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Regulatory Impact Analysis of Implementation Requirements for the Reduction of SO_2 Emissions

U.S. Environmental Protection Agency
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Exective Summary

Sulfur dioxide (SO_2) is created during the combustion of sulfur-containing fossil fuels and during the processing of natural ores. Data show that on occasion, bursts of SO_2 are released from sources due to malfunctions, process upsets, and during start-up/shut-down procedures. Short-term emissions (i.e., over a 5 to 10 minute period) can also occur at sources that use boilers to generate power that is used during facility operations or for the sale to end-users. As such, short-term emissions can occur at refineries, pulp and paper mills, copper smelters, primary lead smelters, coke ovens, electric utilities, and other facilities with similar operations. Short-term bursts of SO_2 are generally disseminated within the local vicinity (less than 20 kilometers) of the emitting source. When SO_2 oxidizes in water, it forms both sulfurous and sulfuric acids. If SO_2 dissolves in the water of the respiratory tract of humans, the resulting acidity is irritating to the pulmonary tissues. Studies have demonstrated that acute exposures over a period of 5 to 10 minutes to elevated concentrations of SO_2 can cause respiratory responses in individuals with lung diseases, such as asthma.

In April 1971, the U.S. Environmental Protection Agency (EPA) established a primary National Ambient Air Quality Standard (NAAQS) for SO_2 that is set to protect public health, requiring ambient air concentrations not to exceed 0.14 parts per million (ppm) over a 24 hour period no more than once a year with a 0.03 ppm annual arithmetic mean. The EPA also promulgated a secondary standard to protect the public welfare (i.e., buildings, vegetation, ecosystems, and human discomfort) of 0.50 ppm not to be exceeded in a 3 hour period more than once per year. In addition, the EPA has also established a 24 hour significant harm level (SHL) program that warns and protects against dangerously high levels of SO_2.

During the review of the current NAAQS, the EPA proposed three regulatory options in March 1995 to address the problems associated with 5-minute peak SO_2 concentrations. The regulatory options considered include: (1) augmenting implementation of the existing standards by focusing monitoring on those sources or source types likely to produce high 5-minute peak SO_2 concentrations, (2) establishing a regulatory program under section 303 of the Act to supplement the protection provided by the existing NAAQS, and (3) revising the existing NAAQS by adding a new 5-minute standard of 0.60 ppm. These regulatory options were evaluated in a Regulatory Impact Analysis prepared in 1995. Because evidence suggests that high short-term SO_2 concentrations are a localized problem rather than a widespread national concern, the current NAAQS was reaffirmed in May 1996 under CFR Part 50.

Even with the existing programs to protect the public from exposures to SO_2, a number of new studies have become available that examine the potential health effects associated with short-term exposures to SO_2. Conclusions from the supplement to the staff paper addendum indicate that effects of SO_2 over a 5 to 10 minute period in a range of 0.60 to 1.0 ppm is of concern because a substantial number of asthmatic individuals during elevated breathing levels experience pronounced changes in lung function that may be viewed as a mild asthma attack, cause discomfort, prompt self-medication, and cause some individuals to alter their activity.

Although 5-minute episodes are infrequent and affect only a subset of the national population, it is clear that 5-minute SO_2 concentrations above 0.60 ppm pose a health threat to sensitive individuals, and the severity of the threat is a function of the concentration and frequency of the peaks and population subject to the episodes. To address the localized problem, the EPA is proposing to implement a supplemental program under CFR Part 51 that effectively addresses valid concerns regarding short-term SO_2 concentrations, while empowering States, local governments, and communities with the ability and flexibility to address a given situation appropriately. For these reasons, the EPA has decided that in lieu of the three implementation options proposed in 1995, it will propose a new "Intervention Level" (IL) program under the authority of section 303 of the Act to supplement protection provided by the existing SO_2 NAAQS. Because the IL program raises novel legal or policy issues, the following Regulatory Impact Analysis (RIA) has been develope dto respond to Executive Order 12866.

With the IL program, a range of concentrations is established to bound the concentrations of concern for short-term peaks of SO_2. The two levels used to bound the concentrations are: (1) a concern level of 0.60 ppm, and (2) and endangerment level of 2.0 ppm. If the concern level is exceeded, the States shall take action as appropriate giving consideration to risk criteria such as: concentration, frequency of episodes, population exposed, and other site specific factors. As the concentration level and frequency of the episode approaches the endangerment level and the health effects are more pronounced, a higher risk to the exposed population is anticipated, so State action will be increasingly more stringent.

Because the IL program is designed to address a localized problem, by providing more flexibility to the implementing authority to protect the affected population from adverse health impacts, there is tremendous uncertainty in determining the exact response to the program by regulatory authorities, the communities, and affected sources. Due to the numerous uncertainties surrounding the implementation of such a program, this document is unable to predict and quantify national impacts of the IL program, but rather provides examples of a variety of responses to the program through detailed case study analyses of a sample of sources.

The cost analysis presents information on the number of exceedances observed in the country based on best available data, and the EPA's best judgement of the number of actions that will occur. The control strategies that can be used in actions taken can vary widely from a low cost alternative such as fuel switching to a very costly alternative such as the installation of add-on control equipment. The cost of control is evaluated through a series of case studies that present information on a sample of control strategies that are viable under the IL program. The types of actions and control strategies analyzed are not exhaustive, however. Time and resource constraints prevent an analysis of all possible control alternatives. In addition, States and local communities while evaluating a 5-minute SO_2 problem may develop new and innovative ways of addressing SO_2 concentrations.

Based on public comments received and the detailed evaluation of existing monitor data submitted by States, the EPA estimates that a total of ten areas throughout the country have a potential to be evaluated for the level of public health risk associated with short-term SO_2 episodes. Several of these areas show indications that the risk to public health would not warrant action under the IL program due to the frequency and/or concentration of the peaks, the location of sources vis-a-vis population, or the time of day of SO_2 peaks. Overall, of the ten areas indicated as having a potential short-term SO_2 problem by ambient monitoring data, the EPA reasonably estimates that action under the IL program could be warranted for approximately five areas. In making this judgement about the likelihood of action under the IL program, EPA is using several types of information, including: 1) historical knowledge about the situation based on interactions between the EPA Regions, States and local sources; 2) comments provided in response to the original proposals by sources, States, and local agencies; 3) air quality and census data; and 4) information about the industrial processes at facilities in the locations of concern.

The case studies indicate the range of annualized cost for solutions to different 5-minute SO_2 problems to be from approximately $300,000 to $2.2 million. In addition, some case studies have no cost associated with the program since action is not warranted under the IL program. Yet, some studies completed for other analyses indicate the potential for a cost savings of approximately $250,000 or a total annualized cost of $30 million. The case studies demonstrate that the IL program provides a significant amount of flexibility to regulatory authorities, communities, and sources to achieve a reasonable solution to short-term SO_2 problems at a substantially lower cost than other potential regulatory vehicles. For example, the previously proposed regulatory option of establishing a new short-term SO_2 NAAQS to eliminate exceedances of 0.60 ppm at any one time in a given year was estimated to cost $1.75 billion. Several of the sources assumed to incur costs under a NAAQS option would have the potential to not have any regulatory action taken upon them under the IL program and thus incur no compliance costs. Even if all five of the actions predicted to occur under the IL program have the highest end of costs estimated in the case studies of this analysis ($2.2 million), the total cost of the IL program would be $11 million, or $1.74 billion less than the NAAQS option. Therefore, the IL program is a very cost-effective solution to the public health risk associated with short-term peaks of SO_2.

Given that implementation of the IL program will only occur in those areas where a regulatory authority has determined that there is a substantial risk to human health, it is unlikely that a vast number of sources in any one industry discussed above will be impacted. Typically, with the uniform implementation of the cost of a regulation on several producers, an industry's marginal producer is more likely to be affected causing the market supply curve to shift, which allows producers to share the burden of a regulation with consumers through an increase in product prices. With the IL program, there is a potential of only one or two sources of an industry to incur additional control costs to resolve a 5-minute SO_2 problem. If the sources affected by the program are not the marginal producers of an industry, the market supply curve is not likely to shift and the source would not share the burden with consumers. Rather, the IL program is likely to cause the source to absorb all of the compliance costs and incorporate them into the cost of production to determine thier optimal level of operation.

Given the uncertainties as to the number of actions taken under the IL program and the types of sources impacted, it is not feasible to interpret the potential impacts on small entities. Small entities exist in nearly all of the industries potentially impacted by the IL program. The cost analysis indicates that the IL program may impact a total of 5 areas of the country[a], which lessens the likelihood of seeing a significant or disproportionate impact on a small entities. If an action under the IL program is taken on a small entity, the costs associated with the action can be quite low if the state allows flexibility in compliance methods for the program.

The quantified benefits of the case studies ranged in value from $2,700 to $44,100. As such the costs exceed benefits by a significant amount. The small magnitude of benefits results from mainly two factors. First, the short-term peaks in SO_2 under consideration impact a fairly small geographic area within the local vicinity of the model plants. The small geographic area leads to a relatively small number of people being exposed to these short term peaks. Second, the benefit estimates are limited to the health benefits accruing to asthmatics who are participating in activities that cause elevated ventilation rates. Also, the controls that may result from an IL action could reduce SO_2 emissions year-round which creates benefits in many other categories. The analysis is unable to consider welfare benefits associated with any ecosystem, visibility, odor, materials damage, or particulate matter improvements that may result from control of short-term peaks in SO_2. Although the costs that are determined for the case studies exceed the quantifiable benefits, the IL program achieves a reasonable

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[a] Note that any one area affected by the IL program could impact only one or several sources.

solution to the short-term SO_2 problem at substantially lower cost than other potential regulatory vehicles, such as the previously proposed new short-term SO_2 NAAQS.

In addition to the lower cost of resolving short-term SO_2 problems, the IL program allows a regulatory authority to consider environmental justice as a criteria to warrant action under the IL program. Executive Order 12898 requires that each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority and low-income populations.

A number of factors indicate that asthma may pose more of a health problem among non-white, children, and urban populations. Considering these factors, a general screening analysis is conducted to examine the sociodemographic characteristics of the case study areas potentially impacted by short-term SO_2 peaks.

Overall, the populations in the case study areas do not show any indications that a disproportionate number of non-white individuals would be impacted by short-term SO_2 ambient concentrations greater than 0.60 ppm. This analysis, however, does not cover all possible areas of the country with short-term SO_2 peak concentrations greater than 0.60 ppm. Other areas of the country may have a higher percentage of non-white citizens. The analysis also indicates that there are twice as many children residing in the case study areas as compared to the national average, and potentially 595 could have asthma and thus experience health impacts during peak SO_2 concentrations. In addition to the large number of children potentially exposed to peak SO_2 concentrations, 27 percent of the households in the case study areas are below the poverty level, which is twice the national average. It should be noted, however, that it is not known how many of the households below the poverty level contain asthmatic individuals. Given the available data, there is an indication that a disproportionate number of children and households below the poverty level are exposed to short-term SO_2 peaks. In general, children do not have the resources to relocate or take action against sources of SO_2 emissions. Similarly, households below the poverty level may be dependent on local industrial sources for employment. In addition to having limited resources to relocate or take action against sources of SO_2 emissions, they may be reluctant to do so if action would be a detriment to employment opportunities.

SECTION 1. INTRODUCTION

1.0 Background

Sulfur dioxide (SO_2), a strongly odorous gas, oxidizes in water to form both sulfurous and sulfuric acids. When SO_2 dissolves in the water of the respiratory tract of humans, the resulting acidity is irritating to the pulmonary tissues. Similarly, when SO_2 dissolves in rain drops, the "acid rain" can cause damage to both aquatic and terrestrial ecosystems as well as corrode various materials. Therefore, the primary health concern for short-term SO_2 emissions is response in the respiratory tract of humans, which places individuals with asthma at higher risk of responding to short-term SO_2 peaks.

SO_2 is created during the combustion of sulfur-containing fossil fuels and during the processing of natural ores. In the atmosphere, SO_2 exists with a variety of particles and other gases, and undergoes chemical and physical interactions with them, forming sulfates and other transformation products. The conversion of SO_2 into sulfates and other products is known to contribute to problems with acid rain or particulate matter. Data show that on occasion, bursts of SO_2 are released from sources due to malfunctions, process upsets, and during start-up/shut-down procedures. Short-term emissions can also occur at sources that use boilers to generate power that is used during facility operations or for sale to end-users. As such, short-term emissions can occur at refineries, pulp and paper mills, copper smelters, primary lead smelters, coke ovens, electric utilities, and other facilities with similar operations. Short-term bursts of SO_2 are generally disseminated within the local vicinity (less than 20 kilometers) of the emitting source. Studies have demonstrated that acute exposures over a period of 5 to 10 minutes to elevated concentrations of SO_2 can cause respiratory responses in individuals with lung diseases.

1.1 Legislative History:

In April 1971, the U.S. Environmental Protection Agency (EPA) established a National Ambient Air Quality Standard (NAAQS) for SO_2 under the authority of Sections 108 and 109 of the Clean Air Act (CAA), which requires the regulation of criteria air pollutants that may endanger public health or welfare. The primary SO_2 NAAQS that is set to protect public health, requires ambient air concentrations not to exceed 0.14 parts per million (ppm) over a 24-hour period no more than once a year and a 0.03 ppm annual arithmetic mean. The EPA also promulgated a secondary standard to protect the public welfare (i.e., buildings, vegetation, ecosystems, and human discomfort) of 0.50 ppm not to be exceeded in a 3-hour period more than once per year (38FR 25881, September 14, 1973). As Table 1-1 shows, there are currently 44 areas designated as not attaining the current NAAQS.

Periodically, EPA reviews the NAAQS to evaluate whether revision is necessary to adequately protect the public health and welfare. In 1988, EPA reviewed the NAAQS and concluded that the current 24-hour and annual standards were both necessary and adequate to protect human health against SO_2 concentrations associated with those averaging periods. These conclusions were based on the scientific data assessed in criteria documents[1,2,3] and staff papers[4,5,6] and with the advice and recommendations of the Clean Air Scientific Advisory Committee of EPA's Science Advisory Board.

Additional protection is also provided under Title IV of the 1990 CAA Amendments, which requires electric utilities to reduce annual SO_2 emissions by 9 million metric tons (10 million short tons) per year from a 1980 baseline of 23.3 million metric tons. This reduction is implemented in two phases with the first phase being completed in 1995 and a larger reduction is expected in the second phase which will be completed by the year 2000. While the primary objective of Title IV is to reduce the total sulfate loadings resulting from regional sulfate transport, some improvements in local SO_2 ambient air quality will be realized as a result of the reductions.

Table 1-1. Sulfur Dioxide NAAQS Designated Non Attainment Areas			
AREA	DESIGNATION[a]	AREA	DESIGNATION
Penobscot, ME	P	Cuyahoga, OH	P
Warren, NJ	P/S	Gallia, OH	P
Allegheny, PA	P	Jefferson, OH	P
Warren, PA[b]	P	Lake, OH	P
Warren, PA[b]	P/S	Lorain, OH	P
Hancock, WV[b]	P	Lucas, OH	P
Hancock, WV[b]	P/S	Marathon, WI	P/S
Boyd, KY	P	Oneida, WI	P/S
Muhlenberg, KY	S	Grant, NM	P
Benton, TN	P/S	Muscatine, IA	P
Humphreys, TN	P/S	Lewis & Clark, MT	P/S
Polk, TN	P/S	Yellowstone, MT	P
Tazewell, IL	P	Cochise, AZ	P
Lake, IN	P	Gila, AZ	P
Laporte, IN	P	Greenlee, AZ	P
Marion, IN	P	Pima, AZ	P
VIGO, IN	P	Pinal, AZ	P
Wayne, IN	P	Pinal, AZ	P
AQCR 131, MN	P	Piti-Cabra, GM	P
Olmested, MN	P	Tanguisson, GM	P
Coshocton, OH	P	Salt Lake, UT	P/S
White Pine, NV	P	Tooele, UT	P/S

[a] The areas are indicated as being nonattainment for the primary, secondary, or both NAAQS by P, S, P/S.

[b] Because areas in Warren County, PA and Hancock, WV were designated at different times, these counties each have two separate nonattainment areas.

Finally, EPA also has established a 24-hour significant harm level (SHL) program that warns and protects against dangerously high levels of SO_2. This program was designed to address emergency episodes that would occur where pollution levels build up over a period of time to unhealthy levels. The program establishes four levels of concern, that if exceeded within a 24-hour period, States must undertake various actions to remedy the situation. The four levels established in the SHL are:

* Alert Level - 0.30 ppm,
* Warning Level - 0.60 ppm,
* Emergency Level - 0.80 ppm, and
* Significant Harm Level - 1.0 ppm.

The SHL program is a proactive program designed to prevent an area from ever reaching the SHL. Between the Alter and Emergency levels that are below the SHL, emission sources in the area are required to take increasingly restrictive action to reduce emissions as specified in the contingency plans with the approved State implementation plan (SIP). Exceedance of the 1.0 ppm concentration of the SHL requires urgent measures contained in the SIP on the part of the State and emission source to correct and prevent the episode from occurring again. From the Alert to the Emergency levels that are below the SHL, emission sources in the area are required to take increasingly restrictive action to reduce emissions as specified in the contingency plan within the approved State implementation plan.

1.2 The Short-Term SO_2 Externality

Even with the existing programs to protect the public from exposures to SO_2, a number of new studies have become available that examine the potential health effects associated with short-term (less than or equal to 1-hour) exposures to SO_2 (see the staff paper supplement for a review of recent studies). In view of these new studies and other relevant new information, EPA prepared a supplement to the criteria document addendum[8] and a supplement to the staff paper addendum[9]. Conclusions from the supplement to the staff paper addendum indicate that effects of SO_2 over a 5 to 10 minute period in a range of 0.60 to 1.0 ppm are of concern because a substantial number of asthmatic individuals (approximately 25 percent) during oronasal (i.e., mouth and nose) breathing experience pronounced changes in lung function that may be viewed as a mild asthma attack, cause discomfort, prompt self-medication, and cause some individuals to alter their activity. The response, however, generally is resolved within an hour, and some individuals can still function effectively despite whatever effects they perceive from the SO_2 exposure[10].

The EPA currently has limited source oriented monitoring information on 5-minute monitoring data for SO_2. However, EPA evaluated data submitted from 16 States for SO_2 ambient air monitors. The data from these monitors indicate that 43 percent of the monitors registered 5-minute averages in excess of 0.60 ppm SO_2. In addition, several of the monitors recorded multiple exceedances of 0.60 ppm. Fifty percent of the monitors that indicated high peaks of SO_2 recorded from 11 to 139 exceedances. This evidence is likely to underestimate the national problem because data were available from only a tenth of the SO_2 monitors nationally, and because the current monitoring network is set-up in urban areas to measure ambient air quality for attainment of the current 3-hour, 24-hour and annual NAAQS. If States decide to relocate monitors to better evaluate 5-minute ambient SO_2 concentrations around sources of concern, the number of measured exceedances of SO_2 peaks could increase significantly.

During a review of the current NAAQS, EPA reviewed the evidence and proposed three regulatory options in March 1995 to address the problems associated with 5-minute peak SO_2 concentrations. The regulatory options considered include: (1) augmenting implementation of the existing standards by focusing monitoring on those sources or source types likely to produce high 5-minute peak SO_2 concentrations, (2) establishing a regulatory program under section 303 of the Act to supplement the protection provided by the existing NAAQS, and (3) revising the existing NAAQS by adding a new 5-minute standard of 0.60 ppm.

These regulatory options were evaluated in a Regulatory Impact Analysis prepared in 1995[11].

Compelling comments received from the March 1995 proposal indicate that (1) there were a limited number of communities showing evidence of a problem and (2) the emissions do not travel far from the source when episodes occur. This suggests that high short-term SO_2 concentrations are a localized problem rather than a widespread national concern. Commenters argued that States should be given the authority and the flexibility to impose appropriate control requirements, especially in cases when the short-term peaks are rare, and the potential for exposure is low. Although 5-minute episodes are infrequent and affect only a subset of the national population, it is clear that 5-minute SO_2 concentrations above 0.60 ppm pose a health threat to sensitive individuals, and the severity of the threat is a function of the concentration and frequency of the peaks and population subject to the episodes. Because every area that is subject to significant short-term peaks has its own unique characteristics, EPA agrees it is prudent to assess each individual situation, and when necessary, act appropriately and efficiently to reduce the risk to the public and that the States, being closest to each individual situation, are in the best position to do so.

In general, the areas that are known to have high 5-minute peak concentrations of SO_2 have market systems that have failed to deal effectively with air pollution. This occurs because the ambient air has been treated as public goods and because most air polluters do not internalize the full damage caused by their emissions.

1.3 Proposed Resolution to the Externality

As a result of comments and additional information received, EPA reaffirmed the current NAAQS program for SO_2 in May of 1996 under CFR Part 50. However, EPA is proposing to implement a supplemental program under CFR Part 51 that effectively addresses valid concerns regarding short-term SO_2 concentrations, while empowering States, local governments, and communities with the ability and flexibility to address a given situation appropriately. For these reasons, EPA has decided that in lieu of the three implementation options proposed in 1995, it will propose a new "Intervention Level" (IL) program under the authority of section 303 of the Act to supplement protection provided by the existing SO_2 NAAQS.

With the IL program, a range of concentrations is established to bound the concentrations of concern for short-term peaks of SO_2. The two levels used to bound the concentrations are: (1) a concern level of 0.60 ppm, and (2) and endangerment level of 2.0 ppm. If the concern level is exceeded, the States shall take action as appropriate giving consideration to risk criteria such as: concentration, frequency of episodes, population exposed, and other site specific factors. As the concentration level and frequency of the episode approaches the endangerment level and the health effects are more pronounced, a higher risk to the exposed population is anticipated, so State action will be increasingly more stringent.

