate (in cfm)
   operating hours (in hrs/yr)
*/

t18_use_equation := 'coalesce(' || equation_type_table_alias || '.name,'''') = ''Type
18'' and coalesce(' || inv_table_alias || '.stktemp, 0) <> 0 and coalesce(' ||
stkflow_expression || ', 0) <> 0 and coalesce(' || inv_table_alias ||
'.annual_avg_hours_per_year, 0.0) <> 0.0';

--use brenda shines approach

t18_fa := '(' || stkflow_expression || ')';

t18_fd := '((' || t18_fa || ') * ((460.0 + 68.0)/(460.0 + ' || inv_table_alias ||
'.stktemp)) * (1.0 - ' || control_measure_equation_table_alias || '.value1 / 100.0))';

t18_so2_conc := '((' || emis_sql || ') * 2000.0 / (64.06) / ' || inv_table_alias ||
'.annual_avg_hours_per_year / 60 * ((0.7302 * 520) / (1.0)) / (    (' || t18_fa || ')
* 520 / ((' || inv_table_alias || '.stktemp) + 460.0))) * 10^6';

t18_tci := '0.0';

t18_tac := '(0.00000387) * (' || t18_so2_conc || ') * (' || t18_fd || ') * (' ||
inv_table_alias || '.annual_avg_hours_per_year)';
```

A.19 Equation Type 19 CoST Code

This is the portion of the source code that is specific for Equation Type 19. The complete source code with overall logic is not included here.

```
--type 19 variables
t19_use_equation text;
t19_fa text;
t19_fd text;
t19_noducts text;
t19_so2_conc text;
t19_tci text;
t19_tac text;
```

```
-- TYPE 19 definition SPRAY DRYER ABSORBER  ---------------
/*
APPENDIX B-6:  SPRAY DRYER ABSORBER COST EQUATIONS
________________________________________

B-6a:  TOTAL CAPITAL INVESTMENT (TCI)

TCI=[(143.76)(F_d )]+[(0.610) (âˆš(F_a )/#_Ducts )^2 ]+[(17412.26) e^(0.017)(âˆš(F_a
)/#_Ducts )  ]+[(53.973) e^(0.014)(âˆš(F_a )/#_Ducts )  ]+(931911.04)

Where:
Fd = Exhaust Flowrate, dry standard cubic feet per minute (DSCFM)
Fa = Exhaust Flowrate, actual cubic feet per minute (ACFM)
#Ducts = If Fd â‰¤ 154042, #Ducts = 1;
If Fd > 154042, #Ducts = Fd / 154042

B-6b:  TOTAL ANNUALIZED COSTS (TAC)

TAC=(ã€–Opã€—_Hrs ){[(0.00162)(F_d )]+[(0.000000684)(C_SO2 )(F_d )]+[(0.0000372)(F_a
)]+(21.157)}+{[0.072+(((i) (1+i)^(ã€–Eqã€—_Life ))/((1+i)^(ã€–Eqã€—_Life )-1))](TCI)}

Where:
Fd = Exhaust Flowrate, dry standard cubic feet per minute (DSCFM)
Fa = Exhaust Flowrate, actual cubic feet per minute (ACFM)
OpHrs  = Annual operating hours of unit (hrs/yr)
CSO2   = Concentration of SO2 in stack gas, dry parts per million by volume (ppmvd)
TCI = Total Capital Investment ($)
i  = Interest rate expressed as a fraction of 1 (percentage divided by 100)
EqLife = Estimated equipment life, years

Equation Type Definition:

Measure Specific Equation Type Variable Inputs:  value1 --> % Moisture
Inventory Inputs:
    stack temperature
    stack flowrate (in cfm)
    operating hours (in hrs/yr)
*/

t19_use_equation := 'coalesce(' || equation_type_table_alias || '.name,'''') = ''Type
19'' and coalesce(' || inv_table_alias || '.stktemp, 0) <> 0 and coalesce(' ||
stkflow_expression || ', 0) <> 0 and coalesce(' || inv_table_alias ||
'.annual_avg_hours_per_year, 0.0) <> 0.0';

--use brenda shines approach

t19_fa := '(' || stkflow_expression || ')';

t19_fd := '((' || t19_fa || ') * ((460.0 + 68.0)/(460.0 + ' || inv_table_alias ||
'.stktemp)) * (1.0 - ' || control_measure_equation_table_alias || '.value1 / 100.0))';

t19_noducts := '(case when  ' || t19_fd || ' <= 154042.0 then 1 else round(' || t19_fd
|| ' / 154042.0) end)';

t19_so2_conc := '((' || emis_sql || ') * 2000.0 / (64.06) / ' || inv_table_alias ||
'.annual_avg_hours_per_year / 60 * ((0.7302 * 520) / (1.0)) / (    (' || t19_fa || ')
* 520 / ((' || inv_table_alias || '.stktemp) + 460.0))) * 10^6';

t19_tci := '((143.76) * (' || t19_fd || '))+((0.610) * (sqrt(' || t19_fa || ')/' ||
t19_noducts || ')^2 )+((17412.26) * exp((0.017) * (sqrt(' || t19_fa || ')/' ||
t19_noducts || ')))+((53.973) * exp((0.014) * (sqrt(' || t19_fa || ')/' || t19_noducts
|| ')))+(931911.04)';
```

```
t19_tac := '(' || inv_table_alias || '.annual_avg_hours_per_year) * (((0.00162) * ('
|| t19_fd || '))+((0.000000684) * (' || t19_so2_conc || ') * (' || t19_fd ||
'))+((0.0000372) * (' || t19_fa || '))+(21.157))+((0.072+(' ||
capital_recovery_factor_expression || ')) * (' || t19_tci || '))';
```

A.20 NO_x Ptnonipm CoST Code – Default Cost per Ton Equations

```
-------------------------------------------------------------------------------------

CREATE OR REPLACE FUNCTION public.get_default_costs(
   discount_rate double precision,
   equipment_life double precision,
   capital_annualized_ratio double precision,
   capital_recovery_factor double precision,
   ref_yr_cost_per_ton double precision,
   emis_reduction double precision,
   OUT annual_cost double precision,
   OUT capital_cost double precision,
   OUT operation_maintenance_cost double precision,
   OUT annualized_capital_cost double precision,
   OUT computed_cost_per_ton double precision)  AS $$
DECLARE
   cap_recovery_factor double precision := capital_recovery_factor;
BEGIN
   -- get capital recovery factor, calculate if it wasn't passed in...
   IF coalesce(discount_rate, 0) != 0 and coalesce(equipment_life, 0) != 0 THEN
                cap_recovery_factor :=
public.calculate_capital_recovery_factor(discount_rate, equipment_life);
          END IF;

