6.0 MODEL PROCESS UNIT CONTROL AND ENHANCED MONITORING COSTS

This chapter discusses the costs of controlling HAP emissions from new and existing combustion sources at kraft and soda pulp and paper mills. The costs of each control option discussed in Chapter 4 are presented for the individual model combustion process units. Also presented are the costs of the enhanced monitoring options discussed in Chapter 4. The enhanced monitoring options are methods of demonstrating continuous compliance with the control options. The total nationwide costs associated with each control option are presented in a separate memorandum.[1]

Section 6.1 of this chapter presents the capital and annual costs for each control option for model process units representing recovery furnaces, BLO units, SDT's, and lime kilns. Section 6.2 discusses the costs of the enhanced monitoring options. Section 6.3 contains the references cited in this chapter.

6.1 CONTROL OPTION COSTS

This section discusses the general costing approach used to develop capital and annual costs for each control option and presents the estimated capital and annual costs of each control option as applied to the model process units. Section 6.1.1 describes the general costing approach. Section 6.1.2 provides the capital and annual costs associated with each recovery furnace control option and model recovery furnace. Sections 6.1.3, 6.1.4, and 6.1.5 provide the capital and annual costs applicable to the control options for model BLO units, SDT's and lime kilns, respectively.

6.1.1 General Costing Approach

A number of assumptions were made in deriving the costs for the control options. The year 1991 was used as the base year for all costs. Capital costs were adjusted to 1991 dollars using the Chemical Engineering Plant Cost Index or the Consumer Price Index, whichever was applicable.[2,3] Operating and maintenance personnel were assumed to work 3 shifts per day, 8 hours per shift, for 365 d/yr, which is equivalent to 8,760 operating hr/yr. All process units were assumed to operate 24 hr/d, for 351 d/yr, which is equivalent to 8,424 operating hr/yr. This operating time accounts for 14 days of scheduled shutdown annually for maintenance and repair. These 14 days could be combined into a single 2-week annual shutdown period to provide sufficient time for the modifications and upgrades both to existing equipment and APCD's needed to comply with the control options. If the scheduled 2-week shutdown did not provide sufficient time for the modifications and upgrades, then pulp production losses were calculated for the number of days beyond the 2-week shutdown that were needed to finish the work.

The procedure used for estimating pulp production losses is described in the following section. The general approaches used to develop capital and annual control costs are provided in Sections 6.1.1.2 and 6.1.1.3, respectively.

6.1.1.1 Estimation of Pulp Production Losses. Pulp production losses were calculated for each pulp type as a product of the pulp loss value and the total quantity of lost pulp production.

Assuming the kraft pulp mills achieve an earnings margin of 25 percent, the pulp loss value was estimated to be equal to approximately 25 percent of the total market value.[3] The 1989 market values of bleached and unbleached kraft pulp were estimated to be approximately $712 and $423, respectively, per ADMP ($646 and $384, respectively, per ADTP). The market values were adjusted to 1991 dollars using the Consumer Price Index.[3]

To estimate for each model recovery furnace the total quantity of lost pulp production associated with the extended recovery furnace downtime, the number of days of shutdown beyond the scheduled 2-week shutdown were multiplied by the appropriate model pulp production rate. Model pulp production rates were determined for kraft bleached and unbleached pulp mills by multiplying model BLS firing rates by the appropriate correlation factor. A correlation factor of 1,800 kg BLS/ADMP (3,600 lb BLS/ADTP) was used for bleached pulp; a correlation factor of 1,500 kg BLS/ADMP (3,000 lb BLS/ADTP) was used for unbleached pulp.[4]

6.1.1.2 <u>Development of Capital Costs</u>. The following sources of cost information were used to develop capital costs (i.e., total capital investment [TCI]) for the control options being considered for kraft and soda pulp mill combustion sources:

1. Actual installed capital costs provided by individual kraft and soda pulp and paper mills;
2. Cost equations and quotes supplied by ESP and scrubber manufacturers;
3. Information supplied by recovery furnace manufacturers;
4. The U. S. EPA Handbook: Control Technologies for Hazardous Air Pollutants;[5] and
5. The U.S. EPA’s OAQPS Control Cost Manual.[6]

Whenever possible, actual cost information from individual mills was used to develop the capital cost estimates. Because many combustion sources are subject to the NSPS for PM emissions from kraft and soda pulp mills, actual mill-specific PM control costs were already available for all of the control options involving control of PM HAP’s. For those control options where actual costs were not available from individual mills or were only available from one mill, or where mill-specific costs varied widely, the EPA reference books (sources 4 and 5, above) were used.

In most cases, cost algorithms were developed, relating costs to the model process unit parameters (e.g., gas flow rate). In a few cases where a direct relationship between the capital cost and the model process unit was not apparent, the "six-tenths rule" was used to extrapolate costs from one model to another.

The "six-tenths rule" assumes a direct relationship between capital cost and capacity taken to the six-tenths power (i.e., $C_1/C_2 = (Q_1/Q_2)^{0.6}$, where C and Q are capital cost and capacity parameter, respectively). The capital costs were extrapolated using either gas flow rate or BLS firing rate as the capacity parameter.

6.1.1.3 Development of Annual Costs. Incremental total annual costs (ITAC) were derived using the annual cost model described in the OAQPS Control Cost Manual.[6] Incremental total annual costs refer to the incremental increase of total annual costs (TAC) over current operation. Total annual costs include both direct annual costs (DAC) and indirect annual costs (IAC). The cost components that comprise the DAC and IAC are discussed in the following sections.

6.1.1.3.1 Direct annual costs. The DAC include operating labor costs, maintenance labor and material costs, utility costs, and wastewater treatment costs.[6] Operating and maintenance labor costs were calculated as a product of the number of working hr/d to perform the required task, the number of operating d/yr, and the hourly wage. Operating and maintenance labor costs were calculated assuming 365 operating d/yr. The hourly wage and number of working hr/d vary with each control option and are based on information from the U. S. EPA's Handbook: Control Technologies for Hazardous Air Pollutants and the OAQPS Control Cost Manual.[5,6] The maintenance hourly wage is equal to approximately 1.5 times the operating hourly wage. The supervisory labor cost is approximately 15 percent of the operating labor cost. With the exception of ESP's, the maintenance materials cost is estimated as approximately 100 percent of the maintenance labor cost.[6] The maintenance materials cost for ESP's is estimated as 1 percent of the flange-to-flange purchased equipment cost (PEC) for ESP's, and the PEC is estimated as 0.6 times the TCI.[5]

Utility costs were broken down into electricity costs and water costs. Electricity costs were calculated as a product of the electricity unit cost and the electricity requirement. The electricity unit cost was assumed to be \$0.06/kWh.[5] Electricity requirements were divided into fan, pump, and operating electricity requirements and were calculated assuming 8,424 operating hr/yr.

The fan electricity requirement (applicable to ESP's and scrubbers) is equal to a numerical factor (0.00018) times the product of the gas flow rate, pressure drop, and operating hr/yr.[6] The gas flow rate varies with each model process unit. The pressure drop is based on information from mills.[4] Although the pressure drop is not the sole parameter that determines PM collection efficiency for lime kiln scrubbers, for the purposes of estimating costs, the pressure drop was used as an indicator of PM collection efficiency for lime kiln scrubbers. Note: A different scrubber design, rather than a higher pressure drop, was used to improve the PM collection efficiency for SDT scrubbers.

The gas flow rate and pressure drop do not change for ESP's relative to current operation when the ESP's are upgraded or replaced to improve PM collection. Therefore, the fan electricity requirements for ESP's do not change relative to current operation. However, if a scrubber is added after an ESP, the gas flow rate would be reduced, thereby reducing the fan electricity requirements for the ESP.

The pump electricity requirement (applicable to packed-bed scrubbers) is equal to a numerical factor (0.000188) times the product of the liquid flow rate, amount of head pressure, and operating hr/yr divided by the pump-motor efficiency.[6] The liquid flow rate varies with each model process unit. A head pressure of 18 m (60 ft) and a pump-motor efficiency of 70 percent were assumed.

The operating electricity requirement (applicable to ESP's) is equal to a numerical factor (0.00194) times the product of the ESP plate area and operating hr/yr.[6] The ESP plate area is calculated as a product of the exhaust gas flow rate and the ESP SCA. The gas flow rate varies with each process unit, and the SCA is based on information from mills.[4] Although the SCA is not the sole parameter that determines PM collection efficiency for ESP’s, for the purposes of estimating costs, the SCA was used as an indicator of PM collection efficiency. The cost analysis does not consider increasing the SCA to account for single-chamber ESP operation at reduced gas flow during maintenance situations. Instead, the regulation will allow for PM emission excursions during maintenance situations as part of the "Startup, Shutdown, Malfunction Plan" described in the General Provisions.[7]

Water costs were calculated as a product of the water unit cost and the water requirement. The water unit cost was assumed to be $\$0.05/m^3$ ($0.20/1,000 gal).[5] The water requirement is equal to a numerical factor (0.060) times the product of the gas flow rate and operating hr/yr.[6] The gas flow rate varies with each model process unit.

For some control options (e.g., PM controls that include upgrading or replacing an existing recovery furnace ESP or replacing an existing SDT scrubber with a new scrubber), the labor and maintenance costs are not expected to increase significantly, and, therefore, the ITAC is represented by the IAC plus the difference in electricity costs before and after implementation of the control options.

6.1.1.3.2 Indirect annual costs. The IAC include overhead costs, administrative charges, property taxes, insurance costs, and capital recovery costs. Overhead costs are approximately 60 percent of all labor and maintenance material costs.[6] Overhead costs are not applicable when labor and maintenance costs do not increase significantly. Administrative, insurance, and property tax costs are approximately 4 percent of the TCI.[6] Capital recovery costs are equal to a capital recovery factor (CRF) multiplied by the TCI. The CRF is estimated using the equation $CRF = [i(1 + i)^n]/[(1 + i)^n - 1]$, where i = interest rate (assumed to be 7 percent) and n = equipment life of the device being installed or modified.[6]

6.1.2 Recovery Furnace Control Options

The following sections discuss the model costs of four control options evaluated for recovery furnaces. These control options include PM controls (Section 6.1.2.1), wet to dry ESP system conversion (Section 6.1.2.2), conversion of a DCE recovery furnace system to an NDCE recovery furnace (Section 6.1.2.3), and addition of a packed-bed scrubber (Section 6.1.2.4).

6.1.2.1 PM Controls. Two PM control options were evaluated for model NDCE recovery furnaces RF-1 through RF-6 and model DCE recovery furnaces RF-7 through RF-9. The control options apply to new and existing recovery furnaces and are described below.

One PM control option that was evaluated would reduce PM emissions from existing recovery furnaces to the NSPS level of 0.10 g/dscm (0.044 gr/dscf). The PM control option evaluated would involve (1) replacing the recovery furnace ESP or (2) upgrading the recovery furnace ESP. The control equipment selected by a particular mill would be site-specific.

A second PM control option that was evaluated would reduce PM emissions from existing recovery furnaces to 0.034 g/dscm (0.015 gr/dscf). This more stringent PM control option would involve replacing or upgrading the recovery furnace ESP and adding a packed-bed scrubber. The second PM control option also applies to new recovery furnaces; the option could be used to evaluate the cost to new sources subject to a more stringent standard (0.034 g/dscm [0.015 gr/dscf]) than the current NSPS.

The PM control costs for existing recovery furnaces with baseline PM emissions above the NSPS level were estimated for model NDCE recovery furnaces RF-1a through RF-6a and model DCE recovery furnaces RF-7a through RF-9a. The PM control costs for new and existing recovery furnaces with baseline PM emissions at or below the NSPS level were estimated for model NDCE recovery furnaces RF-1b through RF-6b and model DCE recovery furnaces RF-7b through RF-9b.

The PM control costs for model NDCE recovery furnaces with dry ESP systems (i.e., RF-1 through RF-3) are assumed to be identical to the PM control costs for model NDCE recovery furnaces with wet ESP systems (i.e., RF-4 through RF-6) because PM emissions are not affected by whether or not black liquor is used in the ESP bottom or PM return system. The capital and annual costs to replace or upgrade ESP’s are presented for the model NDCE and DCE recovery furnaces in the following sections. The capital and annual costs to install a new packed-bed scrubber are presented in Section 6.1.2.4.

Based on the costs presented below, it is more expensive to replace an existing ESP than to upgrade it. However, a replacement may be necessary, depending on the age and condition of the existing ESP, in order to effectively control PM emissions. Site-specific conditions often dictate the cost-effectiveness of replacing or upgrading an ESP.

6.1.2.1.1 ESP replacement: capital costs. The ESP replacement costs for models RF-1a through RF-9a were calculated based on recent ESP replacement costs provided by individual pulp and paper mills (i.e., costs for ESP’s replaced during or after 1989).[4] The cost to dispose of the existing ESP was assumed to be included in the new ESP costs provided by the individual mills. New ESP costs average \$420/m^2 (\$39/ft^2) of ESP plate area for NDCE and DCE recovery furnaces.[4] The ESP plate area for the new ESP was derived from the model exhaust gas flow rates for RF-1a through RF-9a and the SCA for the replacement ESP.

For NDCE recovery furnaces, an SCA of approximately 100 $m^2/(m^3/sec)$ (530 $ft^2/1{,}000$ acfm) was assumed based on ESP SCA information from NDCE recovery furnaces subject to the NSPS (i.e., furnaces installed or replaced during or after 1977 and required to have outlet PM emissions of 0.10 g/dscm [0.044 gr/dscf] or lower).[4] Because dry-bottom ESP’s are used to control PM emissions from approximately 80 percent of NDCE recovery furnaces, it was assumed that all replacement ESP’s for NDCE recovery furnaces would be of the dry-bottom design.[8] The ESP replacement costs for the three model NDCE recovery furnaces are presented in Table 6-1. The total capital costs range from \$4.12 million to \$10.7 million for RF-1a through RF-6a.

For DCE recovery furnaces, an SCA of approximately 90 $m^2/(m^3/sec)$ (430 $ft^2/1,000$ acfm) was assumed based on ESP SCA information from DCE recovery furnaces subject to the NSPS (i.e., furnaces installed or replaced during or after 1977 and required to have outlet PM emissions of 0.10 g/dscm [0.044 gr/dscf] or lower).[4] Because wet-bottom ESP's are used to control PM emissions from approximately 90 percent of DCE recovery furnaces, it was assumed that all new replacement ESP's for DCE recovery furnaces would be of the wet-bottom design.[8] The ESP replacement costs for the three model DCE recovery furnaces are presented in Table 6-1. The TCI costs range from $2.01 million to $6.03 million for RF-7a through RF-9a.