This document analyzes the impacts of such a program on affected sources. It will describe the IL program in detail and evaluate the costs, benefits and economic impacts of the program. Because the IL program is designed to address a localized problem, by providing more flexibility to the implementing authority (i.e., the States) to protect the affected population from adverse health impacts, there is tremendous uncertainty in determining the exact response to the program by regulatory authorities, the communities, and affected sources. This document, therefore, provides examples of a variety of responses to the program through detailed case study analyses of selected sources. Due to the numerous uncertainties surrounding the implementation of such a program, this document is unable to predict and quantify national impacts of the IL program, but rather evaluates the potential national number of actions taken for the IL program based on known exceedances of 0.60 ppm SO_2 and provides a qualitative discussion of national impacts.

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8. Reference 3.

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10. Reference 6.

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SECTION 2. STATEMENT OF NEED FOR ACTION

2.0 Characteristics of Emissions

When there are short-term episodes of SO_2, the emissions of concern are disseminated in local vicinities to the source. All emissions that travel beyond the local vicinity of the source are generally diluted with ambient air to a concentration that will not significantly impact public health.

In addition, there are also instances when short bursts of SO_2 are emitted during thermal inversions, which traps the emission in an area for prolonged periods of time. Thermal inversions occur in unique cases of geography and meteorology. If a source is located in a valley of hilly terrain, weather conditions could exist in which colder air at the elevated levels of the hills or mountains traps warmer air in the valley closer to the ground. Instead of allowing the warmer air to rise and disseminate, it remains stagnant for prolonged periods of time.

There is a potential for numerous short-term SO_2 episodes around various sources that have sulfur as a component of combustion or process operations. The Staff Paper Supplement[1] examined available monitoring data from 1989 to 1993, which indicates the presence of peaks at or above both 0.50 ppm and 0.75 ppm SO_2. Table 2-1 presents the number of hours during which one or more 5-minute peaks at or above 0.50 and 0.75 ppm were observed for a sample of source types based on information contained in the Staff Paper Supplement[2]. In a subsequent study completed in September 1995 by ICF Kaiser, Inc.[3], monitoring data from 16 States were submitted and analyzed for the existence of 5-minute peak SO_2 concentrations. Results of the analysis demonstrate a prevalence of SO_2 concentrations in excess of 0.60 ppm for 43 percent of the monitors evaluated[a].

Currently available information on 5-minute peaks of SO_2 is limited for several reasons. The primary reason is that the placement of monitors within the existing network is designed to measure ambient air quality relative to the existing 3-hour, 24-hour, and annual NAAQS. Therefore, use of hourly SO_2 data for this analysis may underestimate the true potential for 5-minute peaks. Additionally, because there are no requirements to collect and submit 5-minute data, resources have been allocated to other areas of monitoring. Overall, there is sufficient evidence to determine that 5-minute peaks of SO_2 above 0.60 exist and have the potential to affect the population surrounding the

[a] The concluding result of the analysis that 43% of the monitors indicated a 5-minute problem is merely provided to demonstrate that the problem exists. This result cannot be used to determine the severity of a national problem because this estimate is based on data that was voluntarily submitted by States for SO_2 emissions around sources known to have 5-minute problems.

source of emissions.

TABLE 2-1. MONITORED AMBIENT 5-MINUTE SO_2 PEAKS FOR SELECTED SITES, 1989 - 1993

Source	MONITORED PEAK SO_2 VALUE GREATER THAN 0.75 ppm		MONITORED PEAK SO_2 VALUE GREATER THAN 0.50 ppm	
	Number of Observances (1)	Monitoring Period (2)	Number of Observances (1)	Monitoring Period (2)
Sulfuric Acid Plant	18	0.05	38	0.05
Petroleum Refinery/Industrial Complex (3)	56	0.38	114	10.38
Sulfite Paper Mill	83 (3)	1.0	0	na
Allegheny County, PA (3)	35	0.92	0	na
Copper Smelter (4)	73	2.5	0	na
Primary Lead Smelter	72	1.15	125	1.15
Copper Smelter	14	1.0	51	1.0
Steel Mill	32	2.15	74	2.15
Utility/Industrial Complex	15	5.16	88	5.16
Industrial Boiler/Kraft Paper Mill	1	0.31	2	0.31
Petroleum Refinery	0	1.0	0	1.0
Petroleum Refinery	0	1.0	6	1.0

(1) Number of hours in which value was monitored.
(2) Total monitoring period (years).
(3) Actually indicates instantaneous peak concentrations >1.0 ppm
(4) These sources had more than one monitor in their proximity. Data used from all monitors, but hours with peaks only counted once, regardless of how many of the monitors recorded a peak for that hour.

2.1 Health Effects

To better understand the impact of short-term SO_2 emission on human health, the following briefly characterizes asthma and discusses how people with such respiratory conditions would respond to SO_2.

Asthma is a disease that creates breathing difficulties for individuals in response to a variety of environmental, chemical, and physical conditions (i.e., cold or dry air, pollutants, allergies, exercise). The disease can be classified as mild, moderate, or severe and affects approximately 5 percent of the national population[b,4]. The prevalence of asthma is higher among African-Americans, older (8 to 11 year old) children, and urban residents. Because there is a wide degree of variability of the symptoms of asthma, some individuals may be unaware that they have the disease, while others treat the disease through medication and with doctor supervision. Asthma attacks can result in a need to disrupt activities and rest, require self-treatment with inhalers or medicine, or necessitate hospitalization and emergency room treatment[5].

The most striking response to SO_2 for asthmatics and others with hyperactive airways is bronchoconstriction (airway narrowing), usually evidenced as increased airway resistance, and

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[b] Many cases of mild asthma may be unreported, therefore, the true prevalence of asthma may be as high as 7 to 10 percent of the national population.

the occurrence of symptoms such as wheezing, chest tightness, and shortness of breath. The symptoms and response occurs quickly (within 5 to 10 minutes of exposure). The response is also generally brief in duration and if the stimuli are removed, lung function usually returns to normal within 1-hour.

Healthy nonasthmatic individuals are essentially unaffected by acute exposures to SO_2 at concentrations below 2.0 ppm. However, for individuals with asthma or hyperactive airways the effects of SO_2 increases with both increased overall ventilation rates and an increased proportion of oral ventilation in relation to total ventilation. Oral ventilation is thought to accentuate the response because the scrubbing of SO_2 by the nasal passages is bypassed[6]. Ventilation rates that trigger oronasal breathing can occur from activities such as climbing about three flights of stairs, light cycling, shoveling snow, light jogging, playing tennis, or walking up a moderate hill. Moderately higher breathing can occur from activities such as moderate cycling, chopping wood, or light uphill running. Even though such exercise is not strenuous per se, it has been determined that these activities are enough to cause some bypassing of nasal passages in breathing which exposes SO_2-sensitive individuals to a risk of bronchoconstriction. Risk is also present for individuals who are obligate mouth breathers, or who may be breathing through their mouth due to nasal congestion from temporary conditions[7]. In contrast, individuals with more severe asthmatic conditions have poor exercise tolerance and, therefore, are less likely to engage in sufficiently intense activity to achieve the requisite breathing rates for notable SO_2-induced respiratory effects to occur[8,9].

The health effects associated with exposures to the proposed concern level, 0.6 ppm SO_2, 5-minute block average, were the focus of EPA's most recent review of the primary national ambient air quality standards for sulfur oxides (measured as sulfur dioxide). The health effects and the Administrator's conclusions about the public health risks associated with exposure to 0.60 ppm SO_2 are thoroughly discussed in the EPA documents generated during that review: the criteria document supplement[10], the staff paper supplement[11], the November 15, 1994 proposal notice (59 FR 58958) and the [insert date of publication] final decision notice [insert FR cite].

The EPA's concern about the potential public health consequences of exposures to short-term peaks of SO_2 arose from the extensive literature involving brief (2- to 10-minutes) controlled exposures of persons with mild (and, in some cases moderate) asthma across a range of concentrations of SO_2 while at elevated ventilation rates. The major effect of SO_2 on sensitive asthmatic individuals is bronchoconstriction, usually evidenced in these studies by decreased lung function and the occurrence of clinical symptoms such as wheezing, chest tightness, and shortness of breath. The proportion of asthmatic individuals who respond, the magnitude of the response and the occurrence of symptoms increase as SO_2 concentrations and ventilation rates increase. The criteria document supplement contains a summary of the literature on the health effects associated with brief exposures to SO_2, some details of which are provided in the benefits analysis of this document.

Taking into account the available health effects studies and the body of comments on the health effects, the Administrator concluded in the final decision notice [FR cite] that a substantial percentage (20 percent or more) of mild-to-moderate asthmatic individuals exposed to 0.6 to 1.0 ppm SO_2 for 5 to 10 minutes at elevated ventilation rates (such as would be expected during moderate exercise) would be expected to have lung function changes and severity of respiratory symptoms that clearly exceed those experienced from typical daily variation in lung function or in response to other stimuli (e.g., moderate exercise or cold/dry air). For many of the responders, the effects are likely to be both perceptible and thought to be of some health concern; that is, likely to cause some disruption of ongoing activities, use of bronchodilator medication, and/or possibly seeking of medical attention.

During the regulatory review process of the current NAAQS, there was some agreement by medical experts that at this concentration, 0.60 ppm SO_2, the frequency with which such effects are experienced may affect the degree of public health concern that is appropriate. After taking into account the broad range of opinions expressed by CASAC members, medical experts, and the public, in the final decision notice [FR cite] the Administrator concluded that repeated occurrences of such effects should be regarded as significant from a public health standpoint, and that the likely frequency of occurrence of such effects should be a consideration in assessing the overall public health risk in a given situation.

The severity of respiratory symptoms and lung function changes are greater than normal when asthmatic individuals are exposed to SO_2 concentrations of 0.6 to 1.0 ppm SO_2. At 0.60 ppm, some mild or moderate asthmatic individuals at elevated ventilation are likely to respond with bronchoconstriction and effects are likely to be thought of as an immediate health concern. At 1.0 ppm, the effects are likely to be more pronounced. Individuals experience more substantial changes in pulmonary function accompanied by symptoms and may also experience mild bronchoconstriction while at rest, which may cause disruption of ongoing activities, use of medication, and/or possibly seeking medical attention. At concentration levels above 1.0 ppm, concern is increased. At 1.5 ppm, there is an increased fraction of mild and moderate asthmatics who are likely to respond with more pronounced effects, and there is increased concern for more severe asthmatic individuals who have poor exercise tolerance. At 2.0 ppm, approximately 80 percent of the at risk population are likely to respond with effects ranging from moderate to incapacitating. Asthmatic individuals at rest are likely to experience moderate bronchoconstriction that would necessitate medication or hospitalization. At 3.0 to 5.0 ppm, nonasthmatic adults at mild exercise will experience bronchoconstriction, and asthmatic individuals at rest will likely experience pronounced bronchoconstriction.

Many asthmatics take medication to relieve symptoms and functional responses associated with exacerbation of this disease. One of the most commonly used asthma medications (beta-agonists) also inhibits SO_2. This has led to suggestions that asthmatic individuals may be protected from responses to SO_2 because they medicate prior to exercise. However, most mild asthmatic individuals use medication only when symptoms arise. (SP, p. 16). Therefore, pre-exercise bronchodilator use would not be likely to occur for many potentially SO_2-sensitive individuals. In addition, many moderate asthmatics who come from low socioeconomic status may not have adequate access to the health care system, may have poor medication use based on lack of finances to purchase medication and thus may be prone to frequent deterioration of their lung function. Such individuals would be at increased risk from SO_2 exposure because of their potentially lower baseline level of lung function.

2.2 Market Failure

The analysis of recent data also indicate that 5-minute peaks of SO_2 occur in areas that also violate the current SO_2 NAAQS program. As culpable sources strive to attain the current NAAQS, some 5-minute peaks will be resolved, however, there are several occurrences that will not be captured by the current NAAQS. These incidences generally occur in local areas and can be corrected by actions taken by States or local regulatory authorities. Unfortunately, the constitutions of 16 States declare that regulatory measures placed on citizens and businesses of the state may not be any more stringent than federal regulations. This precludes several States from taking independent action for known problems with short-term SO_2 peaks.

In general, the areas that are known to have high 5-minute peak concentrations of SO_2 have market systems that have failed to deal effectively with air pollution. This occurs because the ambient air has been treated as public goods and because most air polluters do not internalize the full damage caused by their emissions. Although States and the Federal government have several programs in place to limit emissions of SO_2 to the atmosphere (and thus help sources internalize the costs of any damages to the environment), bursts of SO_2 continue to be emitted in some areas. Once in the atmosphere, citizens around these sources incur real costs associated with the pollution. In economic theory, this is referred to as a negative externality.

In theory, affected parties could participate in negotiations with the polluting sources to receive compensation for damages incurred, or resolve the pollution problem at the source. However, such resolutions might not occur in the absence of regulatory action because of two major impediments which block the correction of pollution inefficiencies and inequities by the private market. The first is the high transaction costs that occur when a large number of individuals who are affected by the pollution, act independently to negotiate and resolve the problem with the source(s)[c]. In return, the source faces transaction costs to compensate individuals adversely impacted by air pollution by contacting the individuals affected, apportioning injury to each from the various polluting sources, and executing the appropriate damage suits of negotiations. If left to the private market, each polluter and each affected individual would have to litigate or negotiate on their own or else organize into groups for these purposes. The transaction costs involved would be high and could probably exceed the benefits of any reduction in pollution.

The second factor discouraging private sector resolution of any air pollution problems is that pollution abatement tends to be a public good. That is, once emissions from a particular air

[c] It should be noted that the source(s) that citizens would negotiate with for resolution are often the primary employer for the local area and are vital components of the local economy. Citizens may not feel at ease to cause difficulties for such a source.

pollutant have been reduced through abatement measures, the benefits of the abatement can be enjoyed by additional people at no additional cost. This constitutes the classic "free rider" problem. As such, any one individual that is adversely impacted by bursts of short-term SO_2 may be reluctant to contribute their time or money to reduce pollution knowing that the potential exists for him to enjoy the benefits of reduced pollution (at no cost) if another person took abatement action. As a result, without community support or group participation in areas affected by short-term SO_2,action to resolve the problem is unlikely to occur.

Based on comments received from the previous proposal, mechanisms to establish a national regulation to correct the externality has been argued to also be too burdensome and an inefficient use of society's resources. For instance, one regulatory option for national control that was evaluated in the previous RIA was the establishment of a new SO_2 NAAQS. While this option would eliminate the problem at known sources, it would be inefficient for sources in areas with a low public health risk from 5-minute peak concentrations to be required to install control equipment. This document demonstrates that providing a more flexible program that allows States to monitor and remediate short-term peaks based on public health risk appears to provide a more efficient solution to the problem than the three other implementation options evaluated in the previous RIA.

References

1. Review of National Ambient Air Quality Standards for Sulfur Oxides: Updated Assessment of Scientific and Technical Information - Supplement to the 1986 OAQPS Staff Paper Addendum. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards; Document no. EPA-452/r-94-013; September 1994.

2. Regulatory Impact Analysis for the Proposed Regulatory Options to Address Short-Term Peak Sulfur Dioxide Exposures. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards; RTP, N.C. 27711. March 1994.

3. Summary of 1988-1995 Ambient 5-Minute SO_2 Concentration Data, Draft Final Report. ICF Kaiser, Systems Applications International; RTP, N.C. Prepared under contract no. 68-D3-0101, work assignment 7 for the U.S. Environmental Protection Agency. September 1995.

4. 1994 National Prevalence Rates for Asthmatics. National Center for Health Statistics; March 1996.

5. Reference 1.

6. Reference 1.

7. Reference 1.

8. Supplement to the Second Addendum (1986) to Air Quality Criteria for Particulate Matter and Sulfur Oxides(1982): Assessment of New Finding on Sulfur Dioxide Acute Exposure Health Effects in Asthmatic Individuals. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards; RTP, N.C. 27711. Document no. EPA/600/AP-93/002; March 1994.

9. Reference 1.

10. Reference 8.

11. Reference 1.

SECTION 3. PROGRAM DESCRIPTION

3.0 The Intervention Level Program

Given that 5-minute peak SO_2 emission events pose a health threat, but tend to be localized problems in areas scattered throughout the United States, the intervention level program allows for placement of resources and efforts precisely where the problem occurs, instead of requiring a blanket nationwide approach that might call for unnecessary administrative effort.

The Intervention Level (IL) program is derived in part from the SHL program, which has served in the past as a means for implementing the authority granted under section 303 of the CAA. Whereas the SHL program is proactive, establishing measures in advance to prevent pollution levels form exceeding the SHL, the IL program is a reactive approach to prevent future occurrences of unhealthy pollution events once these levels have been reached. The intervention level program establishes a range of concentrations in the *Code of Federal Regulations* with the lower boundary being the concern level, set at 0.60 ppm SO_2, and the upper boundary being the endangerment level, set at 2.0 ppm SO_2[1].

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[1] The measurement of the concentrations are based on a 5-minute block average, which is a 5-minute hourly maximum value for SO_2 obtained by the highest of the 5-

These boundary levels are based on health criteria discussed in chapter 2, and their objective is to protect the population at risk from "...imminent and substantial endangerment to public health or welfare, or the environment...", as stated in section 303 of the CAA.

In the event that the concern level concentration is exceeded in a given area, the State should assess the situation to determine whether intervention is appropriate. In making this determination, the State should consider the concentration of the 5-minute peaks, the frequency of the episodes (based on monitor data and an estimate of the number of 5-minute peaks not recorded by the monitoring network), the history and nature of any citizen complaints, available information on potential population exposure (inferred in part by the population in the vicinity of the source), the type of process being used, a history of past upsets or malfunctions, the type of fuel used, knowledge of how well the source is controlled, and any other considerations deemed necessary by the State.

Because the health effects become more severe as the 5-minute SO_2 concentration approaches the endangerment level, it is expected that the State will respond with more intensive corrective measures as the endangerment level concentration is

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minute averages from the 12 possible nonoverlapping periods during a clock hour.

approached. If the State determines that the circumstances surrounding a source of high 5-minute peaks pose an unacceptable risk of harm, it should take remedial action as appropriate. For example, if the endangerment level is exceeded, the States could consider taking action to shut down the facility until the cause of the high 5-minute peaks can be remedied. If necessary, EPA is prepared to take action under the authority of section 303 if the endangerment level is exceeded in a given area, and the State fails to address the problem.

Like the previously proposed implementation alternatives, a key element of this new implementation strategy is the relocation of existing SO_2 monitors to areas near point sources where peak SO_2 concentrations may exist. The existing SO_2 monitoring network was designed to characterize urban ambient air quality associated with 3-hour, 24-hour, and annual SO_2 concentrations, and cannot adequately measure peak SO_2 concentrations from point sources. To allow for the measurement of short-term peaks, EPA proposed revisions to the ambient air quality surveillance requirements (40 CFR, Part 58) and proposed certain technical changes to the requirements for Ambient Air Monitoring Reference and Equivalent Methods (40 CFR, part 53) in November 1994 and March 1995 notices.

The EPA believes that these changes to the monitoring requirements will give the States the flexibility to locate monitors in areas where they are concerned about 5-minute peaks, and to respan the monitors to measure these peaks. Under the intervention level program, the States would be able to identify areas to be monitored, based on State priorities, source emissions, citizen complaints, or other variables. The EPA will assist the States' efforts to identify and prioritize areas for monitoring 5-minute peak concentrations by providing information compiled from various databases. The EPA leaves the discretion on how best to utilize this information to the States.

Unlike the program originally proposed by EPA under section 303, the intervention level program does not require States to submit revised contingency plans to EPA requiring specific actions for the State and source to undertake when an exceedance occurs. The EPA presumes that the SIPs currently in force provide the States with adequate general authorities to implement the intervention level program without submittal of revised contingency plans because section 110(a)(2)(g) of the CAA requires that the SIPs contain adequate authorities to implement section 303 programs. Elimination of the requirement to submit revise contingency plans is expected to minimize the potential administrative burden on the States.

3.1 Implementation Guidance

The EPA believes the concern level of 0.60 ppm averaged over a 5-minute period is the concentration at which States should be concerned about the health impacts of a peak emission episode. Although a detailed guidance document will be developed and provided to regulatory authorities and the public, the following provides a general description of implementation procedures for the IL program.

Once the concern level has been exceeded in a given area, the State should investigate the episode, and consider the number of episodes (both observed and predicted), the concentration levels, the nature and location of the source (or sources), the proximity of the source to population, and other pertinent factors to characterize risk to the public health. Based on the concentration and frequency of the 5-minute peak concentration events, the State may wish to carry out a compliance inspection of the culpable source(s). If the source is out of compliance with its exiting emission limits (based on the NAAQS or other air pollution requirements), then the State would take necessary steps to bring the source into compliance. If, however, the State determines that bringing the source into compliance with its existing emission limits would not be likely to prevent further exceedances of the concern level, or the State determines the source to be in compliance with all applicable emission limits, then further action may be needed. In such circumstances, the next step would be for the State and source to examine the cause of the emissions, the nature of the peaks, the potential for exposure, and the risk to public health. Once these are determined, the State, source, and community would determine what a course of corrective action, if any, would need to be developed to address the cause of the 5-minute peaks.

Under the intervention level program, EPA is not specifying a time limit in which States and sources must take corrective action, although EPA expects that development of control strategies and implementation of any course of corrective action will occur in an expeditious and efficient manner. The State should determine what is considered to be expeditious for each individual situation, based on the risk to public health, specific processes or operations at the source that cause the peak episodes, the available options for control, the reasonable lead time necessary for planning design, procurement and installation of control devices or process modifications, and other pertinent considerations. Control measures needed to prevent recurrences of 5-minute SO_2 peaks may include better operation and maintenance of control equipment, better capture of fugitive emissions, raising the stack height for intermittent control, restriction of operations during times of peak exposure (i.e., conducting activities during hours when fewer people are outside, or when weather conditions are unfavorable), or other innovative control measures.

In determining the course of corrective action, States may also consider the appropriateness of control alternatives. When the health risk does not warrant the application of specific control measures, States and sources may wish to consider addressing the health risk through alternative approaches. The State must ensure that any corrective action, including non-control approaches, are Federally enforceable against the source.