   -- calculate annual cost
   annual_cost := emis_reduction * ref_yr_cost_per_ton;
   -- calculate capital cost
   capital_cost := annual_cost  * capital_annualized_ratio;
   -- calculate annualized capital cost
   annualized_capital_cost := capital_cost * cap_recovery_factor;
   -- calculate operation maintenance cost
   operation_maintenance_cost := annual_cost - coalesce(annualized_capital_cost, 0);
   -- calculate computed cost per ton
   computed_cost_per_ton :=
      case
         when coalesce(emis_reduction, 0) <> 0 then annual_cost / emis_reduction
         else null
      end;
END;
$$ LANGUAGE plpgsql IMMUTABLE;
```

Appendix B. CoST Equation Control Parameters

Table B-1. ptipm Sector NO_x Control Technology Parameters (Equation Type 1)

CoST CM Abbreviation	Source Group	Control Technology	CE
NLNBOUBCW	Utility Boiler - Coal/Wall	LNBO	55.9
NLNBOUBCW2	Utility Boiler - Coal/Wall2	LNBO	55.3
NLNBUUBCW	Utility Boiler - Coal/Wall	LNB	41
NLNBUUBCW2	Utility Boiler - Coal/Wall2	LNB	40.3
NLNC1UBCT	Utility Boiler - Coal/Tangential	LNC1	33.1
NLNC1UBCT2	Utility Boiler - Coal/Tangential1	LNC1	43.3
NLNC2UBCT	Utility Boiler - Coal/Tangential	LNC2	12.71
NLNC2UBCT2	Utility Boiler - Coal/Tangential2	LNC2	48.3
NLNC3UBCT	Utility Boiler - Coal/Tangential	LNC3	53.1
NLNC3UBCT2	Utility Boiler - Coal/Tangential3	LNC3	58.3
NNGR_UBCT	Utility Boiler - Coal/Tangential	NGR	50
NNGR_UBCW	Utility Boiler - Coal/Wall	NGR	50
NNGR_UBCY	Utility Boiler - Cyclone	NGR	50
NNGR_UBOT	Utility Boiler - Oil-Gas/Tangential	NGR	50
NNGR_UBOW	Utility Boiler - Oil-Gas/Wall	NGR	50
NSCR_UBCT*	Utility Boiler - Coal/Tangential	SCR	90
NSCR_UBCW*	Utility Boiler - Coal/Wall	SCR	90
NSCR_UBCY	Utility Boiler - Cyclone	SCR	90
NSCR_UBOT	Utility Boiler - Oil-Gas/Tangential	SCR	80
NSCR_UBOW	Utility Boiler - Oil-Gas/Wall	SCR	80
NSNCRUBCT	Utility Boiler - Coal/Tangential	SNCR	35
NSNCRUBCW	Utility Boiler - Coal/Wall	SNCR	35
NSNCRUBCY	Utility Boiler - Cyclone	SNCR	35
NSNCRUBOT	Utility Boiler - Oil-Gas/Tangential	SNCR	50
NSNCRUBOW	Utility Boiler - Oil-Gas/Wall	SNCR	50

* Represents measures that use a scaling factor for units < 600 MW. All other measures use a scaling factor for units <500 MW.

Table B-2. ptipm Sector NO_x Control Cost Equation Parameters (Equation Type 1)

CoST CM Abbreviation	Control Cost Equation Variables								
	Capital Cost Multiplier	O&M Cost Multiplier		Scaling Factor		Capacity Factor	Interest Rate*	Equipment Life	Cost Year ($ Year)
		Fixed	Variable	Model Size (MW)	Exponent				
NLNBOUBCW	23.4	0.36	0.07	300	0.36	0.85	7	15	1999
NLNBOUBCW2	23.4	0.36	0.07	300	0.36	0.85	7	15	1999
NLNBUUBCW	17.3	0.26	0.05	300	0.36	0.85	7	15	1999
NLNBUUBCW2	17.3	0.26	0.05	300	0.36	0.85	7	15	1999
NLNC1UBCT	9.1	0.14	0	300	0.36	0.85	7	15	1999
NLNC1UBCT2	9.1	0.14	0	300	0.36	0.85	7	15	1999
NLNC2UBCT	12.7	0.19	0.02	300	0.36	0.85	7	15	1999
NLNC2UBCT2	12.7	0.19	0.02	300	0.36	0.85	7	15	1999
NLNC3UBCT	14.5	0.22	0.02	300	0.36	0.85	7	15	1999
NLNC3UBCT2	14.5	0.22	0.02	300	0.36	0.85	7	15	1999
NNGR_UBCT	26.9	0.41	0	200	0.35	0.65	7	20	1990
NNGR_UBCW	26.9	0.41	0	200	0.35	0.65	7	20	1990
NNGR_UBCY	26.9	0.41	0	200	0.35	0.65	7	20	1990
NNGR_UBOT	16.4	0.25	0.02	200	0.35	0.65	7	20	1990
NNGR_UBOW	16.4	0.25	0.02	200	0.35	0.65	7	20	1990
NSCR_UBCT*	100	0.66	0.6	243	0.27	0.65	7	20	1999
NSCR_UBCW*	100	0.66	0.6	243	0.27	0.65	7	20	1999
NSCR_UBCY	90	0.53	0.37	200	0.35	0.65	7	20	1999
NSCR_UBOT	23.3	0.72	0.08	200	0.35	0.65	7	20	1990
NSCR_UBOW	23.3	0.72	0.08	200	0.35	0.65	7	20	1990
NSNCRUBCT	15.8	0.24	0.73	100	0.68	0.65	7	20	1990
NSNCRUBCW	15.8	0.24	0.73	100	0.68	0.65	7	20	1990
NSNCRUBCY	8	0.12	1.05	100	0.58	0.65	7	20	1990
NSNCRUBOT	7.8	0.12	0.37	200	0.58	0.65	7	20	1990
NSNCRUBOW	7.8	0.12	0.37	200	0.58	0.65	7	20	1990

* A value of 7 percent is typically used as the opportunity cost of capital, consistent with OMB Circular A-94, and so is used as the interest rate for Equation Type 1.

Table B-3. ptipm Sector SO_2 Control Technology Parameters (Equation Type 1)

CoST CM Abbreviation	Source Group	Control Technology	CE (%)
SFGDWUBMS	Utility Boilers - Medium Sulfur Content	FGD Wet Scrubber	90
SFGDWUBHS	Utility Boilers - High Sulfur Content	FGD Wet Scrubber	90
SFGDWUBVHS	Utility Boilers - Very High Sulfur Conte	FGD Wet Scrubber	90
SLSDUBC1	Utility Boilers - Bituminous/Subbituminous Coal (100 to 299 MW)*	Lime Spray Dryer	95
SLSDUBC2	Utility Boilers - Bituminous/Subbituminous Coal (300 to 499 MW)	Lime Spray Dryer	95
SLSDUBC3	Utility Boilers - Bituminous/Subbituminous Coal (500 to 699 MW)	Lime Spray Dryer	95
SLSDUBC4	Utility Boilers - Bituminous/Subbituminous Coal (700 to 999 MW)	Lime Spray Dryer	95
SLSDUBC5	Utility Boilers - Bituminous/Subbituminous Coal (Over 1000 MW)	Lime Spray Dryer	95
SLSFOUBC1	Utility Boilers - Bituminous/Subbituminous Coal (100 to 299 MW)	Limestone Forced Oxidation	90
SLSFOUBC2	Utility Boilers - Bituminous/Subbituminous Coal (300 to 499 MW)	Limestone Forced Oxidation	90
SLSFOUBC3	Utility Boilers - Bituminous/Subbituminous Coal (500 to 699 MW)	Limestone Forced Oxidation	90
SLSFOUBC4	Utility Boilers - Bituminous/Subbituminous Coal (700 to 999 MW)	Limestone Forced Oxidation	90
SLSFOUBC5	Utility Boilers - Bituminous/Subbituminous Coal (Over 1000 MW)	Limestone Forced Oxidation	90

* MW = Boiler Capacity in MW

Table B-4. ptipm Sector SO_2 Control Cost Equation Parameters (Equation Type 1)

CoST CM Abbreviation	Control Cost Equation Variables									
	Capital Cost Multiplier	O&M Cost Multiplier		Scaling Factor		Application Restriction*	Capacity Factor	Interest Rate	Equipment Life	Cost Year ($ Year)
		Fixed	Variable	Model Size (MW)	Exponent					
SFGDWUBMS	149	5.4	0.83	500	0.6	%S <=2*	0.65	7	15	1990
SFGDWUBHS	166	6	6.3	500	0.6	2< %S <=3	0.65	7	15	1990
SFGDWUBVHS	174	6.3	1.8	500	0.6	3< %S	0.65	7	15	1990
SLSDUBC1	286	13	2.4	0	0	100≤MW<300**	1	7	15	2004
SLSDUBC2	155	8	2.4	0	0	300≤MW<500	1	7	15	2004
SLSDUBC3	131	6	2.4	0	0	500≤MW<700	1	7	15	2004
SLSDUBC4	118	5	2.4	0	0	700≤MW<1000	1	7	15	2004
SLSDUBC5	112	4	2.4	0	0	1000≤MW	1	7	15	2004
SLSFOUBC1	468	19	1.4	0	0	100≤MW<300	1	7	15	2004
SLSFOUBC2	230	11	1.4	0	0	300≤MW<500	1	7	15	2004
SLSFOUBC3	174	9	1.4	0	0	500≤MW<700	1	7	15	2004
SLSFOUBC4	142	8	1.4	0	0	700≤MW<1000	1	7	15	2004
SLSFOUBC5	120	7	1.4	0	0	1000≤MW	1	7	15	2004

* %S = % Sulfur in fuel, ** MW = Boiler Capacity in MW

Table B-5. ptipm Sector SO_2 Control Cost Parameter for Low Sulfur Coal Fuel Switching Options

CoST CM Abbreviation	Source Group	Control Technology	CE (%)	Applicable Sulfur Content Level	Cost per Ton Reduced ($/ton)	Cost Year ($ Year)
SCWSHUBCF	Utility Boilers - Coal Fired	Coal Washing	35	All	320	1997
SFWHLUBHS	Utility Boilers - High Sulfur Content	Fuel Switch - High to Low S Content	60	2< %S	140	1995

Table B-6. ptnonipm Sector NO_x Control Technology Parameters (Equation Type 2)

CoST CM Abbreviation	Source Group	Control Technology	CE	CRF
NLNBUGTNG	Gas Turbines - Natural Gas	LNB	68[a]	0.1098
NLNBUGTNG	Gas Turbines - Natural Gas	LNB	84[b]	0.1098

[a] Turbines emitting less than 365 tons NOx/year.
[b] Turbines emitting equal to or greater than 365 tons NOx/year

Table B-7. ptnonipm Sector NO_x Control Cost Equation Parameters (Equation Type 2)

CoST CM Abbreviation	Default Application				Incremental Application				Cost Year ($ Year)
	Capital Cost Variables		Annual Cost Variables		Capital Cost Variables		Annual Cost Variables		
	Mult*	Exp*	Mult	Exp	Mult	Exp	Mult	Exp	
NLNBUGTNG	71281.1	0.51	7826.3	0.51	71281.1	0.51	7826.3	0.51	1990
NSCRLGTNG	86461.8	0.64	19916.7	0.66	33203.7	0.73	13920	0.69	1990
NSCRSGTNG	90606.2	0.67	25936.7	0.69	15278.8	0.85	5477.9	0.84	1990
NSCRWGTNG	121119	0.59	36298.9	0.63	18026.5	0.82	7607	0.78	1990
NSCRWGTOL	123980.2	0.59	36100.2	0.66	70538.9	0.61	28972.5	0.58	1990
NSNCRIBCF	15972.8	0.6	4970.5	0.6	15972.8	0.6	3059.2	0.6	1990
NSNCRIBWF	9855.6	0.6	4185.4	0.6	9855.6	0.6	4185.4	0.6	1990
NSNCRIBWS	65820.1	0.36	17777.1	0.35	65820.1	0.36	17777.1	0.35	1990
NSTINGTNG	9693.1	0.92	764.3	1.15	9693.1	0.92	764.3	1.15	1990
NWTINGTNG	4284.2	1.01	145.7	1.47	4284.2	1.01	145.7	1.47	1990
NWTINGTOL	54453.5	0.57	9687.9	0.76	54453.5	0.57	9687.9	0.76	1990

*Mult = multiplier, Exp = exponent, Greyed Out = Obsolete

Table B-8. ptnonipm Sector SO_2 Control Measure Cost Assignments (Equation Types 3-6)

CoST CM Abbreviation	Source Group	Control Technology	CE	Cost Equation Type #	Cost Year ($Year)
SCOGDCOP	By-Product Coke Manufacturing (Coke Oven Plants)	Coke Oven Gas Desulfurization	90	6	1990
SAMSCSRP95	Sulfur Recovery Plants - Elemental Sulfur (Claus: 2 Stage w/o control (92-95% removal))	Amine Scrubbing	98.4	5	1990
SAMSCSRP96	Sulfur Recovery Plants - Elemental Sulfur (Claus: 3 Stage w/o control (95-96% removal))	Amine Scrubbing	97.8	5	1990
SAMSCSRP97	Sulfur Recovery Plants - Elemental Sulfur (Claus: 3 Stage w/o control (96-97% removal))	Amine Scrubbing	97.1	5	1990
SNS99SACA	Sulfuric Acid Plants - Contact Absorber (99% Conversion)	Increase % Conversion to Meet NSPS (99.7)	75	4	1990
SNS98SACA	Sulfuric Acid Plants - Contact Absorber (98% Conversion)	Increase % Conversion to Meet NSPS (99.7)	85	4	1990
SNS97SACA	Sulfuric Acid Plants - Contact Absorber (97% Conversion)	Increase % Conversion to Meet NSPS (99.7)	90	4	1990
SNS93SACA	Sulfuric Acid Plants - Contact Absorber (93% Conversion)	Increase % Conversion to Meet NSPS (99.7)	95	4	1990
SDLABPLSS	Primary Lead Smelters - Sintering	Dual absorption	99	4	1990
SDLABPZSS	Primary Zinc Smelters - Sintering	Dual absorption	99	4	1990

CoST CM Abbreviation	Source Group	Control Technology	CE	Cost Equation Type #	Cost Year ($Year)
SFGDSCMOP	By-Product Coke Manufacturing (Other Processes)	FGD	90	3	1995
SFGDSPHOG	Process Heaters (Oil and Gas Production Industry)	FGD	90	3	1995
SSADPPRMTL	Primary Metals Industry	Sulfuric Acid Plant	70	3	1995
SFGDSMIPR	Mineral Products Industry	FGD	50	3	1995
SFGDSPPSP	Pulp and Paper Industry (Sulfate Pulping)	FGD	90	3	1995
SFGDSPETR	Petroleum Industry	FGD	90	3	1995
SFGDSIPFBC	In-process Fuel Use - Bituminous/Subbituminous Coal	FGD	90	3	1995
SFGDSSGCO	Steam Generating Unit-Coal/Oil	FGD	90	3	1995
SFGDSIBBC	Bituminous/Subbituminous Coal (Industrial Boilers)	FGD	90	3	1995
SFGDSIBRO	Residual Oil (Industrial Boilers)	FGD	90	3	1995
SFGDSCBBCL	Bituminous/Subbituminous Coal (Commercial/Institutional Boilers)	FGD	90	3	1995
SFGDSIBLG	Lignite (Industrial Boilers)	FGD	90	3	1995
SFGDSCBRO	Residual Oil (Commercial/Institutional Boilers)	FGD	90	3	1995

Greyed Out = Obsolete

Table B-9. ptipm Sector PM Control Cost Equation Parameters (Equation Type 8)

CoST CM Abbreviation	Source Group	Control Technology	Control Efficiency (%)		Typical Control Cost Equation-Based Factors*		Typical Default Cost per Ton Factors			Cost Year ($ Year)
			PM-10	PM-2.5	Capital	O&M	Capital	O&M	Annualized	
PFFMSUBC	Utility Boilers - Coal	Fabric Filter (Mech. Shaker Type)	99	99	29	11	412	62	126	1998
PFFPJUBC	Utility Boilers - Coal	Fabric Filter (Pulse Jet Type)	99	99	13	11	380	28	117	1998
PFFRAUBC	Utility Boilers - Coal	Fabric Filter (Reverse-Air Cleaned Type)	99	99	34	13	0	0	148	1998
PDESPWPUBC	Utility Boilers - Coal	Dry ESP-Wire Plate Type	98	95	27	16	710	41	110	1995
PDESPWPUBO	Utility Boilers - Oil	Dry ESP-Wire Plate Type	98	95	27	16	710	41	110	1995

* $/acfm

Table B-10. ptnonipm Sector PM Control Cost Equation Parameters (Equation Type 8)

CoST CM Abbreviation	Source Group	Control Technology	Control Efficiency (%)		Equipment Life	Typical Control Cost Equation-Based Factors		Cost Year ($ Year)
			PM-10	PM-2.5		Capital	O&M	

CoST CM Abbreviation	Source Group	Control Technology	Control Efficiency (%)		Equipment Life	Typical Control Cost Equation-Based Factors		Cost Year ($ Year)
			PM-10	PM-2.5		Capital	O&M	
PCATFWAT	Beef Cattle Feedlots	Watering	50	25	10			1990
PCHIPHB	Household burning	Substitute chipping for burning		50	0			1999
PCHIPOB	Open burning	Substitute chipping for burning		100	0			1999
PCHRBCAOX	Conveyorized Charbroilers	Catalytic Oxidizer	83	83	10			1990
PCHRBCAOX1	Conveyorized Charbroilers	Catalytic Oxidizer	8.3	8.3	10			1990