Installing a new fan and stack typically comprises approximately 20 percent of the total capital costs of installing a new ESP.[9] Because the fan and stack usually do not need to be replaced when an ESP is replaced, the ESP replacement costs stated above are estimated to be 80 percent of the cost of a completely new ESP. The costs to replace the fan and stack due to the addition of the packed-bed scrubber are presented in Section 6.1.2.4.2.

In some cases, installation of a replacement ESP can be achieved using a "roll-in" procedure, in which the ESP is erected adjacent to its final location and then rolled into position using roller assemblies or rubber-tired dollies. The roll-in technique has been used for a number of years on a wide range of equipment sizes.[9] However, the roll-in technique probably cannot be used for the majority of recovery furnaces due to the location of the ESP (e.g., an elevated position relative to the recovery furnace). Because the ESP replacement costs were based on actual ESP replacement costs provided by individual pulp and paper mills, it was assumed that they were based on recovery furnaces that cannot do ESP roll-ins. Therefore, no contingency factor is needed to adjust ESP replacement costs to account for the furnaces being unable to do ESP roll-ins. However, without the ESP roll-in, an ESP replacement probably could not be completed within the scheduled 2-week shutdown for maintenance. Because no information is available on the time needed to complete an ESP replacement, the maximum time estimated to complete an ESP upgrade, as described in Section 6.1.2.1.3, was used. The estimated maximum time is 30 days. Therefore, pulp production losses for replacing the ESP were calculated for that period of time minus the 2-week (14-day) scheduled mill shutdown. Pulp production losses for the 16-day period are presented in Table 6-2.

For mills producing bleached pulp, the pulp production losses range from $1.19 million to $3.12 million for RF-1a through RF-6a and $710,000 to $2.13 million for RF-7a through RF-9a. For mills producing unbleached pulp, the pulp production losses range from $844,000 to $2.19 million for RF-1a through RF-6a and $506,000 to $1.52 million for RF-7a through RF-9a. The unbleached pulp production losses are lower for each model recovery furnace because unbleached pulp has a lower market value than bleached pulp.

6.1.2.1.2 <u>ESP replacement: incremental annual costs</u>. Labor and maintenance requirements and costs are assumed to be unchanged when the ESP is replaced. However, because the ESP replacement option includes an increase in ESP plate area, electricity costs are increased. The increase in ESP electricity costs resulting from the ESP replacement is based on an increase in the SCA.

For NDCE and DCE recovery furnaces, the baseline SCA values are approximately 90 $m^2/(m^3/sec)$ (430 $ft^2/1,000$ acfm) and 70 $m^2/(m^3/sec)$ (330 $ft^2/1,000$ acfm), respectively. These SCA values are the average values common to ESP’s on NDCE and DCE recovery furnaces installed prior to 1977 (i.e., installed prior to the NSPS and not subject to the NSPS PM standard of 0.10 g/dscm [0.044 gr/dscf]) that also have PM emissions greater than 0.10 g/dscm (0.044 gr/dscf).[4] As a result of the ESP replacement, the baseline SCA would be increased to a value of approximately 100 $m^2/(m^3/sec)$ (530 $ft^2/1,000$ acfm) for NDCE recovery furnaces and 90 $m^2/(m^3/sec)$ (430 $ft^2/1,000$ acfm) for DCE recovery furnaces. These SCA values are the average values common to ESP’s on NDCE and DCE recovery furnaces installed during or after 1977 (i.e., installed after the NSPS and subject to the NSPS standard of 0.10 g/dscm [0.044 gr/dscf]) that also have PM emissions less than or equal to 0.10 g/dscm (0.044 gr/dscf) but greater than 0.034 g/dscm (0.015 gr/dscf) (the more stringent PM control level).[4]

The incremental annual costs for ESP replacements include the difference in electricity costs plus the indirect costs affected by the TCI, which include the administrative, property tax, and insurance costs plus the capital recovery cost. The lifetime of dry-bottom ESP’s typically ranges from 12 to 15 years.[9] Therefore, an average 13.5-year life span was assumed when calculating the capital recovery cost for dry-bottom ESP’s installed on NDCE recovery furnaces. The lifetime of wet-bottom ESP’s is typically 10 years.[9] Therefore, an average 10-year life span was assumed when calculating the capital recovery cost for wet-bottom ESP’s installed on DCE recovery furnaces.

The ITAC for the model NDCE and DCE recovery furnaces, excluding annualized pulp production losses (i.e., capital recovery costs for the pulp production losses), are presented in Table 6-1. The incremental annual costs range from $666,000/yr to $1.73 million/yr for RF-1a through RF-6a and $378,000/yr to $1.14 million/yr for RF-7a through RF-9a. The ITAC for the model NDCE and DCE recovery furnaces, including annualized bleached and unbleached pulp production losses, are presented in Table 6-2. The incremental annual costs, including annualized bleached pulp production losses, range from $805,000/yr to $2.09 million/yr for RF-1a through RF-6a and $764,000/yr through $1.99 million/yr for RF-7a through RF-9a. The incremental annual costs, including annualized unbleached pulp production losses, range from $764,000/yr to $1.99 million/yr for RF-1a through RF-9a and $451,000/yr to $1.36 million/yr for RF-7a through RF-9a.

6.1.2.1.3 ESP upgrade (to 0.10 g/dscm [0.044 gr/dscf]): capital costs. The ESP upgrade costs for existing NDCE and DCE recovery furnaces are based on May 1993 ESP upgrade costs supplied by an ESP manufacturer.[9] The ESP manufacturer supplied costs for a model NDCE recovery furnace with an exhaust gas flow rate of 109 m^3/sec (230,000 acfm) and a model DCE recovery furnace with an exhaust gas flow rate of 160 m^3/sec (340,000 acfm).[9] According to the ESP manufacturer, the proposed upgrade would result in an ESP size adequate to meet an outlet PM level of 0.10 g/dscm (0.044 gr/dscf).[9]

The ESP manufacturer supplied ESP upgrade costs for two different ESP upgrade schedules (Schedules 1 and 2). Schedule 1 is a 21-day, 7-day/week ESP upgrade schedule, including about 14 days of recovery furnace outage and about 3 or 4 days of partial load on both sides of the outage.[9] Three days of partial load before and after the outage were assumed, for a total of 6 days of partial load. Assuming a 50 percent load for 6 days, there would be 3 days of downtime during the period of partial load. Added to the 14 days of recovery furnace outage, there is a total downtime of 17 days, which is 3 days of downtime beyond the annual 2-week shutdown for maintenance. Schedule 2 is a 30-day, 6-day/week upgrade schedule and has no periods of partial load. There would be 30 days of recovery furnace outage.[9] Schedule 2 would have 16 days of downtime beyond the annual 2-week shutdown. For the model NDCE recovery furnace, the cost for Schedule 1 is $1,292,000, and the cost for Schedule 2 is $1,259,000.[9] For the model DCE recovery furnace, the cost for Schedule 1 is $1,504,750, and the cost for Schedule 2 is $1,466,500.[9]

The nature of the ESP upgrades is identical for Schedules 1 and 2. A brief summary of the required modifications is presented in Table 6-3. The ESP upgrades for these schedules include replacing the weighted wire design with a rigid electrode design.[9] Rigid electrode ESP’s generally operate at a higher voltage than weighted wire ESP’s and, in some cases, may require replacement of the transformer and other controls. However, the ESP upgrade cost estimate does not include those costs that vary widely based on site-specific conditions, such as the need for transformer replacement.

The only difference between the two ESP upgrade schedules is that Schedule 2 allows a longer downtime because major modifications to the furnace would be performed at the same time. The costs of the recovery furnace modification are not included because they are not associated with the ESP upgrade. The ESP upgrade work for Schedule 2 would be extended over the 30-day shutdown period.

The ESP upgrade costs were adjusted to 1991 dollars and then scaled using the six-tenths power rule described in Section 6.1.1.2 to derive costs for the model NDCE and DCE recovery furnaces. The model ESP upgrade costs, without pulp production losses, for Schedules 1 and 2 are presented in Tables 6-4 and 6-5, respectively. The ESP upgrade capital costs for Schedule 1 range from $1.20 million to $2.12 million for RF-1a through RF-6a and $811,000 to $1.57 million for RF-7a through RF-9a. The ESP upgrade capital costs for Schedule 2 range from $1.16 million to $2.07 million for RF-1a through RF-6a and $791,000 to $1.53 million for RF-7a through RF-9a.

The pulp production losses associated with shutting down the mill to upgrade the ESP were calculated using the method described in Section 6.1.1.1. The ESP upgrade costs that include bleached and unbleached pulp production losses are presented in Tables 6-6 and 6-7, respectively. The pulp production losses for Schedules 1 and 2 are presented for the model recovery furnaces in Tables 6-6 and 6-7, respectively.

The bleached pulp production losses for Schedule 1 range from $224,000 to $585,000 for RF-1a through RF-6a and $133,000 to $399,000 for RF-7a through RF-9a. The unbleached pulp production losses for Schedule 1 range from $158,000 to $411,000 for RF-1a through RF-6a and $94,900 to $285,000 for RF-7a through RF-9a. The pulp production losses for mills producing unbleached pulp are lower than for mills producing bleached pulp because unbleached pulp has a lower market value than bleached pulp.

Because Schedule 2 is longer than Schedule 1, the pulp production losses are higher for Schedule 2 than for Schedule 1. The bleached pulp production losses for Schedule 2 range from

$1.19 million to $3.12 million for RF-1a through RF-6a and $710,000 to $2.13 million for RF-7a through RF-9a. The unbleached pulp production losses for Schedule 2 range from $844,000 to $2.19 million for RF-1a through RF-6a and $506,000 to $1.52 million for RF-7a through RF-9a.

6.1.2.1.4 ESP upgrade (to 0.10 g/dscm [0.044 gr/dscf]): incremental annual costs. Labor and maintenance costs are assumed to be unchanged when the ESP is upgraded to achieve a PM level of 0.10 g/dscm (0.044 gr/dscf). Therefore, the incremental annual costs for the ESP upgrade include only the electricity costs and the TCI-based indirect annual costs, which include administrative, property tax, insurance, and capital recovery costs. The capital recovery cost for NDCE recovery furnace ESP’s is based on an average 13.5-year life span for dry-bottom ESP’s.[9] The capital recovery cost for DCE recovery furnace ESP’s is based on an average 10-year life span for wet-bottom ESP’s.[9] Although the ESP plate area is not increased with an ESP upgrade, there will be additional electricity costs associated with the new ESP design. The actual increase in electricity costs with an ESP upgrade is not currently known. Therefore, it was assumed that the incremental increase in electricity costs for an upgraded ESP would be the same as for a replacement ESP. Because the electricity cost increases for the replacement ESP in Section 6.1.2.1.2 were based on an increase in SCA from baseline to control levels, the electricity cost increases for the upgraded ESP were calculated in the same manner.[4] The ITAC for the model recovery furnaces are presented in Tables 6-4 through 6-7.

Table 6-4 presents the ITAC for the Schedule 1 ESP upgrade for each model recovery furnace, without accounting for annualized pulp production losses. As shown in the table, the ITAC for the Schedule 1 ESP upgrade, without annualized pulp production losses, range from $207,000/yr to $383,000/yr for RF-1a through RF-6a and $159,000/yr to $322,000/yr for RF-7a through RF-9a. Table 6-5 presents the ITAC for the Schedule 2 ESP upgrade for each model recovery furnace, without accounting for annualized pulp production losses. As shown in the table, the ITAC for the Schedule 2 ESP upgrade, without annualized pulp production losses, range from $202,000/yr to $375,000/yr for RF-1a through RF-6a and $156,000/yr to $314,000/yr for RF-7a through RF-9a.

Table 6-6 presents the ITAC for the Schedule 1 ESP upgrade for each model recovery furnace and includes estimated production losses associated with bleached and unbleached pulp. As shown in the table, the ITAC for the Schedule 1 ESP upgrade, including bleached pulp production losses, range from $233,000/yr to $452,000/yr for RF-1a through RF-6a and $178,000/yr to $379,000/yr for RF-7a through RF-9a. The ITAC for the Schedule 1 ESP upgrade, including unbleached pulp production losses, range from $226,000/yr to $431,000/yr for RF-1a through RF-6a and $173,000/yr to $363,000/yr for RF-7a through RF-9a.

Table 6-7 presents the ITAC for the Schedule 2 ESP upgrade for each model recovery furnace and includes estimated production losses associated with bleached and unbleached pulp. As shown in the table, the ITAC for the Schedule 2 ESP upgrade, including bleached pulp production losses, range from $341,000/yr to $740,000/yr for RF-1a through RF-6a and $257,000/yr to $617,000/yr for RF-7a through RF-9a. The ITAC for the Schedule 2 ESP upgrade, including unbleached pulp production losses, range from $300,000/yr to $631,000/yr for RF-1a through RF-6a and $228,000/yr to $530,000/yr for RF-7a through RF-9a.

6.1.2.1.5 ESP upgrade (to 0.034 g/dscm [0.015 gr/dscf]): capital costs. Control costs have been determined for those new and existing recovery furnaces controlling PM emissions from the NSPS level of 0.10 g/dscm (0.044 gr/dscf) to 0.034 g/dscm (0.015 gr/dscf). These costs would include an ESP upgrade cost and a packed-bed scrubber cost. Because no actual ESP upgrade costs were available for controlling PM emissions to 0.034 g/dscm (0.015 gr/dscf), the upgrade cost for the recovery furnace ESP was instead based on the incremental cost difference between an ESP capable of achieving a PM level less than or equal to 0.10 g/dscm (0.044 gr/dscf) but greater than 0.034 g/dscm

(0.015 gr/dscf) and an ESP capable of achieving a PM level less than or equal to 0.034 g/dscm (0.015 gr/dscf). This section presents the ESP upgrade costs; the packed-bed scrubber costs are presented in Section 6.1.2.4.

The ESP upgrade capital costs were based on recent ESP costs provided by individual pulp and paper mills (i.e., costs for ESP's installed or replaced during or after 1989).[4] The ESP costs average \$420/m^2 (\$39/ft^2) of ESP plate area for recovery furnaces.[4] To determine the ESP upgrade cost, this cost per ESP plate area was multiplied by the increase in ESP plate area assumed to reduce PM emissions from 0.10 g/dscm (0.044 gr/dscf) to 0.034 g/dscm (0.015 gr/dscf).