In the event that a State does not take action once the intervention levels have been exceeded, the EPA would consult with the State to discuss the basis for the State's decision. After consulting with the State, if EPA determines that corrective action is warranted to protect public health, EPA will take action.

The intervention level program also provides a mechanism for involvement by members of the local community to a source of potential emissions. When States evaluate the potential for a short-term SO_2 problem, they should also take into account the number and nature of citizen complaints received, and apply suitable resources to receiving, reviewing, and responding to the concerns of citizens and community groups. Citizens who express concerns about the health and welfare effects due to high ambient concentration peaks should be given every opportunity to present and clarify their concerns to the State. Citizens, in turn, should be made aware of what types and levels of information will be most helpful in determining links between peaks and health effects, and given every opportunity to gather and provide that information. In assessing citizen complaints, and the information provided by citizens, States should be mindful that individual citizens and community groups may not have the resources available to regulatory agencies, or industry. The EPA will serve as an information resource for States and citizens, and provide technical consultation regarding health effects, risk analysis, ambient air concentrations, monitoring, modeling, and other issues, if requested.

After the State completes its assessment of the potential health risk of an emission peak, it may determine one of three things, based on the frequency, magnitude, and nature of 5-minute peak concentrations in an area: (1) corrective action is needed; (2) corrective action is not needed; (3) more information is needed to reasonable determine if corrective actions is needed. The EPA expects that local citizens and community groups will be kept informed during the decision-making process, be informed of the factors and information used to support the decision, and be given and opportunity to comment if they disagree with the decision.

If the State decides that corrective action is necessary, the recommended corrective action should be developed through a collaborative process involving the State, industry, and the local community.

SECTION 4. COST ANALYSIS

4.0 Potential Actions and Costs associated with the IL Program

The IL program is designed to give wide discretion to States and local areas for the implementation and enforcement of the program. There are three steps to estimate the total cost to society of the IL program: (1) develop an estimate of the frequency of exceedances of 0.60 ppm or higher that occur across the nation, (2) predict the number of actions taken by States that would result from these exceedances, and (3) apply the appropriate cost of control for the action to arrive at an estimate of the total cost to society of the program. Because the IL program provides a large amount of flexibility for its implementation, significant uncertainty exists in a cost analysis of the program and it is not possible to complete all three steps above.

The following analysis presents information on the number of exceedances observed in the country based on best available data, and the EPA's best judgment of the number of actions that will occur. The control strategies that can be used in actions taken can vary widely from a low cost alternative such as fuel switching to a very costly alternative such as the installation of add-on control equipment. Because of the huge uncertainty surrounding the control strategies to be chosen for an action, a national cost estimate is not provided. Alternatively, this analysis evaluates the cost of control through a series of case studies that present information on a sample of control strategies that are viable under the IL program. The types of actions and control strategies analyzed are not exhaustive, however. Time and resource constraints prevent an analysis of all possible control alternatives. In addition, States and local communities, while evaluating a 5-minute SO_2 problem, may develop new and innovative ways of addressing SO_2 concentrations.

4.1 Number of Exceedances

As is discussed in the staff paper supplement[1] and the 1994 reproposal of the health standard[2], the occurrence of short-term peaks of SO_2 are relatively infrequent and highly localized around point sources of SO_2. In 1993 and again in 1994, EPA requested that States collect and submit 5-minute SO_2 ambient monitoring data from source-based monitors. Available data have been compiled and statistical parameters calculated in a report for the EPA by ICF Kaiser, Inc[3].

The monitored measurements submitted for the analysis were evaluated for the maximum concentration occurring in any 5-minute block of an hour. The data indicate that concentrations of SO_2 occur in a range from 0.0 ppm to greater than 2.5 ppm. The number of observations recorded at any monitor ranged from 308 to 48,795 hours, with the mean number of observations equaling 7,641 hours (Note that a complete year of hourly maximum 5-minute averages would contain 8,760 observations). There were 63 monitors, located in 16 States, with continuous data sets of either the maximum 5-minute block average per hour or all of the 5-minute block averages per hour. For data sets containing all of the 5-minute block averages per hour, the maximum 5-minute block average for each hour was extracted and that parameter was used throughout the analysis. Of the 63 monitors, 27 (or 43 percent) registered one or more concentrations greater than the proposed concern level of 0.60 ppm SO_2 during the time periods represented for the monitors involved. Of the 27 monitors that recorded exceedances of 0.60 ppm, the number of such exceedances ranged from 1 to 139, which corresponds to 0 to 3 percent of the hours represented in the data. Of the 27 monitors measuring at least one exceedance, 12 monitors recorded from one to five exceedances, while eight monitors recorded from 25 to 139 exceedances. Figure 4-1 displays the distribution of hourly maximum 5-minute SO_2 peaks that exceed 0.50 ppm.

While these data came from source-based monitors, the existing SO_2 monitoring network is designed to characterize ambient air quality associated with 3-hour, 24-hour, and annual SO_2 concentrations rather than to detect short-term peak SO_2 levels. This could have resulted in underestimates of the

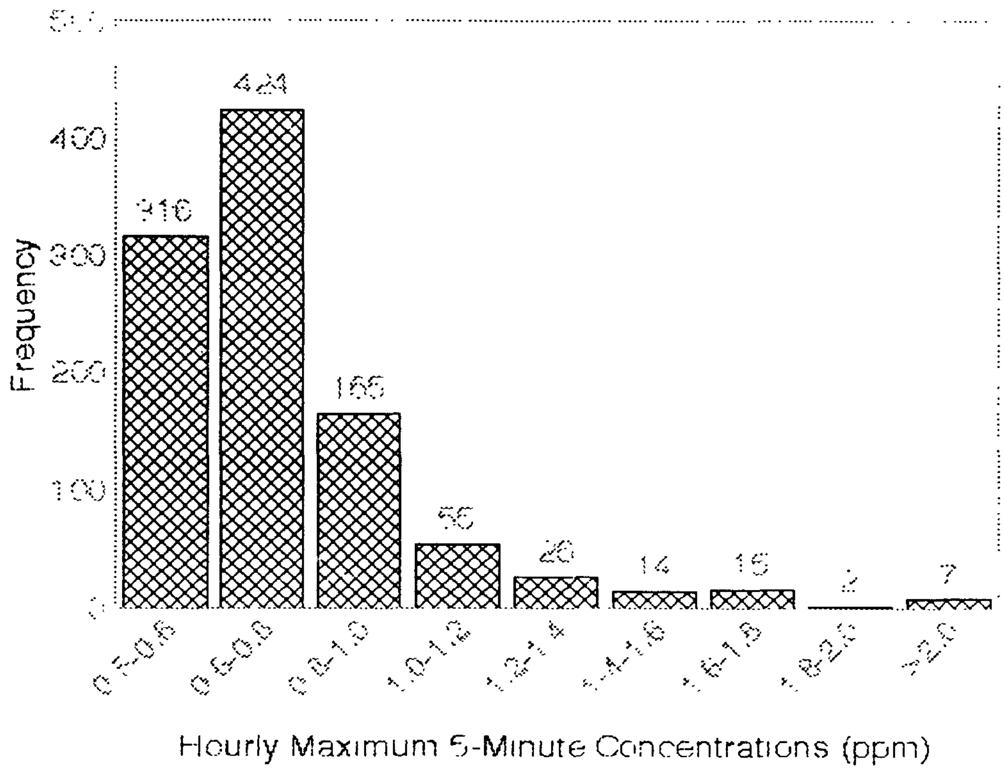

Figure 4-1. Distribution of 5-Minute Exceedances

maximum 5-minute block averages recorded. Therefore, changes in monitor siting and density near SO_2 sources most likely to produce high 5-minute peaks could increase both the number of exceedances and the concentrations of the maximum 5-minute block averages recorded.

4.2 Number of Predicted Actions

The EPA received varied comments from industry groups, States and communities for the 1994 proposal of the implementation of a new NAAQS under CFR Part 51. Some commenters stated that several sources are already well controlled and a new NAAQS would require redundant controls at sources that do not affect a substantial population because they are located in rural areas. Other commenters applauded the proposal of a new NAAQS, as it would resolve problems with frequent exposures to short-term SO_2 episodes. Still other commenters acknowledged the presence of 5-minute peak SO_2 concentrations, but indicated that the episodes occurred during hours of the day in which the at-risk population would not likely be participating in activities that induce oronasal breathing and, therefore, there was little risk to public health. Additionally, many States were concerned that the administrative burden imposed by a traditional regulatory program where risks to public health were minimal, might adversely impact their ability to effectively implement programs for other pollutants.

Based on public comments received and the detailed evaluation of existing monitor data submitted by States, EPA estimates that a total of ten areas throughout the country have a potential to be evaluated for the level of public health risk associated with short-term SO_2 episodes[a]. Several of these areas show indications that the risk to public health would not warrant action under the IL program due to the frequency and/or concentration of the peaks, the location of sources vis-a-vis population, and the time of day of SO_2 peaks. For instance, a source may have a superior record of controlling SO_2 emissions and complying with the current NAAQS, but has an unusual process malfunction that is recorded by a nearby monitor as a 5-minute peak concentration greater than 0.60 ppm. After conferring with the source, the regulatory authority in this instance may decide that due to the infrequency of such malfunctions action is not warranted under the IL program. Alternatively, a source located in a rural area that attains the current NAAQS but has regular or repeated 5-minute peaks may not have action taken because of a low potential for exposures of concern. Similarly, if 5-minute SO_2 peaks occur at night, it could be determined that the potential for exposure to the at-risk population is low and no action needs to be taken.

Overall, of the ten areas indicated as having a potential short-term SO_2 problem by ambient monitoring data, EPA reasonably estimates that action under the IL program could be warranted for approximately five areas. In making this judgment about the

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[a] Because the IL program is designed to be implemented at the States' discretion, this document will not present specific information that implicates an area as violating the concern level of the IL program and thus prescribe to the State when and what type of action should be taken, if any.

likelihood of action under the IL program, EPA is using several types of information, including: 1) historical knowledge about the situation based on interactions between the EPA Regions, States and local sources; 2) comments provided in response to the original proposals by sources, States, and local agencies, which not only provide information about the situation, but also the regulatory agency's likely response (because in this assessment, EPA is not only making a provisional judgment about the potential public health risk engendered in these situations, but also is trying to gauge the responsiveness of the regulatory agency in charge); 3) air quality and census data; and 4) information about the industrial processes at facilities in the locations of concern.

It should be noted, however, that the uncertainties surrounding the estimate of actions to be taken for the IL program are tremendous. One major restriction in the ability to provide a clearer estimate of actions is the lack of data. As is stated above, EPA has evaluated data for 63 SO_2 monitors in the existing network. This represents only a tenth of all SO_2 monitors in operation. The collection of 5-minute data has only recently been undertaken by some States due to interest in a potential short-term SO_2 regulation. Previous data collection efforts were to demonstrate compliance with the 3-hour, 24-hour, and annual NAAQS and as such does not provide sufficient information on 5-minute peaks. Additional uncertainty exists on how the states will prioritize areas for monitoring the public health risk associated with a specific area, and how the negotiations between the State, source, and citizens will result in remedial action.

In addition, as monitors are relocated to better measure 5-minute SO_2 concentrations, additional actions for the IL program could result. This outcome would indicate that the current estimate of the number of actions taken for the IL program is underestimated. At another extreme, due to budgetary constraints, a State could set priorities for environmental actions based on the severity of the problem and decide that other issues such as particulate matter and ozone will utilize all available resources. This decision would result in little effort applied to the IL program and consequently zero actions would be taken. If this happens, then the estimate of five actions taken nationwide could be an overestimate.

4.3 Estimate of Costs per Action Taken

In the previous regulatory impact analysis of proposed implementation plans for a new NAAQS (regulatory option 1) or a program under Section 303 (regulatory option 2), the cost analysis assumed that if an area indicated exceedances of 0.60 ppm at any one time during a year, then controls would have to be installed at sources contributing to the problem. In that analysis, the costs estimation was based on a worst case assumption that add-on control technology, such as SO_2 scrubbers would be applied to resolve short-term SO_2 problems. The upper bound of total cost to society in the analysis was estimated to be $1.75 billion (1993 dollars) based on the cost of implementing a new short-term SO_2 NAAQS with 1 allowable exceedance[4]. The cost of the Section 303 option was demonstrated to be more flexible as far as control alternatives, and therefore, was assumed to cost significantly less than a new NAAQS. In a supplemental analysis, the cost of implementing the Section 303 option at two model utility sources was evaluated for several control alternatives, which demonstrated the wide variance in potential cost of a more flexible regulatory alternative.

The IL program is also proposed as an option under the authority of Section 303, but provides substantially more flexibility for its implementation as compared to the previously proposed regulatory option 2. While the regulatory options described in the previous proposal would be implemented to all areas of the country that show one exceedance of 0.60 ppm, the IL program is to be implemented locally by States or local regulatory agencies based their assessment of public health risk. Control alternatives which may be considered to resolve a short-term SO_2 problem include, but are not limited to[b]:

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[b] The list of control alternatives is not exhaustive and the EPA anticipates that given the flexibility of the IL program, the States and sources will develop new and innovative ways to control for short-term SO_2.

- additional add-on control equipment,
- intermittent control technology to reduce emissions during 5-minute peak episodes,
- improved operating and maintenance procedures,
- various dispersion techniques, and
- switching to combustion fuels with low sulfur content.

The EPA has observed that each scenario of potential action under the IL program is unique based on the types of sources involved, the concentration of emissions, the frequency of emissions, the geographical surroundings and meteorological conditions of the area, and concentration of population.

Although in EPA's best judgment, five actions under the IL program will occur, the choice of control strategies chosen in each action is dependent on the negotiation of resolution between the regulatory authority, the source, and the community. When taking action under the IL program, the regulatory authority could (for reasons specific to the situation) insist on the use of add-on control equipment to remediate the 5-minute problem, or they could provide flexibility to the source to propose an innovative solution to the problem. Because of the huge uncertainty surrounding the control strategies to be chosen for an action, it is not feasible to estimate the total cost of the IL program. Alternatively, this analysis evaluates the cost of control through a series of case studies that present information on a sample of control strategies that are viable under the IL program.

Appendix A presents detailed analyses of seven case studies, while a summary of each case study is provided in the immediate pages that follow. In five of the case studies, the State decides that the risk to public health warrants action under the IL program, while the remaining two studies demonstrate situations in which short-term SO_2 emissions were evaluated by the State but no action is taken.

The selection of the sources and actions investigated in the case studies is primarily based on data availability[c]. The studies utilize information from the report of monitoring data along with prior studies conducted by EPA and public comments received with regard to prior SO_2 proposals. The case studies attempt to evaluate a variety of industries that are known to emit SO_2, but the selection of these industries does not indicate EPA's intent to target any particular industry for control. In addition, the method of evaluation and control strategies that are discussed should not be viewed as guidance on how the IL program should be implemented. Supplemental guidance documents

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[c] While this report presents five case studies of action under the IL program, it is not intended to correlate with the total estimate of five actions presumed to be taken nationally. The selection of case studies was independent of the determination of the total number of actions to be taken for the IL program.

for the program will be issued by the EPA in the future.

4.4 Case Studies

Table 4-2 presents a summary of the case studies prepared for this analysis. The table displays the type of source evaluated, whether action is taken and why, the control strategy imposed and the total annualized cost in 1993 dollars. Specific summaries of each case study is provided below.

Case 1

The first case study evaluates one source whose 5-minute SO_2 emissions exceed 0.60 ppm, which are impacting the local community around the source. The study evaluates a typical copper smelter facility that is located in a valley which creates frequent thermal inversions, thus trapping emissions in the valley for prolonged periods of time. Based on a statistical distribution of available monitoring data at copper smelters, there are 74 exceedances of the concern level (0.60 ppm),26 exceedances of 1.0 ppm, and 34 exceedances at the endangerment level (2.0 ppm).

During the evaluation of the problem, it was discovered that the exceedances were seasonal in nature, occurring primarily between the months of September and February (which contributes to the conclusion that the exceedances are associated with

Table 4-2. Summary of Case Studies

Case Study/Source Type	Action Taken and Why	Control Strategy	Annual Costs (1993 dollars)
1. Copper Smelter	Yes - one source impacting small community with frequent violations of the concern level.	Two taller stacks	$1,870,000
2. Paper Mill	Yes - one source impacting moderate size community and school aged-children frequently.	Double Contact Wet Scrubber	$1,150,000
3. Lead Smelter	Yes - one source impacting small community at the endangerment level.	Packed Bed Scrubber	$344,000
4. Petroleum Refinery	Yes - one source impacting several populated communities across State borders.	Continuous monitoring and Dry Scrubber	$2,224,000
5. Multiple Sources	Yes - several sources deteriorating community ambient air at levels greater than 0.60 ppm.	Trading program	$243,029 to $280,964
6. Several Coke Oven Facilities	No - exceedances occur at night when people not exercising.	N/A	Minimal for monitoring
7. Utility	No - rural location of facility does not present risk to population.	N/A	$0

thermal inversions). The source was assumed to be adequately controlled to attain the current NAAQS. As the process was already controlling for emissions, most SO_2 is already removed from the emission stream. The addition of add-on controls to ensure against future exceedances of the concern level would be redundant and result in costs comparable to the original control equipment yet remove relatively less SO_2, yielding a prohibitively high measure of cost-effectiveness. The source recognizes that compliance with the NAAQS precludes consideration of stack heights greater than Good Engineering Practice (GEP), which is 213 feet or 65 meters. However, the IL program as proposed under Section 303 of the CAAA permits the use of intermittent controls such as greater stack heights as long as the source continues to comply with ambient air requirements at the permitted stack heights. The State and source agree that taller stacks would be used during the period of the year likely to produce thermal inversions. During warmer months the taller stacks would be used during stagnant weather conditions only. As a result, costs of constructing two new stacks at the facility are evaluated to total $14 million in capital costs, which equates to $1.87 million annually.

Case 2

The second case study evaluates short-term SO_2 emissions from a paper mill that impacts a populated community that had submitted complaints of a shortness of breath to the State. The source of short-term SO_2 bursts is from the ending of the sulfite pulping digestion cycle which is a batch operation at the facility. The cycle usually runs for 6 hours and then emissions are vented over a 5 to 10 minute period. In addition to the local community affected by the emissions, the facility is located adjacent to an elementary school, so the school yard receives a large portion of the short-term emissions. Monitor data demonstrates frequent exceedances of both the concern and endangerment levels. Because of the numerous exceedances of the endangerment level and the impact on school-aged children, EPA decided to work with the State to evoke prompt remediation of the public health risk.

The addition of a double contact wet scrubber (along with retrofitting of the digestor) was the only alternative available to resolve the air quality problems. The cost of rebuilding the digestor to accept the scrubber, and installing the scrubber, is calculated to be $9.45 million in capital costs, which is annualized to be $1.15 million per year.

Case 3

The next case study evaluates a single source impacting a less populated area than that of case 2, but the existence of frequent exceedances of the concern and endangerment level coupled with violations of the NAAQS raises concern with the State as to the areas public health risk. The State first investigates improvement in public health risk that can be achieved by attainment of the NAAQS, and discovers that tighter adherence to the current SIP requirements will not provide adequate protection of the short-term ambient conditions. In addition, the source is located in a hilly terrain, so the concern that thermal inversions could cause ambient SO_2 to stay at elevated levels for prolonged periods of time also existed. A primary lead smelter was modeled for this case study and the source and State negotiated the installation of add-on control equipment to the blast furnace. Specifically the analysis looks at the addition of a packed bed scrubber to the blast furnace exhaust. The cost of installing the scrubber and modeling its effectiveness is calculated to be $0.28 million in capital costs or $0.344 million annually.

Case 4

The fourth case study evaluates a petroleum refinery located in a populated area in which the State has received numerous complaints of asthma and respiratory difficulties, plus burning eyes and throats. In addition, emissions from the source are known to transport across State boundaries to another community close to the facility. Coordination of both States with the facility is required to remedy the problem. During the investigation the States found that the facility has an old piece of equipment that has been grandfathered from control requirements. Even with this uncontrolled equipment, the facility usually complies with the NAAQS, however, to resolve the instances when the NAAQS is violated the source is required to practice additional monitoring plus operating and maintenance (O&M) practices to eliminate excess emissions. However, exceedances of the concern level are projected to be approximately 150 per year, with several additional exceedances at 1.0 ppm and 2.0 ppm. To resolve the problems that remain and trigger the IL program, the source is asked to use the currently installed Continuous Emission Monitors (CEMs) to provide continuous data (which is incremental to hourly data provided to show attainment of the NAAQS) for exceedances of the IL program, and report why exceedances occurred plus show O&M practices in place to avoid future exceedances. The cost for increase O&M practices and reporting and record keeping of the CEMs totals $0.034 million annually. The source is also required to add a dry scrubber device to the uncontrolled unit at a capital cost of $20.4 million (or $2.19 million annually). Combining the control strategies results in a total cost of this solution of $20.5 million in capital costs, or $2.224 million annually.

Case 5

The fifth case study evaluates an area that has several industrial sources that contribute to frequent exceedances of both the NAAQS and the IL program. As a result, the regulatory authority implements stricter enforcement of SIP requirements to meet the NAAQS, including a requirement for the installation of a CEMs, and implements additional requirements under the IL program. The sources impacted by the action include two oil refineries, two sulfur recovery plants that support the refineries, and a coal burning power plant.

Prior to enforcing stricter SIP requirements, monitor data indicate an average of 32 instances in an hour of 5-minutes SO2 concentrations exceeding the concern level. After installation of the CEMs, data show an average of twelve violations of the concern level in an hour. Thus, it is concluded that the current SIP strategy does not eliminate 5-minute episodes. Under the SIP requirements, the sources are required to use the CEMs to record and report hourly monitor data to show compliance with the NAAQS. For the IL program, sources are to provide continuous monitor data to record periods of time when 5-minute violations are frequent. After 2 years of collection by the regulatory authority and the sources, the area will implement a trading program among sources to provide intermittent control during periods when 5-minute exceedances are likely. Control strategies considered by the sources to reduce the combined affect on ambient SO_2 concentrations include the temporary scaling back of production and the use of cleaner combustion fuels. The sources that can control at the least-cost would do so in exchange for compensation by other sources that do not control.