PCHRBESP	Conveyorized Charbroilers	ESP for Commercial Cooking	99	99	10			1990
PCHRBESPSM	Commercial Cooking -- large underfired grilling operations	ESP	99	99	10			1990
PCONWATCHM	Construction Activities	Dust Control Plan	62.5	37.5	0			1990
PDESPCIBCL	Commercial Institutional Boilers - Coal	Dry ESP-Wire Plate Type	98	95	20	27	16	1995
PDESPCIBOL	Commercial Institutional Boilers - Oil	Dry ESP-Wire Plate Type	98	95	20	27	16	1995
PDESPCIBWD	Commercial Institutional Boilers - Wood	Dry ESP-Wire Plate Type	90	90	20	27	16	1995
PDESPIBCL	Industrial Boilers - Coal	Dry ESP-Wire Plate Type	98	95	20	27	16	1995
PDESPIBLW	Industrial Boilers - Liquid Waste	Dry ESP-Wire Plate Type	98	95	20	27	16	1995
PDESPIBOL	Industrial Boilers - Oil	Dry ESP-Wire Plate Type	98	95	20	27	16	1995
PDESPIBWD	Industrial Boilers - Wood	Dry ESP-Wire Plate Type	98	95	20	27	16	1995
PDESPMICM	Mineral Products - Cement Manufacture	Dry ESP-Wire Plate Type	98	95	20	27	16	1995
PDESPMIOR	Mineral Products - Other	Dry ESP-Wire Plate Type	98	95	20	27	16	1995
PDESPMISQ	Mineral Products - Stone Quarrying & Processing	Dry ESP-Wire Plate Type	98	95	20	27	16	1995
PDESPMPAM	Non-Ferrous Metals Processing - Aluminum	Dry ESP-Wire Plate Type	98	95	20	27	16	1995
PDESPMPCR	Non-Ferrous Metals Processing - Copper	Dry ESP-Wire Plate Type	98	95	20	27	16	1995

CoST CM Abbreviation	Source Group	Control Technology	Control Efficiency (%)		Equipment Life	Typical Control Cost Equation-Based Factors		Cost Year ($ Year)
			PM-10	PM-2.5		Capital	O&M	
PDESPMPFP	Ferrous Metals Processing - Ferroalloy Production	Dry ESP-Wire Plate Type	98	95	20	27	16	1995
PDESPMPIS	Ferrous Metals Processing - Iron & Steel Production	Dry ESP-Wire Plate Type	98	95	20	27	16	1995
PDESPMPLD	Non-Ferrous Metals Processing - Lead	Dry ESP-Wire Plate Type	98	95	20	27	16	1995
PDESPMPOR	Non-Ferrous Metals Processing - Other	Dry ESP-Wire Plate Type	98	95	20	27	16	1995
PDESPMPZC	Non-Ferrous Metals Processing - Zinc	Dry ESP-Wire Plate Type	98	95	20	27	16	1995
PDESPMUWI	Municipal Waste Incineration	Dry ESP-Wire Plate Type	98	95	20	27	16	1995
PDESPWDPP	Wood Pulp & Paper	Dry ESP-Wire Plate Type	98	95	20	27	16	1995
PDIEOXCAT	IC Diesel Engine	Diesel Oxidation Catalyst (DPF infeasible)	20		0			2003
PDIEPRTFIL	IC Diesel Engine	Diesel Particulate Filter	85		0			2003
PDPFICE	Internal Combustion Engines	Diesel Particulate Filter		90	0			1999
PESPOFBOIL	Oil fired boiler	ESP		75	0			1999
PESPPETCRK	Petroleum Refinery Catalytic and Thermal Cracking Units	ESP	95		0			1999
PFFMSASMN	Asphalt Manufacture	Fabric Filter (Mech. Shaker Type)	99	99	20	29	11	1998
PFFMSMICC	Mineral Products - Coal Cleaning	Fabric Filter (Mech. Shaker Type)	99	99	20	29	11	1998
PFFMSMICM	Mineral Products - Cement Manufacture	Fabric Filter (Mech. Shaker Type)	99	99	20	29	11	1998
PFFMSMIOR	Mineral Products - Other	Fabric Filter (Mech. Shaker Type)	99	99	20	29	11	1998
PFFMSMISQ	Mineral Products - Stone Quarrying & Processing	Fabric Filter (Mech. Shaker Type)	99	99	20	29	11	1998
PFFMSMPAM	Non-Ferrous Metals Processing - Aluminum	Fabric Filter (Mech. Shaker Type)	99	99	20	29	11	1998
PFFMSMPCE	Ferrous Metals Processing - Coke	Fabric Filter (Mech. Shaker Type)	99	99	20	29	11	1998

CoST CM Abbreviation	Source Group	Control Technology	Control Efficiency (%)		Equipment Life	Typical Control Cost Equation-Based Factors		Cost Year ($ Year)
			PM-10	PM-2.5		Capital	O&M	
PFFMSMPCR	Non-Ferrous Metals Processing - Copper	Fabric Filter (Mech. Shaker Type)	99	99	20	29	11	1998
PFFMSMPFP	Ferrous Metals Processing - Ferroalloy Production	Fabric Filter (Mech. Shaker Type)	99	99	20	29	11	1998
PFFMSMPGI	Ferrous Metals Processing - Gray Iron Foundries	Fabric Filter (Mech. Shaker Type)	99	99	20	29	11	1998
PFFMSMPIS	Ferrous Metals Processing - Iron & Steel Production	Fabric Filter (Mech. Shaker Type)	99	99	20	29	11	1998
PFFMSMPLD	Non-Ferrous Metals Processing - Lead	Fabric Filter (Mech. Shaker Type)	99	99	20	29	11	1998
PFFMSMPOR	Non-Ferrous Metals Processing - Other	Fabric Filter (Mech. Shaker Type)	99	99	20	29	11	1998
PFFMSMPSF	Ferrous Metals Processing - Steel Foundries	Fabric Filter (Mech. Shaker Type)	99	99	20	29	11	1998
PFFMSMPZC	Non-Ferrous Metals Processing - Zinc	Fabric Filter (Mech. Shaker Type)	99	99	20	29	11	1998
PFFPJASMN	Asphalt Manufacture	Fabric Filter (Pulse Jet Type)	99	99	20	13	11	1998
PFFPJCIBCL	Commercial Institutional Boilers - Coal	Fabric Filter (Pulse Jet Type)	99	99	20	13	11	1998
PFFPJCIBWD	Commercial Institutional Boilers - Wood	Fabric Filter (Pulse Jet Type)	80	80	20	13	11	1998
PFFPJGRMG	Grain Milling	Fabric Filter (Pulse Jet Type)	99	99	20	13	11	1998
PFFPJIBCL	Industrial Boilers - Coal	Fabric Filter (Pulse Jet Type)	99	99	20	13	11	1998
PFFPJIBWD	Industrial Boilers - Wood	Fabric Filter (Pulse Jet Type)	99	99	20	13	11	1998
PFFPJMICC	Mineral Products - Coal Cleaning	Fabric Filter (Pulse Jet Type)	99	99	20	13	11	1998
PFFPJMICM	Mineral Products - Cement Manufacture	Fabric Filter (Pulse Jet Type)	99	99	20	13	11	1998
PFFPJMIOR	Mineral Products - Other	Fabric Filter (Pulse Jet Type)	99	99	20	13	11	1998

CoST CM Abbreviation	Source Group	Control Technology	Control Efficiency (%)		Equipment Life	Typical Control Cost Equation-Based Factors		Cost Year ($ Year)
			PM-10	PM-2.5		Capital	O&M	
PFFPJMISQ	Mineral Products - Stone Quarrying & Processing	Fabric Filter (Pulse Jet Type)	99	99	20	13	11	1998
PFFPJMPIS	Ferrous Metals Processing - Iron & Steel Production	Fabric Filter (Pulse Jet Type)	99	99	20	13	11	1998
PFFPJMPSF	Ferrous Metals Processing - Steel Foundries	Fabric Filter (Pulse Jet Type)	99	99	20	13	11	1998
PFFRAASMN	Asphalt Manufacture	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFFRACIBCL	Commercial Institutional Boilers - Coal	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFFRACIBWD	Commercial Institutional Boilers - Wood	Fabric Filter - Reverse-Air Cleaned Type	80	80	20	34	13	1998
PFFRAGRMG	Grain Milling	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFFRAIBCL	Industrial Boilers - Coal	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFFRAIBWD	Industrial Boilers - Wood	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFFRAMICC	Mineral Products - Coal Cleaning	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFFRAMICM	Mineral Products - Cement Manufacture	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFFRAMIOR	Mineral Products - Other	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFFRAMISQ	Mineral Products - Stone Quarrying & Processing	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFFRAMPAM	Non-Ferrous Metals Processing - Aluminum	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFFRAMPCE	Ferrous Metals Processing - Coke	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFFRAMPCR	Non-Ferrous Metals Processing - Copper	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFFRAMPFP	Ferrous Metals Processing - Ferroalloy Production	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998

CoST CM Abbreviation	Source Group	Control Technology	Control Efficiency (%)		Equipment Life	Typical Control Cost Equation-Based Factors		Cost Year ($ Year)
			PM-10	PM-2.5		Capital	O&M	
PFFRAMPGI	Ferrous Metals Processing - Gray Iron Foundries	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFFRAMPIS	Ferrous Metals Processing - Iron & Steel Production	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFFRAMPLD	Non-Ferrous Metals Processing - Lead	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFFRAMPOR	Non-Ferrous Metals Processing - Other	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFFRAMPSF	Ferrous Metals Processing - Steel Foundries	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFFRAMPZC	Non-Ferrous Metals Processing - Zinc	Fabric Filter - Reverse-Air Cleaned Type	99	99	20	34	13	1998
PFIRINSHH	Home Heating	Fireplace Inserts		98	0			1999
PISCRMPGI	Ferrous Metals Processing - Gray Iron Foundries	Impingement-plate scrubber	64	64	10	7	25	1995
PLNDFILBRN	Open Burning	Substitution of land filling for open burning	75		0			1999
PPFCCASMN	Asphalt Manufacture	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	20	9	14	1998
PPFCCFMAB	Fabricated Metal Products - Abrasive Blasting	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	20	9	14	1998
PPFCCFMMG	Fabricated Metal Products - Machining	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	20	9	14	1998
PPFCCFMWG	Fabricated Metal Products - Welding	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	20	9	14	1998
PPFCCGRMG	Grain Milling	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	20	9	14	1998
PPFCCMICC	Mineral Products - Coal Cleaning	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	20	9	14	1998

CoST CM Abbreviation	Source Group	Control Technology	Control Efficiency (%)		Equipment Life	Typical Control Cost Equation-Based Factors		Cost Year ($ Year)
			PM-10	PM-2.5		Capital	O&M	
PPFCCMICM	Mineral Products - Cement Manufacture	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	20	9	14	1998
PPFCCMIOR	Mineral Products - Other	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	20	9	14	1998
PPFCCMISQ	Mineral Products - Stone Quarrying & Processing	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	20	9	14	1998
PPRBRNFULM	Prescribed Burning	Increase Fuel Moisture	50	50	0			1990
PRESWDEDAD	Residential Wood Combustion	Education and Advisory Program	50	50	0			1990
PRESWDEDAP	Residential Wood Combustion Generic	Education and Advisory Program	35	35	0			1990
PRESWDSTV1	Residential Wood Combustion	NSPS Compliant Wood Stove	8.2	8.2	0			1990
PRESWDSTV2	Residential Wood Combustion	NSPS Compliant Wood Stove	9.8	9.8	0			1990
PVENTCCU	Catalytic cracking units	Venturi scrubber		90	0			1999
PVESCIBCL	Industrial Boilers - Coal	Venturi Scrubber	82	50	10	11	42	1995
PVESCIBOL	Industrial Boilers - Oil	Venturi Scrubber	92	89	10	11	42	1995
PVESCIBWD	Industrial Boilers - Wood	Venturi Scrubber	93	92	10	11	42	1995
PVSCRMICC	Mineral Products - Coal Cleaning	Venturi Scrubber	99	98	10	11	42	1995
PVSCRMISQ	Mineral Products - Stone Quarrying & Processing	Venturi Scrubber	95	90	10	11	42	1995
PVSCRMPCE	Ferrous Metals Processing - Coke	Venturi Scrubber	93	89	10	11	42	1995
PVSCRMPGI	Ferrous Metals Processing - Gray Iron Foundries	Venturi Scrubber	94	94	10	11	42	1995
PVSCRMPIS	Ferrous Metals Processing - Iron & Steel Production	Venturi Scrubber	73	25	10	11	42	1995
PVSCRMPSF	Ferrous Metals Processing - Steel Foundries	Venturi Scrubber	73	25	10	11	42	1995
PWESPCHMN	Chemical Manufacture	Wet ESP - Wire Plate Type	99	95	20	40	19	1995

CoST CM Abbreviation	Source Group	Control Technology	Control Efficiency (%)		Equipment Life	Typical Control Cost Equation-Based Factors		Cost Year ($ Year)
			PM-10	PM-2.5		Capital	O&M	
PWESPMIOR	Mineral Products - Other	Wet ESP - Wire Plate Type	99	95	20	40	19	1995
PWESPMISQ	Mineral Products - Stone Quarrying & Processing	Wet ESP - Wire Plate Type	99	95	20	40	19	1995
PWESPMPAM	Non-Ferrous Metals Processing - Aluminum	Wet ESP - Wire Plate Type	99	95	20	40	19	1995
PWESPMPCR	Non-Ferrous Metals Processing - Copper	Wet ESP - Wire Plate Type	99	95	20	40	19	1995
PWESPMPIS	Ferrous Metals Processing - Iron & Steel Production	Wet ESP - Wire Plate Type	99	95	20	40	19	1995
PWESPMPLD	Non-Ferrous Metals Processing - Lead	Wet ESP - Wire Plate Type	99	95	20	40	19	1995
PWESPMPOR	Non-Ferrous Metals Processing - Other	Wet ESP - Wire Plate Type	99	95	20	40	19	1995
PWESPMPZC	Non-Ferrous Metals Processing - Zinc	Wet ESP - Wire Plate Type	99	95	20	40	19	1995
PWESPWDPP	Wood Pulp & Paper	Wet ESP - Wire Plate Type	99	95	20	40	19	1995

Greyed Out = Obsolete

Table B-11. ptnonipm Sector PM Controls Default Cost per Ton Factors (Equation Type 8 or Controls Applied to Nonpoint Sources)

CoST CM Abbreviation	Source Group	Control Technology	Control Efficiency (%)		Typical Default Cost per Ton Factors			Cost Year ($ Year)
			PM-10	PM-2.5	Capital	O&M	Annualized	
PCATFWAT	Beef Cattle Feedlots	Watering	50	25			307	1990
PCHIPHB	Household burning	Substitute chipping for burning		50				1999