The ESP plate area for NDCE recovery furnace ESP's achieving a PM level less than or equal to 0.10 g/dscm (0.044 gr/dscf) but greater than 0.034 g/dscm (0.015 gr/dscf) is based on an average SCA of approximately 100 $m^2/(m^3/sec)$ (530 ft^2/1,000 acfm), as discussed in Section 6.1.2.1.2. The ESP plate area for DCE recovery furnace ESP's achieving a PM level less than or equal to 0.10 g/dscm (0.044 gr/dscf) but greater than 0.034 g/dscm (0.015 gr/dscf) is based on an average SCA of approximately 90 $m^2/(m^3/sec)$ (430 ft^2/1,000 acfm), as discussed in Section 6.1.2.1.2.[4] The ESP plate area for recovery furnace ESP's achieving a PM level less than or equal to 0.034 g/dscm (0.015 gr/dscf) is based on an SCA of approximately 120 $m^2/(m^3/sec)$ (620 ft^2/1,000 acfm). This is the SCA value for an ESP achieving a PM emission level of 0.034 g/dscm (0.015 gr/dscf) on a long-term basis.[4,10]

The capital cost attributable to the control option to install new recovery furnace ESP's capable of achieving a PM level of 0.034 g/dscm (0.015 gr/dscf) would not be the cost of a new ESP, but only that portion associated with controlling PM emissions from 0.10 g/dscm (0.044 gr/dscf) to 0.034 g/dscm (0.015 gr/dscf), which is the same as the cost to upgrade existing recovery furnace ESP's to achieve the same PM level of 0.034 g/dscm (0.015 gr/dscf).

The capital costs of the ESP upgrade used to achieve the 0.034 g/dscm (0.015 gr/dscf) PM level are lower than the capital costs of the ESP upgrade used to achieve the 0.10 g/dscm (0.044 gr/dscf) NSPS PM level discussed in Section 6.1.2.1.3. The capital costs for this more stringent ESP upgrade control option, excluding pulp production losses, are presented in Table 6-8 and range from $644,000 to $1.67 million for RF-1b through RF-6b and $387,000 to $1.16 million for RF-7b through RF-9b.

There are no pulp production losses for new recovery furnaces to install an upgraded ESP because the ESP is upgraded prior to installation. No information is currently available for existing recovery furnaces on the amount of time required to complete an ESP upgrade that would allow PM control to 0.034 g/dscm (0.015 gr/dscf). However, it was assumed that the pulp production losses could be as high as those for Schedule 1 of the ESP upgrade control option discussed in Section 6.1.2.1.3. The pulp production losses are presented in Table 6-9.

6.1.2.1.6 ESP upgrade (to 0.034 g/dscm [0.015 gr/dscf]): incremental annual costs. Labor and maintenance costs are assumed to be unchanged when the ESP is upgraded to achieve a PM level of 0.034 g/dscm (0.015 gr/dscf). Therefore, the incremental annual costs for the ESP upgrade include only the electricity costs and TCI-based indirect annual costs, which include administrative, property tax, insurance, and capital recovery costs. The capital recovery cost for NDCE recovery furnace ESP’s is based on an average 13.5-year life span for dry-bottom ESP’s. The capital recovery cost for DCE recovery furnace ESP’s is based on an average 10-year life span for wet-bottom ESP’s. The PM control electricity costs would include both ESP upgrade and packed-bed scrubber electricity costs. The ESP upgrade electricity costs are presented in this section; Section 6.1.2.4 presents the packed-bed scrubber electricity costs. The ESP upgrade electricity costs are based on an increase in SCA from approximately 100 $m^2/(m^3/sec)$ (530 $ft^2/$ 1,000 acfm) for NDCE recovery furnaces and 90 $m^2/(m^3/sec)$

(430 ft^2/1,000 acfm) for DCE recovery furnaces to approximately 120 $m^2/(m^3/sec)$ (620 ft^2/1,000 acfm) for all recovery furnaces.[4]

The electricity costs presented in this section are based on gas flow rates and pressure drops in the absence of a packed-bed scrubber. If a packed-bed scrubber was added after the ESP, the fan electricity costs for the ESP would change slightly from those presented in this section. However, because the total electricity costs are only a small fraction (approximately 10 percent) of the ITAC, a slight change in fan electricity costs would have a negligible effect on the ITAC.

The ITAC for the model recovery furnaces, excluding annualized pulp production losses, are presented in Table 6-8 and range from \$117,000/yr to \$304,000/yr for RF-1b through RF-6b and \$80,300/yr to \$241,000/yr for RF-7b through RF-9b. The ITAC for the model recovery furnaces, including annualized pulp production losses, are presented in Table 6-9. The incremental annual costs, including annualized bleached pulp production losses, range from \$143,000/yr to \$373,000/yr for RF-1b through RF-6b and \$99,000/yr to \$298,000/yr for RF-7b through RF-9b. The incremental annual costs, including annualized unbleached pulp production losses, range from \$136,000/yr to \$352,000/yr for RF-1b through RF-6b and \$94,000/yr to \$282,000/yr for RF-7b through RF-9b.

6.1.2.2 Wet to Dry ESP System Conversion. Two control options were evaluated for reducing emissions of gaseous organic HAP’s such as methanol from existing NDCE recovery furnaces. These control options are (1) converting an ESP system that uses black liquor or HAP-contaminated process water in the ESP bottom or PM return system (referred to as a wet ESP system) to an ESP system that uses "clean" water (i.e., water uncontaminated with methanol and other gaseous organic HAP’s) in the ESP bottom or PM return system; and (2) converting a wet ESP system to a dry-bottom ESP with a dry PM return system (referred to as a dry ESP system). With these two control options, the potential stripping of methanol and other gaseous organic HAP’s from the black liquor or contaminated process water in the ESP system would be eliminated.

Only the costs for the second control option, converting from a wet to a dry ESP system, were evaluated. This decision was based on (1) the uncertainty associated with the available cost estimates for converting to an ESP system that uses "clean" water in the ESP bottom or PM return system; and (2) the fact that very few mills use water in the ESP system.

A cost estimate is available for converting a wet-bottom ESP that uses black liquor in the ESP bottom to one that uses "clean" water in the ESP bottom. This cost estimate is significantly lower than the cost estimates available for converting to a dry-bottom ESP, but the accuracy of this cost estimate is questionable. According to a 1985 EPA estimate for a 900 ADMP/d (1,000 ADTP/d) mill, the capital cost to convert a wet-bottom ESP to one that uses water in the ESP bottom is $154,000. The annual cost is $67,000/yr.[11] These costs are lower than the wet- to dry-bottom conversion costs presented below. Several pulp and paper industry representatives commenting on the estimate indicated that the costs to evaporate the added water should be higher. They also noted that mills may experience a loss of production to evaporate the extra water if excess capacity was not available in the evaporators.[12]

The wet to dry ESP system conversion control option applies to model NDCE recovery furnaces RF-4 through RF-6, which represent existing NDCE recovery furnaces with wet ESP systems. These models represent existing NDCE recovery furnaces only, because no wet ESP systems are expected to be installed on new NDCE recovery furnaces.

The model costs for the wet to dry ESP system conversion control option are based on costs to convert NDCE recovery furnace wet-bottom ESP’s to dry-bottom ESP’s. For the purposes of this cost analysis, these wet- to dry-bottom ESP conversion costs are assumed to apply also to those NDCE recovery furnaces with dry-bottom ESP’s and wet PM return systems. The ESP conversion costs may be lower than those presented if an ESP upgrade to improve PM collection is also performed at the same time. However, no information is currently available on the extent of the cost reduction. The capital and annual costs for the wet to dry ESP system conversion control option are presented in the following sections for existing model NDCE recovery furnaces.

6.1.2.2.1 Capital costs. The wet to dry ESP system conversion capital costs are based on 1993 conversion costs from an ESP manufacturer.[13] These costs were adjusted to 1991 dollars and then scaled, using the six-tenths power rule, to derive costs for the three model NDCE recovery furnaces. The ESP model used by the manufacturer to develop the conversion costs was stated as being three fields in length and two chambers in width, each 6.1 m (20 ft) wide. The cost to remove the existing agitator paddles and liquor piping and install a perpendicular drag scraper system, shallow fallout hoppers, drag chain conveyors, and rotary valves was estimated to be $560,000 for the material and $285,000 for installation. The cost estimate does not include the cost associated with (1) any removal of asbestos, if applicable; (2) any piping beyond the rotary valves; or (3) any equipment beyond the rotary valves, such as an ash mixing tank with associated instrumentation. The ESP conversion costs from the ESP manufacturer are based on working two 10-hour shifts for about 10 days and converting both ESP chambers simultaneously.[13] Therefore, no downtime would be necessary beyond the annual 2-week shutdown, which means no pulp production losses would need to be included in the model ESP conversion costs presented below.

The recovery furnace size used by the ESP manufacturer in calculating the wet-bottom ESP conversion costs was stated to be about 600 to 900 ADMP/d (700 to 1,000 ADTP/d)[13]. A size of 800 ADMP/d (900 ADTP/d) (the size for the mid-size model NDCE recovery furnace RF-5) was used to scale the costs. The capital costs for the three model NDCE recovery furnaces are presented in Table 6-10. The wet to dry ESP system conversion costs range from $596,000 to $1.06 million for RF-4 through RF-6.

6.1.2.2.2 Incremental annual costs. Direct annual costs are not assumed to increase as a result of the wet to dry ESP system conversion. Although there may be some extra maintenance costs, they are expected to be small compared to the increases in capital recovery and other indirect costs. Past dry-bottom ESP designs were associated with higher maintenance costs. Changes in designs have eliminated many of those problems.[14] The costs from the ESP manufacturer used to develop the model costs are based on the modern design. Furthermore, because wet-bottom ESP designs are associated with greater corrosion, switching to dry-bottom ESP designs results in a longer life span for the ESP. Utility costs (i.e., electricity) also do not change significantly because of an equal trade-off in horsepower requirements between the wet and dry ESP system designs.[14]

Based on these assumptions, the ITAC for wet to dry ESP system conversions should only include those indirect annual costs affected by the TCI (i.e., administrative, property tax, insurance, and capital recovery costs). Similar to the ESP replacement costs, the capital recovery cost is also based on an average 13.5-year life for dry-bottom ESP’s operating on NDCE recovery furnaces. The ITAC for the model NDCE recovery furnaces are presented in Table 6-10 and range from $93,500/yr to $166,000/yr for RF-4 through RF-6.

6.1.2.3 Conversion of a DCE Recovery Furnace System to an NDCE Recovery Furnace. Converting a DCE recovery furnace system to an NDCE recovery furnace (or "low-odor conversion") was evaluated as a control option for reducing gaseous organic HAP emissions from DCE recovery furnace systems. The conversion of a DCE recovery furnace system to an NDCE design involves removing the DCE and BLO unit, adding a concentrator, and extending or replacing the boiler economizer. Capital and annual costs have been evaluated for these three tasks. Additional upgrades are included in the low-odor conversion control option, i.e., an ESP upgrade to improve PM collection and a wet to dry ESP system conversion to reduce gaseous organic HAP emissions. Separate capital and annual costs were developed for the ESP upgrade and the wet to dry ESP system conversion. The ESP conversion costs may be lower if an ESP upgrade is also performed at the same time as the ESP conversion. However, no information is currently available on the extent of the cost reduction. Therefore, the costs were developed in the same way as those developed for recovery furnaces in Sections 6.1.2.1 and 6.1.2.2.

Often other upgrades are performed at the same time as a low-odor conversion. These upgrades usually provide additional cost savings because of increased efficiency, increased process capacity, and improved performance and safety. Possible upgrades include combustion air system improvements, composite tubing, and emergency drain and flame safety systems.[15] The capital costs and annual cost savings associated with these additional upgrades have not been evaluated as part of the low-odor conversion control option. The pulp production credits associated with increased process capacity were not included in the low-odor conversion total annual cost estimate because the additional capacity increases may require significant modifications (e.g., expanding the recovery furnace bed or modifying the air system), which would require additional capital expenses.

The low-odor conversion total annual cost estimates also do not include (1) DCE maintenance cost savings, (2) ESP maintenance cost savings, and (3) higher solids firing cost benefits for the reasons described below.

Maintenance requirements associated with the DCE are eliminated with the removal of this piece of equipment during a low-odor conversion. The lower maintenance requirements associated with an NDCE recovery furnace increase furnace availability, which allows for higher utilization of recovery furnace capacity without additional costs. The DCE maintenance cost savings were not included in the low-odor conversion cost estimates because sufficient data are not available to quantify the cost savings.

Lower corrosion rates are associated with NDCE recovery furnace ESP’s than with DCE recovery furnace ESP’s. The lower corrosion rates for NDCE recovery furnace ESP’s are the result of a higher-temperature, lower-moisture content gas stream from NDCE recovery furnaces compared to DCE recovery furnaces, as well as from the predominant use of dry-bottom ESP's. Therefore, converting to an NDCE design would eliminate the need for more frequent ESP replacement resulting from ESP corrosion. The ESP maintenance cost savings were not included in the low-odor conversion cost estimates because sufficient data are not available to quantify the cost savings.

Because concentrators can achieve higher BLS concentrations than DCE's (i.e., 75 to 80 percent vs. 65 percent), converting to an NDCE recovery furnace provides the mill with an opportunity to increase the solids content of the black liquor fired in the furnace.[4,16] However, increasing the solids content of the black liquor to the upper limits requires additional capital expenses, such as modifications to the fuel delivery system to handle a more viscous liquid. Neither the potential cost credits nor the additional capital expenses and any associated maintenance costs associated with higher solids firing are included in the low-odor conversion cost estimates.

Particulate matter control costs are included in the low-odor conversion cost estimates. With the removal of the DCE, which provides some PM control, as stated in Chapter 3, the ESP often must be upgraded or replaced during a low-odor conversion in order to meet applicable PM emission limits. For the purposes of this cost analysis, an ESP upgrade PM control option that would maintain or reduce PM emissions to the NSPS level of 0.10 g/dscm (0.044 gr/dscf) has been evaluated for those existing DCE recovery furnaces that have PM emissions at or above the NSPS level. This PM control option applies to model DCE recovery furnaces RF-7a/7b through RF-9a/9b. These models represent existing sources only, because no new DCE recovery furnaces are expected to be built.

A PM control option that would reduce PM emissions to 0.034 g/dscm (0.015 gr/dscf) has also been evaluated for DCE recovery furnaces that have PM emissions at or below the NSPS level. This PM control option includes an ESP upgrade coupled with the addition of a packed-bed scrubber and applies to model DCE recovery furnaces RF-7b through RF-9b, which, as cited above, represent only existing sources.