Costs associated with this strategy include increased burden for reporting and record keeping of 5-minute continuous monitoring[d] and the cost of a 10-20 percent reduction in emissions beyond the NAAQS emission limits. A unit cost of $270 per ton of emissions reduced is assumed from the market rate for the SO_2 Allowance Trading Program, because a source will either

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[d] However, equipment costs for the CEMs are attributed to meeting the NAAQS.

opt to pay an allowance price of $270 per ton or control at an amount less than $270 per ton. The annualized cost of monitoring, reporting, and record keeping and a 10 percent rollback of emissions is calculated to be $210,855, while a 20 percent rollback in emissions totals $248,890 per year. In addition to costs imposed on sources, the case study estimates that the regulatory authority incurs $32,173 annually for report review and compliance assurance. Therefore, the total cost associated with the case study is from $243,029 to $280,964 per year.

Cases 6 and 7

The case studies presented to this point have demonstrated some situations in which there was a need for implementation of the IL program and have discussed the costs associated with implementation. In the two case studies that follow, the regulatory authorities (State or local agencies) investigate situations where exceedances of the concern level are known, but as a result of a simplified risk assessment, they have determined that the risks associated with the violations were not significant enough to warrant action under the IL program.

In the sixth case study, monitor data are evaluated for a Metropolitan Statistical Area (MSA) with three coke oven facilities (small, medium, and large) in close proximity to each other. Although there is only one recorded violation of the

NAAQS in the past 4 years, exceedances of the concern level of the IL program can occur during shut-downs or malfunctions of the desulfurization plants at these facilities. A review of the monitor data indicated exceedances in the area ranging from 0.60 and 1.0 ppm with a majority of exceedances occurring around 0.80 ppm. A total of 68 exceedances were recorded during 29 hours. Fourteen of the hours that recorded exceedances did not have desulfurization plants in operation at some of the facilities. With concern for the number of exceedances that could affect the highly populated area, the regulatory authority (a local agency) closely examined the data to determine if action under the IL program was necessary. During the investigation, they discover that 55 percent of the hours with exceedances were between the times of 11:00 p.m. and 5:00 a.m., while nearly 80 percent of the exceedance hours occurred between 9:00 p.m. and 6:00 a.m. In addition, the local agency or State had not received any citizen complaints pertaining to a short-term exposure to SO_2. As a result, the local agency concluded that the public health risk from exposures of concern is very low due to time of day when these peaks occur and thus, action was not warranted under the IL program. However, they did decide to continue to review monitor data quarterly to ensure that public health risk did not increase significantly. While there are no costs associated with remedial action for this case study, the regulatory authority would incur a minimal cost associated with the risk assessment and to conduct a quarterly review of data. The EPA estimates the cost to be minimal ranging between a tenth of a man-year and a fourth of a man-year.

In the seventh case study, a local agency evaluates the potential impact of a moderate size coal-fired utility power plant on the local community with a population of less than 1,000. Over a 1-year period, monitor data indicate a total of 10 exceedances of the concern level, but information provided by the source indicated that the peaks lasted less than 5 minutes in duration because of the flat terrain around the source and the quick dispersion of emissions. With this information, the regulatory authority concluded that the risk to public health in the area was low, no action would be taken under the IL program, and that no further investigation of monitor data was necessary.

Other Studies

There are several other control techniques that could be evaluated to measure the cost of an action under the IL program, however, time and resource constraints preclude any additional analysis. There are, however, two analyses that were conducted for other programs that are worth noting in this document. The first analysis is contained in a memo from the Office of Air Quality Planning and Standards to the Office of Management and Budget in response to comments on the 1995 proposal of the regulatory option implemented under the authority of section 303 of the CAAA. In this analysis, various control techniques such as the installation of taller stacks, increasing the capacity of an existing Flue Gas Desulfurization unit (FGD scrubber), installing a new FGD unit, and stack gas reheat. The analysis considers controls for two sizes of utility sources (100 megawatt and 1,000 megawatt boilers). The construction of new taller stacks was found to be the least costly alternative, while the installation of a new FGD unit was the most costly. The annual cost for the small utility ranged from $0.2 to $6.9 million, while the cost for the large utility ranged from $0.4 to $30 million.

In addition, SAIC conducted an analysis of fuel switching on industrial boilers from fuel oil to natural gas. An example of the analysis that is provided below concludes that with current prices of fuel oil and natural gas, sources with the ability to switch between these fuels could achieve incremental SO_2 emission reductions at a cost savings. An example of a fuel switching analysis is provided below.

Many oil fired boilers are equipped to burn both fuel oil and natural gas through burners designed for use of both fuels. For these facilities, it is often a matter of current fuel costs that dictate the choice of fuels. In recent years, fuel oil costs have remained slightly higher than natural gas costs making natural gas the preferred fuel. As natural gas prices are typically higher during the winter heating season, the ability to burn fuel oil during the winter is an advantage. Facilities that have the ability to interrupt gas usage during peak consumption periods and operate on a secondary fuel can typically purchase gas on an interruptible basis at substantially reduced costs. For facilities that are already equipped to switch fuels, this change can be accomplished quickly and easily and can be done based on current market fuel prices or fuel availability.

This example assumes a boiler at a source is currently equipped to burn only fuel oil. Therefore, the cost of converting a 165 mmBtu industrial boiler to dual-fuel (natural gas and fuel oil) capability is examined. The boiler is currently fueled by #4 fuel oil with a maximum sulfur content of 0.5 percent. For the purpose of this example, it is assumed that the boiler is located in an ozone nonattainment area and that low-NO_x technology is required to comply with local air quality regulations. As the cost of boiler replacement is relatively low, this provides a reasonably high-end cost for conversion from fuel oil to natural gas. The low-NO_x technology employed in this example is a low-NO_x burner combined with flue gas recirculation (FGR).

The initial capital cost of retrofitting the boiler of $288,685 is based on vendor quotes. Assuming a 25-year equipment life expectancy and 7 percent interest rate, the capital recovery factor is 8.6 percent. This results in an annual cost for retrofitting of $24,772.

The cost estimate was simplified by assuming that all operational costs remained the same with the exception of fuel costs. The boiler is assumed to run at approximately half capacity for 8760 hours per year for both fuels. This resulted in annual fuel cost of $5,911,578 when burning natural gas and $6,193,894 for #4 fuel oil. An annual fuel cost savings of $282,316 is produced by this switching of fuels. It should be noted that the unit fuel costs ($3.25/cubic foot for natural gas and $4.67/gallon for fuel oil) upon which these calculations are based can vary with time and location. At the present time, fuel oil prices are increasing making natural gas a relatively inexpensive option.

A total of 378 tons per year of SO_2 were reduced by switching to natural gas, based upon 8760 hours of annual operation. Because there is an annual cost savings of $257,544 (i.e., fuel savings less equipment costs), there is a cost savings per ton of SO_2 reduced of $681 resulting from switching to natural gas fuel. As discussed in the introduction to this example, this relatively low natural gas cost is based on interruptible service; this could require periods of operation on fuel oil that would decrease the overall savings by a minimal amount. As stated above, variation in fuel costs will heavily impact the actual cost per ton of SO_2 removed for a specific facility.

4.5 Summary

This section provided information on the number of known exceedances of the concern level of the IL program, and gave the best estimate of the number of actions that will be taken upon promulgation of the IL program. The occurrence of high 5-minute peaks was demonstrated to be a unique scenario for each of the case studies presented. Control alternatives for each case study were evaluated in depth to determine the cost of implementing the control at a source(s). The case studies indicate the range of annualized cost for solutions to different 5-minute SO_2 problems to be from approximately $300,000 to $2.2 million. In addition, some case studies have no cost associated with the program since action is not taken. Yet, other studies indicate the potential for a cost savings of $257,544 or a total annualized cost of $30 million.

Because of the significant uncertainty surrounding the determination of the total number of actions to be taken and due to the wide range of potential costs associated with various types of control alternatives, any attempt to present an estimate of the total cost of the IL program in this analysis would be meaningless. One could argue that an average cost of an action could be determined based on the case studies provided, however, this too would not provide a reliable estimate of total cost of the IL program. While the case studies attempt to present information on a representative sample of outcomes of an IL action, time and resource constraints preclude the evaluation of every variation of control alternatives.

This analysis demonstrates that the IL program provides a significant amount of flexibility to regulatory authorities, communities, and sources to achieve a reasonable solution to short-term SO_2 problems at a substantially lower cost than other potential regulatory vehicles. For example, the previously proposed regulatory option of establishing a new short-term SO_2 NAAQS to eliminate exceedances of 0.60 ppm at any one time in a given year was estimated to cost $1.75 billion. Several of the sources assumed to incur costs under a NAAQS option would have the potential to not have any regulatory action taken upon them under the IL program and thus incur no compliance costs. Even if all five of the actions predicted to occur under the IL program have the highest end of costs estimated in the case studies of this analysis ($2.2 million), the total cost of the IL program would be $11 million, or $1.74 billion less than the NAAQS option. Therefore, the IL program is a very cost-effective solution to the public health risk associated with short-term peaks of SO_2.

REFERENCES

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2. National Ambient Air Quality Standards for Sulfur Oxides (SO_2)-Reproposal. U.S. Environmental Protection Agency. (59FR58958-58980), November 1994.

3. Summary of 1988-1995 Ambient 5-Minute SO_2 Concentration Data. Prepared by Systems Applications International under subcontract to ICF Kaiser, Inc. for the U.S. Environmental Protection Agency; RTP, N.C.; September 1995.

4. Regulatory Impact Analysis for the Proposed Regulatory Options to Address Short-Term Peak Sulfur Dioxide Exposures. U.S. Environmental Protection Agency; RTP, N.C.; November 1994.

SECTION 5. ECONOMIC IMPACTS

5.0 Introduction

Analyzing the economic impacts of the alternative SO_2 regulatory options on non-utility sources is a very difficult task. The set of sources potentially affected by the IL program is quite broad, covering a wide variety of industry sectors in the U.S. economy from Standard Industrial Classification (SIC) codes 13 through 38, which encompasses any source that uses fossil fuels such as coal, fuel oil, coke, or natural gas to generate power in a boiler or to generate heat in a production process. Several industrial sources and electric utilities use boilers to generate power for process operations or for sale to end-users. In addition, several of the metal industries (i.e., copper smelting, lead smelting, coke production) release SO_2 emissions during batch processes, such as when metal ores are heated to very high temperatures to extract certain properties from the ore. The Pulp and Paper industry is another industry that emits SO_2 at the end of a batch process from the sulfite pulping digestion cycle of the production process.

The breadth of industries potentially affected by the IL program precludes the usual depth of coverage of a traditional economic analysis. In this analysis, market characteristics of a sample of industries potentially affected by the program are presented and discussed briefly. Then a qualitative discussion of facility impacts is provided in Section 5.3.

5.1 Industry Background

Characteristics of a sample of the industries potentially affected by the IL program are presented in Table 5-1. to identify the magnitude of potential impacts on the affected industries. Several factors such as the number of facilities and companies in an industry, availability of product substitutes, international competition, plus historical sales and employment are used to evaluate each industry's level of competitiveness (and thus industry structure), and stability to determine how additional compliance costs will impact the industry[a].

The last element provided in Table 5-1 to characterize an industry is a determination of the existence of small entities. Company employment levels indicate the existence or absence of small entities in the industry. When data on company employment levels are unavailable, a determination of the existence of any

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[a] Other factors specific to a particular industry such as expected future growth or expected new markets are also considered in the determination of industry stability, but are not included in Table VI-1. For more information on a particular industry, refer to Reference 1: "Industry Profiles for a Short-Term National Ambient Air Standard of Sulfur Dioxide."

small entities is based on the percent of companies owning only one establishment (versus companies owning multiple establishments that tend to have higher employment levels) and employment levels of the majority of facilities in the industry.

The information presented in Table 5-1 indicates that most of the industries analyzed at the 2-digit SIC code level have few substitutes available and international competition is prevalent, limiting the ability of some industries to recover compliance costs (and thus limit economic impacts) through increase prices[b]. In addition, practically all of the industries have small entities.

Four industries, including food and kindred products, chemicals and allied products, rubber and miscellaneous products, and electronic equipment do not have close substitutes available, which gives an indication of a minimal economic impact to be anticipated. Although, these industries also face a competitive international market that could increase their impacts[c], the markets of these industries are experiencing growth in the U.S., which limits the influence of foreign competition. Other

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[b] The trends indicated in the table may occur because of the broad scope of analysis of these industries at the 2-digit SIC code level.

[c] The electronic equipment industry has international competition, but the U.S. has strong foreign market opportunities.

TABLE 5-1
CHARACTERISTICS OF INDUSTRIES SELECTED FOR ANALYSIS[1]

INDUSTRY CHARACTERISTIC	SIC 13 - OIL & GAS EXTRACTION	SIC 20 - FOOD & KINDRED PRODUCTS	SIC 22 - TEXTILES	SIC 26 - PAPER & ALLIED PRODUCTS	SIC 28 - CHEMICALS & ALLIED PRODUCTS
I. MARKET CHARACTERISTICS:					
- Number of Facilities (1987)	22,910	20,583	6,065	6,292	12,039
- Number of Companies (1987)	not available	15,692	4,982	4,215	8,313
- Close Substitutes Available	NO	NO	NO	NO	NO
- International Competition	YES	YES	YES	YES	YES
SIGNIFICANT COST PASS THROUGH	NO	YES	NO	NO	YES
II. INDUSTRY STABILITY:	VOLATILE	INCREASING	STABLE	STABLE	INCREASING
- 1982 Value of Shipments (1)	306,707	415,471	70,371	118,327	252,866
- 1987 Value of Shipments (1)	115,482	383,547	71,447	129,419	286,472
- 1991 Value of Shipments (1)	not available	400,112	35,545	132,509	303,746
- Employment History	DECLINING	STEADY	DECLINING	STEADY	STEADY
III. SMALL ENTITIES	YES	YES	N/A	YES	N/A

TABLE 5-1 (continued)
CHARACTERISTICS OF INDUSTRIES SELECTED FOR ANALYSIS

INDUSTRY CHARACTERISTIC	SIC 29 - PETROLEUM AND COAL PRODUCTS	SIC 30 - RUBBER AND MISCELLANEOUS PLASTICS	SIC 33 - PRIMARY METALS	SIC 36 - ELECTRONIC EQUIPMENT	SIC 37 - TRANSPORTATION EQUIPMENT
I. MARKET CHARACTERISTICS:					
- Number of Facilities (1987)	2,232	14,589	6,661	15,922	10,505
- Number of Companies (1987)	1,320	12,149	5,400	13,523	9,158
- Close Substitutes Available	YES	NO	NO	NO	NO
- International Competition	YES	YES	YES	NO	YES
SIGNIFICANT COST PASS THROUGH	YES	YES	NO	YES	YES
II. INDUSTRY STABILITY:	STABLE	INCREASING	STABLE	INCREASING	STABLE
- 1982 Value of Shipments (1)	309,414	82,073	155,015	219,109	298,199
- 1987 Value of Shipments (1)	152,666	100,776	136,679	206,090	397,430
- 1991 Value of Shipments (1)	156,990	103,917	134,935	204,665	384,131
Employment History	DECLINING	INCREASING	DECLINING	DECLINING	STEADY
III. SMALL ENTITIES	YES	YES	YES	YES	not available

TABLE 5-1 (continued)
CHARACTERISTICS OF INDUSTRIES SELECTED FOR ANALYSIS

INDUSTRY CHARACTERISTIC	SIC 26113 - SULFATE PULP MILLS	SIC 26114 - SULFITE PULP MILLS	SIC 28193 - SULFURIC ACID PRODUCTION	SIC 2895 - CARBON BLACK	SIC 2911 - PETROLEUM REFINERIES
I. MARKET CHARACTERISTICS:					
- Number of Facilities (1987)	39	(2)	662	22	309
- Number of Companies (1987)	26	(2)	447	7	200
- Close Substitutes Available	NO	NO	NO	YES	NO
- International Competition	YES	(2)	not available	YES	YES
SIGNIFICANT COST PASS THROUGH	NO	(2)	YES	NO	YES
II. INDUSTRY STABILITY:	STABLE	(2)	STABLE	STABLE	STABLE
- 1982 Value of Shipments (1)	3,631	173	819	1,163	184,174
- 1987 Value of Shipments (1)	4,340	218	590	601	134,058
- 1991 Value of Shipments (1)	5,329	(2)	570	603	137,593
- Employment History	STEADY	(2)	DECLINING	STEADY	DECLINING
III. SMALL ENTITIES	YES	(2)	YES	YES	YES

TABLE 5-1 (continued)
CHARACTERISTICS OF INDUSTRIES SELECTED FOR ANALYSIS

INDUSTRY CHARACTERISTIC	SIC 3312 - COKE PRODUCTION	SIC 3331 - PRIMARY COPPER SMELTING	SIC 3339 - PRIMARY LEAD SMELTING
I. MARKET CHARACTERISTICS:			
- Number of Facilities (1987)	30	13	6
- Number of Companies (1987)	22	8	not available
- Close Substitutes Available	YES	YES	YES
- International Competition	YES	not available	YES
SIGNIFICANT COST PASS THROUGH	NO	NO	NO
II. INDUSTRY STABILITY:	DECLINING	STABLE	STABLE
- 1982 Value of Shipments (1)	3,682	3,452	1,899
- 1987 Value of Shipments (1)	2,601	1,949	1,180
- 1991 Value of Shipments (1)	2,245	3,859	not available
- Employment History	DECLINING	DECLINING	DECLINING
III. SMALL ENTITIES	YES	YES	YES

(1) Millions of 1993 dollars.
(2) Information on sulfite pulp mills is included with sulfate pulp mills.

industries, including textiles, paper and allied products and primary metals also do not have close substitutes available, but because the markets in these industries are mature and expect little growth in the future, significant competition (both domestically and internationally) influences the ability to raise prices and minimize impacts. Therefore, producers in these industries will probably absorb any compliance costs incurred and experience significant economic impacts.

The remaining industries analyzed at the 2-digit SIC code level each have individual indications as to the level of impacts to be expected. The oil and gas extraction industry faces heavy international competition and a volatile U.S. market, which increases the likelihood of significant economic impacts. The petroleum refining industry faces alternative fuel substitutes and international competition, however, because the U.S. market is the largest demander for petroleum products in the world and imports are only expected to fill the gap between domestic production and consumer demand, the impact on industry is expected to be minimal. The transportation equipment industry does not have close substitutes, and has a strong position in the international market (particularly in the aerospace sector). Therefore, the EPA expects that any impacts on this industry will be minimal.

The majority of the industries analyzed at the 4-digit SIC code level show indications that significant impact could exist due to the availability of close substitutes and/or international competition. The sulfuric acid production industry and the petroleum refining industry are the exceptions in that the products of these industries are key inputs to most industries in the U.S. and there are no close substitutes available. As a result, these industries are expected to experience minimal impacts.

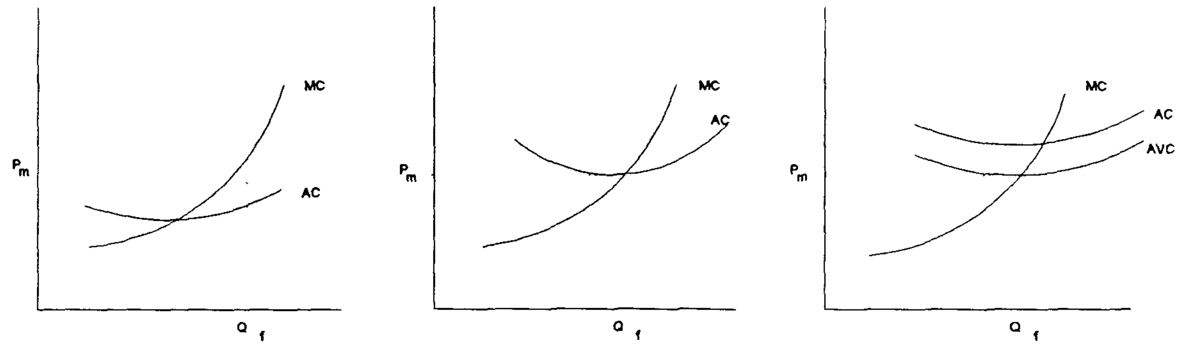
Although the electric utility industry is not included in Table 5-1, facilities in this industry are currently considered regulated monopolies because power generation and distribution is limited to a pre-determined area associated with a power plant. Because they do not face competition, regulated monopolies will pass on all costs of operation to consumers. If the industry is deregulated to open competition at the wholesale level (as is currently proposed by the Federal Energy Regulatory Commission), then the industry would face competitive decisions for changes in market price.

5.2 Facility Impacts

Given that implementation of the IL program will only occur in those areas where a regulatory authority has determined that there is a substantial risk to human health, it is unlikely that a vast number of sources in any one industry discussed above will be impacted. Although evaluating the industry's potential response to additional costs of production is valuable, that evaluation assumes that several producers in an industry face the same unit compliance costs. With uniform implementation of the cost on several producers, an industry's marginal producer is more likely to be affected which causes the market supply curve to shift. A shift in supply reduces the economic impact on sources through an increase in prices that allows producers to recover some of the compliance costs incurred. With the IL program, there is a potential of only one or two sources of an industry to incur additional control costs to resolve a 5-minute SO_2 problem. If the sources affected by the program are the marginal producers of an industry, the market supply curve is not likely to shift and the source would not benefit from increased prices. Rather, the source would absorb the compliance costs and incorporate them into the cost of production to determine their optimal level of operation.