PCHIPOB	Open burning	Substitute chipping for burning		100				1999
PCHRBCAOX	Conveyorized Charbroilers	Catalytic Oxidizer	83	83			2150	1990
PCHRBCAOX1	Conveyorized Charbroilers	Catalytic Oxidizer	8.3	8.3			2150	1990
PCHRBESP	Conveyorized Charbroilers	ESP for Commercial Cooking	99	99			7000	1990
PCHRBESPSM	Commercial Cooking -- large underfired grilling operations	ESP	99	99			7000	1990
PCONWATCHM	Construction Activities	Dust Control Plan	62.5	37.5			3600	1990

CoST CM Abbreviation	Source Group	Control Technology	Control Efficiency (%)		Typical Default Cost per Ton Factors			Cost Year ($ Year)
			PM-10	PM-2.5	Capital	O&M	Annualized	
PDESPCIBCL	Commercial Institutional Boilers - Coal	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDESPCIBOL	Commercial Institutional Boilers - Oil	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDESPCIBWD	Commercial Institutional Boilers - Wood	Dry ESP-Wire Plate Type	90	90	710	41	110	1995
PDESPIBCL	Industrial Boilers - Coal	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDESPIBLW	Industrial Boilers - Liquid Waste	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDESPIBOL	Industrial Boilers – Oil	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDESPIBWD	Industrial Boilers - Wood	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDESPMICM	Mineral Products - Cement Manufacture	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDESPMIOR	Mineral Products - Other	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDESPMISQ	Mineral Products - Stone Quarrying & Processing	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDESPMPAM	Non-Ferrous Metals Processing - Aluminum	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDESPMPCR	Non-Ferrous Metals Processing - Copper	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDESPMPFP	Ferrous Metals Processing - Ferroalloy Production	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDESPMPIS	Ferrous Metals Processing - Iron & Steel Production	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDESPMPLD	Non-Ferrous Metals Processing - Lead	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDESPMPOR	Non-Ferrous Metals Processing - Other	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDESPMPZC	Non-Ferrous Metals Processing - Zinc	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDESPMUWI	Municipal Waste Incineration	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDESPWDPP	Wood Pulp & Paper	Dry ESP-Wire Plate Type	98	95	710	41	110	1995
PDIEOXCAT	IC Diesel Engine	Diesel Oxidation Catalyst (DPF infeasible)	20				1500	2003
PDIEPRTFIL	IC Diesel Engine	Diesel Particulate Filter	85				10500	2003
PDPFICE	Internal Combustion Engines	Diesel Particulate Filter		90				1999
PESPOFBOIL	Oil fired boiler	ESP		75				1999
PESPPETCRK	Petroleum Refinery Catalytic and Thermal Cracking Units	ESP	95				5050	1999
PFFMSASMN	Asphalt Manufacture	Fabric Filter (Mech. Shaker Type)	99	99	412	62	126	1998

CoST CM Abbreviation	Source Group	Control Technology	Control Efficiency (%)		Typical Default Cost per Ton Factors			Cost Year ($ Year)
			PM-10	PM-2.5	Capital	O&M	Annualized	
PFFMSMICC	Mineral Products - Coal Cleaning	Fabric Filter (Mech. Shaker Type)	99	99	412	62	126	1998
PFFMSMICM	Mineral Products - Cement Manufacture	Fabric Filter (Mech. Shaker Type)	99	99	412	62	126	1998
PFFMSMIOR	Mineral Products - Other	Fabric Filter (Mech. Shaker Type)	99	99	412	62	126	1998
PFFMSMISQ	Mineral Products - Stone Quarrying & Processing	Fabric Filter (Mech. Shaker Type)	99	99	412	62	126	1998
PFFMSMPAM	Non-Ferrous Metals Processing - Aluminum	Fabric Filter (Mech. Shaker Type)	99	99	412	62	126	1998
PFFMSMPCE	Ferrous Metals Processing - Coke	Fabric Filter (Mech. Shaker Type)	99	99	412	62	126	1998
PFFMSMPCR	Non-Ferrous Metals Processing - Copper	Fabric Filter (Mech. Shaker Type)	99	99	412	62	126	1998
PFFMSMPFP	Ferrous Metals Processing - Ferroalloy Production	Fabric Filter (Mech. Shaker Type)	99	99	412	62	126	1998
PFFMSMPGI	Ferrous Metals Processing - Gray Iron Foundries	Fabric Filter (Mech. Shaker Type)	99	99	412	62	126	1998
PFFMSMPIS	Ferrous Metals Processing - Iron & Steel Production	Fabric Filter (Mech. Shaker Type)	99	99	412	62	126	1998
PFFMSMPLD	Non-Ferrous Metals Processing - Lead	Fabric Filter (Mech. Shaker Type)	99	99	412	62	126	1998
PFFMSMPOR	Non-Ferrous Metals Processing - Other	Fabric Filter (Mech. Shaker Type)	99	99	412	62	126	1998
PFFMSMPSF	Ferrous Metals Processing - Steel Foundries	Fabric Filter (Mech. Shaker Type)	99	99	412	62	126	1998
PFFMSMPZC	Non-Ferrous Metals Processing - Zinc	Fabric Filter (Mech. Shaker Type)	99	99	412	62	126	1998
PFFPJASMN	Asphalt Manufacture	Fabric Filter (Pulse Jet Type)	99	99	380	28	117	1998
PFFPJCIBCL	Commercial Institutional Boilers - Coal	Fabric Filter (Pulse Jet Type)	99	99	380	28	117	1998
PFFPJCIBWD	Commercial Institutional Boilers - Wood	Fabric Filter (Pulse Jet Type)	80	80	380	28	117	1998
PFFPJGRMG	Grain Milling	Fabric Filter (Pulse Jet Type)	99	99	380	28	117	1998
PFFPJIBCL	Industrial Boilers - Coal	Fabric Filter (Pulse Jet Type)	99	99	380	28	117	1998
PFFPJIBWD	Industrial Boilers - Wood	Fabric Filter (Pulse Jet Type)	99	99	380	28	117	1998

CoST CM Abbreviation	Source Group	Control Technology	Control Efficiency (%)		Typical Default Cost per Ton Factors			Cost Year ($ Year)
			PM-10	PM-2.5	Capital	O&M	Annualized	
PFFPJMICC	Mineral Products - Coal Cleaning	Fabric Filter (Pulse Jet Type)	99	99	380	28	117	1998
PFFPJMICM	Mineral Products - Cement Manufacture	Fabric Filter (Pulse Jet Type)	99	99	380	28	117	1998
PFFPJMIOR	Mineral Products - Other	Fabric Filter (Pulse Jet Type)	99	99	380	28	117	1998
PFFPJMISQ	Mineral Products - Stone Quarrying & Processing	Fabric Filter (Pulse Jet Type)	99	99	380	28	117	1998
PFFPJMPIS	Ferrous Metals Processing - Iron & Steel Production	Fabric Filter (Pulse Jet Type)	99	99	380	28	117	1998
PFFPJMPSF	Ferrous Metals Processing - Steel Foundries	Fabric Filter (Pulse Jet Type)	99	99	380	28	117	1998
PFFRAASMN	Asphalt Manufacture	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFFRACIBCL	Commercial Institutional Boilers - Coal	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFFRACIBWD	Commercial Institutional Boilers - Wood	Fabric Filter - Reverse-Air Cleaned Type	80	80	0	0	148	1998
PFFRAGRMG	Grain Milling	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFFRAIBCL	Industrial Boilers - Coal	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFFRAIBWD	Industrial Boilers - Wood	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFFRAMICC	Mineral Products - Coal Cleaning	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFFRAMICM	Mineral Products - Cement Manufacture	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFFRAMIOR	Mineral Products - Other	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFFRAMISQ	Mineral Products - Stone Quarrying & Processing	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFFRAMPAM	Non-Ferrous Metals Processing - Aluminum	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFFRAMPCE	Ferrous Metals Processing - Coke	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFFRAMPCR	Non-Ferrous Metals Processing - Copper	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFFRAMPFP	Ferrous Metals Processing - Ferroalloy Production	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998

CoST CM Abbreviation	Source Group	Control Technology	Control Efficiency (%)		Typical Default Cost per Ton Factors			Cost Year ($ Year)
			PM-10	PM-2.5	Capital	O&M	Annualized	
PFFRAMPGI	Ferrous Metals Processing - Gray Iron Foundries	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFFRAMPIS	Ferrous Metals Processing - Iron & Steel Production	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFFRAMPLD	Non-Ferrous Metals Processing - Lead	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFFRAMPOR	Non-Ferrous Metals Processing - Other	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFFRAMPSF	Ferrous Metals Processing - Steel Foundries	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFFRAMPZC	Non-Ferrous Metals Processing - Zinc	Fabric Filter - Reverse-Air Cleaned Type	99	99	0	0	148	1998
PFIRINSHH	Home Heating	Fireplace Inserts		98				1999
PISCRMPGI	Ferrous Metals Processing - Gray Iron Foundries	Impingement-plate scrubber	64	64	87	417	431	1995
PLNDFILBRN	Open Burning	Substitution of land filling for open burning	75				3500	1999
PPFCCASMN	Asphalt Manufacture	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	0	0	142	1998
PPFCCFMAB	Fabricated Metal Products - Abrasive Blasting	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	0	0	142	1998
PPFCCFMMG	Fabricated Metal Products - Machining	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	0	0	142	1998
PPFCCFMWG	Fabricated Metal Products - Welding	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	0	0	142	1998
PPFCCGRMG	Grain Milling	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	0	0	142	1998
PPFCCMICC	Mineral Products - Coal Cleaning	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	0	0	142	1998
PPFCCMICM	Mineral Products - Cement Manufacture	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	0	0	142	1998
PPFCCMIOR	Mineral Products - Other	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	0	0	142	1998
PPFCCMISQ	Mineral Products - Stone Quarrying & Processing	Paper/Nonwoven Filters - Cartridge Collector Type	99	99	0	0	142	1998
PPRBRNFULM	Prescribed Burning	Increase Fuel Moisture	50	50			2617	1990
PRESWDEDAD	Residential Wood Combustion	Education and Advisory Program	50	50			1320	1990
PRESWDEDAP	Residential Wood Combustion Generic	Education and Advisory Program	35	35			1320	1990

CoST CM Abbreviation	Source Group	Control Technology	Control Efficiency (%)		Typical Default Cost per Ton Factors			Cost Year ($ Year)
			PM-10	PM-2.5	Capital	O&M	Annualized	
PRESWDSTV1	Residential Wood Combustion	NSPS Compliant Wood Stove	8.2	8.2			1454	1990
PRESWDSTV2	Residential Wood Combustion	NSPS Compliant Wood Stove	9.8	9.8			1454	1990
PVENTCCU	Catalytic cracking units	Venturi scrubber		90				1999
PVESCIBCL	Industrial Boilers - Coal	Venturi Scrubber	82	50	189	713	751	1995
PVESCIBOL	Industrial Boilers - Oil	Venturi Scrubber	92	89	189	713	751	1995
PVESCIBWD	Industrial Boilers - Wood	Venturi Scrubber	93	92	189	713	751	1995
PVSCRMICC	Mineral Products - Coal Cleaning	Venturi Scrubber	99	98	189	713	751	1995
PVSCRMISQ	Mineral Products - Stone Quarrying & Processing	Venturi Scrubber	95	90	189	713	751	1995
PVSCRMPCE	Ferrous Metals Processing - Coke	Venturi Scrubber	93	89	189	713	751	1995
PVSCRMPGI	Ferrous Metals Processing - Gray Iron Foundries	Venturi Scrubber	94	94	189	713	751	1995
PVSCRMPIS	Ferrous Metals Processing - Iron & Steel Production	Venturi Scrubber	73	25	189	713	751	1995
PVSCRMPSF	Ferrous Metals Processing - Steel Foundries	Venturi Scrubber	73	25	189	713	751	1995
PWESPCHMN	Chemical Manufacture	Wet ESP - Wire Plate Type	99	95	923	135	220	1995
PWESPMIOR	Mineral Products - Other	Wet ESP - Wire Plate Type	99	95	923	135	220	1995
PWESPMISQ	Mineral Products - Stone Quarrying & Processing	Wet ESP - Wire Plate Type	99	95	923	135	220	1995
PWESPMPAM	Non-Ferrous Metals Processing - Aluminum	Wet ESP - Wire Plate Type	99	95	923	135	220	1995
PWESPMPCR	Non-Ferrous Metals Processing - Copper	Wet ESP - Wire Plate Type	99	95	923	135	220	1995
PWESPMPIS	Ferrous Metals Processing - Iron & Steel Production	Wet ESP - Wire Plate Type	99	95	923	135	220	1995
PWESPMPLD	Non-Ferrous Metals Processing - Lead	Wet ESP - Wire Plate Type	99	95	923	135	220	1995
PWESPMPOR	Non-Ferrous Metals Processing - Other	Wet ESP - Wire Plate Type	99	95	923	135	220	1995
PWESPMPZC	Non-Ferrous Metals Processing - Zinc	Wet ESP - Wire Plate Type	99	95	923	135	220	1995
PWESPWDPP	Wood Pulp & Paper	Wet ESP - Wire Plate Type	99	95	923	135	220	1995

Table B-12. ptipm Sector PM Control Cost Equation Parameters (Equation Type 9)

CoST CM Abbreviation	Source Group	Control Technology	Control Efficiency (%)		Capital Cost Variables			O&M Cost Variables						Cost Year ($ Yr)