The capital and annual costs for low-odor conversions are presented in the following sections for model DCE recovery furnaces.

6.1.2.3.1 Capital costs: introduction. The total capital cost of the low-odor conversion control option includes purchase and installation costs of the extended economizer with associated soot blowers and ash handling equipment; demolition costs for the DCE and BLO unit; purchase and installation costs of the black liquor concentrator; ESP upgrade capital costs; and wet to dry ESP system conversion capital costs.

6.1.2.3.2 Capital costs: economizer expansion, demolition, and concentrator. The cost of economizer expansion and demolition has been estimated at $6.5 million for a mid-size recovery furnace. The cost estimate is based on cost data from three sources--two recovery furnace manufacturers and one kraft pulp mill, at which three low-odor conversions were completed over a 3-year period. A 20 percent contingency factor was added to the supplier costs to account for site-specific tie-in work. Where applicable, the available cost data were adjusted to 1991 dollars and scaled for a 0.7 million kg BLS/d (1.5 million lb BLS/d) furnace using the six-tenths power rule. The $6.5 million cost estimate is the average of the adjusted costs from the three sources--$6 million, $4.8 million, and $8.6 million.[4,17,18]

The concentrator costs are based on cost information from a concentrator manufacturer. The equipment costs for a falling film concentrator range from $1.5 to $3 million. Total capital costs, including installation, are approximately two times the equipment cost.[19] Based on this information, the average total capital cost estimate for a concentrator is approximately $4.5 million. The concentrator capital cost estimate does not include liquor storage and piping costs or the cost for the addition of a cooling tower cell.

The total economizer expansion, demolition, and concentrator cost for the mid-size model DCE recovery furnace (i.e., RF-8) is approximately $11 million, equal to the sum of the $6.5 million for the economizer expansion and demolition and the $4.5 million for the concentrator. The six-tenths power rule was used to calculate the capital costs for the small and large model DCE recovery furnaces (i.e., RF-7 and RF-9). The low-odor conversion capital costs (excluding the pulp production losses) are presented in Table 6-11. The capital costs, excluding the ESP upgrade and wet to dry ESP system conversion costs, range from $8.09 million to $15.7 million for model DCE recovery furnaces RF-7 through RF-9.

6.1.2.3.3 Capital costs: ESP upgrade. Electrostatic precipitator upgrade costs to achieve total outlet PM emissions of 0.10 g/dscm (0.044 gr/dscf) have been determined for the applicable DCE recovery furnace models. The ESP upgrade capital costs to control PM to NSPS levels for model DCE recovery furnaces RF-7a through RF-9a are derived from the Schedule 1 ESP manufacturer costs discussed in Section 6.1.2.1.3 and presented in Table 6-4.[9] The Schedule 1 costs were chosen because the ESP upgrade could be completed within the scheduled time for the low-odor conversion. The six-tenths power rule was used to calculate the capital costs for the model DCE recovery furnaces. The ESP upgrade costs to control PM emissions to NSPS levels for the model DCE recovery furnaces are presented in Table 6-11, excluding pulp production losses. The ESP upgrade costs range from $881,000 to $1.70 million for RF-7a through RF-9a. The bleached and unbleached pulp production losses are presented in Table 6-12. Although NSPS PM emission levels are associated with model DCE recovery furnaces RF-7b through RF-9b at baseline, once they are converted to NDCE recovery furnaces, the ESP's must be upgraded in order to maintain PM emissions at NSPS levels. The ESP upgrade costs presented above for model furnaces RF-7a through RF-9a were applied, as a worst-case cost estimate, for model DCE recovery furnaces RF-7b through RF-9b.

Control costs to achieve total outlet PM emissions of 0.034 g/dscm (0.015 gr/dscf) have been determined for the applicable DCE recovery furnace models. These PM control costs would include both ESP upgrade costs and packed-bed scrubber costs. This section presents the ESP upgrade costs; the packed-bed scrubber costs are presented in Section 6.1.2.4. The capital costs for an ESP upgrade to control PM emissions to 0.034 g/dscm (0.015 gr/dscf) were estimated by summing the Schedule 1 ESP upgrade costs presented above and the ESP upgrade costs presented in Table 6-8 and discussed in Section 6.1.2.1.5. These costs apply to model DCE recovery furnaces RF-7a through RF-9a. The ESP upgrade costs for model DCE recovery furnaces are presented in Table 6-13, excluding pulp production losses, and range from $9.80 million to $19.4 million for RF-7a through RF-9a. The bleached and unbleached pulp production losses are presented in Table 6-14. Using the same reasoning stated in the previous paragraph, the ESP upgrade costs presented above for model recovery furnaces RF-7a through RF-9a were applied, as a worst-case cost estimate, for model DCE recovery furnaces RF-7b through RF-9b.

6.1.2.3.4 <u>Capital costs: wet to dry ESP system conversion</u>. The wet to dry ESP system conversion costs for model DCE recovery furnaces RF-7 through RF-9 are based on ESP manufacturer costs presented in Table 6-10 and discussed in Section 6.1.2.2.1 for converting NDCE recovery furnace wet ESP systems to the dry ESP system design.[13] The ESP manufacturer costs were converted to 1991 dollars and then scaled for the model DCE recovery furnaces using the six-tenths power rule. The conversion costs include the costs to remove the existing agitator paddles and liquor piping and install a perpendicular drag scraper system, shallow fallout hoppers, drag chain conveyors, and rotary valves but do not include the costs for asbestos removal or equipment or piping beyond the rotary valves (e.g., an ash mixing tank and associated equipment).[13] The ESP system conversion costs for the model DCE recovery furnaces are presented in Table 6-11 and range from $439,000 to $849,000 for RF-7 through RF-9.

6.1.2.3.5 Capital costs: total costs. The total capital costs for the low-odor conversion option are equal to the sum of the economizer expansion, demolition, and concentrator costs plus the ESP upgrade and wet to dry ESP system conversion costs. These costs, excluding pulp production losses, are presented in Table 6-11 and range from $9.41 million to $18.2 million for RF-7a/7b through RF-9a/9b.

6.1.2.3.6 Capital costs: pulp production losses. The production losses attributed to a low-odor conversion are site-specific and depend on factors such as liquor storage capacity, liquor trade or sell options, and coordination with scheduled mill shutdowns.[15] Pulp production losses were calculated assuming an average additional shutdown period of 11 days beyond the scheduled 2-week shutdown period (i.e., a total of 25 days of downtime). The pulp production losses were calculated using the market values of bleached and unbleached pulp discussed in Section 6.1.1.1 and an earnings margin of 25 percent.[3]

The average 25-day shutdown was estimated based on the following information:

1. A time frame for completion of 21 to 30 days with proper pre-shutdown planning and prefabrication;[15]
2. A case study where one mill completed three low-odor conversions over a 4-week outage (i.e., 31 days);[20] and
3. A case study that involved two shutdowns; the first shutdown was for several days to relocate ductwork, and the second was for approximately 10 days to tie in the new systems.[21]

The total capital costs that include pulp production losses associated with the low-odor conversion are presented in Tables 6-12 and 6-14. For mills producing bleached pulp, the pulp production losses associated with a low-odor conversion range from $488,000 to $1.46 million for RF-7a/7b through RF-9a/9b. For mills producing unbleached pulp, the pulp production losses associated with a low-odor conversion range from $348,000 to $1.04 million for RF-7a/7b through RF-9a/9b.

6.1.2.3.7 Incremental annual costs: introduction. The ITAC estimate includes the following six primary components:

1. Capital recovery;
2. Administrative costs, taxes, and insurance;
3. Steam production credits;
4. Operating cost savings for the BLO;
5. Concentrator steam costs; and
6. Operating electricity costs for the ESP.

The annual costs of these six primary components were estimated for the three model DCE recovery furnaces and summed to determine the ITAC. As discussed in Section 6.1.2.3, certain other potential cost savings were not quantified. These potential cost savings include (1) maintenance cost savings resulting from eliminating the DCE; (2) ESP replacement cost savings resulting from a less corrosive exit gas stream associated with NDCE recovery furnaces; and (3) pulp production credits for those mills that choose to provide for additional capacity during the low-odor conversion.

6.1.2.3.8 Incremental annual costs: capital recovery. For a low-odor conversion, the capital recovery costs for the model DCE recovery furnaces are based on the following:

1. An equipment life of 20 years;
2. The model capital costs presented in Tables 6-11 through 6-14;
3. The model bleached and unbleached pulp production losses incurred during construction, which are presented in Tables 6-12 and 6-14; and
4. An interest rate of 7 percent.

Total capital recovery costs were calculated for each PM control level for the following three scenarios:

1. Without annualized pulp production losses (Scenario 1);
2. With annualized bleached pulp production losses (Scenario 2); and
3. With annualized unbleached pulp production losses (Scenario 3).

Design parameters for each model furnace are presented in Table 6-15.

The low-odor conversion capital recovery costs for Scenarios 1, 2, and 3 for model DCE recovery furnaces (including an ESP upgrade to control PM emissions to NSPS levels) are presented in Tables 6-16, 6-17, and 6-18, respectively. For Scenario 1, capital recovery costs range from $918,000/yr to $1.78 million/yr for RF-7a/7b through RF-9a/9b. For Scenario 2, capital recovery costs range from $964,000/yr to $1.92 million/yr for RF-7a/7b through RF-9a/9b. For Scenario 3, capital recovery costs range from $951,000/yr to $1.88 million/yr for RF-7a/7b through RF-9a/9b.

The low-odor conversion capital recovery costs for Scenarios 1, 2, and 3 for model DCE recovery furnaces (including an ESP upgrade to control PM emissions to 0.034 g/dscm [0.015 gr/dscf]) are presented in Tables 6-19, 6-20, and 6-21, respectively. For Scenario 1, capital recovery costs range from $963,000/yr to $1.91 million/yr for RF-7a/7b through RF-9a/9b. For Scenario 2, capital recovery costs range from $1.01 million/yr to $2.05 million/yr for RF-7a/7b through RF-9a/9b. For Scenario 3, capital recovery costs range from $996,000/yr to $2.01 million/yr for RF-7a/7b through RF-9a/9b.

6.1.2.3.9 Incremental annual costs: administrative, taxes, and insurance costs. Administrative, tax, and insurance costs were estimated as 4 percent of the TCI and are presented in each of the low-odor conversion annual cost tables, starting with Table 6-16.[6]

6.1.2.3.10 Incremental annual costs: steam production credits. Steam production credits result from the improved steam flow that occurs with a low-odor conversion.[22] The steam production credit is assumed to be equal to the cost of the power boiler fuel that has been displaced by black liquor in steam generation. It was assumed that mills would first reduce the use of higher-cost power boiler fuels, i.e., natural gas or fuel oil. Therefore, only the reduction in the use of natural gas and fuel oil was considered in determining the displaced fuel cost and not reductions in the use of lower-cost hogged wood or coal. To determine the displaced fuel cost, the increase in the thermal efficiency that results from a low-odor conversion was estimated.

The increase in the thermal efficiency that results from a low-odor conversion is estimated to be 10 percentage points. The supporting data for this estimate are as follows:

1. Direct contact evaporator recovery furnaces operate at thermal efficiencies of 53 to 58 percent, whereas NDCE recovery furnaces operate at thermal efficiencies of 63 to 68 percent;[15] and

2. The thermal efficiency of a recovery furnace increases approximately 1 percentage point for every 22°C (40°F) drop in exit temperature.[16] The difference in the exit flue gas temperatures before and after a low-odor conversion is about 200°C (400°F), which corresponds to a 10 percentage point increase in thermal efficiency. For DCE recovery furnaces, the exit flue gas temperature is 371°C to 427°C (700°F to 800°F).[15] This high temperature range is needed to operate the DCE. For NDCE recovery furnaces, the design exit flue gas temperature range is 177°C to 357°C (350°F to 375°F).[16] The exit flue gas temperature for NDCE recovery furnaces is limited by the optimum operable range for the ESP (163°C to 204°C [325°F to 400°F]) and recovery furnace operating and design parameters (163°C [325°F] minimum).[16]

The steam production credit estimates are presented in each of the low-odor conversion annual cost tables, starting with Table 6-16. If natural gas is the displaced steam generation fuel, the average steam production credit is estimated to range from $758,000/yr to $2.27 million/yr for RF-7a/7b through RF-9a/9b. If oil is the displaced fuel, the average steam production credit is estimated to range from $1.19 million/yr to $3.58 million/yr for RF-7a/7b through RF-9a/9b. These estimates are based on the following information:

1. A thermal efficiency increase of 10 percentage points (from 56 to 66 percent);

2. Model BLS firing rates of 0.7, 1.2, and 1.8 million kg BLS/d (0.9, 1.5, and 2.7 million lb BLS/d), with a BLS heat content of 13,900 kJ/kg (6,000 Btu/lb);[8]

3. A natural gas heat content of 38,100 kJ/m^3 (1,024 Btu/ft^3) and cost of \$0.12/m^3 (\$3.48/1,000 ft^3);[23,24]

4. A fuel oil heat content of 40,400 kJ/L (145,000 Btu/gal) and cost of \$0.20/L (\$0.77/gal);[23,25] and

5. A power boiler thermal efficiency of 85 percent.[21]

6.1.2.3.11 <u>Incremental annual costs: BLO operating cost savings</u>. The high operating costs associated with air-sparging BLO units are eliminated with the removal of the BLO unit during a low-odor conversion. Most of the BLO operating costs (about 60 percent) is for power to operate the blowers and pumps. The remaining 40 percent is for operating the reheater.[26] These cost savings are included as a credit in the total annual cost estimate. The annual operating costs of a BLO system that oxidizes black liquor for a DCE recovery furnace range from \$103,000 to \$309,000 for RF-7 through RF-9. The cost savings from removal of the BLO unit are presented in each of the low-odor conversion annual cost tables, beginning with Table 6-16. The cost savings are based on total annual costs of \$251,900/yr for a BLO unit that oxidizes black liquor fired in two DCE recovery furnaces with a total black liquor firing rate of 1.0 million kg BLS/d (2.2 million lb BLS/d)[4].