Compliance costs that would be absorbed by a firm are considered fixed costs because the cost is usually associated with control equipment, so the level of the cost does not vary with the level of production. However, in the short-run it is assumed that because a firm could shut-down and never buy control equipment, all costs are variable. This results in an upward shift of the average variable cost (AVC) curve that measures the firms operating costs resulting from the imposition of control cost. If the AVC is greater than market price (P_m), then the firm would decide to not purchase control equipment and temporarily shut-down operations[2].

A firm's decision process is somewhat different in the long run. In the long run, the firm considers the marginal cost (MC) function, the average cost (AC) function (that incorporates both variable and fixed costs) and the market price (P_m), which is equated to a horizontal demand curve for the firm. If P_m is greater than the firm's AVC, then the firm would continue to operate at the same level of production. The figures below display three potential outcomes of the implementation of the IL program and its effect on a firm's decision process. First, panel (a) shows an industry in which the market price is above the firm's average cost function, and the firm's optimal level of production is at Q_f, where marginal cost (MC) equals price (P_m). In this scenario, the firm is earning an economic profit because price is higher than the costs the firm faces. This could occur in an industry in which the majority of producers had already incurred the cost of applying pollution control equipment to their operations prior to the implementation of the IL program, which resulted in an increase in the market price. The producers that did not install equipment have temporarily enjoyed the benefit of a price that is higher than their cost of operations. In the second panel, the firm is operating at a level that



(a) (b) (c)

Figure 5-1. Firm's Position in the Market Before Control Costs

equates price, marginal cost, and average cost, so the firm is earning zero economic profits[d]. Finally, panel © shows a firm that is earning negative profits, but because of a short-run decision that the firm could still cover obligations on average variable costs, the firm has continued to operate temporarily.

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[d] Earning an economic profit is not likely to continue for an extended period of time in a competitive industry because the existence of economic profits provides incentive for other firms to enter the market to claim a portion of the profits. When firms enter the market, the industry supply curve shifts out and decreases market price and therefore profits. Firms will continue to enter the market until all firms are earning zero economic profit.

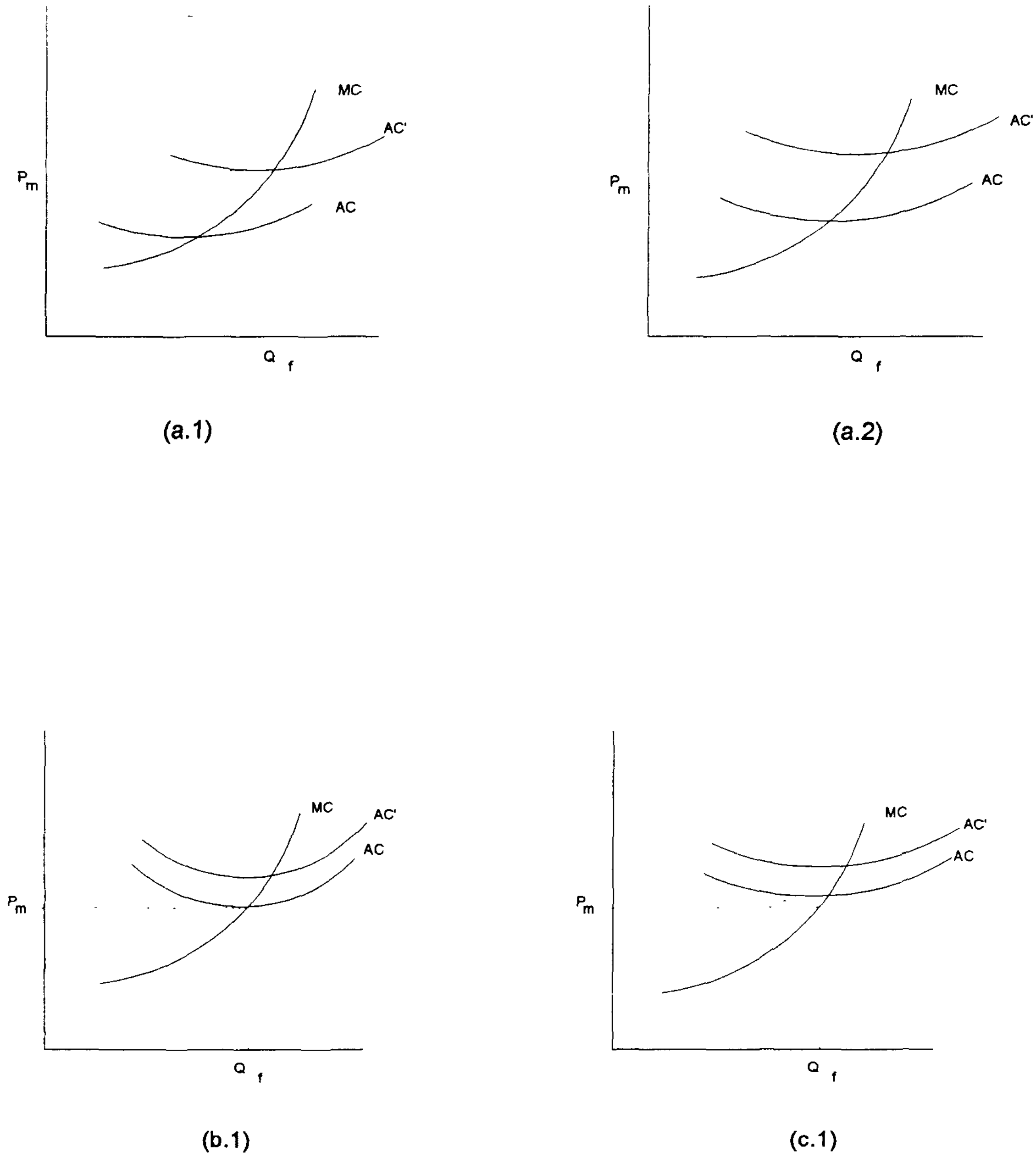

Figure 5-2. Firm's Position in the Market
After Control Costs

Figure 5-2 shows a firm's position in the market after imposition of the IL program. There are two potential outcomes of the firm portrayed in panel (a) of Figure 5-1. First, after the imposition of control costs for the IL program on the firm, the AC curve rises. If the increase in AC is just enough to equate with the market price (thus bringing the firm closer to the average cost in the industry), the firm would be operating at it's optimal level and earn zero economic profit. Another outcome, as shown in panel (a.2), could be that the firm's AC increases to a level above the market price. This would result in the firm earning negative profits and deciding to close permanently.

The outcomes for the firm in panel (b) of Figure 5-1 are limited since the firm is currently operating where AC equals price and marginal cost. Panel (b.1) shows that the increase in AC that results from the increase in control costs could cause the firm to close permanently because average operating costs (AC) are greater than market price. The firm could reduce AC in other areas to counteract the additional compliance costs and potentially remain in the market earning zero economic profits. The firm in panel (c) of Figure 5-1 who was on the verge of temporarily shutting-down due to AC exceeding price, would close permanently according to panel (c.1) if additional costs were imposed for the IL program.

5.3 Summary of Economic Impacts

Overall, the impact of the IL program on the industries described in Section 5.1 is dependent on the effects on the marginal producer of the industry. It is assumed that the marginal producer is operating at the competitive equilibrium that determines market price. If the marginal producer is impacted by the IL program, the following industries have market characteristics that indicate a potential to minimize impacts by recovering compliance costs through increased market prices:

- food and kindred products
- chemicals and allied products
- petroleum refining
- rubber and miscellaneous products
- electronic equipment, and
- transportation equipment.

Firms of an industry who are not considered "marginal" are implied to operate above the marginal producer[e]. If the marginal producer is not impacted by the IL program, then the impacted firm must be operating at an average cost that is less than market price and is earning an economic profit. Increased costs of operation from the imposition of compliance costs will move the firm's AC up closer to market price which lowers economic

[e] Firms operating below the marginal producer would be operating at a loss and therefore exit from the industry.

profit closer to the industry's competitive equilibrium.

Section 5.1 also indicates that compliance costs would more likely be absorbed by any producer in industries, such as: textiles, pulp and paper products, metals, and oil and gas extraction. Because market price would not rise to recover compliance costs, producers would face operating decisions similar to the examples provided in Figures 5-1 and 5-2.

5.4 Impacts on Small Entities

Given the uncertainties as to the distribution of cost across affect sources in the industries, it is not feasible to interpret the potential impacts on small entities. Table 5-1 indicates the presence of small entities in nearly all of the industries potentially impacted by the IL program. However, the cost analysis indicates that the IL program may impact a total of 5 areas of the country, which lessens the likelihood of seeing an impact on a small entity. If a action under the IL program is taken on a small entity, the costs associated with the action can be quite low if the state allows flexibility in compliance methods for the program. If action is taken on a small entity in a declining industry (as indicated in Table 5-1), the impact could be significant.

REFERENCES

1. Research Triangle Institute; "Industry Profiles for a Short-Term National Ambient Air Quality Standard of Sulfur Dioxide",Prepared under Contract 68-D1-0143, Work Assignment number 72; December 1993.

2. Landsburg, Steven; Price Theory and Applications; The Dryden Press, 1989; pg142-196.

SECTION 6. BENEFIT ANALYSIS

6.0 Introduction

The current primary National Ambient Air Quality Standard (NAAQS) for SO_2 was implemented to protect against the adverse health effects of long-term, chronic exposure to SO_2. As has been discussed in previous sections, there are certain areas of the country, where the current NAAQS does not ensure human health protection against short-term, acute exposure to SO_2. Short-term exposure over a 5-minute period to elevated levels of SO_2 has been shown to have adverse health effects, particularly to exercising asthmatics.

Because short-term peaks of SO_2 concentrations appear to be source specific and because of the lack of representative national monitoring data on these short-term peaks, the benefit analysis shall use the same model plant case studies as discussed in the cost analysis. However, benefits are estimated only for the case studies that indicated action to be taken under the IL Program. Although seven case studies were originally presented in the cost analysis, only five of the studies had action taken. Therefore, the benefit analysis is conducted for these five case study areas. The model plants within these case study areas reflect emission characteristics in industries where short-term peaks of SO_2 are likely to be a problem. Each model plant is designed to be a composite of several facilities and does not necessarily reflect the process or ambient air quality of any particular plant.

The purpose of this analysis is to outline the steps required to calculate the health benefits associated with attainment of a 5-minute SO_2 standard of 0.6 ppm for the case study areas. The first section of the chapter contains an overview of the benefit calculation procedures. Quantitative estimates of benefits, along with the qualifications associated with these estimates will conclude the chapter.

6.1 Benefit Calculation Procedures

The benefit calculations for the case studies in this analysis follow a five step procedure. The first step is to identify concentration- response functions that quantify the relationship between short term exposure to SO_2 and human health status. These functions can be used to estimate the improvement in health that may result from a regulatory program designed to reduce short term emissions of SO_2. The second step is to estimate the magnitude of the ambient air quality improvement associated with the IL Program. The third step is to determine the population cohorts that will be affected by the improvement in ambient SO_2 air quality. Asthmatics are considered to be the population cohort most likely to be affected by short-term peaks in SO_2 levels. The fourth step is to impute an economic value to the estimated changes in health status for the relevant population. This step relies on existing studies that have calculated the willingness to pay for improvements in health status. And finally, the fifth step combines the information obtained in the first four steps to estimate the health benefits associated with the proposed program. Each of these steps is discussed in detail below.

6.1.1 Step 1: Identify the Relevant Concentration-Response Functions

Numerous clinical studies have shown that asthmatic individuals are particularly sensitive to short term exposures to SO_2. The SO_2 Criteria Document, Staff Paper, and its Addendum have summarized the results of these studies[1,2,3,4,5,6]. These documents suggest that moderately exercising asthmatics are particularly sensitive to short term exposure (i.e., 5 to 10 minutes) to SO_2 in the range of 0.6 to 1.0 parts per million (ppm). (An example of moderate exercise is climbing one flight of stairs.) Concentrations within this range are likely to result in lung function changes along with respiratory symptoms such as wheezing, chest tightness, and shortness of breath. Although the severity of these symptoms is likely to vary among the sensitive individuals, the intensity of the response is likely to be perceived by the individual as a mild asthma attack.

Although some individuals may reduce activity, most individuals exposed at these levels do not feel such a need and can still function normally. Medication may be used to mitigate the effects at these levels.

At short-term SO_2 levels greater than 1.0 ppm, an increasingly greater percentage of exercising asthmatics will be adversely affected. In addition, the responses are likely to be more severe than those experienced at lower SO_2 levels. At these levels non-exercising asthmatics will also begin to be affected. Effects at these levels are likely to cause overt symptoms and will probably cause the asthmatic to temporarily cease activity and/or use medication to alleviate the respiratory symptoms.

Beneath short term levels of 0.6 ppm, the studies suggest that less than 10 to 20 percent of exercising asthmatics will experience significant lung function changes and respiratory symptoms. Although some exceptionally sensitive individuals may experience effects at these levels, the health effects for the majority of individuals are unlikely to be perceptible and are therefore not considered to be of major concern. Based on the results of these studies, the benefit analysis will use the ambient concentration of 0.6 ppm as a threshold beneath which no significant health effects are likely to occur.

Unfortunately, there is no one clinical study that has developed a continuous concentration-response function relating SO_2 exposure to health status for the range of SO_2 levels considered in this analysis. In addition, the concentration-response functions developed for exercising asthmatics may not be applicable to non-exercising asthmatics. It is therefore necessary to select a number of concentration-response functions to calculate effects for the numerous SO_2 levels under consideration. Consistent with the underlying data contained in the SO_2 clinical studies, the concentration-response functions are divided into two categories:

- SO_2 levels greater than 1.0 ppm, and
- SO_2 levels greater than 0.6 ppm and less than or equal to 1.0 ppm.

SO_2 Levels Greater Than 1.0 ppm

Horstman et al.[7] examined the effect of 10-minute exposure to SO_2 ranging from 0.25 to 2.0 ppm on the specific airway resistance (SRaw) of exercising asthmatics. The subjects were young adults who were classified as `mild' asthmatics. They found that the prevalence of a 100 percent increase in SRaw went from about 56 percent of the subjects at 1.0 ppm to 85 percent of the subjects at 2.0 ppm. For the remaining 15 percent of subjects who did not exhibit any significant response at 2.0 ppm, the results were extrapolated to predict that all subjects were adversely affected at 10.0 ppm.

The data contained in this study are used to develop the following simple linear concentration-response function for short-term SO_2 exposure over 1.0 ppm and less than or equal to 2.0 ppm:

$$\% \text{ Response} = 0.345 + 0.278\ SO_2 \qquad (1)$$

% Response = the percentage of the exercising asthmatic population experiencing a 100 percent or greater increase in SRaw

SO_2 = 10-minute exposure to sulfur dioxide measured in parts per million

For SO_2 levels equal to or in excess of 2.0 ppm, the following concentration-response function is developed from the extrapolated Horstman et al. data:

$$\% \text{ Response} = 0.836 + 0.0169\ SO_2 \qquad (2)$$

Table 6-1 displays the percentage of exercising asthmatics predicted to have changes in SRaw greater than 100 percent at various short-term SO_2 levels above 1.0 ppm.

As previously mentioned, non-exercising asthmatics are also likely to be affected at short term SO_2 exposure levels equal to or greater than 1.0 ppm. Sheppard et al.[8] provides data on the responses of non-exercising asthmatics to 10 minute SO_2 exposures of 1.0, 3.0, and 5.0 ppm. At 1.0 ppm, two out of seven asthmatics at rest developed symptoms (i.e. chest tightness and wheezing). Five out of seven experienced symptoms at 5.0 ppm. These data are used to estimate the following dose-response function for non-exercising asthmatics exposed to 10 minute SO_2 levels in excess of 1.0 ppm:

$$\% \text{ Symptoms} = 0.1547 + 0.1071 \, SO_2 \qquad (3)$$

Additionally, table 6-2 reports the percentage of non-exercising asthmatics experiencing symptoms at various SO_2 levels above 1.0 ppm.

TABLE 6-1

PREVALENCE OF SRAW > 100% ASSOCIATED WITH SHORT-TERM SO_2 LEVELS FOR EXERCISING ASTHMATICS*

10 Minute SO_2 (PPM)	% RESPONSE
1.1	0.651
1.2	0.679
1.3	0.706
1.5	0.762
1.75	0.832
2.0	0.870
2.5	0.879
3.0	0.887
3.5	0.895

* Estimated from Horstman et al. (1986).

TABLE 6-2

SYMPTOM PREVALENCE ASSOCIATED WITH
SHORT-TERM SO_2 LEVELS FOR NON-EXERCISING ASTHMATICS*

10 Minute SO_2 (PPM)	% RESPONSE
1.1	0.273
1.2	0.283
1.3	0.294
1.5	0.315
1.75	0.342
2.0	0.369
2.5	0.423
3.0	0.476
3.5	0.530

* Estimated from Sheppard et al. (1980).

SO_2 Levels Greater Than 0.6 ppm And Less Than Or Equal To 1.0 ppm--

For this range of SO_2 levels, the concentration-response function developed by Abt Associates in a study for the EPA[9] will be used to estimate the improvement in health status. This concentration-response function was developed from four studies that examined the effect of short-term exposure (5 to 75 minutes) to SO_2 ranging from 0.0 to 1.0 ppm[10,11,12,13] and Roger et al.[14] The groups studied were exercising young adults who were diagnosed with mild or moderate asthma. The following concentration-response function was estimated:

$$\text{log odds (Symptom)} = -5.65 + 5.89\ SO_2 + 1.10\ \text{Status} \qquad (4)$$

where Symptom = any respiratory symptom such as chest tightness, shortness of breath, wheezing, coughing, etc.

SO_2 = SO_2 concentrations in ppm for various exposure periods (5 to 75 minutes)

Status = a dummy variable reflecting asthma severity; 0 = mild, 1 = moderate.

The probability of experiencing a symptom can be calculated by transforming the log odds equation into a probability:

$$\text{Prob(Symptom)} = \frac{e^{**}(\text{log odds(Symptom)})}{1+e^{**}(\text{log odds(Symptom}} \tag{5}$$

For a 5-minute SO_2 exposure level of 1.0 ppm, the probability of experiencing a symptom is 0.56 for a mild asthmatic and 0.79 for a moderate asthmatic. The probabilities predicted for different SO_2 levels are reported in Table 6-3.

Table 6-3

SYMPTOM PROBABILITY ASSOCIATED WITH SHORT-TERM SO_2 LEVELS FOR EXERCISING ASTHMATICS*

SO_2 CONCENTRATION (PPM)**	PROB (SYMPTOM) MILD ASTHMATIC	PROB (SYMPTOM) MODERATE ASTHMATIC
0.6	0.108	0.266
0.7	0.179	0.395
0.8	0.218	0.540
0.9	0.414	0.679
1.0	0.560	0.793

* Estimated by Abt Associates (1996)

** Exposure to the SO_2 concentrations ranged from 5 to 75 minutes.

Underlying Assumptions

A number of assumptions must be made before the above functions can be used in a benefits analysis. First, it is assumed that the exposure conditions created to measure effects in the laboratory environment are similar to that experienced under ambient conditions. This assumption is especially tenuous with respect to the Sheppard et al. study because SO_2 exposure occurred through a mouthpiece. The actual dose of SO_2 in that study was probably higher than that which would occur under ambient conditions.

Second, the concentration-response functions developed above are based on exposure durations of at least 10 minutes. It is assumed that these functions can be used to estimate the health effects associated with a minimum of 5 minutes of exposure to SO_2. The impact of this assumption is likely to be minimal since studies reviewed in the Second Addendum to the Criteria Document[15] have found that the response to elevated levels of SO_2 has a rapid onset and reaches a peak within 5 to 10 minutes of exposure. Longer periods of exposure while exercising (e.g. 30 minutes) do not appear to significantly alter the initial response. In addition there appears to be a "refractory period" during which repeated exposures to SO_2 result in a period of diminished responsiveness. The duration of this refractory period is unclear, although it appears to last no longer than 5 hours[16]. The issue of the refractory period will be addressed in the next section when the air quality data are discussed.

Third, the Sheppard et al. concentration-response function used to predict effects above 1.0 ppm is based on a sample of only seven non-exercising asthmatics. In addition, the Horstman et al. function for levels above 2.0 ppm is based on data extrapolated from the actual responses observed at levels beneath 2.0 ppm. The benefits calculated from these functions need to be viewed in light of these limitatons.

Fourth, the above concentration-response functions were developed from laboratory conditions that were designed to examine the effect of exposure to short-term SO_2 in the absence of pre-medication with common asthma medications such as cromolyn sodium and various beta agonists. These medications have been shown to inhibit responses to SO_2. If the asthmatics residing in the case study areas typically pre-medicate to control their asthma, then the concentration-response functions developed above will overestimate effects. The extent of this overestimation may be minimized, however, since evidence suggests that mild asthmatics typically do not pre-medicate and only use their medication on an as needed basis. In addition, only about 20 percent of moderate asthmatics use their medication on a regular basis[17].

Finally, the effects predicted by the above equations are based on studies that examine the effect of SO_2 on young adults diagnosed with mild or moderate asthma. It is assumed that these results can be applied to the entire asthmatic population. If certain segments of the asthmatic population (i.e., children, elderly, severe asthmatics) are more sensitive to SO_2 than these equations indicate, then effects will be underestimated.

6.1.2 Step 2: Identify the Improvement in Ambient Air Quality

The regulatory option under consideration establishes a 5 minute SO_2 average of 0.6 ppm as the target level for control. To calculate the benefits associated with the program, both baseline (pre-control) and post-control air quality data are needed. This step discusses the procedures and assumptions used to develop these data.

The baseline scenario reflects ambient SO_2 in the presence of the current NAAQS and other existing regulations. Pre-control levels were estimated using monitoring data from ambient monitoring sites located in areas near actual facilities. These data were used to design a theoretical Gamma distribution for each of the model plants. Each probability curve predicted the likelihood of exceeding the 5-minute SO_2 concentration of 0.6 ppm during a
1-year period. The curve was used to determine the number of times during the year that 0.6 ppm was exceeded and the

magnitude of each exceedance. The probability curve was then re-estimated to allow only one exceedance of 0.6 ppm during the 1-year period. The SO_2 levels associated with this curve represent the post control scenario.