			PM-10	PM-2.5	tecs	teci	ec to cc	els	eli	dds	ddi	brs	bri	
PFFMSUBC2	Utility Boilers – Coal	Fabric Filter - Mechanical Shaker	99	99	5.702	77489	2.17	0.194	-15.96	0.7406	1.146	0.25	1221	1990
PFFMSUBG	Utility Boilers - Gas/Oil	Fabric Filter - Mechanical Shaker	95	95	5.702	77489	2.17	0.188	-19.58	0.0007	0.19	0.241	1224	1990

tecs = Total Equipment Cost Factor, teci = Total Equipment Cost Constant, ec to cc = Equipment to Capital Cost Multiplier, els = Electricity Factor, eli = Electricity Constant, dds = Dust Dispersal Factor, ddi = Dust Disposal Constant, brs = Bag Replacement Factor, bri = Bag Replacement Constant

Table B-13. ptipm Sector PM Control Cost Equation Factors (Equation Type 10)

CoST CM Abbreviation	Source Group	Control Technology	Pollutant	Capital Cost		Variable O&M	Fixed O&M		Cost Year ($ Year)
				Mult	Exp	Mult	Mult	Exp	
PDESPMAGG	Utility Boilers – Coal	Agglomerator	PM2.5	8.0	0.3	0.021	0.0	0.0	2005
PDESPM1FLD	Utility Boilers – Coal	Adding Surface Area of One ESP Field	PM2.5	13.75	0.3	0.0090	0.24	0.3	2005
PDESPM2FLD	Utility Boilers – Coal	Adding Surface Area of Two ESP Fields	PM2.5	17.5	0.3	0.013	0.31	0.3	2005
PDESPM2FAF	Utility Boilers – Coal	Adding Surface Area of Two ESP Fields, an Agglomerator, and ID Fans	PM2.5	37.2	0.3	0.042	0.53	0.3	2005

Table B-14. ptnonipm Sector SO_2 Controls Default Cost per Ton Values (Equation Type 11)

CoST CM Abbreviation	Source Group	Control Technology	CE (%)	Boiler Capacity Bin (mmBtu/hr)	Cost Per Ton Reduced ($/ton)	Capital to Annual Ratio	Equipment Life	Interest Rate	Cost Year ($ Year)
SSRBINJICB	ICI Boilers	In-duct Sorbent Injection	40	All Sizes	1069		0		2003
SCHMADDHOM	Residential Nonpoint Source	Chemical Additives to Waste	75	All Sizes	2350		0		2002
SFGDICB	ICI Boilers	Flue Gas Desulfurization	90	All Sizes	1109		0		2003
SLSFICB	ICI Boilers	Low Sulfur Fuel	80	All Sizes	2350		0		1999
SFGDICBOIL	ICI Boilers	Flue Gas Desulfurization	90	All Sizes	2898		0		1999
SFUELSWECB	External Combustion Boilers2	Fuel Switching	75	All Sizes	2350		0		1999
SSCRBPETCK	Petroleum Refinery Catalytic and Thermal Cracking Units	Wet Gas Scrubber	97	All Sizes	665		0		2004
SSCRBPETPH	Petroleum Refinery Process Heaters	Scrubbing	96	All Sizes	26529		0		2004
SFUELSFC	Stationary Source Fuel Combustion	Fuel Switching	75	All Sizes	2350		0		1999
SCATPETCRK	Petroleum Refinery Catalytic and Thermal Cracking Units	Catalyst Additive	43	All Sizes	1493		0		2004
SSCRBCEMKL	Cement Kilns	Wet Gas Scrubber	90	All Sizes	7000		0		2002
SSCRBDRKL	Cement Kilns	Wet Gas Scrubber	90	All Sizes	4000		0		2002
SSCRBPRKL	Cement Kilns	Wet Gas Scrubber	90	All Sizes	35000		0		2002
SSCRBPRPR	Cement Kilns	Wet Gas Scrubber	90	All Sizes	25000		0		2002
SSPRADRKL	Cement Kilns	Spray Dry Absorber	90	All Sizes	4000		0		2002
SSPRAPRPR	Cement Kilns	Spray Dry Absorber	90	All Sizes	25000		0		2002
SSPRAPRKL	Cement Kilns	Spray Dry Absorber	90	All Sizes	35000		0		2002
SSRTGSRP95	Sulfur Recovery Plants - Elemental Sulfur (Claus: 2 Stage w/o control (92-95% removal))	Sulfur Recovery and/or Tail Gas Treatment	99.84	All Sizes	643		15	7	1990
SSRTGSRP96	Sulfur Recovery Plants - Elemental Sulfur (Claus: 3 Stage w/o control (95-96% removal))	Sulfur Recovery and/or Tail Gas Treatment	99.78	All Sizes	643		15	7	1990

CoST CM Abbreviation	Source Group	Control Technology	CE (%)	Boiler Capacity Bin (mmBtu/hr)	Cost Per Ton Reduced ($/ton)	Capital to Annual Ratio	Equipment Life	Interest Rate	Cost Year ($ Year)
SSRTGSRP97	Sulfur Recovery Plants - Elemental Sulfur (Claus: 3 Stage w/o control (96-97% removal))	Sulfur Recovery and/or Tail Gas Treatment	99.71	All Sizes	643		15	7	1990
SIDISIBBCL	Bituminous/Subbituminous Coal (Industrial Boilers)	IDIS	40	<100	2107		30	7	1999
SIDISIBBCL	Bituminous/Subbituminous Coal (Industrial Boilers)	IDIS	40	100-250	1526		30	7	1999
SIDISIBBCL	Bituminous/Subbituminous Coal (Industrial Boilers)	IDIS	40	>250	1110		30	7	1999
SSDA_IBBCL	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	90	<100	1973		30	7	1999
SSDA_IBBCL	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	90	100-250	1341		30	7	1999
SSDA_IBBCL	Bituminous/Subbituminous Coal (Industrial Boilers)	SDA	90	>250	804		30	7	1999
SWFGSIBBCL	Bituminous/Subbituminous Coal (Industrial Boilers)	Wet FGD	90	<100	1980		30	7	1999
SWFGSIBBCL	Bituminous/Subbituminous Coal (Industrial Boilers)	Wet FGD	90	100-250	1535		30	7	1999
SWFGSIBBCL	Bituminous/Subbituminous Coal (Industrial Boilers)	Wet FGD	90	>250	1027		30	7	1999
SIDISIBLG	Lignite (Industrial Boilers)	IDIS	40	<100	2107		30	7	1999
SIDISIBLG	Lignite (Industrial Boilers)	IDIS	40	100-250	1526		30	7	1999
SIDISIBLG	Lignite (Industrial Boilers)	IDIS	40	>250	1110		30	7	1999
SSDA_IBLG	Lignite (Industrial Boilers)	SDA	90	<100	1973		30	7	1999
SSDA_IBLG	Lignite (Industrial Boilers)	SDA	90	100-250	1341		30	7	1999
SSDA_IBLG	Lignite (Industrial Boilers)	SDA	90	>250	804		30	7	1999
SWFGDIBLG	Lignite (Industrial Boilers)	Wet FGD	90	<100	1980		30	7	1999
SWFGDIBLG	Lignite (Industrial Boilers)	Wet FGD	90	100-250	1535		30	7	1999
SWFGDIBLG	Lignite (Industrial Boilers)	Wet FGD	90	>250	1027		30	7	1999
SWFGDIBRO	Residual Oil (Industrial Boilers)	Wet FGD	90	<100	4524		30	7	1999
SWFGDIBRO	Residual Oil (Industrial Boilers)	Wet FGD	90	100-250	3489		30	7	1999
SWFGDIBRO	Residual Oil (Industrial Boilers)	Wet FGD	90	>250	2295		30	7	1999
SLSFRESHET	Residential Heating	Low Sulfur Fuel	75	All Sizes	2350		0		2002

Greyed Out = Obsolete

Table B-15. ptnonipm Sector NO_x Control Cost Parameters (Equation Type 12)

CoST CM Abbreviation	Source Group	Outlet Conc. (ppmv)	Fixed Capital Cost Multiplier	Variable Capital Cost Multiplier	Fixed O&M Cost Multiplier	Variable O&M Cost Multiplier	CRF
PRGFPREO2C	Petroleum Refinery Gas-Fired Process Heaters; Excess O2 Control	80	$20,000	-	$4,000	-	0.243890694
PRGFPRULNB	Petroleum Refinery Gas-Fired Process Heaters; Ultra Low NOX Burners	40	-	$1,154,000	$56,000	$74,702	0.094392926
PRGFPRSCR	Petroleum Refinery Gas-Fired Process Heaters; SCR	20	-	$6,837,075	$121,000	$972,483	0.094392926
PRGFPRSC95	Petroleum Refinery Gas-Fired Process Heaters; SCR-95%	10	-	$8,888,198	$121,000	$1,171,507	0.094392926

Table B-16. ptnonipm ICI Boiler NOx Control Technology Parameters (Equation Type 13)

CoST CM Abbreviation	Source Group	Control Technology	RE (%)	CE (%)	RP (%)	Equipment Life (Years)
NBFIBDO	ICI Boilers - Distillate Oil	FGR	40	100	100	15
NBFIBLP	ICI Boilers - LPG	FGR	40	100	100	15
NBFIBNG	ICI Boilers - Natural Gas	FGR	40	100	100	15
NBFIBPG	ICI Boilers - Process Gas	FGR	40	100	100	15
NBFIBRO	ICI Boilers - Residual Oil	FGR	40	100	100	15
NDSCRIBCF	ICI Boilers - Coal/FBC	SCR	80	100	100	15
NDSCRIBCS	ICI Boilers - Coal/Stoker	SCR	80	100	100	15
NDSCRIBLP	ICI Boilers - LPG	SCR	80	100	100	15
NDSCRIBPG	ICI Boilers - Process Gas	SCR	80	100	100	15
NLNBFIBDO	ICI Boilers - Distillate Oil	LNB and FGR	61	100	100	15
NLNBFIBLP	ICI Boilers - LPG	LNB and FGR	61	100	100	15
NLNBFIBNG	ICI Boilers - Natural Gas	LNB and FGR	61	100	100	15
NLNBFIBPG	ICI Boilers - Process Gas	LNB and FGR	61	100	100	15
NLNBFIBRO	ICI Boilers - Residual Oil	LNB and FGR	61	100	100	15
NLNBUIBCW	ICI Boilers - Coal/Wall	LNB	47.5	100	100	15
NLNBUIBDO	ICI Boilers - Distillate Oil	LNB	47.5	100	100	15
NLNBUIBLP	ICI Boilers - LPG	LNB	47.5	100	100	15
NLNBUIBNG	ICI Boilers - Natural Gas	LNB	47.5	100	100	15
NLNBUIBPG	ICI Boilers - Process Gas	LNB	47.5	100	100	15
NLNBUIBRO	ICI Boilers - Residual Oil	LNB	47.5	100	100	15
NLNDSCRIBLP	ICI Boilers - LPG	LNB and SCR	91	100	100	15
NLNDSCRIBPG	ICI Boilers - Process Gas	LNB and SCR	91	100	100	15
NLNSCRIBCW	ICI Boilers - Coal/Wall	LNB and SCR	91	100	100	15
NLNSCRIBDO	ICI Boilers - Distillate Oil	LNB and SCR	91	100	100	15
NLNSCRIBNG	ICI Boilers - Natural Gas	LNB and SCR	91	100	100	15
NLNSCRICBG	ICI Boilers - Gas	LNB and SCR	91	100	100	15
NLNSNCRIBCW	ICI Boilers - Coal/Wall	LNB and SNCR	69.5	100	100	15
NLNSNCRIBDO	ICI Boilers - Distillate Oil	LNB and SNCR	69.5	100	100	15
NLNSNCRIBNG	ICI Boilers - Natural Gas	LNB and SNCR	69.5	100	100	15
NLNSNCRIBRO	ICI Boilers - Residual Oil	LNB and SNCR	69.5	100	100	15
NLNSNCRICBG	ICI Boilers - Gas	LNB and SNCR	69.5	100	100	15
NSCRIBCC	ICI Boilers - Coal/Cyclone	SCR	80	100	100	15
NSCRIBCW	ICI Boilers - Coal/Wall	SCR	80	100	100	15
NSCRIBDO	ICI Boilers - Distillate Oil	SCR	80	100	100	15
NSCRIBNG	ICI Boilers - Natural Gas	SCR	80	100	100	15
NSCRICBG	ICI Boilers - Gas	SCR	80	100	100	15
NSCRICBO	ICI Boilers - Oil	SCR	80	100	100	15
NSNCRIBCC	ICI Boilers - Coal/Cyclone	SNCR	45	100	100	15

NSNCRIBCS	ICI Boilers - Coal/Stoker	SNCR	45	100	100	15
NSNCRIBCW	ICI Boilers - Coal/Wall	SNCR	45	100	100	15
NSNCRIBDO	ICI Boilers - Distillate Oil	SNCR	45	100	100	15
NSNCRIBNG	ICI Boilers - Natural Gas	SNCR	45	100	100	15
NSNCRIBRO	ICI Boilers - Residual Oil	SNCR	45	100	100	15
NSNCRICBG	ICI Boilers - Gas	SNCR	45	100	100	15
NSNCRICBO	ICI Boilers - Oil	SNCR	45	100	100	15
NBFIBRO	ICI Boilers - Residual Oil	FGR	40	100	100	15

Table B-17. ptnonipm ICI Boiler NO_x Control Cost Equation Parameters (Equation Type 13)

CoST CM Abbreviation	Capital Cost Variables				O&M Cost Variables						
	Mult1	Exp1	Mult2	Exp2	Known Costs ($)	Mult1	Exp1	Mult2	Exp2	Flowrate Multiplier	Emissions Multiplier
NBFIBDO	86330.02	0.228	0	0	225238.9	3453.2	0.228	0	0	19.3	0
NBFIBLP	86330.02	0.228	0	0	225238.9	3453.2	0.228	0	0	19.3	0
NBFIBNG	86330.02	0.228	0	0	225238.9	3453.2	0.228	0	0	19.3	0
NBFIBPG	86330.02	0.228	0	0	225238.9	3453.2	0.228	0	0	19.3	0
NBFIBRO	86330.02	0.228	0	0	225238.9	3453.2	0.228	0	0	19.3	0
NDSCRIBCF	41040.93	0.5954	0	0	471911.2	1641.64	0.5954	0	0	43.96	139.54
NDSCRIBCS	41040.93	0.5954	0	0	471911.2	1641.64	0.5954	0	0	43.96	139.54
NDSCRIBLP	41040.93	0.5954	0	0	471911.2	1641.64	0.5954	0	0	43.96	139.54
NDSCRIBPG	41040.93	0.5954	0	0	471911.2	1641.64	0.5954	0	0	43.96	139.54
NLNBFIBDO	5460.27	0.65	86330.02	0.22	389766.8	218.4	0.65	3453.2	0.228	19.3	0
NLNBFIBLP	5460.27	0.65	86330.02	0.22	389766.8	218.4	0.65	3453.2	0.228	19.3	0
NLNBFIBNG	5460.27	0.65	86330.02	0.22	389766.8	218.4	0.65	3453.2	0.228	19.3	0
NLNBFIBPG	5460.27	0.65	86330.02	0.22	389766.8	218.4	0.65	3453.2	0.228	19.3	0
NLNBFIBRO	5460.27	0.65	86330.02	0.22	389766.8	218.4	0.65	3453.2	0.228	19.3	0
NLNBUIBCW	5460.27	0.65	0	0	164527.9	218.4	0.65	0	0	0	0
NLNBUIBDO	5460.27	0.65	0	0	164527.9	218.4	0.65	0	0	0	0
NLNBUIBLP	5460.27	0.65	0	0	164527.9	218.4	0.65	0	0	0	0
NLNBUIBNG	5460.27	0.65	0	0	164527.9	218.4	0.65	0	0	0	0
NLNBUIBPG	5460.27	0.65	0	0	164527.9	218.4	0.65	0	0	0	0
NLNBUIBRO	5460.27	0.65	0	0	164527.9	218.4	0.65	0	0	0	0
NLNDSCRIBLP	5460.27	0.65	41040.93	0.59	636439.1	218.4	0.65	1641.64	0.5954	43.96	139.54
NLNDSCRIBPG	5460.27	0.65	41040.93	0.59	636439.1	218.4	0.65	1641.64	0.5954	43.96	139.54
NLNSCRIBCW	5460.27	0.65	41040.93	0.59	636439.1	218.4	0.65	1641.64	0.5954	43.96	139.54
NLNSCRIBDO	5460.27	0.65	41040.93	0.59	636439.1	218.4	0.65	1641.64	0.5954	43.96	139.54

NLNSCRIBNG	5460.27	0.65	41040.93	0.59	636439.1	218.4	0.65	1641.64	0.5954	43.96	139.54
NLNSCRICBG	5460.27	0.65	41040.93	0.59	636439.1	218.4	0.65	1641.64	0.5954	43.96	139.54
NLNSNCRIBCW	5460.27	0.65	208706.86	0.21	297928.9	218.4	0.65	8348.3	0.211	19.24	425.3
NLNSNCRIBDO	5460.27	0.65	208706.86	0.21	297928.9	218.4	0.65	8348.3	0.211	19.24	425.3
NLNSNCRIBNG	5460.27	0.65	208706.86	0.21	297928.9	218.4	0.65	8348.3	0.211	19.24	425.3
NLNSNCRIBRO	5460.27	0.65	208706.86	0.21	297928.9	218.4	0.65	8348.3	0.211	19.24	425.3
NLNSNCRICBG	5460.27	0.65	208706.86	0.21	297928.9	218.4	0.65	8348.3	0.211	19.24	425.3
NSCRIBCC	41040.93	0.5954	0	0	471911.2	1641.64	0.5954	0	0	43.96	139.54
NSCRIBCW	41040.93	0.5954	0	0	471911.2	1641.64	0.5954	0	0	43.96	139.54
NSCRIBDO	41040.93	0.5954	0	0	471911.2	1641.64	0.5954	0	0	43.96	139.54
NSCRIBNG	41040.93	0.5954	0	0	471911.2	1641.64	0.5954	0	0	43.96	139.54
NSCRICBG	41040.93	0.5954	0	0	471911.2	1641.64	0.5954	0	0	43.96	139.54
NSCRICBO	41040.93	0.5954	0	0	471911.2	1641.64	0.5954	0	0	43.96	139.54
NSNCRIBCC	208706.86	0.211	0	0	133401	8348.3	0.211	0	0	19.24	425.3
NSNCRIBCS	208706.86	0.211	0	0	133401	8348.3	0.211	0	0	19.24	425.3