6.1.2.3.12 <u>Incremental annual costs: concentrator steam costs</u>. The concentrator that replaces the DCE in a low-odor conversion uses low-pressure steam to evaporate moisture from the black liquor. The vapor from the concentrator can be used for additional evaporation at lower black liquor solids levels, or can be used to heat water. Concentrator steam costs were estimated for each model DCE recovery furnace, assuming that steam usage is proportional to the amount of black liquor concentrated. The annual concentrator steam costs for the model recovery furnaces range from \$57,800 to \$173,000 for RF-7 through RF-9. The concentrator steam costs are presented in each of the low-odor conversion annual cost tables, beginning with

Table 6-16. Concentrator steam costs are based on the following information:

1. A steam requirement of approximately 4,500 kg/hr (10,000 lb/hr) of low-pressure steam for a 1.1 million kg BLS/d (2.4 million lb BLS/d) furnace;[27] and

2. A cost of $4.02/Mg ($3.65/ton) for low-pressure steam.[28]

6.1.2.3.13 Incremental annual costs: electricity costs. The increase in electricity costs for upgrading the ESP to maintain or reduce PM emissions to the NSPS level of 0.10 g/dscm (0.044 gr/dscf) was estimated for model DCE recovery furnaces RF-7a/7b through RF-9a/9b. The actual increase in electricity costs for the ESP upgrade is not known. It was assumed that the incremental increase in electricity costs for an upgraded ESP would be the same as for a replacement ESP. Because the electricity cost increases for the replacement ESP in Section 6.1.2.1.2 were based on an increase in SCA, the electricity cost increases for the upgraded ESP were calculated in the same manner.

For DCE recovery furnaces RF-7a through RF-9a, with baseline PM emissions above 0.10 g/dscm (0.044 gr/dscf), the ESP electricity costs were estimated based on an increase in SCA values from approximately 70 $m^2/(m^3/sec)$ (330 $ft^2/1,000$ acfm) to approximately 100 $m^2/(m^3/sec)$ (530 $ft^2/1,000$ acfm).[4] For DCE recovery furnaces RF-7b through RF-9b, with baseline PM emissions less than or equal to 0.10 g/dscm (0.044 gr/dscf) but greater than 0.034 g/dscm (0.015 gr/dscf), the ESP electricity costs were estimated based on an increase in SCA values from approximately 90 $m^2/(m^3/sec)$ (430 $ft^2/1,000$ acfm) to approximately 100 $m^2/(m^3/sec)$ (530 $ft^2/1,000$ acfm).[4] The increase in ESP electricity costs resulting from the maintenance or control of PM emissions to the NSPS level are presented in Tables 6-16 through 6-18 for each of the model DCE recovery furnaces and range from $23,300/yr to $70,000/yr for RF-7a through RF-9a and $11,700/yr to $35,000/yr for RF-7b through RF-9b.

The increase in electricity costs resulting from the implementation of PM controls to reduce PM emissions to

0.034 g/dscm (0.015 gr/dscf) was estimated for model DCE recovery furnaces RF-7a/7b through RF-9a/9b. The PM control electricity costs would include both ESP upgrade and packed-bed scrubber electricity costs. The ESP upgrade electricity costs are presented in this section; Section 6.1.2.4 presents the packed-bed scrubber electricity costs.

For DCE recovery furnaces RF-7a through RF-9a, with baseline PM emissions above 0.10 g/dscm (0.044 gr/dscf), the increase in ESP electricity costs is based on an increase in the SCA from a baseline value of approximately 70 $m^2/(m^3/sec)$ (330 $ft^2/$ 1,000 acfm) to approximately 120 $m^2/(m^3/sec)$ (620 $ft^2/$ 1,000 acfm).[4] For DCE recovery furnaces RF-7b through RF-9b, with baseline PM emissions less than or equal to 0.10 g/dscm (0.044 gr/dscf) but greater than 0.034 g/dscm (0.015 gr/dscf), the ESP electricity costs were estimated based on an increase in SCA values from approximately 90 $m^2/(m^3/sec)$ (430 $ft^2/1{,}000$ acfm) to approximately 120 $m^2/(m^3/sec)$ (620 $ft^2/1{,}000$ acfm).[4] The increase in ESP electricity costs resulting from the control of PM emissions to 0.034 g/dscm (0.015 gr/dscf) are presented in Tables 6-19 through 6-21 for each of the model DCE recovery furnaces and range from $33,100/yr to $99,200/yr for RF-7a through RF-9a and $21,400/yr to $64,200/yr for RF-7b through RF-9b.

As stated in Section 6.1.2.2.2, electricity costs do not change significantly when a wet ESP system is converted to the dry ESP system design because of an equal trade-off in horsepower requirements between the wet and dry ESP system designs. Therefore, no electricity costs for the wet to dry ESP system conversion are presented in this cost analysis.

6.1.2.3.14 Incremental annual costs: total costs. Incremental total annual costs were estimated for converting model DCE recovery furnaces to an NDCE design for each of the PM control levels, each of the scenarios, and each of the displaced fuels. The scenarios were discussed in Section 6.1.2.3.8. Scenario 1 excludes annualized pulp production losses from the ITAC; Scenario 2 includes annualized bleached pulp production losses in the ITAC; and Scenario 3 includes annualized unbleached pulp production losses in the ITAC.

The ITAC estimates for Scenario 1 for DCE recovery furnaces with controlled PM emissions at NSPS levels are presented in Table 6-16. For Scenario 1, with natural gas as the displaced steam generation fuel, the ITAC range from $520,000/yr to $170,000/yr for RF-7a through RF-9a and $508,000/yr to $140,000/yr for RF-7b through RF-9b. If fuel oil is the displaced steam generation fuel, the ITAC for Scenario 1 range from a cost of $90,000/yr for RF-7a to a cost savings of $1.14 million/yr for RF-9a; for RF-7b through RF-9b, the ITAC for Scenario 1 range from a cost of $80,000/yr to a cost savings of $1.17 million/yr.

The ITAC estimates for Scenario 2 for DCE recovery furnaces with controlled PM emissions at NSPS levels are presented in Table 6-17. For Scenario 2, with natural gas as the displaced steam generation fuel, the ITAC estimates range from $560,000/yr to $310,000/yr for RF-7a through RF-9a and $548,000/yr to $280,000/yr for RF-7b through RF-9b. If fuel oil is the displaced steam generation fuel, the ITAC for Scenario 2 range from $130,000/yr for RF-7a to $120,000/yr for RF-7a to a cost savings of $1.00 million/yr for RF-9a; for RF-7b through RF-9b, the ITAC for Scenario 2 range from a cost of $120,000/yr to a cost savings of $1.03 million/yr.

The ITAC estimates for Scenario 3 for DCE recovery furnaces with controlled PM emissions at NSPS levels are presented in Table 6-18. For Scenario 3, with natural gas as the displaced steam generation fuel, the ITAC range from $550,000/yr to $270,000/yr for RF-7a through RF-9a and $538,000/yr to $240,000/yr for RF-7b through RF-9b. If fuel oil is the displaced steam generation fuel, the ITAC for Scenario 3 range from a cost of $120,000/yr for RF-7a to a cost savings of $1.04 million/yr for RF-9a; for RF-7b through RF-9b, the ITAC for Scenario 3 range from a cost of $110,000/yr to a cost savings of $1.07 million/yr.

The ITAC estimates for Scenario 1 for DCE recovery furnaces with controlled PM emissions of 0.034 g/dscm (0.015 gr/dscf) are presented in Table 6-19. For Scenario 1, with natural gas as the displaced steam generation fuel, the ITAC range from $590,000/yr to $380,000/yr for RF-7a through RF-9a and $578,000/yr to $350,000/yr for RF-7b through RF-9b. If fuel oil is the displaced steam generation fuel, the ITAC for Scenario 1 range from a cost of $160,000/yr to a cost savings of $930,000/yr for RF-9a; for RF-7b through RF-9b, the ITAC for Scenario 1 range from a cost of $150,000/yr to a cost savings of $960,000/yr.

The ITAC estimates for Scenario 2 for DCE recovery furnaces with controlled PM emissins of 0.034 g/dscm (0.015 gr/dscf) are presented in Table 6-20. For Scenario 2, with natural gas as the displaced steam generation fuel, the ITAC range from $630,000/yr to $520,000/yr for RF-7a through RF-9a and $618,000/yr to $490,000/yr for RF-7b through RF-9b. If fuel oil is the displaced steam generation fuel, the ITAC for Scenario 2 range from a cost of $200,000/yr for RF-7a to a cost savings of $790,000/yr for RF-9a; for RF-7b through RF-9b, the ITAC for Scenario 2 range from a cost of $190,000/yr to a cost savings of $820,000/yr.

The ITAC estimates for Scenario 3 for DCE recovery furnaces with controlled PM emissions of 0.034 g/dscm (0.015 gr/dscf) are presented in Table 6-21. For Scenario 3, with natural gas as the displaced steam generation fuel, the ITAC range from 620,000/yr to $480,000/yr for RF-7a through RF-9a and $608,000/yr to $450,000/yr for RF-7b for RF-9b. If fuel oil is the displaced steam generation fuel, the ITAC for Scenario 3 range from a cost of $190,000/yr for RF-7a to a cost savings of $830,000/yr for RF-9a; for RF-7b through RF-9b, the ITAC for Scenario 3 range from a cost of $180,000/yr to a cost savings of $860,000/yr.

6.1.2.4 Addition of Packed-Bed Scrubber. The addition of a packed-bed scrubber downstream of the ESP is included in two of the control options examined for recovery furnaces. These control options are (1) the use of an ESP plus a packed-bed scrubber to meet an outlet PM emission level of 0.034 g/dscm

(0.015 gr/dscf); and (2) the use of a packed-bed scrubber to reduce HCl emissions from recovery furnaces.

The costs of replacing or upgrading ESP's to control PM emissions are presented in Sections 6.1.2.1 and 6.1.2.3 for NDCE and DCE recovery furnaces. This section discusses the design and cost of packed-bed scrubbers for nine model recovery furnaces. The design and cost of packed-bed scrubbers are presented for the three model DCE recovery furnaces both with and without a low-odor conversion. The applicable model recovery furnaces for the packed-bed scrubber control option are RF-1 through RF-9. Exhaust gas stream parameters for each model and associated absorber are shown in Table 6-22.

6.1.2.4.1 Packed-bed scrubber design. Because only limited information was available from a scrubber manufacturer regarding the design parameters associated with a scrubber used to control HCl emissions from kraft recovery furnaces, the model packed-bed scrubbers were designed based on the procedures presented in Chapter 9 of the OAQPS Control Cost Manual for counterflow towers.[6,29] Two assumptions were made to simplify the packed-bed scrubber design analysis. First, it was assumed that the gas stream exiting the ESP is cooled to saturation by a water spray before it enters the packed-bed scrubber. As a result, the gas stream flow rates into and out of the packed-bed scrubber are the same. Insufficient design information was available from the OAQPS Control Cost Manual and a scrubber manufacturer to include in the design analysis a quench chamber for cooling the gas stream. A second simplifying assumption was that the diffusivity of HCl in the gas stream is approximated by the diffusivity of HCl in the air.

Because the model gas flow rates are large and the inlet HCl concentrations are low (only 9.7 ppmv for model NDCE and converted model DCE recovery furnaces and 9.2 ppmv for unconverted model DCE recovery furnaces), the diameters of the model towers are 11 to 23 times the height of the packing. The packing height was about 0.60 m (1.54 ft) for each model NDCE and converted model DCE recovery furnace and 0.43 m (1.41 ft) for each unconverted model DCE recovery furnace. The tower diameters ranged from 5.2 to 11 m (17 to 36 ft) for model NDCE and converted model DCE recovery furnaces and 5.4 to 9.3 m (18 to 30 ft) for unconverted model DCE recovery furnaces. Design and operating parameters for each model recovery furnace packed-bed scrubber are shown in Table 6-23. The algorithm showing the procedures and equations used to determine the packed-bed scrubber design parameters is presented in a separate memorandum.[30]

6.1.2.4.2 Capital costs. Capital costs were calculated based on procedures presented in the OAQPS Control Cost Manual.[6] The unit costs used in calculating the capital and annual costs were derived from the OAQPS Control Cost Manual and from background information for the Medical Waste Incinerator standard.[6,31] The unit costs are shown in Table 6-24. Capital costs in 1991 dollars are presented in Table 6-25 for each model recovery furnace. These costs were compared to those obtained from a scrubber manufacturer.[29]

Capital costs consist of purchased equipment and installation costs. Purchased equipment costs consist of equipment, instrumentation, sales tax, and freight costs. Equipment includes a fiberglass reinforced polyester stack, fiberglass absorber tower, 5-cm (2-in.) randomly packed ceramic Raschig rings, a liquid recirculating pump, an induced draft fan, and a fan motor.

The addition of a packed-bed scrubber may result in additional dissolved solids loading to the wastewater treatment system. For those mills with restrictive total dissolved solids (TDS) effluent limitations, the additional solids loading from the scrubber may require internal process measures to reduce dissolved loading from other areas of the mill. These internal process measures will have associated engineering, equipment, and construction costs. However, because the additional costs are so site-specific, they cannot be estimated on a model basis and may even be offset by any heat recovery benefits realized as a result of adding an HCl scrubber.

All equipment costs were estimated as functions of various design parameters. Specifically, the stack cost was based on the length and diameter of the stack; the packed tower cost was based on the surface area of the tower; the packing cost was based on the volume of packing; the fan cost was based on the impeller diameter; the fan motor cost was based on the horsepower rating; and the pump cost was based on the design liquid flow rate.[5,6] In most cases, the referenced costing equations were developed for much smaller equipment. Thus, the costs for the models in this analysis were developed by extrapolating well beyond the largest parameter value for which the equations were developed.[30]

Instrumentation, sales tax, and freight were estimated to be equal to 18 percent of the equipment costs. Installation was estimated to be equal to 120 percent of the purchased equipment costs.[6] Total capital costs were estimated for each of the model recovery furnaces. The model furnaces include both new and existing furnaces. For model NDCE recovery furnaces RF-1 through RF-6, the total capital costs range from $1.10 million to $2.58 million. For unconverted model DCE recovery furnaces RF-7 through RF-9, the total capital costs range from $736,000 to $1.93 million. The total capital costs for the model DCE recovery furnaces converted to the NDCE design are slightly lower because of the change in furnace characteristics that occurs after a low-odor conversion. The total capital costs for the converted model DCE recovery furnaces RF-7 through RF-9 are identical to those for comparably sized model NDCE recovery furnaces and range from $707,000 to $1.85 million.