Exceedance data were generated for two areas of impact around each of the model plants. The first area was only a few kilometers from the source and was identified as the primary area. This area contained the highest SO_2 concentrations associated with the model plant emissions. The second area was further downwind from the source and contained relatively lower SO_2 concentrations. This area was identified as the secondary area. Table 4 reports the number of exceedances in the baseline scenario for both the primary and secondary areas for each of the five case study areas. As expected, most of the exceedances occur within the primary area and fall within the 0.6 to 1.0 ppm range. Across the five case studies, a 5-minute SO_2 average of 3.0 ppm was exceeded only 20 times during the year.

In order to calculate the changes in health risk associated with this regulatory program, it is first necessary to determine how many of the exceedances are likely to have an impact on the risk of an asthma attack. The values reported in Table 4 reflect the number of times within a given year a specific SO_2 value is exceeded for at least one 5-minute period during an hour. Multiple 5-minute exceedances occurring within a 1 hour period are not reflected in the table. Since the refractory period associated with exposure to SO_2 is at least an hour, the incremental health effects from multiple exceedances that occur during a 1-hour period are likely to be minimal. Exceedances that occur over sequential hours need to be taken into account, however, since these exceedances may also occur during the refractory period and therefore may not cause any additional health effects beyond those associated with the first exceedance. In addition, exceedances that occur outside of waking hours should not be considered to have an impact on the risk of an asthma attack. Unfortunately, information on the sequence and timing of exceedances is not available from the underlying monitoring data used to estimate the data reported in Table 6-4. However, an estimate of the average number of exceedance hours within an exceedance day of 1.67 hours is available from a Summary of 1988-1995 Ambient 5-Minute SO_2 Concentration Data[18]. This estimate is used to adjust the exceedances reported in Table 4 to account for multiple exceedances during an exceedance day. Although no specific adjustment can be made to account for exceedances that occur outside of waking hours, anecdotal evidence from one area suggests that the majority of the exceedances under consideration occur during waking hours.

Table 6-4
PREDICTED ANNUAL EXCEEDANCES OF ALTERNATIVE
5-MINUTE SO_2 CONCENTRATIONS*

5-Minute SO_2 (ppm)	Case Study 1		Case Study 2		Case Study 3		Case Study 4		Case Study 5	
	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary
0.6	18	4	86	0	20	8	30	18	30	2
0.7	13	2	75	0	16	5	23	12	22	1
0.8	10	1	65	0	13	3	18	6	16	0
0.9	7	0	58	0	11	0	14	3	12	0
1.0	6	0	51	0	9	0	12	1	9	0
1.1	4	0	46	0	7	0	9	0	7	0
1.2	3	0	41	0	6	0	8	0	5	0
1.3	5	0	37	0	10	0	11	0	4	0
1.5	3	0	30	0	9	0	9	0	3	0
1.75	2	0	24	0	6	0	6	0	1	0
2.0	2	0	19	0	7	0	7	0	1	0
2.5	1	0	12	0	4	0	3	0	0	0
3.0	0	0	8	0	2	0	1	0	0	0
3.5	0	0	5	0	3	0	1	0	0	0
TOTAL	74	7	557	0	123	16	152	40	110	3

* Exceedances reported are incremental exceedances. As an example, 0.7 ppm was exceeded 57 times during the year for Case Study 1, but the exceedance fell between 0.7 ppm and 0.8 ppm only 13 times.

6.1.3 Step 3: Determine the Population Affected By the Change in Air Quality

One of the necessary components for the benefit analysis is information about the population exposed to the pre- and post-control SO_2 concentrations estimated in Step 2. In this step, information on the size and shape of the SO_2 plumes emitted from the five model plants is combined with population data that characterize the geographic areas with SO_2 emission sources to develop estimates of the exposed population. This step discusses the techniques and assumptions used to develop these estimates. First, estimates of population densities that characterize areas around SO_2 emission sources are developed. Then, the area of land affected by modeled SO_2 plumes is determined. Finally, the population densities and the land areas are combined to form estimates of potentially exposed populations.

Demographic Characteristics--

Table 6-5 presents qualitative population characteristics for the five areas near the SO_2 emission source as well as at a distance away from the source. The meaning of the population characteristic descriptors is discussed further below.

Table 6-5
POPULATION CHARACTERISTICS

Study Area	Primary Area	Secondary Area
Area 1	Town	Rural
Area 2	Town	No impact
Area 3	Town	Town
Area 4	Town	Small Urban
Area 5	Small Urban	Small Urban

Population Density

As shown in Table 6-5, and described in the associated text, the populations in the case study areas were characterized as "small urban," "town," "rural" and "no impact" in decreasing order of population density. These terms are not meant to reflect an official definition, but are designed to be generally descriptive of the study area. The following discussion describes the determination of characteristic population densities.

When possible, 1986 population figures from the 1988 City-County Data Book[19] were used to determine population and area of the case study area. In addition, similar data were collected for the surrounding county and any nearby metropolitan areas. To obtain population density, the ratio of population to land area was computed. In those instances where no data was available in the City-County Data Book, The Rand McNally Road Atlas was used to obtain population information.

To determine population and area of the surrounding "rural" county area, the population and area of any metropolitan area was subtracted from county population and area within the study area to form a "non-urban" population and land area value. Computing the ratio of the "urban-excluded" population and area provides a "rural-only" population density value.

Table 6-6 presents the results of this data analysis. The first column indicates the case study area. The second and third columns show population (rounded to hundreds, as appropriate) and area in square miles. The fourth column presents the population density in persons per square mile. Finally, population density in persons per square kilometer are presented in the fifth column. The equivalence of 1 mile to 1.609 km was used to make the conversion of 1 square mile to 2.589 square kilometers. The fourth column is divided by 2.589 to form the fifth column which presents population per square kilometer.

Selection of Representative Characteristics--

Based on the population densities displayed in Table 6-6, "typical" numbers were chosen that appeared to reflect the population density characteristics for the demographic characteristics shown in Table 6-5. Table 6-7 shows the correspondence between the labels used and the densities chosen.

As can be seen from Table 6-7, the term "Small Urban" reflects the population density characteristic of the downtown areas of small metropolitan areas and is set at $1000/km^2$ (one thousand people per square kilometer). "Town" reflects the population density characteristic of the central areas of small rural towns and is set at $500/km^2$. "Rural" reflects the population density characteristic of the more rural areas outside central areas of small towns and is set at $20/km^2$, which ~~is~~ the average of the rural areas in Table 6-6. Finally, "No Impact" reflects the population density characteristic of the open countryside and is set at $0/km^2$.

Parabolic Exhaust Plume--

The next step is to determine the land area impacted by SO_2 emissions. Once the area of impact is determined, the population density characteristics can be used to estimate the population exposed to high short-term SO_2 concentrations.

Table 6-6
POPULATION DENSITY TABLE

Location	Population	Area (sqmi)	Density (Pop/sqmi)	Density (Pop/sqkm)
Area 1 - County	102,400	5300	19.3	7.5
Area 1 - Town	4,000*	3.0**	1333.3	515.0
Area 1 - Rural	98,400	5300	18.6	7.2
Area 2 - County	112,500	1,600	70.3	27.2
Area 2 - Small Urban	32,200	14	2,300.0	888.4
Area 2 - Town	3,300*	2.0**	1,650.0	637.3
Area 2 - Rural	80,300	1,580	50.8	19.6
Area 3 - County	164,500	700	234.3	90.7
Area 3 - Town	2,500*	3.00*	833.3	322.0
Area 4 - County	104,700	300	349.0	134.8
Area 4 - Small Urban	59,300	17	3488.2	1347.4
Area 4 - Rural	45,400	300	151.3	58.5
Area 5 - County	120,100	2,600	46.2	17.8
Area 5 - Small Urban	80,300	30	2676.7	1033.9
Area 5 - Rural	39,800	2600	15.3	5.9

Source: 1988 City-County Data Book, 1986 population figures, unless otherwise indicated (See text).

*/ 1994 population obtained from Rand McNally Road Atlas.

**/ Area estimated by review of maps.

Table 6-7
POPULATION DENSITY CHARACTERISTICS USED IN IMPACT ANALYSIS

Demographic Characteristic	Population Density (People/km^2)
Small Urban	1000
Town	500
Rural	20
No Impact	0

Based on concentration dispersion data for each of the case study areas, estimates can be made of the size of the SO_2 plume as a function of downwind distance. It is assumed that the intersection of the ground with a plume is parabolic in shape with the emission source located at the turning point in the parabola. Plume widths for each case study area were estimated at a distance from each emission source where no 5-minute SO_2 concentrations in excess of 0.6 ppm were predicted to occur. Column two of Table 6-8 reports these distances to the source and the width of the plume at this distance. With these data, it is possible to compute the area within the parabolic plume at any arbitrary distance from the emissions source.

Table 6-8
SO_2 PLUME CHARACTERISTICS

Study Area	Distance to Source	Width of Plume
Area 1	14 km	2 km
Area 2	14 km	2 km
Area 3	14 km	2 km
Area 4	21 km	3 km
Area 5	14 km	2 km

Primary and Secondary Exposure--

The modeled SO_2 plume touches down and will expose any person at ground level to possibly high values of SO_2 when that individual is near the emission source. This short-range area of impact is called the primary area. This distance is generally only a few kilometers from the emission source. Farther downwind the level of SO_2 is not as high but more people may be exposed since a larger area is affected. This area is called the secondary area. The farthest distance for which exceedances are observed is generally about 15 kilometers. Beyond this distance, sufficient dissipation and dispersion occurs that little health impact from high SO_2 concentrations is believed to occur from the given emission source.

Using the case study models, the distances to the primary and secondary exposure boundaries were identified. These boundary values are reported in Table 6-9. Table 6-9 also reports the area (km^2) within each primary and secondary exposure region based on the exposure boundaries and the parabola shape characteristics reported in Table 6-8. In Area 2, it was predicted that no short term exceedances would be observed in the secondary area due to a relatively short stack height at the model plant and the modeled dispersion characteristics.

Exposed Population--

The data on exposed areas within the SO_2 plume shadow presented in Table 6-9 are combined with the area characteristics presented in Table 6-5 and the associated population densities for these areas presented in Table 6-7 to form estimates of the exposed population.

Table 6-9
SO_2 PLUME AREAS

Study Area	Primary Region Distance (km)	Primary Region Area (km^2)	Secondary Region Distance (km)	Secondary Region Area (km^2)
Area 1	3.0	1.8516	14.0	16.8150
Area 2	3.5	2.3333	N/A	N/A
Area 3	3.0	1.8516	14.0	16.8150
Area 4	3.5	2.8577	21.0	27.1423
Area 5	3.5	2.3333	14.0	16.3334

Table 6-10 presents the estimates of the exposed population in each of the case study areas. The population at risk from exposure to short-term elevations in SO_2 are a subset of these population estimates -- namely, exercising asthmatics and to a lesser extent non-exercising asthmatics. The population estimates are multiplied by the most recent national estimates of the prevalence rate for asthma obtained from National Center for Health Statistics[20] to estimate the number of asthmatics at risk. Since the prevalence rate is higher for children (7 percent) than for adults (5 percent), the population estimates contained in Table 6-10 are first broken down by age using information from EPA's Environmental Justice Data Base on the percent of the population under age 18. The resulting population estimates are then multiplied by the relevant prevalence rates to obtain estimates of the asthmatics exposed in the case study areas. Estimates of the number of asthmatics exercising during any waking hour range from 0.2 percent to 3.3 percent. A value of

1.7 percent is used in this analysis which is consistent with the value used in Abt Associates[21]. Estimates of the number of exercising and non-exercising asthmatics for the case study areas are provided in Table 6-11.

Table 6-10
EXPOSED POPULATION

Study Area	Exposed Population
Area 1	1,262
Area 2	1,167
Area 3	9,333
Area 4	28,571
Area 5	18,667

Table 6-11
ASTHMATIC POPULATION AT RISK

	Primary Area		Secondary Area	
Case Study	Exercising	Non-Exercising	Exercising	Non-Exercising
1	<1	52	<1	19
2	1	64	no impact	no impact
3	1	50	8	465
4	1	76	25	1,445
5	2	127	15	887

Limitations--

The exposed population values presented here reflect various assumptions about the size and shape of SO_2 emission plumes, and the density and distribution of populations exposed to the SO_2 concentrations found within the emission plumes. It was assumed that the emission plume was oriented in a specific direction over population areas which reflected a "worst-case" scenario. Actual wind always determines which direction a plume dissipates emissions from any source. Knowledge of prevailing winds could better assist in ascertaining the likelihood that the case study plumes actually shadow population areas. However, no account was taken of local meteorology except for the stability class characteristics which influence the size and shape of the emission plumes.

Estimates of the asthmatic population are obtained using data on national asthma prevalence rates. The EPA has recieved comments on the 1994 proposal that indicates the prevalence of asthma in areas that are known to have SO_2 problems can be higher than the national average. If the population exposed in these study areas have different prevalence rates due to SO_2 or other factors, then the estimates presented in Table 6-11 may be biased. The use of one estimate to characterize the percentage of waking hours devoted to exercise for all asthmatics may result in biased estimates if activity patterns vary significantly among asthmatics. For example, exercise may be encouraged for mild and moderate asthmatics as a way of controlling their asthma. Severe asthmatics, on the other hand, may be discouraged from exercising. In addition, the exercise patterns of asthmatic children and young adults are likely to be much different than the exercise patterns of asthmatic adults.

6.1.4 Step 4: Valuation of the Improvement in Human Health

The previous three steps are required to estimate the changes in health risk associated with the short-term SO_2 changes under consideration. This step involves the economic valuation of these health risk changes. The improvement in an asthmatic's health resulting from a reduction in short-term exposure to SO_2 may manifest itself in a variety of ways. Certain improvements in lung function may not be perceived by the individual and therefore are very difficult to value. Others, such as changes in symptoms like chest tightness and wheezing are likely to be perceived by the individual. A decrease in symptoms is likely to result in reductions in discomfort, the need to undertake averting behavior, the loss of leisure, work or school time, and medical expenditures. Members of the individual's family may also experience a reduction in the emotional and financial costs associated with coping with the individual's symptoms.

It is very difficult to determine the true economic value of a reduction in symptoms. There are four valuation techniques that have been used to estimate the economic value of air-pollution induced changes in health: contingent valuation, cost of illness, averting behavior, and hedonic valuation. Although none of these techniques completely measures economic benefits, they have been used as approximations. The advantages and shortcomings of these approaches have been reviewed in IEC[22], U.S. Department of Commerce[23], and elsewhere.

The results of two of the contingent valuation studies reviewed by IEC are directly applicable to this analysis. Rowe and Chestnut[24,25] used a 1983 survey of 82 asthmatic individuals living in Glendora, California to collect data on asthma severity, medication use, and activities undertaken to mitigate asthma. These data were used to obtain estimates of the willingness to pay (WTP) to reduce the frequency of an asthma-related illness. The results of the study indicate a WTP of $43.53 to avoid one bad asthma day with mild symptoms and $59.48 to avoid one bad asthma day with moderate symptoms (1993 dollars).

Before using the results of the Rowe and Chestnut studies to value the health risk changes estimated in the previous steps it is necessary to make a few adjustments. First, the concentration-response functions identified in Step 1 predict two types of health risks: percentage changes in specific airway resistance (SRaw) and percentage changes in symptoms. It is difficult to determine the value of a change in SRaw because a change in this health indicator may not be perceived by the individual. For purposes of this analysis, it is assumed that the percentage changes in SRaw estimated from the concentration-response function are accompanied by asthma symptoms that the individual can perceive.

Second, symptom severity is not identified in the concentration-response functions developed in Step 1. The EPA[26] provides information on symptom severity based on percentage changes in SRaw and percentage changes in forced expiratory volume (FEV). Table 12 reports the gradation of response severity for alternative SRaw and FEV percentage changes. Abt[27] developed a regression equation from data contained in Linn et al.[28] and Roger et al.[29] that relates the percentage change in SRaw to alternative SO_2 levels:

$$\%\Delta SRaw = 201.03\ \Delta SO_2 \qquad (6)$$

where $\%\Delta SRaw$ = the percentage change in specific airway resistance

ΔSO_2 = the change in the 5-minute concentration of SO_2 in ppm.

Equation 6 can be used to estimate the changes in SO_2 required to produce a change in SRaw between 100 percent and 200 percent (defined in Table 12 as a moderate effect) and greater than 200 percent (defined in Table 12 as a severe effect) for alternative SO_2 changes. The equation can also be used to estimate the SO_2 change associated with a change in SRaw of less than 100 percent (defined in Table 6-12 as a mild effect). Based on the above information, the baseline SO_2 levels associated with symptom severity can be obtained. These results are reported in Table 6-13.

Table 6-12
COMPARATIVE INDICES OF SEVERITY OF RESPIRATORY EFFECTS SYMPTOMS, SPIRONETRY, AND RESISTANCE

Type of Response	Mild	Moderate	Severe
Δ in SRAW	Increase < 100%	Increases up to 200%	Increases more than 200%
Δ in FEV 1.0 FVC	< 10%	Decrease of 10 to 20%	Decrease > 20%
Duration of Effect/ Treatment	Spontaneous recovery < 30 minutes	Spontaneous recovery < 1 hour	Bronchodilator required to resolve symptoms
Symptoms	Mild, no wheeze or chest tightness	Some wheeze or chest tightness	Obvious wheeze, marked chest tightness, breathing distress

Source: EPA (1994a).

Third, the WTP estimates from Rowe and Chestnut are limited to mild and moderate symptoms. An estimate of $78.10 for the WTP to avoid a severe asthma attack is obtained by assuming that a severe attack differs from a moderate attack in that the individual will cease activity for two as opposed to 1 hour and there is some additional discomfort associated with a severe attack.

Table 6-13
ASTHMA SYMPTOM SEVERITY RELATED TO 5 MINUTE SO_2 EXPOSURE

SO_2 (ppm)	Symptom Severity
1.0 and below	Mild
1.1 to 1.5	Moderate
Above 1.5	Severe

Fourth, the WTP estimates from Rowe and Chestnut are for a symptom day. It is unclear, however, whether a symptom day is limited to just one asthma attack. Because information on the timing of the 5-minute exceedances is not available for the five case study areas, it is possible that multiple exceedances will occur during a day. Although the impact of multiple exceedances occurring during the refractory period has been addressed in Step 2, exceedances that occur outside the refractory period cannot be addressed. If these types of multiple exceedances are numerous, then multiple asthma attacks may occur during a one day period and the use of the Rowe and Chestnut WTP estimates may result in an overestimate of benefits.

Fifth, the WTP estimates are based on a survey undertaken in 1983. The WTP estimates have been adjusted to 1993 dollars using the Consumer Price Index (CPI). The 1993 WTP estimates only account for price changes that have occurred during this time period and do not reflect any increases in WTP for symptom reductions that may have occurred over the same time period due to increases in real income or changes in preferences. Consequently, the 1993 values may be underestimates of the true WTP.

And sixth, the WTP estimates are taken from contingent value studies that may not capture all the economic benefits associated with reducing symptoms. For example, benefits to relatives and employers are excluded. Also, medical costs not borne directly by the individual with the symptoms (e.g. insurance) will not be included. The contingent valuation itself may result in biased estimates if participants in the survey give strategic responses. The valuation of symptom reductions based on the contingent valuation approach will not reflect any improvements in productivity or reductions in medical expenditures that are not perceived by the individual.

One comment recieved by EPA indicates that "in 1990 the cost of illness for asthma was $6.2 billion; the cost of school absenteeism due to asthma was nearly $1 billion, and 43 percent of the costs was associated with emergency room use, hospitalization, and death[30]. Although only a portion of the $6.2 billion estimate of cost of illness for asthma can be attributed to short-term SO2 peaks, the statement indicates that the WTP measure obtained from the 1983 study may not have captured all areas of cost associated with asthma.

Another factor to consider is that it is uncertain whether the individuals surveyed for the WTP estimate incorporated a value for side effects of asthma medication. While the Staff Paper recognizes that the use of medication can mitigate some of the effects of short-term SO2 peaks, the EPA recieved comments that state that the staff paper "failed to summarize the side effects of these medications."[31] The commenter indicates that brochodilators are used for acute need, however, the medication's effect lasts for hours. Common side effects of some medications include heart palpitations, tachycardia, nausea, muscle tremors, diziness, weakness, restlessness, apprehension, and anxiety. Individuals taking medication (such as steroids) for severe asthma can experience side effects such as stunted growth and osteoporosis[32]. Additional medication to combat some of the side effects may be necessary, which adds to medical costs and can create other additional side effects.

6.1.5 Step 5: Estimate Benefits

The fifth and final step of the benefits analysis combines the information obtained in the previous steps to calculate benefits. From the concentration-response functions, the change in asthma symptom prevalence resulting from a change in short-term exposure to SO_2 can be calculated for the relevant population cohorts. These estimates are then multiplied by the population estimates developed in Step 3 and the WTP estimates reported in Step 4 to yield monetary benefit estimates. A sample calculation for the inner area of Case Study 1 for the non-exercising asthmatic cohort is provided below for illustrative purposes.

Based on the SO_2 related symptom severity defined in Table 13 and the Sheppard et al. equation (Equation 3), the change in the prevalence of severe and moderate symptoms associated with a change in SO_2 can be calculated from:

$$\Delta \text{prevalence(severe)} = \sum_{i=1}^{s} 0.1071(SO_2(sev_i) - 1.0) \qquad (6)$$

$$\Delta \text{Prevalence (mod)} = \sum_{i=1}^{m} 0.1071(SO_2(mod_i) - 1.0) \qquad (7)$$

where:

ΔPrevalence(severe)	=	change in the % of the non-exercising asthmatic population experiencing a severe symptom during a one year period,
ΔPrevalence(mod)	=	change in the % of the non-exercising asthmatic population experiencing a moderate symptom during a 1-year period,
$SO_2(sev_i)$	=	average SO_2 that exceeds 1.5 ppm during the ith 5-minute period,
$SO_2(mod_i)$	=	average SO_2 that exceeds 1.0 ppm and is less than or equal to 1.5 ppm during the ith 5-minute period,
s	=	the number of exceedances greater than 1.5 ppm during 1 year, and
m	=	the number of exceedances greater than 1.0 and less than or equal to 1.5 ppm during 1 year.