NSNCRIBCW	208706.86	0.211	0	0	133401	8348.3	0.211	0	0	19.24	425.3
NSNCRIBDO	208706.86	0.211	0	0	133401	8348.3	0.211	0	0	19.24	425.3
NSNCRIBNG	208706.86	0.211	0	0	133401	8348.3	0.211	0	0	19.24	425.3
NSNCRIBRO	208706.86	0.211	0	0	133401	8348.3	0.211	0	0	19.24	425.3
NSNCRICBG	208706.86	0.211	0	0	133401	8348.3	0.211	0	0	19.24	425.3
NSNCRICBO	208706.86	0.211	0	0	133401	8348.3	0.211	0	0	19.24	425.3

Table B-18. Assumptions used in constructing Equation Type 13.

Control Technology	Assumption	Value
Multiple	Cost Year	2008
	Equipment Life (years)	15
	Minimum Emissions (tons)	25.0
	Operator Rate ($/hr)	25.38
	Maintenance Labor Rate ($/hr)	17.77
	Supervisor Multiplier	15%
	Maintenance Material Multiplier	100%
	Electricity Cost ($/kW)	0.04692
	Utilization	66$
LNB	LNB Operator Labor (hrs/shift)	2
	LNB Maintenance Labor (hrs/shift)	1
SNCR	SNCR Operator Labor (hrs/shift)	2
	SNCR Maintenance Labor (hrs/shift)	0.5
	Variable Electricity Usage (kW-hr/acfm)	0.00118
	Stoichiometry – Urea 50% Sol'n Usage (lb/lb NOx)	2.26
	Urea 50% Sol'n ($/lb)	0.103
	Compressed Air Usage (scfm per lb/hr Urea)	0.08
	Compressed Air Cost ($/Mscf)	0.274
	Water Usage (gpm)	8
	Water Cost ($/Mgal)	0.223
SCR	SCR Operator Labor (hrs/shift)	0.5
	SCR Maintenance Labor (hrs/shift)	0.5
	Variable Electricity Usage (kW-hr/acfm)	0.002695
	Stoichiometry – Ammonaia (lb/lb NOx)	0.37
	Ammonia Slip (lb NH3/hr)	3.50
	Anhydrous Ammonia ($/ton)	411.17
	SCR Volume (ft3)	5,513
	SW Disposal ($/ton)	359,256
	Replacement Parts ($/yr)	25.38
	Catalyst Density (lbs/ft3)	67.44
	Catalyst Cost (with freight and sales tax)	35.0
	Captial Recover Factor – Catalyst (4-years)	1,377,791
	Captial Recovery Factor – Replacement Parts (4-years)	0.2986
FGR	FGR Operator Labor (hrs per shift)	2
	FGR Maintenance Labor (hrs per shift)	1
	Variable electricity usage (kW-hr/acfm)	0.00118

Control Technology	Assumption	Value
	Fixed electricity usage (kW-hr)	223.8

Table B-19. Assumptions used in constructing Equation Types 14-19.

Assumption	Value
Cost year	2008
Length of ductwork required	500 ft
Number of elbows per length of ductwork	0.02 per ft
Exhaust fan coefficient	22.1
Exhaust fan exponent	1.55
Exhaust fan diameter	35.5 in
Exhaust fan efficiency	70%
Gas transport velocity	3000 ft/min
Operating labor rate	$51.26 per hr
Electricity cost	$0.069981 per kWh
Dust disposal cost	$42.1411 per ton
Compressed air cost	$0.31 per scf
Lime cost	$95 per ton

Table B-20 Assumptions used in construction Equations Type 16

Assumption	Value
Density of exhaust gas	0.0709 lb/ft^3
Density of scrubbing liquid	62.4 lb/ft^3
Packing constant	28 ft^2/ft^3
Packing cost factor	$20 per ft^3
Factor to convert from FRP to other material	1
Minimum wetting rate	1.3 ft^2/hr
Cost factor for pump	$23.64 per gpm
Moles of caustic required per mole of SO_2	1.0
Molecular weight of caustic	62 lb/lb-mol
Cost factor for caustic	$440 per ton
Molecular weight of gaseous exhaust stream	29 lb/lb-mol
Moles of salt produced per mole of SO_2	1
Molecular weight of salt	58.5 lb/lb-mol
Fraction of waste stream that is treated	0.1
Wastewater disposal cost	$0.0054 per gal
Water cost	$0.00060 per gal
Adjustment for 76% Na_2O solution	0.76
Pump pressure	60 ft H_2O
Pump efficiency	70%
Packing constant 1	0.24
Packing constant 2	0.17
Friction loss factor for elbows in ductwork	0.35

Table B-21. Assumptions used in constructing Equations Type 17

Assumption	Value
Water cost	$0.20 per 1,000 gal
Makeup lime stoichiometric ratio	2.5 to 1

Table B-22 Assumptions used in constructing Equations Type 18

Assumption	Value
Sodium bicarbonate cost	$440 per ton
Makeup lime stoichiometric ratio	2.5 to 1

Table B-23. NO_x ptnonipm Default Control Technologies

CoST CM Abbreviation	Source Group	Control Technology	CE
NAFRICGS	Internal Combustion Engines - Gas	AF RATIO	20
NAFRIICGS	Internal Combustion Engines - Gas	AF + IR	30
NBINTCEMK	Cement Kilns	Biosolid Injection Technology	23
NCLPTGMCN	Glass Manufacturing - Container	Cullet Preheat	25
NCLRBIBCC	ICI Boilers - Coal/Cyclone	Coal Reburn	50
NCUPHGMPD	Glass Manufacturing - Pressed	Cullet Preheat	25
NDOXYFGMG	Glass Manufacturing - General	OXY-Firing	85
NDSCRBCCK	In-Process; Bituminous Coal; Cement Kiln	SCR	90
NDSCRBCGN	In-Process Fuel Use;Bituminous Coal; Gen	SCR	90
NDSCRBCLK	In-Process; Bituminous Coal; Lime Kiln	SCR	90
NDSCRCMDY	Cement Manufacturing - Dry	SCR	90
NDSCRCMWT	Cement Manufacturing - Wet	SCR	90
NDSCRFEP	Taconite Iron Ore Processing - Induration - Coal or Gas	SCR	90
NDSCRFFCCU	Fluid Cat Cracking Units; Cracking Unit	SCR	90
NDSCRFPGCO	In-Process; Process Gas; Coke Oven Gas	SCR	90
NDSCRIBCF	ICI Boilers - Coal/FBC	SCR	90
NDSCRIBCK	ICI Boilers - Coke	SCR	90
NDSCRIBCS	ICI Boilers - Coal/Stoker	SCR	90
NDSCRIBLP	ICI Boilers - LPG	SCR	90
NDSCRIBLW	ICI Boilers - Liquid Waste	SCR	90
NDSCRIBPG	ICI Boilers - Process Gas	SCR	90
NDSCRIBW	ICI Boilers - Wood/Bark/Waste	SCR	90
NDSCRIDIN	Indust. Incinerators	SCR	90
NDSCRISAN	Iron & Steel Mills - Annealing	SCR	90
NDSCRNAMF	Nitric Acid Manufacturing	SCR	90
NDSCRPPNG	Pulp and Paper - Natural Gas - Incinerators	SCR	90
NDSCRSPRF	Sulfate Pulping - Recovery Furnaces	SCR	90
NDSCRSPRF	Sulfate Pulping - Recovery Furnaces	SCR	80
NDSCRSWIN	Solid Waste Disp;Gov;Other Incin;Sludge	SCR	90
NDSCRUNGGN	In-Process Fuel Use; Natural Gas; Gen	SCR	90
NDSCRUPGCO	In-Process; Process Gas; Coke Oven Gas2	SCR	90
NDSCRUROGN	In-Process Fuel Use; Residual Oil; Gen	SCR	90
NELBOGMCN	Glass Manufacturing - Container	Electric Boost	10
NELBOGMFT	Glass Manufacturing - Flat	Electric Boost	10
NELBOGMPD	Glass Manufacturing - Pressed	Electric Boost	10
NEPABURN96	Agricultural Burning	Seasonal Ban (Ozone Season Daily Only)	100
NEPOBRUN96	Open Burning	Episodic Ban (Daily Only)	100
NEXABADMF	Adipic Acid Manufacturing	Extended Absorption	86

CoST CM Abbreviation	Source Group	Control Technology	CE
NEXABNAMF	Nitric Acid Manufacturing	Extended Absorption	95
NIRICGD	IC Engines - Gas/ Diesel/ LPG	IR	25
NIRICGS	Internal Combustion Engines - Gas	IR	20
NIRICOL	Internal Combustion Engines - Oil	IR	25
NIRRICOIL	Reciprocating IC Engines - Oil	IR	25
NLEAISRH	Iron & Steel Mills - Reheating	LEA	13
NLECICEGAS	Lean Burn IC Engine - Gas	Low Emission Combustion	87
NLECINGIC2	Industrial NG ICE, 2cycle (lean)	Low Emission Combustion	87
NLELSICGS	Internal Combustion Engines - Gas	L-E (Low Speed)	87
NLEMSICGS	Internal Combustion Engines - Gas	L-E (Medium Speed)	87
NLNBFAPFD	Ammonia Prod; Feedstock Desulfurization	LNB + FGR	60
NLNBFCOBF	In-Proc;Process Gas;Coke Oven/Blast Furn	LNB + FGR	55
NLNBFCSRS	Pri Cop Smel; Reverb Smelt Furn	LNB + FGR	60
NLNBFFCCU	Fluid Cat Cracking Units; Cracking Unit	LNB + FGR	55
NLNBFFPHP	Fuel Fired Equip; Process Htrs; Pro Gas	LNB + FGR	55
NLNBFFRNG	Ammonia - NG-Fired Reformers	LNB + FGR	60
NLNBFFROL	Ammonia - Oil-Fired Reformers	LNB + FGR	60
NLNBFGROFA	ICI Boilers - Gas	LNB + FGR + Over Fire Air	80
NLNBFGRPH	Fuel Fired Equip/ Process Heaters	LNB + FGR	50
NLNBFIBDO	ICI Boilers - Distillate Oil	LNB + FGR	60
NLNBFIBLP	ICI Boilers - LPG	LNB + FGR	60
NLNBFIBLW	ICI Boilers - Liquid Waste	LNB + FGR	60
NLNBFIBNG	ICI Boilers - Natural Gas	LNB + FGR	60
NLNBFIBPG	ICI Boilers - Process Gas	LNB + FGR	60
NLNBFIBRO	ICI Boilers - Residual Oil	LNB + FGR	60
NLNBFIPBH	Iron Prod; Blast Furn; Blast Htg Stoves	LNB + FGR	77
NLNBFISAN	Iron & Steel Mills - Annealing	LNB + FGR	60
NLNBFISGV	Iron & Steel Mills - Galvanizing	LNB + FGR	60
NLNBFISRH	Iron & Steel Mills - Reheating	LNB + FGR	77
NLNBFPHDO	Process Heaters - Distillate Oil	LNB + FGR	48
NLNBFPHLG	Process Heaters - LPG	LNB + FGR	55
NLNBFPHLG	Process Heaters - LPG	LNB + FGR	48[4]
NLNBFPHLP	Process Heaters - LPG	LNB + FGR	48
NLNBFPHNG	Process Heaters - Natural Gas	LNB + FGR	55
NLNBFPHOF	Process Heaters - Other Fuel	LNB + FGR	34
NLNBFPHPG	Process Heaters - Process Gas	LNB + FGR	55
NLNBFPHRO	Process Heaters - Residual Oil	LNB + FGR	34

[4] Emissions cutoff < 365 tons/yr

CoST CM Abbreviation	Source Group	Control Technology	CE
NLNBFPPAR	Plastics Prod-Specific; (ABS) Resin	LNB + FGR	55
NLNBFSGDR	Sand/Gravel; Dryer	LNB + FGR	55
NLNBFSHDO	Space Heaters - Distillate Oil	LNB + FGR	60
NLNBFSHNG	Space Heaters - Natural Gas	LNB + FGR	60
NLNBFSMCO	Starch Mfg; Combined Operations	LNB + FGR	55
NLNBFSPRF	Sulfate Pulping - Recovery Furnaces	LNB + FGR	60
NLNBFSPSP	Steel Prod; Soaking Pits	LNB + FGR	60
NLNBICB	ICI Boilers - Coal/ subbituminous	LNB	51
NLNBICISWH	ICI Space and Water Heaters	LNB	7
NLNBNISAN	Iron & Steel Mills - Annealing	LNB + SNCR	80
NLNBNPHDO	Process Heaters - Distillate Oil	LNB + SNCR	78
NLNBNPHLP	Process Heaters - LPG	LNB + SNCR	78
NLNBNPHNG	Process Heaters - Natural Gas	LNB + SNCR	80
NLNBNPHOF	Process Heaters - Other Fuel	LNB + SNCR	75
NLNBNPHPG	Process Heaters - Process Gas	LNB + SNCR	80
NLNBNPHRO	Process Heaters - Distillate & Residual Oil	LNB + SNCR	75
NLNBOAICBG	ICI Boilers - Gas	LNB + Over Fire Air	60
NLNBOAICBO	ICI Boilers - Oil	LNB + Over Fire Air	50
NLNBOAICBO	ICI Boilers - Oil	LNB + Over Fire Air	30[5]
NLNBOFAICB	ICI Boilers - Coal/ bituminous	LNB + Over Fire Air	51
NLNBOFAICS	ICI Boilers - Coal/ subbituminous	LNB + Over Fire Air	65
NLNBPHLP	Process Heaters - LPG	LNB	45
NLNBSASF	Sec Alum Prod; Smelting Furn/Reverb	LNB	50
NLNBSISAN	Iron & Steel Mills - Annealing	LNB + SCR	90
NLNBSPHDO	Process Heaters - Distillate Oil	LNB + SCR	90
NLNBSPHLP	Process Heaters - LPG	LNB + SCR	92
NLNBSPHNG	Process Heaters - Natural Gas	LNB + SCR	80
NLNBSPHNG	Process Heaters - Natural Gas	LNB + SCR	90[4]
NLNBSPHOF	Process Heaters - Other Fuel	LNB + SCR	91
NLNBSPHPG	Process Heaters - Process Gas	LNB + SCR	90
NLNBSPHRO	Process Heaters - Residual Oil	LNB + SCR	90
NLNBSPWHNG	Water Heater, Space Heater - Natural Gas	LNB	7
NLNBUACCP	Asphaltic Conc; Rotary Dryer; Conv Plant	LNB	50
NLNBUCCAB	Conv Coating of Prod; Acid Cleaning Bath	LNB	50
NLNBUCCFB	Coal Cleaning-Thrml Dryer; Fluidized Bed	LNB	50
NLNBUCCMD	Ceramic Clay Mfg; Drying	LNB	50
NLNBUCHNG	Surf Coat Oper;Coating Oven Htr;Nat Gas	LNB	50

[5] Emissions cutoff < 365 tons/yr

CoST CM Abbreviation	Source Group	Control Technology	CE
NLNBUCMDY	Cement Manufacturing - Dry	LNB	25
NLNBUCMWT	Cement Manufacturing - Wet	LNB	25
NLNBUFFNG	Fuel Fired Equip; Furnaces; Natural Gas	LNB	50
NLNBUFMTF	Fbrglass Mfg; Txtle-Type Fbr; Recup Furn	LNB	40
NLNBUFRNG	Ammonia - NG-Fired Reformers	LNB	50
NLNBUFROL	Ammonia - Oil-Fired Reformers	LNB	50
NLNBUGMCN	Glass Manufacturing - Container	LNB	40
NLNBUGMFT	Glass Manufacturing - Flat	LNB	40
NLNBUGMPD	Glass Manufacturing - Pressed	LNB	40
NLNBUIBCK	ICI Boilers - Coke	LNB	50
NLNBUIBDO	ICI Boilers - Distillate Oil	LNB	50
NLNBUIBLP	ICI Boilers - LPG	LNB	50
NLNBUIBLW	ICI Boilers - Liquid Waste	LNB	50
NLNBUIBNG	ICI Boilers - Natural Gas	LNB	50
NLNBUIBPG	ICI Boilers - Process Gas	LNB	50
NLNBUIBRO	ICI Boilers - Residual Oil	LNB	50
NLNBUISAN	Iron & Steel Mills - Annealing	LNB	50
NLNBUISGV	Iron & Steel Mills - Galvanizing	LNB	50
NLNBUISRH	Iron & Steel Mills - Reheating	LNB	66
NLNBULMKN	Lime Kilns	LNB	30
NLNBUNGGN	In-Process Fuel Use; Natural Gas; Gen	LNB	50
NLNBUPGCO	In-Process; Process Gas; Coke Oven Gas	LNB	50
NLNBUPHDO	Process Heaters - Distillate Oil	LNB	45
NLNBUPHLG	Process Heaters - LPG	LNB	50
NLNBUPHNG	Process Heaters - Natural Gas	LNB	50
NLNBUPHOF	Process Heaters - Other Fuel	LNB	37
NLNBUPHPG	Process Heaters - Process Gas	LNB	50
NLNBUPHRO	Process Heaters - Residual Oil	LNB	37
NLNBUROGN	In-Process Fuel Use; Residual Oil; Gen	LNB	37
NLNBUSFHT	Steel Foundries; Heat Treating Furn	LNB	50
NLNBUSHDO	Space Heaters - Distillate Oil	LNB	50
NLNBUSHNG	Space Heaters - Natural Gas	LNB	50
NLNBUSPRF	Sulfate Pulping - Recovery Furnaces	LNB	50
NLNCMNGC03	Commercial/Institutional - NG	LNB (1997 AQMD)	75
NLNRSNGC03	Residential NG	LNB (1997 AQMD)	75
NMKFRCMDY	Cement Manufacturing - Dry	Mid-Kiln Firing	30
NMKFRCMWT	Cement Manufacturing - Wet	Mid-Kiln Firing	30
NNGRIBCC	ICI Boilers - Coal/Cyclone	NGR	55
NNSCRNAMF	Nitric Acid Manufacturing	NSCR	98

CoST CM Abbreviation	Source Group	Control Technology	CE
NNSCRRBGD	Rich Burn IC Engines - Gas/ Diesel/ LPG	NSCR	90