Capital costs for a packed-bed scrubber were also obtained from a scrubber manufacturer. The manufacturer provided packed-bed scrubber capital costs of $895,000, $1.69 million, and $2.30 million for three model furnaces with scrubber inlet gas flow rates of 47.2, 118, and 189 m^3/sec (100,000, 250,000, and 400,000 acfm), respectively. These costs include the cost for a quench, packed tower, mist eliminator, recirculation system (including two recirculation pumps and recirculation piping), instrumentation, engineering costs, and exhaust stack.[29]

Corrected for differences in gas flow rates from the model costs presented in the previous paragraph, the costs from the scrubber manufacturer differ by approximately 5 to 25 percent from the OAQPS costs presented in the previous paragraph for comparably sized model furnaces. This cost difference is within the ±30 percent range of accuracy that OAQPS costs should have, according to the OAQPS Control Cost Manual.[6] However, it should be noted that the OAQPS costs estimated here do not include quench costs.

6.1.2.4.3 Annual costs. Annual costs for the packed-bed scrubber were also calculated based on procedures presented in the OAQPS Control Cost Manual. Unit costs used in the annual cost calculations are shown in Table 6-24. Total annual costs in 1991 dollars are presented in Table 6-26 for the model recovery furnaces.

Annual costs were developed for labor, maintenance materials, water, caustic, wastewater disposal, electricity, overhead, property taxes, insurance, administrative charges, and capital recovery. Operator labor and maintenance labor were both assumed to be 0.5 hr per 8-hr shift, with three shifts per day. Supervisory labor costs were estimated to be equal to 15 percent of the operator labor costs. Maintenance materials costs were estimated to be equal to 100 percent of the maintenance labor costs.[6] The wastewater flow rate was estimated based on the assumption that the NaCl concentration in the recirculating water would be limited to 10 percent by weight. As a result, blowdown is approximately 0.08 to 0.09 percent of the recirculating liquid flow rate. Makeup water is needed for evaporative cooling before the packed-bed scrubber and to replace the blowdown losses. A stoichiometric amount of caustic is needed to react with all of the HCl in the exhaust gas stream; an additional amount of caustic must be added to react with the SO_2 also present in the exhaust gas stream (assuming 50 percent SO_2 control). Electricity usage by the fan was based on the gas flow rate out of the quench shown in Table 6-22 and the pressure drop and fan-motor efficiency shown in Table 6-23. Electricity usage by the pump was based on the gas flow rate out of the quench shown in Table 6-22, the pump-motor efficiency shown in Table 6-23, and an assumed pressure head of 18 m (60 ft). Overhead costs were estimated to be equal to 60 percent of all labor and maintenance materials costs.[6] Collectively, property taxes, insurance, and administrative charges were estimated to be equal to 4 percent of the TCI.[6] Capital recovery was estimated to be equal to a CRF times the TCI.[6] The CRF is 0.1098, based on an equipment life of 15 years and an interest rate of 7 percent.

For model NDCE recovery furnaces RF-1 through RF-6, the TAC (as shown in Table 6-26) range from $348,000/yr to $790,000/yr. For model unconverted DCE recovery furnaces RF-7 through RF-9, the TAC range from $229,000/yr to $554,000/yr. The TAC for the model DCE recovery furnaces converted to the NDCE design are slightly higher because of higher costs for caustic, water, and wastewater disposal. The higher costs are a result of the higher SO_2 emission factor included in the equations for those costs. Based on the limited information available, SO_2 emissions are slightly higher, on average, from NDCE recovery furnaces than from DCE recovery furnaces.[32] The TAC for the converted model DCE recovery furnaces RF-7 through RF-9 are identical to those for comparably sized model NDCE recovery furnaces and range from $234,000/yr to 571,000/yr.

6.1.3 <u>Black Liquor Oxidation Unit Control Options</u>

Two control options, conversion of a DCE recovery furnace system to an NDCE recovery furnace and incineration of BLO vent gases, were evaluated for controlling gaseous organic HAP emissions from air-sparging BLO units. The cost of the first option--converting DCE recovery furnace systems to NDCE recovery furnaces--was presented in Section 6.1.2.3. The following section presents the capital and annual costs of the second BLO control option--incineration of BLO vent gases. This BLO control option applies to model BLO units BLO-1 through BLO-3, which represent existing BLO units associated with DCE recovery furnaces. These models represent only existing BLO units because no new DCE recovery furnace systems with BLO units are expected to be installed.

6.1.3.1 Capital Costs. The total capital costs to collect BLO vent gases and incinerate them in a power boiler or other incineration device are based on a 1990 BLO control cost estimate of $4.8 million supplied by industry for a 730 ADMP/d (800 ADTP/d) kraft pulp mill.[33] The 1990 BLO control cost estimate includes piping, fans, condensers, and safety-related equipment, such as flame arrestors, rupture disks, etc. No major power boiler modifications (such as scrubber modifications) are included. The BLO control cost estimate was adjusted to 1991 dollars and then scaled using the six-tenths power rule described in Section 6.1.1.2 to derive BLO control costs for the model BLO units. A conversion factor of 1,700 kg BLS/ADMP (3,400 lb BLS/ADTP) (the average for bleached and unbleached pulp mills together) was assumed in scaling the cost. Design parameters for each model BLO unit are presented in Table 6-27. The model BLO control capital costs are presented in Table 6-28. The BLO control capital costs range from $2.5 million to $4.83 million for BLO-1 through BLO-3. Because the BLO collection and incineration system for one mill was installed within a 1-week maintenance shutdown, it was assumed that no downtime would be necessary beyond the annual 2-week shutdown used in determining costs.[34] As a result, no pulp production losses are included in these costs.

6.1.3.2 Annual Costs. Annual costs were estimated for operating and supervisory labor, maintenance labor and materials, electricity, steam, and indirect costs (e.g., overhead, administrative, taxes, insurance, and capital recovery). The BLO control annual costs were estimated for each model BLO unit based on the following sources:

1. Annual operating requirements provided by one mill (Mill A) for its BLO vent gas control system;[26]
2. Operating labor costs from the U. S. EPA Handbook: Control Technologies for Hazardous Air Pollutants;[5] and

3. Supervisory labor and maintenance costs and indirect costs from the OAQPS Control Cost Manual.[6]

The operating labor costs were estimated assuming 0.5 hours per shift per condenser for two condensers for three 8-hour shifts per day.[5] The operating labor hourly rate was assumed to be $17/hr.[5] The annual operating labor hours were assumed to be 365 d/yr. The supervisory labor costs were assumed to be 15 percent of the operating labor costs.[6] The maintenance labor costs were estimated at 1.5 times the operating labor costs.[6] The maintenance materials costs were estimated at 100 percent of the maintenance labor costs.[6]

Electricity costs were estimated based on the total kW (hp) requirements to operate the BLO vent gas control equipment at Mill A and scaled for the model BLO units assuming a direct relationship between BLO vent gas flow rate and electricity costs. For Mill A, with a BLO vent gas flow rate of 7.7 m^3/sec (16,327 acfm), 980 kW (100 hp) are required to operate the mill water booster pump motor, 29 kW (3 hp) to operate the BLO condenser condensate pump motor, and 3,900 kW (400 hp) to operate the BLO off gas blower motor.[26] The model electricity costs were estimated assuming 8,424 operating hr/yr and $0.06/kWh.

Steam costs were estimated based on the steam requirements and unit steam cost for the BLO off-gas reheater at Mill A--730 kg steam/hr (1,600 lb steam/hr) and $7/Mg of steam ($3/1,000 lb of steam), respectively--and scaled for the model BLO units assuming a direct relationship between BLO vent gas flow rate and steam costs.[26] The model steam costs were estimated assuming 8,424 operating hr/yr.

Indirect costs were estimated using assumptions in the OAQPS Control Cost Manual. Overhead costs were estimated as 60 percent of labor and maintenance costs. Administrative, taxes, and insurance costs were estimated as 4 percent of the TCI. Capital recovery costs were calculated as the product of the CRF and the TCI.[6] The CRF is 0.1424, based on a 10-yr equipment life for the ductwork and condenser and an interest rate of 7 percent.[5,24]

Total annual costs are presented in Table 6-28 and range from $681,000/yr to $1.32 million/yr for BLO-1 through BLO-3.

6.1.4 Smelt Dissolving Tank Control Options

Two PM control options that would reduce PM emissions from SDT’s have been evaluated. The first option would reduce PM emissions from existing SDT’s to the NSPS level of 0.10 kg/Mg (0.20 lb/ton) BLS. The second option would reduce PM emissions from existing SDT’s to a more stringent level of 0.06 kg/Mg (0.12 lb/ton) BLS; the second option also applies to new SPTs; the option could be used to evaluate the cost to new sources subject to a more stringent standard (0.06 kg/Mg [0.12 lb/ton] BLS) than the current NSPS.

For mills with existing SDT scrubbers, the costs of both PM control options were estimated based on replacing the existing scrubber with a new scrubber. These costs were estimated for SDT models SDT-1 through SDT-4. For mills with new SDT scrubbers, the costs of installing scrubbers under the second, more stringent PM control option also apply to SDT-1 through SDT-4. For the purposes of this cost analysis, the capital cost to install a new SDT scrubber capable of meeting 0.06 kg/Mg (0.12 lb/ton) BLS was assumed to be the same as the cost to replace an existing scrubber with a new scrubber capable of meeting 0.06 kg/Mg (0.12 lb/ton) BLS. However, that may be an overestimate because the capital cost that would be attributable to the 0.06 kg/Mg (0.12 lb/ton) BLS control option would only be that cost associated with controlling PM emissions from the current NSPS level of 0.10 kg/Mg (0.2 lb/ton) BLS to 0.06 kg/Mg (0.12 lb/ton) BLS. Such a cost is more similar to a scrubber modification cost than a scrubber replacement cost.

For mills with existing SDT mist eliminators, the costs of both PM control options were estimated based on replacing the existing mist eliminator with a new scrubber. These costs were estimated for SDT models SDT-5 through SDT-7. The costs of installing new mist eliminators were not examined because mist eliminators are not assumed to be installed on new SDT’s.

Note: For at least one scrubber type (wetted-wheel scrubbers), the scrubber replacement capital and annual costs would be approximately equal to the cost of replacing a mist eliminator with a scrubber. Similar to mist eliminators, the total capital costs would be based on replacement of the entire scrubber system. Also similar to mist eliminators, the incremental annual costs would include electricity costs based on replacing an existing scrubber that has a low pressure drop with another that has a significantly higher pressure drop, as well as indirect costs based on a capital cost of replacing the entire scrubber system. The capital and annual costs to replace wetted-wheel scrubbers will not be presented in this cost analysis because there is insufficient information to estimate the costs and because only 13 percent of SDT's have wetted-wheel scrubbers.[4]

The following sections present the capital and annual costs to replace existing wet scrubbers and mist eliminators with new wet scrubbers under the SDT PM control options.

6.1.4.1 Replacement of Existing Scrubber with New Scrubber: Capital Costs. The conditions under which replacing a scrubber is more cost-effective than modifying an existing scrubber are very site-specific. To be conservative, only the cost to replace a scrubber was evaluated. The cost to dispose of the existing scrubber was assumed to be included in the scrubber replacement costs. The capital costs to replace the scrubber are based on recent costs provided by a pulp and paper mill for an SDT scrubber.[4] The available long-term PM emissions data for the scrubber show that it is capable of consistently meeting both of the SDT PM emission limits--0.10 kg/Mg (0.20 lb/ton) BLS and 0.06 kg/Mg (0.12 lb/ton) BLS.[10] The SDT scrubber is a packed-tower scrubber with a gas flow rate of 3.8 m^3/sec (8,071 acfm) at 60 to 70 percent of recovery furnace capacity. The costs provided by the pulp and paper mill are packed-tower scrubber costs and scrubber modification costs. The packed-tower scrubber cost is $280,000 (1988 dollars); the scrubber modification cost is $50,000 (1991 dollars).[4] The 1988 scrubber cost was adjusted to 1991 dollars using the Chemical Engineering Plant Cost Index and then summed with the scrubber modification costs to obtain the total capital cost in 1991 dollars. The six-tenths rule was used to extrapolate the total capital cost for each of the model SDT's. Based on information from a scrubber manufacturer, the on-site work time to replace a scrubber is about 2 days.[35] Therefore, no downtime beyond the annual 2-week shutdown is necessary for the scrubber replacement, which means that no pulp production losses are expected for this control option.

The model scrubber replacement costs are presented in Table 6-29. Total capital investment costs for the SDT models SDT-1 through SDT-4 range from $292,000 to $706,000.

6.1.4.2 Replacement of Existing Scrubber with New Scrubber: Incremental Annual Costs. The ITAC for each SDT model include the indirect costs associated with the TCI of the new scrubber (i.e., administrative, property tax, and insurance costs plus the capital recovery costs). The administrative, taxes, and insurance costs were estimated to be equal to 4 percent of the TCI.[6] A properly designed and maintained venturi scrubber can operate for 20 years.[35] Other types of scrubbers may have different life spans. To be conservative, a 15-year life span for replacement scrubbers was assumed. The capital recovery cost was estimated based on a 15-year scrubber life and a 7 percent interest rate. The increase in electricity costs from the scrubber replacement is not included in the ITAC estimate because it is not significant relative to the total annual cost. The average pressure drop for existing SDT scrubbers with PM emissions greater than 0.10 kg/Mg (0.20 lb/ton) BLS (i.e., baseline pressure drop) is approximately the same as the average pressure drop for those SDT scrubbers capable of meeting both SDT PM emission limits (0.10 kg/Mg [0.20 lb/ton] BLS) and 0.06 kg/Mg [0.12 lb/ton] BLS) on a long-term basis.[4,10] The baseline and control level pressure drops are 12 mm Hg (6.5 in. H_2O) and 13 mm Hg (7 in. H_2O), respectively.[4] All other direct costs (i.e., costs for operating labor, maintenance, water, and wastewater treatment) are assumed to be the same as those incurred by the existing scrubber and, therefore, are not included in the ITAC estimate.

The ITAC for the four model SDT’s are presented in Table 6-29. The ITAC estimates range from $43,800/yr to $106,000/yr for SDT-1 through SDT-4.

6.1.4.3 <u>Replacement of Existing Mist Eliminator with New Scrubber: Capital Costs</u>. The capital costs to replace an existing mist eliminator with a new scrubber include the costs for the new scrubber and all auxiliary equipment (i.e., fans, ductwork, etc.) that would be required at a new source. Based on information from a scrubber manufacturer, a completely new scrubber system would cost about twice as much as replacing only the scrubber, as described in Section 6.1.4.1.[35] The cost to dispose of the existing mist eliminator was assumed to be included in these replacement costs. Therefore, the capital costs for the three model SDT’s are equal to twice the scrubber replacement costs for the three corresponding size model SDT’s presented in Section 6.1.4.1. It is assumed that no downtime beyond the annual 2-week shutdown is necessary for replacing a mist eliminator with a scrubber.