Only changes in SO_2 exposure above the 1.0 ppm level are calculated for Equations 6 and 7, since non-exercising asthmatics are not considered to be sensitive beneath this level. For Case Study 1, ΔPrevalence(sev) is 0.5355 and ΔPrevalence(mod) is 0.4284.

Once the changes in prevalence rates are obtained , they are divided by the factor of 1.67 to account for the possibility of multiple exceedances occurring during the refractory period.

Finally, benefits for a 1-year period are calculated by multiplying the change in prevalence rates by the non-exercising asthmatic population (Nonexpop) and the appropriate estimate of WTP:

$$\text{Benefits} = \left(\frac{\Delta\text{Prevalence(sev)}}{1.67} * \text{Nonexpop} * 78.10\right) + \left(\frac{\Delta\text{Prevalence(mod)}}{1.67} * \text{Nonexpop} * 59.48\right)$$

The benefits accruing to the non-exercising population in the primary area of Case Study 1 are equal to approximately $2,100.

Benefits for the other asthmatic cohorts and the other case study areas can be calculated in a similar manner.

6.2 Quantification of Estimates

Benefits for the case study areas are reported in Tables 14 through 18 in 1993 dollars. Of the areas under consideration, Case Study 2 has the largest benefits. This result is due primarily to the fact that the 5-minute SO_2 average of 0.6 ppm was exceeded 471 times during the 1-year period examined in the analysis. Case Study 4 has the second highest benefits. These estimates appear to be driven by the large number of exceedances and large population in the secondary area along with the relatively large number of exceedances in the primary area. Case Study 1 has the smallest benefits due to a combination of small population and relatively few exceedances.

On the whole, the benefits reported in Tables 6-14 through 6-18 are relatively small. The predominant reason for this result is that the short-term peaks in SO_2 under examination impact a fairly small geographic area within the local vicinity of the model plants. The small geographic area coupled with the fraction of the local population assumed to be "exercising asthmatics" significantly limits the number of people considered to be at risk. Although non-exercising asthmatics are relatively less sensitive to mild peaks in short-term exposure to SO_2 than exercising asthmatics, the benefits accruing to this population cohort drive the benefit estimates because there are so many of them compared to the exercising asthmatics. Because of the relatively large number of exceedances in *both* the primary and secondary areas, a sensitivity analysis on the non-exercising asthmatic population was done for *Case Study 4 to see how* altering the assumptions regarding the underlying concentration-response would impact the benefit estimates. In the sensitivity analysis, the Horstman et al. concentration-response

Table 6-14
BENEFITS FOR CASE STUDY 1

	Severe Incidents	Moderate Incidents	Mild Incidents	Total
Primary Area				
Exercising Asthmatics	$ 157.47	$ 283.30	$ 197.20	$ 637.97
Non-Exercising Asthmatics	1,303.00	793.88	0	2,096.88
Secondary Area				
Exercising Asthmatics	0	0	3.24	3.24
Non-Exercising Asthmatics	0	0	0	0
Total	$1,460.47	$1,077.18	$200.44	$2,738.09

Table 6-15
BENEFITS FOR CASE STUDY 2

	Severe Incidents	Moderate Incidents	Mild Incidents	Total
Primary Area				
Exercising Asthmatics	$ 2,639.71	$ 3,535.33	$1,844.85	$ 8,019.89
Non-Exercising Asthmatics	26,626.02	9,446.90	0	36,072.92
Secondary Area				
Exercising Asthmatics	0	0	0	0
Non-Exercising Asthmatics	0	0	0	0
Total	$29,265.73	$12,982.23	$1,844.85	$44,092.81

Table 6-16
BENEFITS FOR CASE STUDY 3

	Severe Incidents	Moderate Incidents	Mild Incidents	Total
Primary Area				
Exercising Asthmatics	$ 674.29	$ 588.01	$272.57	$ 1,534.87
Non-Exercising Asthmatics	7,260.07	1,792.22	0	9,052.29
Secondary Area				
Exercising Asthmatics	0	0	657.73	657.73
Non-Exercising Asthmatics	0	0	0	0
Total	$7,934.36	$2,380.23	$930.30	$11,244.89

Table 6-17
BENEFITS FOR CASE STUDY 4

	Severe Incidents	Moderate Incidents	Mild Incidents	Total
Primary Area				
Exercising Asthmatics	$ 837.58	$1,031.76	$ 558.63	$ 2,427.97
Non-Exercising Asthmatics	7,844.39	3001.67	0	10,846.06
Secondary Area				
Exercising Asthmatics	0	0	2,495.31	2,495.31
Non-Exercising Asthmatics	0	0	0	0
Total	$8,681.97	$4,033.43	$3,053.94	$15,769.34

Table 6-18
BENEFITS FOR CASE STUDY 5

	Severe Incidents	Moderate Incidents	Mild Incidents	Total
Primary Area				
Exercising Asthmatics	$ 152.68	$ 861.77	$ 779.04	$1,793.49
Non-Exercising Asthmatics	1,113.63	2,132.43	0	3,246.06
Secondary Area				
Exercising Asthmatics	0	0	36.1	36.1
Non-Exercising Asthmatics	0	0	0	0
Total	$1,266.31	$2,994.20	$815.14	$5,075.65

Table 6-19
SENSITIVITY ANALYSIS OF BENEFITS FOR CASE STUDY 4

	Severe Incidents	Moderate Incidents	Mild Incidents	Total
Primary Area				
Exercising Asthmatics	$ 837.58	$ 1,031.76	$ 558.63	$ 2,427.97
Non-Exercising Asthmatics	24,225.52	14,921.00	0	39,146.52
Secondary Area				
Exercising Asthmatics	0	0	2,495.31	2,495.31
Non-Exercising Asthmatics	0	0	0	0
Total	$25,063.10	15,952.76	$3,053.94	$44,069.80

function was used along with the assumption that 25 percent of the non-exercising asthmatics would respond like that predicted by Horstman et al. for SO_2 levels equal to at least 1.0 ppm, and 50 percent would respond at levels above 1.5 ppm. The results of this analysis are reported in Table 6-19. Benefits increased by a factor of three, suggesting that the underlying concentration-response function has a significant impact on benefits.

6.3 Limitations of Analysis

The benefit estimates provided in this analysis need to be viewed in light of numerous qualifications. Although these qualifications have been discussed in detail in the preceding sections, they are briefly summarized here to conclude the chapter.

Concentration-response functions--

The concentration-response functions used to calculate benefits in this chapter are developed from data obtained in controlled laboratory settings for small samples of mild and moderate asthmatics. The applicability of these functions to the five case study areas may be tenuous if the populations and exposure conditions and relationships observed in the underlying studies are not representative of the case study areas.

One example of a limitation with respect to these functions is that the functions do not consider the effect that pre-medication may have on the relationship between SO_2 and exposure. Although mild and moderate asthmatics are typically not known to premedicate, the omission of this possibility may bias the benefit estimates.

Air quality data--

Pre-control data for each of the five case study areas were estimated using monitoring data from sites located in areas near actual facilities. Data on meteorology were not available; consequently the SO_2 plumes were oriented in a direction which would impact the most people. Ideally, incorporation of local meteorological conditions would have provided better estimates of the impacted population.

Information of the number of exceedances occurring during the refractory period (i.e., the period of reduced responsiveness to short-term SO_2 exposure) could not be obtained from the monitoring data. The exceedance data were adjusted using national monitoring data from 1988 to 1995. If the national data are unrepresentative of the conditions that would exist in the five case study areas, then the resulting benefit estimates will be biased.

Population data--

Again, national data were used to estimate the data required for the five case study areas. In this case, national estimates of the asthma prevalence rate and the percentage of waking hours spent exercising were used to estimate the exercising and non-exercising asthmatic population in the case study areas. The EPA has received comments on the 1994 proposal that indicate that the prevalence of asthma in area that are known to have SO2 problems can be much higher than the national average[33]. If the asthmatic population in these areas differs significantly from that estimated from the national data, the affected population estimates used in this analysis may be inaccurate.

Willingness to pay--

The willingness to pay (WTP) estimates were taken from the results of a contingent valuation survey undertaken in 1983. If preferences have changed since the survey was undertaken, the 1983 WTP may be inaccurate. Also, the WTP estimates obtained from the contingent valuation approach probably underestimate the true economic benefit associated with air quality improvements because they exclude the value of unperceived improvements in health status, the benefits accruing to relatives and employers, and costs not typically borne by the individual.

Other Benefit Categories -

The benefits reported in this analysis are limited to the health benefits accruing to the asthmatic population from changes in their short-term exposure to SO_2. The welfare benefits associated with any visibility improvements and reductions in materials and agricultural damage that may accompany the implementation of a program designed to limit short-term SO_2 exceedances have not been evaluated in this analysis. Because the control strategies chosen to resolve a short-term SO_2 problem can subsequently achieve longer term SO_2 emission reductions year-round, there are secondary benefits that can be achieved in these other benefit categories. In this sense the benefits reported in this chapter are underestimates. The nature of these unquantified benefit categories is described below.

Ecosystem Impacts

In addition to causing human health effects, sulfur dioxide can also impact vegetation and ecosystems. Low doses of SO_2 can increase growth and yield in plants growing in sulfur-deficient soils. However, if the rate of absorption of SO_2 is greater than the plant's ability to metabolize SO_2, toxic metabolites can reach sufficient concentrations within the plant to cause foliar injury, reduction in growth and yield, and with acute exposures, plant death. A number of studies have developed dose-response functions for crop species such as soybeans, oats and wheat. The revised EPA SO_2 staff paper[34] indicates that in nonarid regions where there is high temperature, high humidity, and abundant sunlight -- conditions that increase plant responsiveness to SO_2 -- visible injury may develop in sensitive species to 5-minute exposures of 1 to 2 ppm SO_2.

Responses to sulfur dioxide at the individual plant level can have broader impacts at the community and ecosystem level. Injury to vegetation can affect species composition and nutrient cycling within terrestrial ecosystems. Studies on grassland ecosystems have shown impacts of low ambient concentrations (greater than 0.02 ppm) of SO_2 to different trophic levels within the ecosystem.

Sulfur dioxide emissions have been implicated as a cause of acid precipitation and the acidification of aquatic ecosystems. Decreases in pH levels in streams, ponds, and lakes can affect all trophic levels of the aquatic ecosystem, resulting in a loss in species diversity of phytoplankton, zooplankton and various fish species. The National Acid Precipitation Assessment Program reports the loss of lake trout, rainbow trout and walleye and smallmouth bass at pH levels below 5.5.

Odors

The 1982 EPA SO_2 staff paper (4) reports that studies have found the odor threshold for SO_2 to range from 0.47 ppm to 1 ppm. Regarding this subject, one member of the Clean Air Scientific Advisory Committee (CASAC) of EPA's Science Advisory Board wrote that he has "the strong impression that for a substantial portion of the general public, likely a majority, experiencing perceptible SO_2 (over, perhaps, .4 ppm) in ambient air degrades the quality of life by making people perceive that they live in polluted air" (5). To the extent that this regulatory program reduces short-term SO_2 peaks below the odor threshold, positive benefits would be achieved in terms of reduced occurrences of noxious odor.

Materials Damage

Much research has been conducted on the effects of sulfur oxides on materials. Sulfur dioxide, specifically, can accelerate the corrosion of metals such as iron, galvanized steel, copper and aluminum-based metals. Additionally, SO_2 can erode and soil stone and paints. Dose-response functions have been developed that relate ambient SO_2 concentrations to physical damage to a number of materials. For this analysis, however, it is not possible to determine the level of reductions in short-term SO_2 peaks in respect to materials damage, so this category is not investigated.

Particulate Matter Benefits

A portion of SO_2 emissions will be transformed in the atmosphere to particulate sulfate. Epidemiology studies have shown statistically significant associations between ambient particulate matter concentrations and incidence of respiratory symptoms, emergency room visits and hospital admissions for respiratory conditions, exacerbation of chronic respiratory disease and mortality. Additionally, ambient particulate matter contributes to visibility impairment and soiling of materials. To the extent that SO_2 emission reductions are achieved through the IL program, it is expected that particulate matter benefits would also be attributable to this action. Although the program may also have an impact on the annual emissions of SO_2 and therefore on the production of sulfates, these impacts have not been addressed. Consequently, any health and welfare benefits that may result from reductions in sulfate levels are omitted from this analysis.

6.4 Environmental Justice Considerations

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations", directs each Federal agency to "make achieving environmental justice part of its mission by identifying and addressing ... disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations." In order to comply with the provisions of this Order, a general screening analysis has been conducted to examine the sociodemographic characteristics of the case study areas in which controls could be necessary.

A number of factors indicate that asthma may pose more of a health problem among non-white and urban populations. As the SO_2 criteria document[35] indicates, there is a higher prevalence of asthma among African-American and urban populations. Additionally, mortality rates due to asthma are at least 100 percent higher among non-whites than the national average, although death due to asthma is a rare event (1 per 10,000 asthmatic individuals). In New York and Chicago for example, non-white mortality rates from asthma may exceed the city average by up to five-fold and exceed the national average by an even larger factor.

With respect to the effects of short-term SO_2 exposures on asthmatics, the SO_2 criteria document[36] indicates that controlled human exposure studies have not systematically studied African-American and Hispanic adolescents and young adults. Therefore, it is not known the extent to which the controlled exposure studies, as discussed in the criteria document and staff paper, reflect accurately the responses to 5-minute SO_2 exposures among minority populations. Additionally, one CASAC member stated in his comments on the SO_2 staff paper that staff paper results may be important in that moderate asthmatics from urban areas and lower socioeconomic status may be at particularly high risk if exposed to SO_2 above 0.60 ppm while at a high level of activity. Asthmatic individuals from these subpopulations in general may have inadequate medical follow-up, may have irregular medication use and frequent lung function deterioration[37].

Considering the above factors, a general screening analysis is conducted to examine the sociodemographic characteristics of the case study areas potentially impacted by short-term SO_2 peaks. For each area, data from the EPA's Environmental Justice Database is used to obtain population estimates that are disaggregated by non-white population and non-white asthmatic population (using the national average asthma rate of 5 percent). As has been stated, research indicates that asthma prevalence among non-white individuals is potentially higher than the national average, but also children tend to have a higher prevalence rate than that of adults. Although, there is insufficient information at this time to define asthma prevalence among non-whites for specific geographic areas, the National Center for Health Statistics has provided a prevalence rate for children (of ages less than 18 years) at 7 percent. In addition to population data, information on households below the poverty level[a] (including minority households below the poverty level) is also provided.

For the localized areas in which the SO_2 plumes of the case studies are assumed to disseminate, the total population of each area ranged from 7600 to nearly 100,000 people, with an average population of 34,000. On average, 5 percent of the population in the case study areas are non-white, and more than 25 percent are

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[a] For the screening analysis, the poverty level has been defined as any household income below $15,000 per year.

children. Nationally, 16.5 percent of the population is non-white and 11 percent is less than 18 years of age[38]. While the percent on non-white individuals in the case study areas is below the national average, the percentage of children residing in these areas is more than double the national average.

Using the national average of asthma prevalence, a typical area would have 1700 asthmatic individuals potentially impacted by short-term burst of SO2[b], or 85 non-white asthmatic individuals[c], and 595 athmatic children[d].

Additionally, the areas also have an average of 14,850 households. Twenty-seven percent of these households would be classified below the poverty level and five percent of these households below the poverty level are occupied by non-white individuals. Nationally, only 12.7 percent of the total households in the U.S. are below the poverty level, indicating that the case study areas have twice as many households below the poverty level.

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[b] Calculation: 34,000 average population x 5 percent asthma prevalence rate = 1700 asthmatics on average in the case study areas.

[c] Calculation: 34,000 avg. population x 5 percent non-white population on average x 5 percent ashtma prevalence rate = 85 non-white asthmatic individuals on average in the case study areas.

[d] Calculation: 34,000 avg. population x 25 percent children in population on average x 7 percent asthma prevalence rate = 595 asthmatic children on average in the cae study areas.

Overall, the populations in the case study areas do not show any indications that a disproportionate number of non-white individuals would be impacted by short-term SO_2 ambient concentrations greater than 0.60 ppm. This analysis, however, does not cover all possible areas of the country with short-term SO_2 peak concentrations greater than 0.60 ppm. Other areas of the country may have a higher percentage of non-white citizens. The analysis indicates that there are twice as many children residing in the case study areas as compared to the national average, and potentially 595 could have asthma and thus experience health impacts during peak SO_2 concentrations. In addition to the large number of children potentially exposed to peak SO_2 concentrations, 27 percent of the households in the case study areas are below the poverty level, which twice the national average. It should be noted, however, that it is not known how many of the households below the poverty level contain asthmatic individuals. Given the available data, this analysis gives an indication that a disproportionate number of children and households below the poverty level are exposed to short-term SO_2 peaks. In general, children do not have the resources to relocate or take action against sources of SO_2 emissions. Similarly, households below the poverty level may be dependent on the local industrial sources for employment. In addition to having limited resources to relocate or take action against sources of SO_2 emissions, they may be reluctant to do so if action would detriment employment opportunities.

During an evaluation 5-minute ambient concentrations for the IL program, a regulatory authority would use information specific to the area of analysis to determine if there were indications that under the criteria for environmental justice action would be warranted.

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SECTION 7. BENEFIT-COST ANALYSIS

7.0 Net Benefit Analysis

This section provides comparisons of the estimated benefits and costs associated with the IL program. Comparisons of the benefits and costs are referred to as a benefit-cost analysis (or net benefit analysis) and are presented here in response to Executive Order 12866 and the Unfunded Mandates Reform Act of 1995 which require a qualitative and quantitative comparison of benefits and costs of any regulatory action that is considered to be "significant." While the EPA does not believe the IL program will have a significant impact on the national economy, the IL program evolved in part due to comments received on earlier proposed implementation strategies, which were deemed to be significant. Also, the characteristics of the IL program - local responsibility, flexibility, community involvement - represents a novel regulatory approach. For these reasons, the EPA has judged the IL program to be significant as defined by E.O. 12866 and thus prepared the analyses of costs and benefits.

The implementation of the IL program will lead to favorable health and other welfare effects that represent a clear improvement in the economic well-being of some members of society. At the same time, however, costs may be incurred as additional resources are committed to reduce emissions to permissible levels. These costs cause a reduction in the economic well-being of some members of society. Given that these costs are generally incurred as air quality is improved, an evaluation of the net impact of an air quality improvement on society's economic well-being requires an assessment of both benefits and costs.

Because of tremendous uncertainties in estimating the circumstances when an action under the IL program will be implemented, a national estimate of the cost and benefits of the program is not feasible. Instead, the benefit and cost analyses utilized case studies to evaluate a sample of potential actions. The results of these analyses are displayed in Table 7-1 in annualized 1993 dollars. As indicated by the table, costs exceed benefits by a significant amount. The small magnitude of benefits results from mainly two factors. First, the short-term peaks in SO_2 under consideration impact a fairly small geographic area within the local vicinity of the model plants. The small geographic area leads to a relatively small number of people being exposed to these short term peaks. Second, the benefit estimates are limited to the health benefits accruing to asthmatics. The welfare benefits associated with any ecosystem, visibility, odor, materials damage, or particulate matter improvements that may result from control of short-term peaks in SO_2 have not been considered.

Table 7-1
QUANTIFIED BENEFITS AND COSTS
OF SELECTED CASE STUDIES
(Annualized values in 1993 dollars)

Case Study	Benefits	Costs
1	$ 2,700	$1.87 million
2	44,100	1.15 million
3	11,200	0.34 million
4	15,800	2.24 million
5*	5,100	0.27 million to 0.31 million

* Two cost estimates are provided for Case Study 5. The first one represents the costs associated with a 10% rollback in emissions while the second assumes a 20% rollback. See Section __ for a discussion.

Although the cost that are determined for the case studies exceed the quantifiable benefits, the IL program provides a significant amount of flexibility to regulatory authorities, communities and sources to achieve a reasonable solution to short-term SO_2 problems at substantially lower cost than other potential regulatory vehicles to address the problem. For example, the previously proposed regulatory option of establishing a new short-term SO_2 NAAQS to eliminate exceedances of 0.60 ppm at any one time in a given year was estimated to cost $1.75 billion. Several of the sources assumed to incur costs under a NAAQS option would have the potential to not have any regulatory action taken upon them under the IL program and thus incur no compliance costs. Even if all five of the actions predicted to occur under the IL program have the highest end of costs estimated in the case studies of this analysis ($2.2 million), the total cost of the IL program would be approximately $11 million, which is $1.739 billion less than the NAAQS option. Therefore, the IL program is a very cost-effective solution to the public health risk associated with short-term peaks of SO_2.

Additionally, Executive Order 12898 requires that each federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority and low-income populations. A screening analysis of the population residing in the case study areas indicates .....

Overall, the IL program will be precipitated by community involvement. The value a community places on resolving a 5-minute problem could be substantially different than values used to estimate benefits in this analysis. The willingness-to-pay to avoid experiencing any symptoms of an asthma attack, and/or the population of asthmatics in the community could be higher than the national average used in the benefit analysis. In addition, communities may have an intrinsic value to place on environmental justice, and have an indication of the level of benefits accrued for visibility improvement, reduction in odor or materials damage, or reduced level of particulate matter that can be achieved by controls installed to resolve a short-term SO_2 problem. Conversely, the control strategies chosen for the case studies may not be the method of resolution chosen in actual IL program actions. The flexibility provided by the program allows for new and innovative methods of control that have the potential of being less costly that some of the alternatives examined in the case studies. It is anticipated that regulatory authorities, citizens, and sources will use the IL program as guidance to determine if the level of public health risk in the local area warrants action to resolve a 5-minute SO_2 problem.