NNSCRRBIC	Rich Burn Internal Combustion Engines - Diesel	NSCR	90
NNSCRRBIC2	Rich Burn Internal Combustion Engines - Nat. Gas	NSCR	90
NOTWIFRNG	Ammonia - NG-Fired Reformers	OT + WI	65
NOTWIIBNG	ICI Boilers - Natural Gas	OT + WI	65
NOTWIIBPG	ICI Boilers - Process Gas	OT + WI	65
NOTWISHNG	Space Heaters - Natural Gas	OT + WI	65
NOTWISPRF	Sulfate Pulping - Recovery Furnaces	OT + WI	65
NOXYFGMCN	Glass Manufacturing - Container	OXY-Firing	85
NOXYFGMFT	Glass Manufacturing - Flat	OXY-Firing	85
NOXYFGMPD	Glass Manufacturing - Pressed	OXY-Firing	85
NR25COL96	Industrial Coal Combustion	RACT to 25 tpy (LNB)	21
NR25NGC96	Industrial NG Combustion	RACT to 25 tpy (LNB)	31
NR25OIL96	Industrial Oil Combustion	RACT to 25 tpy (LNB)	36
NR50COL96	Industrial Coal Combustion	RACT to 50 tpy (LNB)	21
NR50NGC96	Industrial NG Combustion	RACT to 50 tpy (LNB)	31
NR50OIL96	Industrial Oil Combustion	RACT to 50 tpy (LNB)	36
NSCRCMDY	Cement Manufacturing - Dry2	SCR	80
NSCRFRNG	Ammonia - NG-Fired Reformers2	SCR	90
NSCRFROL	Ammonia - Oil-Fired Reformers	SCR	80
NSCRGMCN	Glass Manufacturing - Container	SCR	75
NSCRGMFT	Glass Manufacturing - Flat	SCR	75
NSCRGMPD	Glass Manufacturing - Pressed	SCR	75
NSCRIBCC	ICI Boilers - Coal/Cyclone	SCR	90
NSCRIBCK	ICI Boilers - Coke2	SCR	90
NSCRIBCOAL	ICI Boilers - Coal	SCR	80
NSCRIBLP	ICI Boilers - LPG2	SCR	90
NSCRIBLW	ICI Boilers - Liquid Waste2	SCR	90
NSCRIBPG	ICI Boilers - Process Gas2	SCR	90
NSCRICBG	ICI Boilers - Gas	SCR	80
NSCRICBO	ICI Boilers - Oil	SCR	80
NSCRICGD	IC Engines - Gas/ Diesel/ LPG	SCR	80
NSCRICGS	Internal Combustion Engines - Gas	SCR	90
NSCRICOL	Internal Combustion Engines - Oil	SCR	80
NSCRISAN	Iron & Steel Mills - Annealing2	SCR	90
NSCRISAN	Iron & Steel Mills - Annealing2	SCR	99[6]
NSCRNAMF	Nitric Acid Manufacturing2	SCR	90

[6] Emissions cutoff < 365 tons/yr

CoST CM Abbreviation	Source Group	Control Technology	CE
NSCRNGCP	Natural Gas Prod; Compressors	SCR	20
NSCRPHDO	Process Heaters - Distillate Oil	SCR	75
NSCRPHLP	Process Heaters - LPG	SCR	75
NSCRPHNG	Process Heaters - Natural Gas	SCR	75
NSCRPHOF	Process Heaters - Other Fuel	SCR	75
NSCRPHPG	Process Heaters - Process Gas	SCR	75
NSCRPHRO	Process Heaters - Residual Oil	SCR	75
NSCRRICOIL	Reciprocating IC Engines - Oil	SCR	80
NSCRSHDO	Space Heaters - Distillate Oil	SCR	80
NSCRSHNG	Space Heaters - Natural Gas	SCR	80
NSCRSPRF	Sulfate Pulping - Recovery Furnaces2	SCR	90
NSCRWGTJF	Gas Turbines - Jet Fuel	SCR + Water Injecti	90
NSNCNCMDY	Cement Manufacturing - Dry	SNCR - NH3 Based	50
NSNCRBCCK	In-Process; Bituminous Coal; Cement Kiln	SNCR - urea based	50
NSNCRBCGN	In-Process Fuel Use; Bituminous Coal; Gen	SNCR	40
NSNCRBCLK	In-Process; Bituminous Coal; Lime Kiln	SNCR - urea based	50
NSNCRCIIN	Comm./Inst. Incinerators	SNCR	45
NSNCRCMDY	Cement Manufacturing - Dry	SNCR - Urea Based	50
NSNCRCMOU	By-Product Coke Mfg; Oven Underfiring	SNCR	60
NSNCRFRNG	Ammonia - NG-Fired Reformers	SNCR	50
NSNCRFROL	Ammonia - Oil-Fired Reformers	SNCR	50
NSNCRGMCN	Glass Manufacturing - Container	SNCR	40
NSNCRGMFT	Glass Manufacturing - Flat	SNCR	40
NSNCRGMPD	Glass Manufacturing - Pressed	SNCR	40
NSNCRIBC	ICI Boilers - Coal	SNCR	40
NSNCRIBCC	ICI Boilers - Coal/Cyclone	SNCR	35
NSNCRIBCK	ICI Boilers - Coke	SNCR	40
NSNCRIBGA	ICI Boilers - Bagasse	SNCR - Urea	55
NSNCRIBLP	ICI Boilers - LPG	SNCR	50
NSNCRIBLW	ICI Boilers - Liquid Waste	SNCR	50
NSNCRIBMS	ICI Boilers - MSW/Stoker	SNCR - Urea	55
NSNCRICBG	ICI Boilers - Gas	SNCR	40
NSNCRICBO	ICI Boilers - Oil	SNCR	40
NSNCRICGS	Internal Combustion Engines - Gas	SNCR	90
NSNCRIDIN	Indust. Incinerators	SNCR	45
NSNCRINGI4	Industrial NG ICE, 4cycle (rich)	SNCR	90
NSNCRISAN	Iron & Steel Mills - Annealing	SNCR	60
NSNCRMWCB	Municipal Waste Combustors	SNCR	45
NSNCRMWIN	Medical Waste Incinerators	SNCR	45

CoST CM Abbreviation	Source Group	Control Technology	CE
NSNCRPHDO	Process Heaters - Distillate Oil	SNCR	60
NSNCRPHLP	Process Heaters - LPG	SNCR	60
NSNCRPHNG	Process Heaters - Natural Gas	SNCR	60
NSNCRPHOF	Process Heaters - Other Fuel	SNCR	60
NSNCRPHPG	Process Heaters - Process Gas	SNCR	60
NSNCRPHRO	Process Heaters - Residual Oil	SNCR	60
NSNCRSHDO	Space Heaters - Distillate Oil	SNCR	50
NSNCRSHNG	Space Heaters - Natural Gas	SNCR	50
NSNCRSPRF	Sulfate Pulping - Recovery Furnaces	SNCR	50
NSNCRSWIN	Solid Waste Disp; Gov; Other Incin; Sludge	SNCR	45
NTHRDADMF	Adipic Acid Manufacturing	Thermal Reduction	81
NULNBPHDO	Process Heaters - Distillate Oil	ULNB	74
NULNBPHLP	Process Heaters - LPG	ULNB	74
NULNBPHNG	Process Heaters - Natural Gas	ULNB	75
NULNBPHOF	Process Heaters - Other Fuel	ULNB	73
NULNBPHPG	Process Heaters - Process Gas	ULNB	75
NULNBPHRO	Process Heaters - Residual Oil	ULNB	73
NWHCMNGC99	Commercial/Institutional - NG	Water heater replacement	7-45
NWHRSNGC99	Residential NG	Water heater replacement	7-45
NWIGTAGT	Gas Turbines	Water Injection	40
NWLCMNGC99	Commercial/Institutional - NG	Water heater + LNB Space heaters	7-44
NWLRSNGC99	Residential NG	Water heater + LNB Space heaters	7-44
NWTINGTJF	Gas Turbines - Jet Fuel	Water Injection	68

Table B-24. NO_x ptnonipm Default Cost per Ton Values

CoST CM Abbreviation	Cost per Ton ($/ton reduced)		Capital /Annual Cost Ratio	CRF	Cost Year ($Year)	Emissions Cutoff (tons/yr)
	Default	Incremental				
NAFRICGS	380	380	1.5	0.1098	1990	> 365
NAFRICGS	1570	1570	2.8	0.1098	1990	< 365
NAFRIICGS	460	150	1.2	0.1098	1990	> 365
NAFRIICGS	1440	270	2.6	0.1098	1990	< 365
NBINTCEMK	310		7.3	0.1098	1997	
NCLPTGMCN	940	940	4.5	0.1424	1990	> 365
NCLPTGMCN	940	940	4.5	0.1424	1990	< 365
NCLRBIBCC	300	300	2	0.0944	1990	> 365
NCLRBIBCC	1570	1570	2	0.0944	1990	< 365
NCUPHGMPD	810	810	4.5	0.1424	1990	> 365

CoST CM Abbreviation	Cost per Ton ($/ton reduced)		Capital /Annual Cost Ratio	CRF	Cost Year ($Year)	Emissions Cutoff (tons/yr)
	Default	Incremental				
NCUPHGMPD	810	810	4.5	0.1424	1990	< 365
NDOXYFGMG	4277				1999	
NDSCRBCCK	2119				1999	
NDSCRBCGN	3027				1999	
NDSCRBCLK	2119				1999	
NDSCRCMDY	4636				1999	
NDSCRCMWT	3962				1999	
NDSCRFEP	5269				1999	
NDSCRFFCCU	3457				1999	
NDSCRFPGCO	6371				1999	
NDSCRIBCF	1159				1999	
NDSCRIBCK	1610				1999	
NDSCRIBCS	2531				1999	
NDSCRIBLP	2958				1990	
NDSCRIBLW	1568				1999	
NDSCRIBPG	2366				1999	
NDSCRIBW	3274				1999	
NDSCRIDIN	3109				1999	
NDSCRISAN	5269				1999	
NDSCRNAMF	812				1999	
NDSCRPPNG	3109				1999	
NDSCRSPRF	2366				1999	
NDSCRSPRF	1720				1990	
NDSCRSWIN	3109				1999	
NDSCRUNGGN	4953				1999	
NDSCRUPGCO	4953				1999	
NDSCRUROGN	4458				1999	
NELBOGMCN	7150	7150	0	0.1424	1990	> 365
NELBOGMCN	7150	7150	0	0.1424	1990	< 365
NELBOGMFT	2320	2320	0	0.1424	1990	> 365
NELBOGMFT	2320	2320	0	0.1424	1990	< 365
NELBOGMPD	8760	8760	0	0.1424	1990	> 365
NELBOGMPD	2320	8760	0	0.1424	1990	< 365
NEPABURN96	0				1990	
NEPOBRUN96	0				1990	
NEXABADMF	90	90	6.7	0.1424	1990	> 365
NEXABADMF	90	90	6.7	0.1424	1990	< 365
NEXABNAMF	480	480	8.1	0.1424	1990	> 365

CoST CM Abbreviation	Cost per Ton ($/ton reduced)		Capital /Annual Cost Ratio	CRF	Cost Year ($Year)	Emissions Cutoff (tons/yr)
	Default	Incremental				
NEXABNAMF	480	480	8.1	0.1424	1990	< 365
NIRICGD	490	490	0.6	0.1098	1990	> 365
NIRICGD	770	770	1.1	0.1098	1990	< 365
NIRICGS	550	550	0.7	0.1098	1990	> 365
NIRICGS	1020	1020	1.2	0.1098	1990	< 365
NIRICOL	490	490	0.6	0.1098	1990	> 365
NIRICOL	770	770	1.1	0.1098	1990	< 365
NIRRICOIL	770		1.1		1999	
NLEAISRH	1320	1320	3.8	0.1424	1990	> 365
NLEAISRH	1320	1320	3.8	0.1424	1990	< 365
NLECICEGAS	422		2.3		1993	
NLECINGIC2	521				1999	
NLELSICGS	630			0.1098	1990	> 365
NLELSICGS	1680			0.1098	1990	< 365
NLEMSICGS	380			0.1098	1990	> 365
NLEMSICGS	380			0.1098	1990	< 365
NLNBFAPFD	590	280	7.5	0.1424	1990	> 365
NLNBFAPFD	2560	2470	5.9	0.1424	1990	< 365
NLNBFCOBF	2470	830	6.8	0.1098	1990	> 365
NLNBFCOBF	3190	1430	6.9	0.1098	1990	< 365
NLNBFCSRS	750	250	7	0.1424	1990	> 365
NLNBFCSRS	750	250	7	0.1424	1990	< 365
NLNBFFCCU	2470	830	6.8	0.1098	1990	> 365
NLNBFFCCU	3190	1430	6.9	0.1098	1990	< 365
NLNBFFPHP	2470	830	6.8	0.1098	1990	> 365
NLNBFFPHP	3190	1430	6.9	0.1098	1990	< 365
NLNBFFRNG	590	280	7.5	0.1424	1990	> 365
NLNBFFRNG	2560	2470	5.9	0.1424	1990	< 365
NLNBFFROL	390	190	7.5	0.1424	1990	> 365
NLNBFFROL	1120	1080	5.9	0.1424	1990	< 365
NLNBFGROFA	368		7.8		2003	> 365
NLNBFGROFA	1278		7.8		2003	< 365
NLNBFGRPH	570		7.3	0.1098	1990	
NLNBFIBDO	760	370	7.5	0.1424	1990	> 365
NLNBFIBDO	2490	1090	5.9	0.1424	1990	< 365
NLNBFIBLP	760	370	7.5	0.1424	1990	> 365
NLNBFIBLP	2490	1090	5.9	0.1424	1990	< 365
NLNBFIBLW	390	190	7.5	0.1424	1990	> 365

CoST CM Abbreviation	Cost per Ton ($/ton reduced)		Capital /Annual Cost Ratio	CRF	Cost Year ($Year)	Emissions Cutoff (tons/yr)
	Default	Incremental				
NLNBFIBLW	1120	1080	5.9	0.1424	1990	< 365
NLNBFIBNG	590	280	7.5	0.1424	1990	> 365
NLNBFIBNG	2560	2470	5.9	0.1424	1990	< 365
NLNBFIBPG	590	280	7.5	0.1424	1990	> 365
NLNBFIBPG	2560	2470	5.9	0.1424	1990	< 365
NLNBFIBRO	390	190	7.5	0.1424	1990	> 365
NLNBFIBRO	1120	1080	5.9	0.1424	1990	< 365
NLNBFIPBH	380	150	4.1	0.2439	1990	> 365
NLNBFIPBH	380	150	4.1	0.2439	1990	< 365
NLNBFISAN	750	250	7	0.1424	1990	> 365
NLNBFISAN	750	250	7	0.1424	1990	< 365
NLNBFISGV	580	190	6.5	0.15350001	1990	> 365
NLNBFISGV	580	190	6.5	0.15350001	1990	< 365
NLNBFISRH	380	150	4.1	0.2439	1990	> 365
NLNBFISRH	380	150	4.1	0.2439	1990	< 365
NLNBFPHDO	1680	16680	6.8	0.1098	1990	> 365
NLNBFPHDO	4250	19540	7.1	0.1098	1990	< 365
NLNBFPHLG	3200		7.1	0.1098	1990	> 365
NLNBFPHLG	4200		7.1	0.1098	1990	< 365
NLNBFPHLP	1680	16680	6.8	0.1098	1990	> 365
NLNBFPHLP	4250	19540	7.1	0.1098	1990	< 365
NLNBFPHNG	3200	9160	6.8	0.1098	1990	> 365
NLNBFPHNG	4200	15580	6.9	0.1098	1990	< 365
NLNBFPHOF	1380	1380	6.8	0.1098	1990	> 365
NLNBFPHOF	3490	3490	7.1	0.1098	1990	< 365
NLNBFPHPG	3200	9160	6.8	0.1098	1990	> 365
NLNBFPHPG	4200	15580	6.9	0.1098	1990	< 365
NLNBFPHRO	1380	1380	6.8	0.1098	1990	> 365
NLNBFPHRO	3490	3490	7.1	0.1098	1990	< 365
NLNBFPPAR	2470	830	6.8	0.1098	1990	> 365
NLNBFPPAR	3190	1430	6.9	0.1098	1990	< 365
NLNBFSGDR	2470	830	6.8	0.1098	1990	> 365
NLNBFSGDR	3190	1430	6.9	0.1098	1990	< 365
NLNBFSHDO	760	370	7.5	0.1424	1990	> 365
NLNBFSHDO	2500	1090	5.9	0.1424	1990	< 365
NLNBFSHNG	590	280	7.5	0.1424	1990	> 365
NLNBFSHNG	2650	2470	5.9	0.1424	1990	< 365
NLNBFSMCO	2470	830	6.8	0.1098	1990	> 365

CoST CM Abbreviation	Cost per Ton ($/ton reduced)		Capital /Annual Cost Ratio	CRF	Cost Year ($Year)	Emissions Cutoff (tons/yr)
	Default	Incremental				
NLNBFSMCO	3190	1430	6.9	0.1098	1990	< 365
NLNBFSPRF	590	280	7.5	0.1424	1990	> 365
NLNBFSPRF	2560	2470	5.9	0.1424	1990	< 365
NLNBFSPSP	750	250	7	0.1424	1990	> 365
NLNBFSPSP	750	250	7	0.1424	1990	< 365
NLNBICB	256		4.5		2003	> 365
NLNBICB	850		4.5		2003	< 365
NLNBICISWH	1230		5.5		1990	
NLNBNISAN	1720	1320	3.7	0.1424	1990	> 365
NLNBNISAN	1720	1320	3.7	0.1424	1990	< 365
NLNBNPHDO	1880	3150	5.9	0.1098	1990	> 365
NLNBNPHDO	3620	3830	6.5	0.1098	1990	< 365
NLNBNPHLP	1880	3150	5.9	0.1098	1990	> 365
NLNBNPHLP	3620	3830	6.5	0.1098	1990	< 365
NLNBNPHNG	2590	3900	6.4	0.1098	1990	> 365
NLNBNPHNG	3520	6600	6.7	0.1098	1990	< 365
NLNBNPHOF	1240	1760	5.5	0.1098	1990	> 365
NLNBNPHOF	2300	2080	6.4	0.1098	1990	< 365
NLNBNPHPG	2590	3900	6.4	0.1098	1990	> 365
NLNBNPHPG	3520	6600	6.7	0.1098	1990	< 365
NLNBNPHRO	1240	1760	5.5	0.1098	1990	> 365
NLNBNPHRO	2300	2080	6.4	0.1098	1990	< 365
NLNBOAICBG	280		2.7		2003	> 365
NLNBOAICBG	1052		2.7		2003	< 365
NLNBOAICBO	306		2.9		2003	> 365
NLNBOAICBO	1052		2.9		2003	< 365
NLNBOFAICB	392		3.3		2003	> 365
NLNBOFAICB	1239		3.3		2003	< 365
NLNBOFAICS	306		3.1		2003	> 365
NLNBOFAICS	972		3.1		2003	< 365
NLNBPHLP	970	970	7.3	0.1098	1990	> 365
NLNBPHLP	3470	3470	7.3	0.1098	1990	< 365
NLNBSASF	570	570	7	0.1424	1990	> 365
NLNBSASF	570	570	7	0.1424	1990	< 365
NLNBSISAN	4080	3720	5.1	0.1424	1990	> 365
NLNBSISAN	4080	3720	5.1	0.1424	1990	< 365
NLNBSPHDO	8687	8687	7	0.1098	1999	
NLNBSPHLP	9120	9430	7	0.1098	1990	> 365

CoST CM Abbreviation	Cost per Ton ($/ton reduced)		Capital /Annual Cost Ratio	CRF	Cost Year ($Year)	Emissions Cutoff (tons/yr)
	Default	Incremental				
NLNBSPHLP	11500	15350	6.5	0.1098	1990	< 365
NLNBSPHNG	12378	12378	6.8	0.11	1999	> 365