The design parameters for the three SDT models are presented in Table 6-30. Capital costs for replacing a mist eliminator with a new scrubber are presented in Table 6-31. Total capital investment costs for the SDT models SDT-5 through SDT-7 range from $584,000 to $1.13 million.

6.1.4.4 <u>Replacement of Existing Mist Eliminator with New Scrubber: Incremental Annual Costs</u>. Incremental total annual costs were estimated for each of the three model SDT’s. The ITAC for each SDT model include both direct and indirect annual costs, with the exception of operating labor. No changes in operator and supervisor personnel were assumed to be required. The increase in maintenance labor costs was estimated, assuming 3 hr/d at a wage rate of $25/hr.[6] Maintenance materials were estimated at 100 percent of maintenance labor costs.[6] As discussed in Section 6.1.1.3.1, for the purposes of calculating costs, pressure drop is used as an indicator of PM collection efficiency. Electricity requirements and costs increase as a result of increasing the pressure drop to reduce PM emissions to 0.10 kg/Mg (0.20 lb/ton) BLS and to 0.06 kg/Mg (0.12 lb/ton) BLS. The average pressure drop is 1.3 mm Hg (0.7 in. H_2O) for those SDT mist eliminators with PM emissions above 0.06 kg/Mg (0.12 lb/ton) BLS (i.e., baseline pressure drop); the average pressure drop is 13 mm Hg (7 in. H_2O) for those SDT scrubbers capable of meeting both PM emission limits (0.10 kg/Mg [0.20 lb/ton] and 0.06 kg/Mg [0.12 lb/ton] BLS) on a long-term basis.[4,10] Therefore, an increase in pressure drop from 1.3 to 13 mm Hg (0.7 to 7 in. H_2O) was used to estimate the increase in electricity requirements and resulting increase in electricity costs. The overhead cost was estimated to be equal to 60 percent of the total maintenance cost.[6] The administrative, taxes, and insurance costs were estimated to be equal to 4 percent of the TCI.[6] The capital recovery cost was estimated to be equal to the product of a CRF and the TCI.[6] The CRF is 0.1098, based on a 15-year scrubber life and a 7 percent interest rate.

The ITAC for the SDT models SDT-5 through SDT-7 are presented in Table 6-31 and range from $190,000/yr to $301,000/yr.

6.1.5 Lime Kiln Control Options

Two PM control options have been evaluated for existing and new lime kilns. One PM control option that has been evaluated for existing lime kilns would reduce PM emissions to the NSPS level for gas-fired lime kilns--0.15 g/dscm (0.067 gr/dscf). For existing lime kilns with wet scrubbers, the control option would involve replacing the existing scrubber with an ESP. However, the actual control device (e.g., ESP or high-efficiency scrubber) selected by a particular mill would be site-specific. The costs for this PM control option were estimated for lime kiln models LK-1 through LK-3, which represent existing lime kilns controlled with wet scrubbers.

Based on PM emissions data supplied by mills, lime kilns controlled with ESP’s already achieve a PM level of 0.15 g/dscm (0.067 gr/dscf).[4,10] Therefore, costs were not estimated for the control option reducing PM emissions to 0.15 g/dscm (0.067 gr/dscf) for lime kilns controlled with ESP’s (represented by models LK-4 through LK-6).

A second PM control option that was evaluated for new and existing lime kilns would reduce PM emissions to 0.023 g/dscm (0.010 gr/dscf). For existing lime kilns with wet scrubbers, the control option would involve replacing the existing scrubber with an ESP; costs would be estimated for models LK-1 through LK-3. For existing lime kilns with ESP’s, the control option would involve upgrading the existing ESP. For new lime kilns, the control option would involve installing a new ESP capable of achieving the 0.023 g/dscm (0.010 gr/dscf) PM level. The costs for upgrading or installing a new ESP were estimated for models LK-4 through LK-6. The actual control device selected by a particular mill would actually be site-specific. The capital and annual costs for each of these options are presented in the following sections.

6.1.5.1 Replacement of Existing Scrubber with ESP: Capital Costs. The costs of replacing a scrubber with an ESP were calculated based on recent ESP costs provided by individual pulp and paper mills.[4] The cost to dispose of the existing scrubber was assumed to be included in the new ESP costs provided by the individual mills. New lime kiln ESP costs average \$484/m^2 (\$45/ft^2) of ESP plate area.[4] The ESP plate area for each model lime kiln was derived from the model gas flow rate at the ESP inlet and the SCA for the new ESP. The SCA for model lime kiln ESP’s meeting a PM level of 0.15 g/dscm (0.067 gr/dscf) is estimated to be 90 $m^2/(m^3/sec)$ (460 ft^2/1,000 acfm).[4] The SCA value is based on the SCA of an actual lime kiln ESP for which long-term PM emissions data are available to demonstrate that its PM emissions are consistently at or below 0.15 g/dscm (0.067 gr/dscf).[10] The SCA for model lime kiln ESP’s meeting a PM level of 0.023 g/dscm (0.010 gr/dscf) is estimated to be 220 $m^2/(m^3/sec)$ (1,120 ft^2/1,000 acfm).[4] The SCA value is based on the SCA of an actual lime kiln ESP for which long-term PM emissions data are available to demonstrate that its PM emissions are consistently at or below 0.023 g/dscm (0.010 gr/dscf).[10]

Installing a new fan and stack typically comprises approximately 20 percent of the total capital costs of installing a new ESP. Because the fan and stack usually do not need to be replaced when a scrubber is replaced with an ESP, the cost for replacing a scrubber with an ESP is only about 80 percent of the cost of a completely new ESP.[9] Based on information from an ESP manufacturer, the lifetime of the replacement ESP is about 15 years.[36]

Table 6-32 presents the model replacement costs to control PM emissions to 0.15 g/dscm (0.067 gr/dscf). The costs range from $457,000 to $1.50 million for LK-1 through LK-3. Table 6-33 presents the model replacement costs to control PM emissions to 0.023 g/dscm (0.010 gr/dscf). The costs range from $1.11 million to $3.65 million for LK-1 through LK-3.

It was assumed that installation of the ESP could be completed within the 2-week scheduled shutdown, and, therefore, pulp production losses were not included in these cost estimates. Further information is needed to determine the validity of this assumption (e.g., the lack of available space complicating ESP installation and thereby increasing costs).

6.1.5.2 <u>Replacement of Existing Scrubber with ESP: Incremental Annual Costs</u>. To determine the incremental annual costs of replacing the existing scrubber with a new ESP for each model lime kiln, the annual costs for operating the existing scrubber were subtracted from the annual costs for operating a new ESP. To be conservative, the TCI-related indirect costs for the existing scrubber (i.e., the administrative, property tax, insurance, and capital recovery costs) were not included in the cost comparison.

The incremental annual costs of replacing the existing scrubber with a new ESP are presented in Tables 6-32 and 6-33. Design parameters and costs for the existing scrubber at baseline PM levels are presented in Tables 6-34 and 6-35, respectively. Because over 80 percent of lime kiln scrubbers are venturi scrubbers, the scrubber design parameters presented in Table 6-34 are based on a venturi scrubber as the baseline control device.[8] Design parameters for the new ESP are presented in Table 6-36, and the ESP costs at the 0.15 g/dscm (0.067 gr/dscf) and 0.023 g/dscm (0.010 gr/dscf) PM levels are presented in Tables 6-37 and 6-38, respectively.

Direct annual costs (i.e., operating labor costs, maintenance costs, and utility costs) are reduced significantly when the existing scrubber is replaced with an ESP. Overhead costs are also reduced because they are a function of the labor and maintenance costs. For model lime kilns LK-1 through LK-3 controlling PM emissions to 0.15 g/dscm (0.067 gr/dscf), the reduction in direct annual costs and overhead costs obtained by switching from a scrubber to an ESP was greater than the TCI-related indirect annual costs for the new ESP. As a result, the ITAC are actually cost savings of \$104,000/yr to \$53,000/yr for LK-1 through LK-3. The ITAC savings for the model lime kilns are presented in Table 6-32.

For model lime kilns LK-1 through LK-3 controlling PM emissions to 0.023 g/dscm (0.010 gr/dscf), the reduction in direct annual costs and overhead costs was less than the TCI-related indirect costs for the ESP. As a result, there are annual costs associated with replacing the existing scrubber with a new ESP, ranging from \$17,400/yr to \$342,000/yr for LK-1 through LK-3. The TCI-related indirect annual costs for the ESP were strongly influenced by the high SCA value used to estimate the TCI. The SCA for new ESP’s meeting a PM level of 0.023 g/dscm (0.010 gr/dscf) is approximately 220 $m^2/(m^3/sec)$ (1,120 ft^2/1,000 acfm).[4] The ITAC for the model lime kilns are presented in Table 6-33.

Approximately 15 percent of lime kiln scrubbers for which data are available have pressure drops below 19 mm Hg (10 in. H_2O), or are low-energy, low-pressure, or ejector type scrubbers.[4] These scrubbers operate at a lower pressure drop than the venturi scrubber used as the baseline control device. The annual costs to replace these low-pressure drop scrubbers with ESP's would be higher than the costs and cost saving presented above. The additional annual costs for replacing low-pressure drop scrubbers were estimated based on the difference in pressure drop between the low-pressure drop scrubbers and the venturi scrubber used as the baseline control device. The average pressure drop is 7.5 mm Hg (4 in. H_2O) for those low-pressure drop lime kiln scrubbers with PM emissions greater than 0.15 g/dscm (0.067 gr/dscf). The average pressure drop is 39 mm Hg (21 in. H_2O) for the baseline venturi scrubber. To estimate the incremental annual costs of replacing low-pressure drop lime kiln scrubbers with ESP's, annual costs of $34,500/yr for LK-1, $65,700 for LK-2, and $112,000/yr for LK-3 should be added to the annual costs and cost savings presented above.

6.1.5.3 <u>Upgrade of Existing ESP: Capital Costs</u>. Because no actual ESP upgrade costs were available for controlling PM emissions from a level of 0.15 g/dscm (0.067 gr/dscf) to a level of 0.023 g/dscm (0.010 gr/dscf), the upgrade cost for the lime kiln ESP was instead based on the incremental cost difference between an ESP capable of achieving a PM level of 0.15 g/dscm (0.067 gr/dscf) and one capable of achieving a PM level of 0.023 g/dscm (0.010 gr/dscf).

The ESP upgrade capital costs were based on the recent ESP costs provided by individual pulp and paper mills (i.e., costs for ESP's installed or replaced during or after 1989).[4] The new lime kiln ESP costs average $484/$m^2$ ($45/$ft^2$) of ESP plate area.[4] To determine the ESP upgrade cost, this cost per ESP plate area was multiplied by the increase in ESP plate area assumed to reduce PM emissions from 0.15 g/dscm (0.067 gr/dscf) to 0.023 g/dscm (0.010 gr/dscf). The ESP plate area for each model lime kiln was derived from the model gas flow rate at the ESP inlet and the ESP SCA. The model SCA for an ESP meeting a long-term PM level of 0.15 g/dscm (0.067 gr/dscf) is approximately 90 $m^2/(m^3/sec)$ (460 ft^2/1,000 acfm).[4,10] The model SCA for an ESP meeting a long-term PM level of 0.023 g/dscm (0.010 gr/dscf) is approximately 220 $m^2/(m^3/sec)$ (1,120 ft^2/1,000 acfm).[4,10]

For new lime kilns installing ESP's to control PM emissiosn to 0.023 g/dscm (0.010 gr/dscf), the capital cost attributable to the control option would not be the cost of a new ESP but only that portion associated with controlling PM emissions from the current NSPS level of 0.15 g/dscm (0.067 gr/dscf) to 0.023 g/dscm (0.010 gr/dscf). Such a cost would be the same as the cost to upgrade existing lime kiln ESP's to achieve the same PM level of 0.023 g/dscm (0.010 gr/dscf).

The capital costs, excluding pulp production losses, for the ESP upgrade control option for new and existing model lime kilns are presented in Table 6-39 and range from $654,000 to $2.15 million for LK-4 through LK-6. No information is currently available for existing lime kilns on the amount of time required to complete an ESP upgrade that would achieve a PM control level of 0.023 g/dscm (0.010 gr/dscf). As a result, no pulp production losses were estimated for this ESP upgrade control option.

6.1.5.4 Upgrade of Existing ESP: Incremental Annual Costs. Labor and maintenance costs are assumed to be unchanged when the ESP is upgraded to achieve a PM level of 0.023 g/dscm (0.010 gr/dscf). Therefore, the incremental annual costs for the ESP upgrade include only the increase in electricity costs and the TCI-based indirect annual costs, which include administrative, property tax, insurance, and capital recovery costs. The capital recovery cost is based on an average 15-year life span for lime kiln ESP's.[36] The increased electricity costs are based on an increase in SCA from 90 $m^2/(m^3/sec)$ (460 $ft^2/1{,}000$ acfm) to 220 $m^2/(m^3/sec)$ (1,120 $ft^2/1{,}000$ acfm).[4] The ITAC for the new and existing model lime kilns, without taking pulp production losses into account, are presented in Table 6-39 and range from $112,000/yr to $369,000/yr for LK-4 through LK-6.

6.2 ENHANCED MONITORING COSTS

The following sections present the estimated costs for the enhanced monitoring options discussed in Chapter 4. Table 6-40 presents a summary of the enhanced monitoring costs, and Table 6-41 presents the itemized capital and annual costs for opacity monitors and HCl CEM’s. Enhanced monitoring costs were not estimated for control options other than those presented in Chapter 4; if facilities choose to meet the emission limits through the application of other control options, and a CEM is not applicable because of cost and/or technology constraints, the facilities must develop an enhanced monitoring plan that demonstrates the ability of the selected parameter to gauge a change in emissions.

6.2.1 Recovery Furnace Enhanced Monitoring

The following sections present the costs of enhanced monitoring options that can be used to demonstrate compliance with recovery furnace emission limits for PM or PM HAP’s, total gaseous organic HAP’s, and HCl.

6.2.1.1 Enhanced Monitoring for PM or PM HAP’s Controlled with an ESP. Because opacity is the surrogate measurement that best characterizes the level of recovery furnace PM emissions, installation of an opacity monitor after the ESP is one option being considered as a means of demonstrating compliance with a PM or PM HAP emission limit for recovery furnaces. For those recovery furnaces with a wet scrubber following the ESP, an opacity monitor must be located after the ESP but prior to the scrubber. A computer program distributed by the Emission Measurement Technical Information Center (EMTIC) of EPA was used to estimate capital and annual costs for an opacity monitor.

The capital cost from EMTIC to purchase and install an in-situ opacity monitor (i.e., an opacity monitor that measures emissions in the stack or duct) is approximately $34,800. The capital costs include planning, selecting the type of equipment, providing support facilities, PEC, installing and checking CEM’s, performance specification tests (certification), and preparing the quality assurance/quality control (QA/QC) plan required by appendix F (40 CFR 60). The PEC includes the cost to purchase a data acquisition system (DAS) which includes data reduction and reporting hardware/software.[37]

The annual costs from EMTIC equal $16,500/yr and include costs for operating and maintenance, reporting and recordkeeping, and annual review and update.[37] Administrative, insurance, property tax, and capital recovery costs were estimated separately and added to the annual costs from the EMTIC program. The administrative, insurance, and property tax costs were calculated as 4 percent of the TCI, based on guidance in the OAQPS Control Cost Manual.[6] The capital recovery cost was calculated as a product of a CRF and the TCI.[6] The CRF was calculated assuming a 20-year equipment life and 7 percent interest. The total annual cost for the opacity monitor is approximately $21,200/yr.

Method 5, Method 29, or Method 17 compliance tests could be performed periodically (e.g., semiannually) as a substitute for an opacity monitor. The estimated cost for one three-run, EPA Method 5 compliance test is $8,500.[37] The estimated cost for one three-run, EPA Method 29 compliance test is $12,000.[38] No costs are available for a three-run, EPA Method 17 compliance test. If performed semiannually, the Method 5 tests would cost $17,000/yr; the Method 29 tests would cost $24,000/yr.

Another option being considered is for the facility to develop a monitoring plan that specifies ESP operating parameters to be monitored. Operating parameters for the ESP would be site-specific and would be based on the parameters measured during a three-run, EPA Method 5, Method 29, or Method 17 compliance test that showed the facility to be in compliance with the applicable PM or PM HAP emission limit. The cost to implement a monitoring plan has not been estimated. The estimated costs for three-run, EPA Method 5 or Method 29 compliance tests were discussed in the previous paragraph. No costs are available for a three-run, EPA Method 17 compliance test.

6.2.1.2 Enhanced Monitoring for PM or PM HAP’s Controlled with a Wet Scrubber. For those recovery furnaces that can comply with a PM or PM HAP emission limit with existing wet scrubbers, the use of an opacity monitor to demonstrate compliance with the PM emission limit may be inappropriate. The exhaust from the recovery furnace wet scrubber will have a high moisture content and will interfere with the readings from an opacity monitor.

Monitoring scrubber operating parameters (i.e., pressure drop and scrubber liquid flow rate) is an alternative enhanced monitoring option for showing compliance with a PM or PM HAP emission limit for recovery furnaces. The pressure drop and liquid flow rate are indirect measurements of the performance of the scrubber.

The pressure drop across a wet scrubber can be determined by using a basic magnehelic gauge coupled with the S-type pitot tube and would require manual reading. The pressure drop can also be determined using a similar arrangement with an electronic magnehelic gauge that produces a digital signal. The cost for a manual read-out system would be less than $300. The additional cost for the electronic magnehelic gauge is not currently known.

There are various techniques for measuring liquid flow rate in a wet scrubber. These techniques include ultra-sonic detection mounted externally on the in-flowing water pipe and turbine devices that are mounted within the pipe, both of which generate an electrical signal that can be logically displayed in a control room. The cost for these flow-measuring techniques can vary from $2,000 to $25,000, depending on the device sensitivity and distance from the control room.[37]

Pressure drop and scrubber liquid flow rate levels would be site-specific and would be based on the operating parameters measured during a three-run, EPA Method 5, Method 29, or Method 17 compliance test that showed the facility to be in compliance with the applicable PM or PM HAP emission limit. Method 5, Method 29, or Method 17 compliance tests could also be performed periodically (e.g., semiannually) as a substitute for monitoring scrubber operating parameters. The estimated costs for three-run, EPA Method 5 and Method 29 compliance tests were discussed in Section 6.2.1.1. No costs are available for a three-run, EPA Method 17 compliance test.

6.2.1.3 Enhanced Monitoring for Gaseous Organic HAP's. Control of gaseous organic HAP emissions from recovery furnaces can be achieved by using NDCE recovery furnaces equipped with dry ESP systems. Therefore, enhanced monitoring for recovery furnace gaseous organic HAP emissions can be achieved simply by confirming that the furnace is an NDCE recovery furnace with a dry ESP system. No costs are associated with this enhanced monitoring option.

If the recovery furnace is a DCE recovery furnace or an NDCE recovery furnace equipped with a wet ESP system, the facility could measure methanol emissions with a methanol CEM (e.g, a fourier transform infrared, or FTIR, spectroscopy monitoring system). The capital and annual costs for an FTIR monitor have been estimated to be approximately 160,000 and 71,500/yr, respectively.[39]

6.2.1.4 Enhanced Monitoring for HCl. Hydrochloric acid emissions can be measured directly using an HCl CEM. An HCl CEM could be installed after the packed-bed scrubber to demonstrate continuous compliance with an HCl emission standard. An HCl CEM could also be used after the ESP for those recovery furnaces that could comply with an HCl emission limit without a packed-bed scrubber. The capital and annual costs for an HCl CEM were determined using the EMTIC CEM cost program.

The capital cost from EMTIC to purchase and install an extractive HCl monitor (i.e., an HCl CEM that extracts a sample and transports the sample through a conditioning system and into a gas analyzer) is approximately $126,900.[37] The capital costs include planning, selecting the type of equipment, providing support facilities, PEC, installing and checking CEM’s, performance specification tests (certification), and preparing the QA/QC plan required by Appendix F (40 CFR 60). The PEC costs include the cost for a DAS for data reduction and reporting. A performance specification for HCl monitors is currently under development for the CFR. However, one has already been developed by the Northeast States for Coordinated Air Use Management, or NESCAUM, and is being evaluated by EPA.[37]

The direct annual costs from EMTIC equal $60,300/yr and include costs for operating and maintenance, reporting and recordkeeping, and annual review and update.[37] Administrative, insurance, property tax, and capital recovery costs were estimated separately and added to the program costs. The administrative, insurance, and property tax costs were calculated as 4 percent of the TCI, based on guidance in the OAQPS Control Cost Manual.[6] The capital recovery cost was calculated as a product of a CRF and the TCI.[6] The CRF was calculated assuming a 20-year equipment life and 7 percent interest.[6] The total annual cost for the HCl CEM is approximately $77,400/yr.

The feasibility of using HCl CEM's to demonstrate compliance with an HCl standard has not been determined. The low HCl concentrations and high moisture content associated with the recovery furnace flue gas may make the use of HCl CEM's more difficult. However, additional information is needed before an HCl CEM can be definitively ruled out for recovery furnaces.

Because HCl emissions can be controlled with a packed-bed scrubber, monitoring scrubber operating parameters is another monitoring option being considered for those recovery furnaces that comply with an HCl emission limit using a packed-bed scrubber. The scrubber operating parameters to be monitored are scrubber liquid pH and scrubber liquid flow rate. The cost for a pH monitoring system for scrubber water is approximately $5,000.[37] The cost to measure scrubber liquid flow rate was discussed in Section 6.2.1.2 and ranges from $2,000 to $25,000, depending on the devices' sensitivity and distance from the control room.[37] Scrubber liquid flow rate and pH levels would be site-specific and would be based on the operating parameters measured during a three-run, EPA Method 26A HCl compliance test that showed the facility to be in compliance with an HCl emission limit. Method 26A must be used when the measurement point is downstream of a wet scrubber. The estimated cost for one three-run, EPA Method 26 HCl compliance test is $9,100 if performed alone, or $600 if performed in conjunction with EPA Method 5, Method 29, or Method 17 testing.[40] The $600 would be in addition to the cost of the PM or PM HAP testing.

Alternative enhanced monitoring options are also available to demonstrate compliance for those recovery furnaces that could comply with an HCl emission limit without a packed-bed scrubber. One option would require the facility to develop a monitoring plan that specifies operating parameters to be monitored. Operating parameters would be site-specific and would be based on the parameters measured during a three-run, EPA Method 26 or 26A HCl compliance test that showed the facility to be in compliance with the applicable HCl emission limit. Either Method 26 or 26A could be used if the measurement point does not follow a wet scrubber. The cost to implement a monitoring plan has not been estimated. The estimated cost for a three-run EPA Method 26 HCl compliance test would be the same as the estimated cost for a three-run, EPA Method 26A HCl compliance test, which was discussed in the previous paragraph. A second option would require periodic (e.g., annual) Method 26 or 26A HCl compliance tests to demonstrate compliance. The annual cost of EPA Method 26 or 26A HCl compliance testing is $9,100/yr if the test is performed annually and without EPA Method 5, Method 29, or Method 17 testing.[40] The annual cost is $600/yr if performed annually and in conjunction with EPA Method 5, Method 29, or Method 17 testing.[40] The $600 would be in addition to the annual cost of the PM or PM HAP testing.

6.2.2 Black Liquor Oxidation Unit Enhanced Monitoring

This section presents the costs of the enhanced monitoring options that can be used to demonstrate compliance with a total gaseous organic HAP emission limit for DCE recovery furnace systems (which include the BLO unit).

One control option presented for the BLO unit involves the removal of this piece of equipment from the chemical recovery process by converting a DCE recovery furnace system equipped with a wet ESP system to an NDCE recovery furnace equipped with a dry ESP system. Demonstrating that this conversion has been completed assures compliance with the applicable total gaseous organic HAP emission limit. No costs are associated with this enhanced monitoring option.

A second control option involves incineration of the BLO emissions. Enhanced monitoring for BLO incineration could be achieved simply by affirming that the BLO control equipment is in place. No cost is associated with this enhanced monitoring option. Another enhanced monitoring option would be for the facility to monitor the temperature of the power boiler or other incineration device. The cost of a temperature monitor is assumed to be zero because temperature monitoring is already conducted by mills.

6.2.3 Smelt Dissolving Tank Enhanced Monitoring

This section presents the costs of the enhanced monitoring options that can be used to demonstrate compliance with an SDT emission limit for PM or PM HAP’s.

6.2.3.1 Enhanced Monitoring for PM or PM HAP’s Controlled with a Wet Scrubber. Because the exhaust from the SDT wet scrubber will have a high moisture content and will interfere with the readings from an opacity monitor, the use of an opacity monitor to demonstrate compliance with a PM or PM HAP emission limit for SDT’s may be inappropriate. Monitoring scrubber operating parameters (i.e., pressure drop and scrubber liquid flow rate) is an alternate enhanced monitoring option for showing compliance with a PM or PM HAP emission limit for SDT’s. The pressure drop and liquid flow rate are indirect measurements of the performance of the scrubber. The costs to monitor pressure drop and scrubber liquid flow rate were discussed in Section 6.2.1.2.

Pressure drop and scrubber liquid flow rate levels would be site-specific and would be based on the operating parameters measured during a three-run, EPA Method 5, Method 29, or Method 17 compliance test that showed the facility to be in compliance with the applicable PM or PM HAP emission limit. Method 5, Method 29, or Method 17 compliance tests could also be performed periodically (e.g., semiannually) as a substitute for monitoring scrubber operating parameters. The estimated costs for three-run, EPA Method 5 and Method 29 compliance tests were discussed in Section 6.2.1.1. No costs are available for a three-run, EPA Method 17 compliance test.

6.2.4 Lime Kiln Enhanced Monitoring

The following sections present the costs of the enhanced monitoring options that can be used to demonstrate compliance with a lime kiln emission limit for PM or PM HAP's.

6.2.4.1 Enhanced Monitoring for PM or PM HAP's Controlled with an ESP. Because opacity is the surrogate measurement that best characterizes the level of lime kiln PM emissions, installation of an opacity monitor is one option being considered as a means of demonstrating compliance with a PM or PM HAP emission limit for lime kilns controlled with ESP's. For those lime kilns with a wet scrubber following the ESP, an opacity monitor must be located after the ESP but prior to the scrubber. The capital and annual costs for the opacity monitor were discussed in Section 6.2.1.1. Method 5, Method 29, or Method 17 compliance tests could be performed periodically (e.g., semiannually) as a substitute for an opacity monitor. The estimated costs for three-run, EPA Method 5 and Method 29 compliance tests were discussed in Section 6.2.1.1. No costs are available for a three-run, EPA Method 17 compliance test.

Another option being considered is for the facility to develop a monitoring plan that specifies ESP parameters to be monitored. Operating parameters for the ESP would be site-specific and would be based on the parameters measured during a three-run, EPA Method 5, Method 29, or Method 17 compliance test that showed the facility to be in compliance with the applicable PM or PM HAP emission limit. The cost to implement a monitoring plan has not been estimated. The estimated costs for three-run, EPA Method 5 and Method 29 compliance tests were discussed in Section 6.2.1.1. No costs are available for a three-run, EPA Method 17 compliance test.

6.2.4.2 Enhanced Monitoring for PM or PM HAP's Controlled with a Wet Scrubber. For those lime kilns that can comply with a lime kiln PM or PM HAP emission limit with existing wet scrubbers, the use of an opacity monitor to demonstrate compliance with a PM or PM HAP emission limit may be inappropriate. The exhaust from the lime kiln wet scrubber will have a high moisture content and will interfere with the readings from an opacity monitor. Monitoring scrubber operating parameters (i.e., pressure drop and scrubber liquid flow rate) is an alternative enhanced monitoring option for showing compliance with the applicable PM or PM HAP emission limit for lime kilns. The pressure drop and liquid flow rate are indirect measurements of the performance of the scrubber. The costs to monitor pressure drop and scrubber liquid flow rate were discussed in Section 6.2.1.2.

Pressure drop and scrubber liquid flow rate levels would be site-specific and would be based on the operating parameters measured during a three-run, EPA Method 5, Method 29, or Method 17 compliance test that showed the facility to be in compliance with the applicable PM or PM HAP emission limit. Method 5, Method 29, or Method 17 compliance tests could also be performed periodically (e.g., semiannually) as a substitute for monitoring scrubber operating parameters. The estimated costs for three-run, EPA Method 5 and Method 29 compliance tests were discussed in Section 6.2.1.1. No costs are available for a three-run, EPA Method 17 compliance test.