NLNBSPHNG	12378	12378	6.8	0.1098	1999	< 365
NLNBSPHOF	3160	4840	7	0.1098	1990	> 365
NLNBSPHOF	5420	7680	6.6	0.1098	1990	< 365
NLNBSPHPG	12378	12378	6.4	0.1098	1999	> 365
NLNBSPHPG	12378	12378	6.8	0.1098	1999	< 365
NLNBSPHRO	5240	5240	6.6	0.1098	1999	< 365
NLNBSPWHNG	770				1999	
NLNBUACCP	1800	1800	7.3	0.1098	1990	> 365
NLNBUACCP	2200	2200	7.3	0.1098	1990	< 365
NLNBUCCAB	1800	1800	7.3	0.1098	1990	> 365
NLNBUCCAB	2200	2200	7.3	0.1098	1990	< 365
NLNBUCCFB	200	1090	4.5	0.1424	2003	> 365
NLNBUCCFB	1000	1460	4.5	0.1424	2003	< 365
NLNBUCCMD	1800	1800	7.3	0.1098	1990	> 365
NLNBUCCMD	2200	2200	7.3	0.1098	1990	< 365
NLNBUCHNG	1800	1800	7.3	0.1098	1990	> 365
NLNBUCHNG	2200	2200	7.3	0.1098	1990	< 365
NLNBUCMDY	440	440	5	0.1098	1997	> 365
NLNBUCMDY	440	440	5	0.1098	1997	< 365
NLNBUCMWT	440	440	5	0.1098	1997	> 365
NLNBUCMWT	440	440	5	0.1098	1997	< 365
NLNBUFFNG	570	570	7	0.1424	1990	> 365
NLNBUFFNG	570	570	7	0.1424	1990	< 365
NLNBUFMTF	1690	1690	2.2	0.3811	1990	> 365
NLNBUFMTF	1690	1690	2.2	0.3811	1990	< 365
NLNBUFRNG	650	650	5.5	0.1424	1990	> 365
NLNBUFRNG	820	820	5.5	0.1424	1990	< 365
NLNBUFROL	430	430	5.5	0.1424	1990	> 365
NLNBUFROL	400	400	5.5	0.1424	1990	< 365
NLNBUGMCN	700	1690	2.2	0.1424	1990	> 365
NLNBUGMCN	700	1690	2.2	0.1424	1990	< 365
NLNBUGMFT	700	700	2.2	0.3811	1990	> 365
NLNBUGMFT	700	700	2.2	0.3811	1990	< 365
NLNBUGMPD	1500	1500	2.2	0.1424	1990	> 365
NLNBUGMPD	1500	1500	2.2	0.1424	1990	< 365
NLNBUIBCK	1090	1090	4.5	0.1424	1990	> 365

CoST CM Abbreviation	Cost per Ton ($/ton reduced)		Capital /Annual Cost Ratio	CRF	Cost Year ($Year)	Emissions Cutoff (tons/yr)
	Default	Incremental				
NLNBUIBCK	1460	1460	4.5	0.1424	1990	< 365
NLNBUIBDO	2070	2070	5.5	0.1424	1990	> 365
NLNBUIBDO	1180	1180	5.5	0.1424	1990	< 365
NLNBUIBLP	2070	2070	5.5	0.1424	1990	> 365
NLNBUIBLP	1180	1180	5.5	0.1424	1990	< 365
NLNBUIBLW	430	430	5.5	0.1424	1990	> 365
NLNBUIBLW	400	400	5.5	0.1424	1990	< 365
NLNBUIBNG	650	650	5.5	0.1424	1990	> 365
NLNBUIBNG	820	820	5.5	0.1424	1990	< 365
NLNBUIBPG	650	650	5.5	0.1424	1990	> 365
NLNBUIBPG	820	820	5.5	0.1424	1990	< 365
NLNBUIBRO	430	430	5.5	0.1424	1990	> 365
NLNBUIBRO	400	400	5.5	0.1424	1990	< 365
NLNBUISAN	570	570	7	0.1424	1990	> 365
NLNBUISAN	570	570	7	0.1424	1990	< 365
NLNBUISGV	490	490	6.5	0.1535	1990	> 365
NLNBUISGV	490	490	6.5	0.1535	1990	< 365
NLNBUISRH	300	300	4.1	0.2439	1990	> 365
NLNBUISRH	300	300	4.1	0.2439	1990	< 365
NLNBULMKN	560	560	5	0.1098	1990	> 365
NLNBULMKN	560	560	5	0.1098	1990	< 365
NLNBUNGGN	1800	1800	7.3	0.1098	1990	> 365
NLNBUNGGN	2200	2200	7.3	0.1098	1990	< 365
NLNBUPGCO	1800	1800	7.3	0.1098	1990	> 365
NLNBUPGCO	2200	2200	7.3	0.1098	1990	< 365
NLNBUPHDO	970	970	7.3	0.1098	1990	> 365
NLNBUPHDO	3470	3470	7.3	0.1098	1990	< 365
NLNBUPHLG	3740		2	0.1098	1990	
NLNBUPHNG	1800	1800	7.3	0.1098	1990	> 365
NLNBUPHNG	2200	2200	7.3	0.1098	1990	< 365
NLNBUPHOF	710	710	7.3	0.1098	1990	> 365
NLNBUPHOF	2520	2520	7.3	0.1098	1990	< 365
NLNBUPHPG	1800	1800	7.3	0.1098	1990	> 365
NLNBUPHPG	2200	2200	7.3	0.1098	1990	< 365
NLNBUPHRO	710	710	7.3	0.1098	1990	> 365
NLNBUPHRO	2520	2520	7.3	0.1098	1990	< 365
NLNBUROGN	710	710	7.3	0.1098	1990	> 365
NLNBUROGN	2520	2520	7.3	0.1098	1990	< 365

CoST CM Abbreviation	Cost per Ton ($/ton reduced)		Capital /Annual Cost Ratio	CRF	Cost Year ($Year)	Emissions Cutoff (tons/yr)
	Default	Incremental				
NLNBUSFHT	570	570	7	0.1424	1990	> 365
NLNBUSFHT	570	570	7	0.1424	1990	< 365
NLNBUSHDO	2070	2070	5.5	0.1424	1990	> 365
NLNBUSHDO	1180	1180	5.5	0.1424	1990	< 365
NLNBUSHNG	650	650	5.5	0.1424	1990	> 365
NLNBUSHNG	820	820	5.5	0.1424	1990	< 365
NLNBUSPRF	650	650	5.5	0.1424	1990	> 365
NLNBUSPRF	820	820	5.5	0.1424	1990	< 365
NLNCMNGC03	595				1990	
NLNCMNGC03	595				1990	
NLNCMNGC03	595				1990	
NLNCMNGC03	595				1990	
NLNCMNGC03	595				1990	
NLNCMNGC03	595				1990	
NLNRSNGC03	595				1990	
NLNRSNGC03	595				1990	
NLNRSNGC03	595				1990	
NLNRSNGC03	595				1990	
NLNRSNGC03	595				1990	
NLNRSNGC03	595				1990	
NMKFRCMDY	55	55	3.4	0.1098	1997	> 365
NMKFRCMDY	55	55	3.4	0.1098	1997	< 365
NMKFRCMWT	55	55	3.6	0.1098	1997	> 365
NMKFRCMWT	55	55	3.6	0.1098	1997	< 365
NNGRIBCC	300	300	2	0.0944	1990	> 365
NNGRIBCC	1570	1570	2	0.0944	1990	< 365
NNSCRNAMF	550	550	2.4	0.1424	1990	> 365
NNSCRNAMF	550	550	2.4	0.1424	1990	< 365
NNSCRRBGD	342	342	2	0.1098	1999	> 365
NNSCRRBGD	342	342	2	0.1098	1999	< 365
NNSCRRBIC	342			0.1098	1990	> 365
NNSCRRBIC	342	342	2	0.1098	1990	< 365
NNSCRRBIC2	521		3.4	0.1098	1999	
NOTWIFRNG	320	320	2.9	0.1424	1990	> 365
NOTWIFRNG	680	680	2.9	0.1424	1990	< 365
NOTWIIBNG	320	320	2.9	0.1424	1990	> 365
NOTWIIBNG	680	680	2.9	0.1424	1990	< 365
NOTWIIBPG	320	320	2.9	0.1424	1990	> 365

CoST CM Abbreviation	Cost per Ton ($/ton reduced)		Capital /Annual Cost Ratio	CRF	Cost Year ($Year)	Emissions Cutoff (tons/yr)
	Default	Incremental				
NOTWIIBPG	680	680	2.9	0.1424	1990	< 365
NOTWISHNG	320	320	2.9	0.1424	1990	> 365
NOTWISHNG	680	680	2.9	0.1424	1990	< 365
NOTWISPRF	320	320	2.9	0.1424	1990	> 365
NOTWISPRF	680	680	2.9	0.1424	1990	< 365
NOXYFGMCN	4590	4590	2.7	0.1424	1990	> 365
NOXYFGMCN	4590	4590	2.7	0.1424	1990	< 365
NOXYFGMFT	1900	1900	2.7	0.1424	1990	> 365
NOXYFGMFT	1900	1900	2.7	0.1424	1990	< 365
NOXYFGMPD	3900	3900	2.7	0.1424	1990	> 365
NOXYFGMPD	3900	3900	2.7	0.1424	1990	< 365
NR25COL96	1350				1990	> 25
NR25NGC96	770				1990	> 25
NR25OIL96	1180				1990	> 25
NR50COL96	1350				1990	> 50
NR50NGC96	770				1990	> 50
NR50OIL96	1180				1990	> 50
NSCRCMDY	3370	3370	4.4	0.1098	1999	> 365
NSCRCMDY	3370	3370	4.4	0.1098	1999	< 365
NSCRFRNG	2366	2366	9.6	0.0944	1999	> 365
NSCRFRNG	2366	2366	10	0.0944	1999	< 365
NSCRFROL	810	940	9.6	0.0944	1990	> 365
NSCRFROL	1480	1910	10	0.0944	1990	< 365
NSCRGMCN	2200	2200	1.8	0.1424	1990	> 365
NSCRGMCN	2200	2200	1.8	0.1424	1990	< 365
NSCRGMFT	710	710	2.2	0.1424	1990	> 365
NSCRGMFT	3370	710	2.2	0.1424	1990	< 365
NSCRGMPD	2530	2530	1.3	0.1424	1990	> 365
NSCRGMPD	2530	2530	1.3	0.1424	1990	< 365
NSCRIBCC	700	700	6.3	0.0944	1990	> 365
NSCRIBCC	820	820	7	0.0944	1990	< 365
NSCRIBCK	1610	1610	6.5	0.0944	1999	> 365
NSCRIBCK	1610	1610	7.1	0.0944	1999	< 365
NSCRIBCOAL	876		7		2003	> 365
NSCRIBCOAL	2141		7		2003	< 365
NSCRIBLP	2958	2958	9.6	0.0944	1999	> 365
NSCRIBLP	2958	2958	10	0.0944	1999	< 365
NSCRIBLW	1568	1568	9.6	0.0944	1999	> 365

CoST CM Abbreviation	Cost per Ton ($/ton reduced)		Capital /Annual Cost Ratio	CRF	Cost Year ($Year)	Emissions Cutoff (tons/yr)
	Default	Incremental				
NSCRIBLW	1568	1568	10	0.0944	1999	< 365
NSCRIBPG	2366	2366	9.6	0.0944	1999	> 365
NSCRIBPG	2366	2366	10	0.0944	1999	< 365
NSCRICBG	986		7		2003	> 365
NSCRICBG	2933		7		2003	< 365
NSCRICBO	760		7		2003	> 365
NSCRICBO	2014		7		2003	< 365
NSCRICGD	920	920	2.2	0.1098	1990	> 365
NSCRICGD	2340	2340	1.8	0.1098	1990	< 365
NSCRICGS	2769		7		1990	
NSCRICOL	920	920	2.2	0.1098	1990	> 365
NSCRICOL	2340	2340	1.8	0.1098	1990	< 365
NSCRISAN	5296	5296	5	0.1424	1999	> 365
NSCRISAN	5296	5296	5	0.1424	1999	< 365
NSCRNAMF	812	812	2.5	0.1424	1999	> 365
NSCRNAMF	812	812	2.5	0.1424	1999	< 365
NSCRNGCP	533			0.1098	1990	> 365
NSCRNGCP	2769			0.1098	1990	< 365
NSCRPHDO	6030	6030	7	0.1098	1990	> 365
NSCRPHDO	9230	9230	6.4	0.1098	1990	< 365
NSCRPHLP	5350	6030	7	0.1098	1990	> 365
NSCRPHLP	12040	9230	6.4	0.1098	1990	< 365
NSCRPHNG	8160	8160	6.3	0.1098	1990	> 365
NSCRPHNG	12040	12040	6.7	0.1098	1990	< 365
NSCRPHOF	3590	3590	6.9	0.1098	1990	> 365
NSCRPHOF	5350	5350	6.5	0.1098	1990	< 365
NSCRPHPG	8160	8160	6.3	0.1098	1990	> 365
NSCRPHPG	12040	12040	6.7	0.1098	1990	< 365
NSCRPHRO	3590	3590	6.9	0.1098	1990	> 365
NSCRPHRO	5350	5350	6.5	0.1098	1990	< 365
NSCRRICOIL	1066		7		1993	
NSCRSHDO	1510	1750	9.6	0.0944	1990	> 365
NSCRSHDO	2780	3570	10	0.0944	1990	< 365
NSCRSHNG	1210	1410	9.6	0.0944	1990	> 365
NSCRSHNG	2860	2860	10	0.0944	1990	< 365
NSCRSPRF	2366	2366	9.6	0.0944	1999	> 365
NSCRSPRF	2366	2366	10	0.0944	1999	< 365
NSCRWGTJF	1010	2280	2.3	0.1098	1990	> 365

CoST CM Abbreviation	Cost per Ton ($/ton reduced)		Capital /Annual Cost Ratio	CRF	Cost Year ($Year)	Emissions Cutoff (tons/yr)
	Default	Incremental				
NSCRWGTJF	2300	7850	2.8	0.1098	1990	< 365
NSNCNCMDY	850	850	3.3	0.1098	1990	> 365
NSNCNCMDY	850	850	3.3	0.1098	1990	< 365
NSNCRBCCK	770	770	1.6	0.1098	1999	> 365
NSNCRBCCK	770	770	1.6	0.1098	1999	< 365
NSNCRBCGN	940	940	1.2	0.0944	1990	> 365
NSNCRBCGN	1260	1260	1.2	0.0944	1990	< 365
NSNCRBCLK	770	770	1.6	0.1098	1990	> 365
NSNCRBCLK	770	770	1.6	0.1098	1990	< 365
NSNCRCIIN	1130	1130	4.1	0.0944	1990	> 365
NSNCRCIIN	1130	1130	4.1	0.0944	1990	< 365
NSNCRCMDY	770	770	2.1	0.1098	1990	> 365
NSNCRCMDY	770	770	2.1	0.1098	1990	< 365
NSNCRCMOU	1640	1640	2.7	0.1424	1990	> 365
NSNCRCMOU	1640	1640	2.7	0.1424	1990	< 365
NSNCRFRNG	1570	840	8.2	0.0944	1990	> 365
NSNCRFRNG	3870	2900	9.4	0.0944	1990	< 365
NSNCRFROL	1050	560	8.2	0.0944	1990	> 365
NSNCRFROL	2580	1940	9.4	0.0944	1990	< 365
NSNCRGMCN	1770	1770	2.4	0.1424	1990	> 365
NSNCRGMCN	1770	1770	2.4	0.1424	1990	< 365
NSNCRGMFT	740	740	2.4	0.1424	1990	> 365
NSNCRGMFT	740	740	2.4	0.1424	1990	< 365
NSNCRGMPD	1640	1640	2.4	0.1424	1990	> 365
NSNCRGMPD	1640	1640	2.4	0.1424	1990	< 365
NSNCRIBC	1285		5.8		2003	> 365
NSNCRIBC	2073		5.8		2003	< 365
NSNCRIBCC	700	700	6.4	0.0944	1990	> 365
NSNCRIBCC	840	840	7.5	0.0944	1990	< 365
NSNCRIBCK	840	260	6.6	0.0944	1990	> 365
NSNCRIBCK	1040	400	7.7	0.0944	1990	< 365
NSNCRIBGA	930	930	6.8	0.0944	1990	> 365
NSNCRIBGA	1440	1440	6.3	0.0944	1990	< 365
NSNCRIBLP	1890	1010	8.2	0.0944	1990	> 365
NSNCRIBLP	4640	3470	9.4	0.0944	1990	< 365
NSNCRIBLW	1050	560	8.2	0.0944	1990	> 365
NSNCRIBLW	2580	1940	9.4	0.0944	1990	< 365
NSNCRIBMS	1250	1250	6.2	0.0944	1990	> 365

CoST CM Abbreviation	Cost per Ton ($/ton reduced)		Capital /Annual Cost Ratio	CRF	Cost Year ($Year)	Emissions Cutoff (tons/yr)
	Default	Incremental				
NSNCRIBMS	1690	1690	6.8	0.0944	1990	< 365
NSNCRICBG	280		5.2		2003	> 365
NSNCRICBG	1052		5.2		2003	< 365
NSNCRICBO	1485		5.5		2003	> 365
NSNCRICBO	2367		5.5		2003	< 365
NSNCRICGS	521		4.4	0.1098	1990	
NSNCRIDIN	1130	1130	4.1	0.0944	1990	> 365
NSNCRIDIN	1130	1130	4.1	0.0944	1990	< 365
NSNCRINGI4	422				1999	
NSNCRISAN	1640	1640	2.7	0.1424	1990	> 365
NSNCRISAN	1640	1640	2.7	0.1424	1990	< 365
NSNCRMWCB	1130	1130	4.1	0.0944	1990	> 365
NSNCRMWCB	1130	1130	4.1	0.0944	1990	< 365
NSNCRMWIN	4510	4510	4.1	0.0944	1990	> 365
NSNCRMWIN	4510	4510	4.1	0.0944	1990	< 365
NSNCRPHDO	1720	1720	5.2	0.1098	1990	> 365
NSNCRPHDO	3180	3180	6.2	0.1098	1990	< 365
NSNCRPHLP	1720	1720	5.2	0.1098	1990	> 365
NSNCRPHLP	3180	3180	6.2	0.1098	1990	< 365
NSNCRPHNG	1950	1950	5.7	0.1098	1990	> 365
NSNCRPHNG	2850	2850	6.4	0.1098	1990	< 365
NSNCRPHOF	1100	1100	4.8	0.1098	1990	> 365
NSNCRPHOF	1930	1930	6	0.1098	1990	< 365
NSNCRPHPG	1950	1950	5.7	0.1098	1990	> 365
NSNCRPHPG	2850	2850	6.4	0.1098	1990	< 365
NSNCRPHRO	1100	1100	4.8	0.1098	1990	> 365
NSNCRPHRO	1930	1930	6	0.1098	1990	< 365
NSNCRSHDO	1890	1010	8.2	0.0944	1990	> 365
NSNCRSHDO	4640	3470	9.4	0.0944	1990	< 365
NSNCRSHNG	1570	840	8.2	0.0944	1990	> 365
NSNCRSHNG	3870	2900	9.4	0.0944	1990	< 365
NSNCRSPRF	1570	840	8.2	0.0944	1990	> 365
NSNCRSPRF	3870	2900	9.4	0.0944	1990	< 365
NSNCRSWIN	1130	1130	4.1	0.0944	1990	> 365
NSNCRSWIN	1130	1130	4.1	0.0944	1990	< 365
NTHRDADMF	420	420	2.3	0.1424	1990	> 365
NTHRDADMF	420	420	2.3	0.1424	1990	< 365
NULNBPHDO	610	610	7.3	0.1098	1990	> 365

CoST CM Abbreviation	Cost per Ton ($/ton reduced)		Capital /Annual Cost Ratio	CRF	Cost Year ($Year)	Emissions Cutoff (tons/yr)
	Default	Incremental				
NULNBPHDO	2140	2140	7.3	0.1098	1990	< 365
NULNBPHLP	610	610	7.3	0.1098	1990	> 365
NULNBPHLP	2140	2140	7.3	0.1098	1990	< 365
NULNBPHNG	1200	1200	7.3	0.1098	1990	> 365
NULNBPHNG	1500	1500	7.3	0.1098	1990	< 365
NULNBPHOF	360	360	7.3	0.1098	1990	> 365
NULNBPHOF	1290	1290	7.3	0.1098	1990	< 365
NULNBPHPG	1200	1200	7.3	0.1098	1990	> 365
NULNBPHPG	1500	1500	7.3	0.1098	1990	< 365
NULNBPHRO	360	360	7.3	0.1098	1990	> 365
NULNBPHRO	1290	1290	7.3	0.1098	1990	< 365
NWHCMNGC99	0				1990	
NWHRSNGC99	0				1990	
NWIGTAGT	44000		2.8		2005	
NWLCMNGC99	1230				1990	
NWTINGTJF	650	650	1.6	0.1098	1990	> 365
NWTINGTJF	1290	1290	2.9	0.1098	1990	< 365