APPENDIX A

CASE STUDIES OF ALTERNATIVE CONTROL STRATEGIES FOR THE INTERVENTION LEVEL PROGRAM

APPENDIX A. CASE STUDIES OF ALTERNATIVE CONTROL STRATEGIES FOR THE IL PROGRAM

As is discussed in Section 4, a cost analysis of all possible outcomes of the implementation of the IL program is not feasible. Alternatively, the cost of program is evaluated using representative case study examples. The case studies are intended to represent typical, real-world situations. The are not intended to represent or prejudge any particular facility. Actual short-term SO_2 monitoring data was available for a limited number of sites. This monitoring data was used to develop statistical profiles of ambient SO_2 concentrations typical of areas near certain industries or groups of industries. Process equipment described in the case studies is intended to be representative of equipment found in facilities typical of the particular case study. In order to avoid any appearance of prejudging the real-world situations these cases were derived from, changes were made to the process equipment, control equipment or control strategies, and/or affected population descriptions. Efforts were made to describe processes typical of the represented industry to the extent that these modification could still reasonably conform to the situations presented.

A.1 Case Study 1: One Source Impacting a Local Community at the Concern Level

There are currently eight operating copper smelters in the U.S. Several of these smelters are located in rural Western U.S. settings in towns with relatively small populations. This case study represents a larger smelter located in a valley setting in the Western U.S. As a larger smelter, it is assumed to have an annual production capacity of 250,000 tons per year. Information on the copper smelting industry was derived from the report for the Primary Copper Smelters National Emission Standard for Hazardous Air Pollutants (NESHAP)[1].

For the purposes of this study, the model smelter was assumed to be located in a valley setting. Although the facility had installed air pollution controls sufficient to meet the National Ambient Air Quality Standards (NAAQS), stagnant weather conditions and thermal inversions produced high short-term ambient concentrations. For this reason, the use of tall stacks with the ability to enhance dispersion under these weather conditions was used to correct short-term problems. Based on the limited short-term SO_2 monitoring information available, monitoring indicates that copper smelters are in the middle range for both number and severity of exceedances of the proposed 5-minute concern level of 0.6 ppm.

Description of Model Plant

The model plant, depicted in Figure A-1.1., is a composite of several typical facilities and does not necessarily reflect the process of any one actual plant. Case studies from Primary Copper Smelters NESHAP and the AWMA Air Pollution Engineering Manual[2] were used to develop the sample facility. The model facility utilizes a flash furnace smelting system that combines the roasting and smelting stages of the production process. Through roasting and smelting, raw ore concentrate and silica fluxes produce high-grade copper matte (largely cuprous sulfide and ferrous sulfide). The remaining iron and sulfur are removed from the matte in a converter to yield molten blister copper. A Pierce-Smith converter, the most commonly used converter in the U.S., is assumed to be used in this model plant. Finally, the blister copper undergoes both fire and electrolytic refining to eliminate any contaminants and produce copper that can be as much as 99.97 percent pure. Because a flash furnace is used, an electric arc furnace is employed to clean the flash furnace of copper buildup.

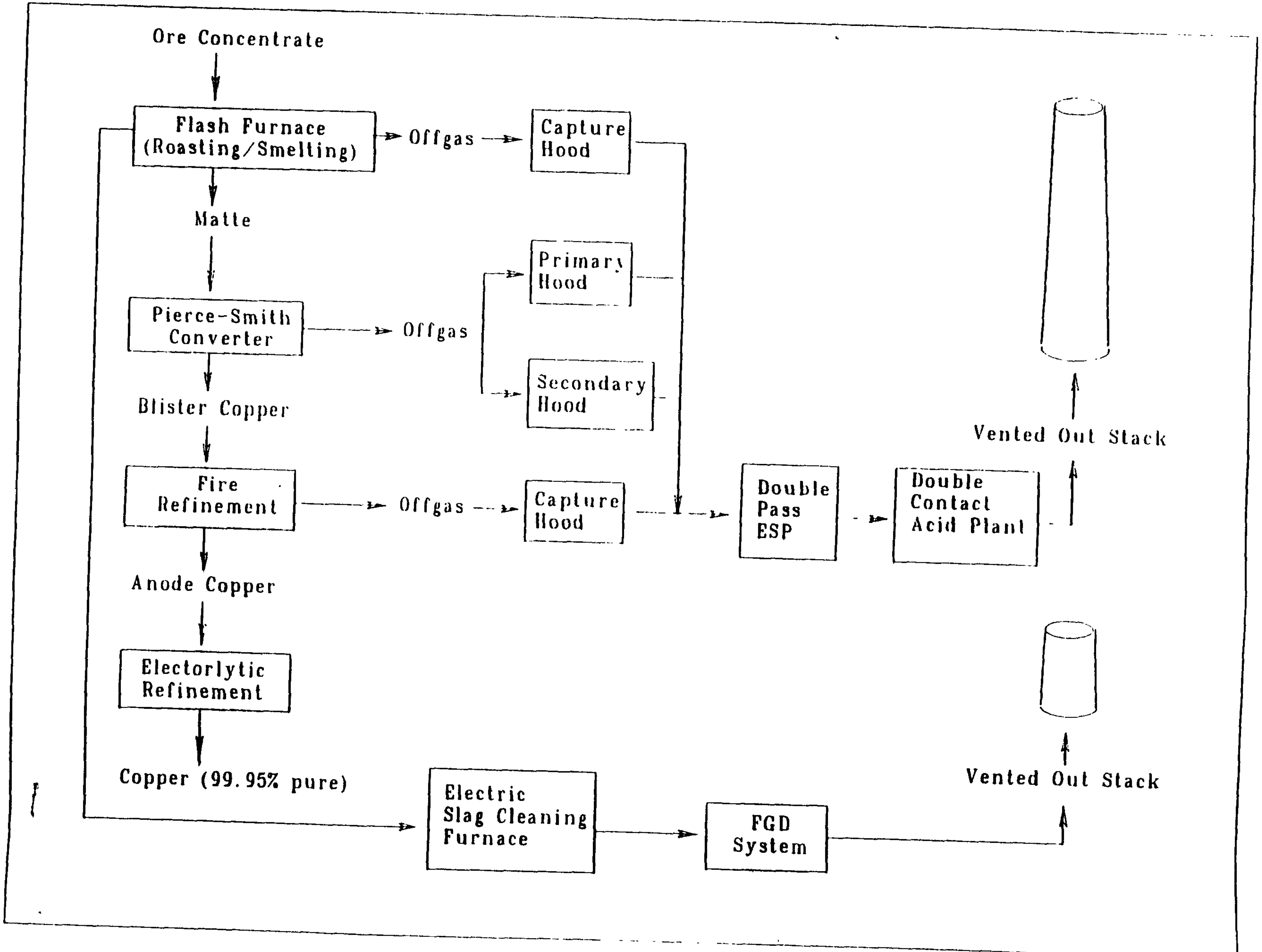
Sulfur dioxide and particulate matter are produced during the roasting/smelting, conversion, and fire refinement stages. The converter is the most significant source of SO_2 gas. For this reason, both primary hoods located at the furnace mouth, and secondary hoods that vent the building containment area, are used to control converter emissions. Primary capture hoods alone are sufficient to control emissions from the flash furnace and the fire refinement equipment. The gas effluent streams of fugitive SO_2 emissions that are not captured by hoods are combined for SO_2 and particulate removal. Typically, double pass electrostatic precipitators (ESP) and sulfuric acid plants are used to remove particulate matter and SO_2, respectively. Once treated, the effluent gases are released through the main common stack.

Emissions from the electric arc slag cleaning furnace are captured and treated separately from effluent produced by the other stages. The model plant employs a flue gas desulfurization scrubber to remove SO_2 before it is vented out of its own stack. Typical copper smelters have one stack (or more) for gases treated by the acid plant and one stack (or more) for gas streams with lower SO_2 concentrations. The model plant has a total of two stacks.

Monitoring Data

Using monitoring data obtained from the "Summary of 1988-1995 Ambient 5-Minute SO2 Concentration Data[3]," a statistical distribution was developed to predict the number of annual exceedances and severity (in concentration) at typical copper smelting facilities. The probability curve was based on

Figure A-1.1. Copper Smelter Model Plant Process Diagram



the Gamma distribution and predicted the likelihood of exceeding the threshold concentrations (0.6, 1.0 and 2.0 ppm). The right side tail of this distribution shows the estimated pre-control concentration and is presented in Figure A-1.2. This figure shows 74 annual exceedances of 0.6 ppm for a 5-minute period within an hour. An annual average of 24 exceedances of 1.0 ppm and three exceedances of 2.0 ppm are predicted (see Table A-1.1.). This table shows the total number of annual exceedances of the 5-minute SO_2 value as well as the number in the concentration increment (i.e., 0.6 to 0.7 ppm). Since the IL program is based on public endangerment, both the frequency and severity of the exceedances will be considered in determining appropriate remedial action. As human health impacts are dependant on ambient concentrations, this information is equally important in determining regulatory benefits that will be derived from reductions in ambient levels.

Baseline Conditions

The copper smelter example represents a scenario with a fairly high number of exceedances, however, the potential to exceed 2.0 ppm is fairly small. This represents a "middle of the road" scenario based on currently known exceedance situations. The IL program offers states flexibility in addressing this type of situation. The burden on the affected facility can vary substantially based on the severity of the problem and the availability of remediation options that would be acceptable to the state. Therefore, a discussion of the selected remedial plan and its associated costs is provided below. This situation represents a departure from traditional "end-of-pipe" controls in that the selected plan contains intermittent controls and use of stacks greater in height than GEP. Presently, compliance with NAAQS cannot consider stack heights greater than GE (213 ft. Or 65m.). As this short-term SO_2 is proposed under section 303, current SIP preclusions against intermittent controls and stack heights greater than GEP would not apply to control strategies under this program, as long as the source continuous to comply with ambient air requirements as would occur at permitted stack heights.

1) Existing monitoring data shows a high number of exceedances of the 5-minute level of concern. Analysis of 3 years of data showed exceedances of the 0.6 ppm level of concern occurred an average of 74 hours per year. 3 years of exceedance data are presented in Table A-1.2.

2) Upon review of NESHAP Primary Copper Smelter Final Report, it was determined that the majority of copper smelters were located in small, rural towns with populations of 2,000 or less. For this reason a small, rural town scenario was chosen for this study. Given

Figure A-1.2. Annual Exceedances for Copper Smelter Model Plant

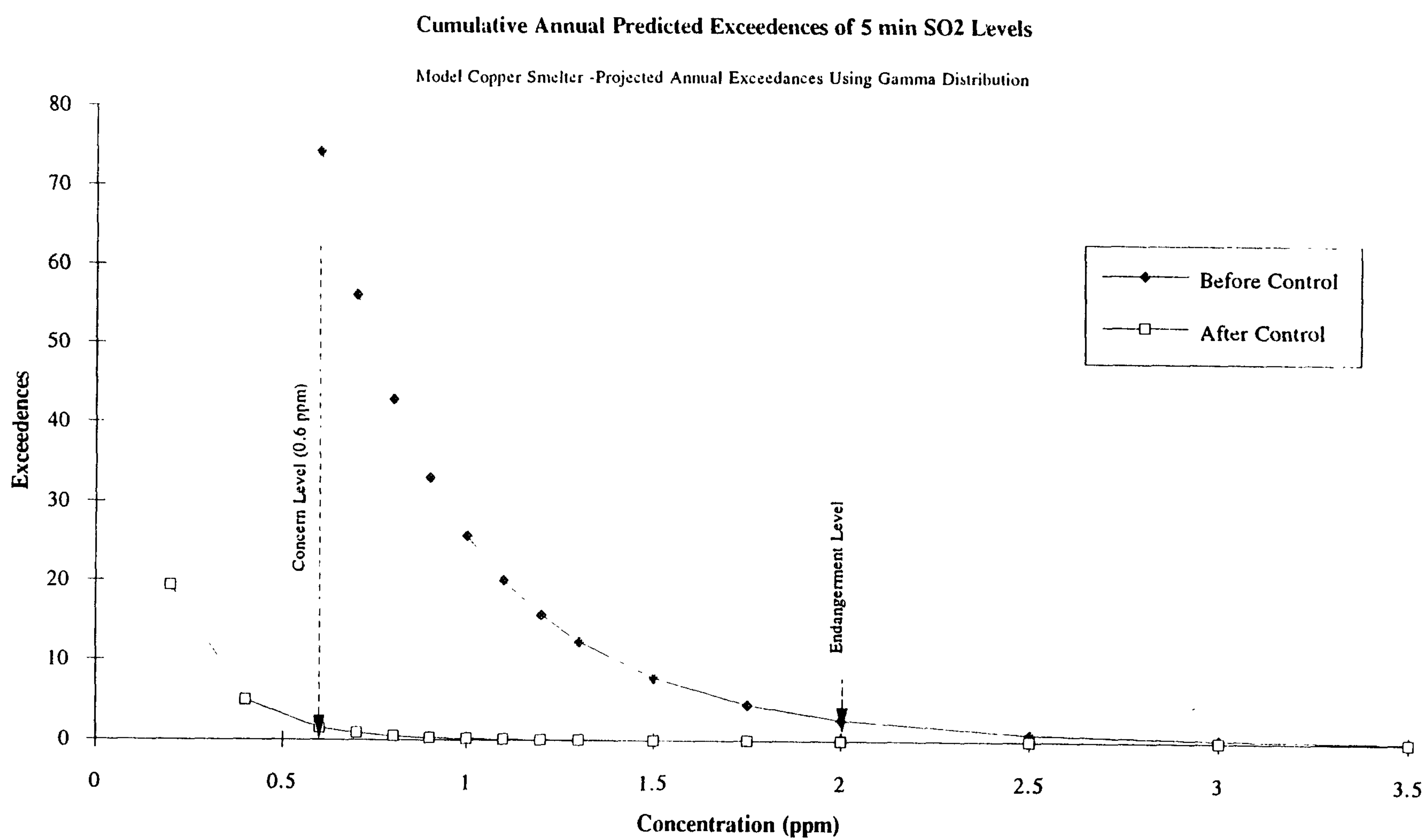


Table A-1.1. Predicted Annual Exceedances: Copper Smelter Model Plant

SO_2 Concentration[a]	0.2	0.4	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.5	1.75	2.0	2.5	3.0	3.5
# Annual Exceedances			74	56	43	33	26	20	16	12	8	4	3	1	0	0
# Exceedances in Increment			18	13	10	7	6	4	3	5	3	2	2	1	0	0
# Exceedances After Control[b]	19	5	1	1	0	0	0	0	0	0	0	0	0	0	0	0

a. Source: Gamma distribution of monitor data from ICF Kaiser, 1995
b. Control strategy: stack height of 1040 ft., and 800 ft. for the acid plant.

the large number of violations indicated by the distribution function, it is likely that the local community around the model facility is exposed to levels of SO_2 greater than 0.60 ppm, and as much as 3 annual exceedances of 2.0 ppm. This analysis assumes the state has decided to act on the 0.6 ppm level of concern and that the state operates two air quality monitors around the model plant in which the smelter is located.

3) Additional investigation of the monitoring data shows a seasonal nature in the exceedances, indicating that the exceedances could more closely be related to thermal inversions and stagnant weather conditions than to high emissions or upset conditions occurring at the facility. It is also assumed that the facility has installed adequate controls that demonstrate attainment of the current SO_2 NAAQS. As the process is already controlled, most SO_2 is already removed from the emission stream. In negotiation with the state to implement the IL program, the facility asserts that the location of the town and the smelter in a valley would require the addition of redundant controls to ensure against future exceedances of the concern level. If the facility was required to install additional add-on air pollution controls to streams with existing controls, these additional controls would have costs comparable to the original control equipment yet remove relatively less SO_2, yielding low cost effectiveness. Due to the presence of thermal inversion the facility asserts that if the stack is built tall enough to overcome the "inversion cap" then the stack emissions will be released outside of the valley and away from the town. The state agrees to consider review of such an alternative pending dispersion modeling conducted by the facility as a basis to compare control alternatives.

4) The facility submitted roll back modeling to evaluate options for additional controls and to evaluate the use of taller stacks to improve dispersion during periods of poor atmospheric mixing. The facility used 1991 data (as the worst year from Table A-1.2.) and modeled those hourly conditions that had produced exceedances during that year. Three major emissions points were modeled, these were the main stack, the slag stack, and fugitive process emissions. Most emissions came from the main stack. Increased stack height was demonstrated to elevate the plume out of the valley and result in substantial improvement in ambient air quality. In order to achieve similar improvements in ambient air quality, additional controls would be

needed. The facility estimated improvements to capture efficiency for converter hoods (initial SO_2 capture) and improvements to the acid plant SO_2 removal efficiency would cost between $120 million and $185 million (based on information submitted to EPA during public comment), respectively, in order to achieve the same benefit as the stack height increase. Addition of two new stacks of 1,040 and 800 feet would result in equivalent ambient air quality improvement during stagnant air conditions at an estimated cost of $13.9 million. Based on this information, an agreement to proceed with a plan for the use of taller stacks was approved.

5) Although the state and the facility agreed to the principal of using tall stacks, one major point of contention remained. The state asserted that use of the tall stacks would only be permitted on an intermittent basis. The facility asserted that brief (i.e., less than 1 month) and intermittent use of the stacks would cause chemical and thermal damage to the system because repeated cycling between stacks would elevate acid formation in the stack leading to chemical damage and increased stress on refractory due to increased temperature changes. Specifically, intermittent switching to and from the taller stack could cause condensation of acid vapors on the cool surfaces of the stack and promote corrosion. Another concern is that repeated heating and cooling of the refractory lining of the ducts and stacks would cause damage due to the expansion and contraction of the heating and cooling bricks. The state expressed concern that prolonged use of taller stacks might have long-range adverse impacts on the environment, such as decreased visibility, increased ecological damages, or an increased contribution to acid rain concentrations. The facility performed visibility modeling and predicted no adverse impacts. A compromise allowed for use of the tall stacks constantly from September through February. During warm weather months, the tall stacks would be used during stagnant conditions only, a decision would be made on a daily basis based on pre-established meteorological and stack dispersion characteristics determined by the modeling effort as to whether use of the tall stacks would be required.

Cost of Control

The capital and annual costs for remediation of short-term SO_2 concentrations through the use of tall stacks are presented below. For the purposes of this case study, it was assumed that two tall stacks would be needed to control two major gas streams

Table A-1.2. Model Copper Smelter-3 Years of Exceedance Data

at the facility. This study also assumes that it was not economical to try to extend the stacks and that two new stacks were required. A summary of these estimates is presented in Table A-1.3., while Tables A-1.4 and A.5 present detailed information on the cost calculation using a format derived from the OAQPS Control Cost Manual[4]. The stack 's useful life was assumed to be 30 years and the annualized costs were calculated using an interest rate of 7.0 percent for the payment of the capital cost of the stack. Overall stack costs were taken from a memorandum regarding the Supplemental Section 303 Cost Analysis for the Regulatory Impact Analysis for the Proposed Regulatory Options to Address Short-term Peak Sulfur Dioxide Exposures[5]. Maintenance costs and costs of other items such as electricity for elevators and airplane warning lights were estimated based on the engineering judgement.

Additional capital costs included money necessary to perform air dispersion modeling to determine adequate stack heights. The modeling is assumed to cost $100,000 and will be redone every 5 years. The capital recovery factor for the modeling is 4.39 percent for 5 years. The annualized modeling cost is $24,390 per year. The annual costs for operation and maintenance of the tall stacks were adjusted upward to reflect higher anticipated costs resulting from elevated levels of acid gases in the stacks in addition to heating and cooling stress on the refractory lining in the duct work and stack. The costs are summarized below.

Table A-1.3
Case 1: Cost of Control (1993 dollars)

Affected Unit	**Capital Cost**	**Annualized Cost**
Main Stack (1040 ft)	$7.3 million	$0.97 million
Slag Stack (800 ft)	$6.6 million	$0.88 million
Dispersion Modeling	$0.1 million	$0.024 million
Total	$14 million	$1.87 million

Summary

For the copper smelter case study, the majority of the concentrations of SO_2 measured over a 5-minute period occur around the concern level of the IL program. The frequency of these occurrences, the geography of the area, and the historical weather patterns give evidence that the risk is great enough for the State to require action to protect the health of the at-risk population surrounding the model plant.

Because of the existence of seasonal thermal inversions around the facility, the State and source negotiated a plan of intermittent control for 6 months of the year. It was determined that add-on controls would be costly (capital costs of approximately $120 to $185 million). Such controls would result in minimal annual emissions reductions because they would be redundant to existing controls. The intermittent use of taller stacks to push plumes above thermal inversion layers would reduce the risk of exposure to the local population at significantly lower costs than air pollution control equipment. The source provided dispersion modeling to demonstrate that the use of taller stacks would not affect attainment of the NAAQS, adversely impact ecological and agricultural species, or contribute to increased acid rain. The State allowed the use of taller stacks to address the 5-minute problem only if current requirements in the source's permit to attain the current NAAQS were not violated. The resulting cost of the resolution is approximately $2 million per year, which is substantially less that other options.

Table A-1.4(a) Cost of New Intermittent Main Stack

CAPITAL COST DETERMINATION
Construction of Tall Stacks for Copper Smelter
Main Stack (1040 feet)

irect Costs	

'urchased equipment costs	$425,000.00
Additional ID Fan, Elevator	
Aircraft Avoidance Lights	
Ductwork, Ash Hopper	
Freight (.05 of EC)	$21,250.00

Purchased eqpmt. cost, PEC	$446,250.00
irect installation costs	
Foundations & supports	$500,000.00
Construction & Materials	$5,900,000.00
Electrical (.10 of PEC)	$44,625.00
Ductwork	$320,000.00
Insulation for ductwork	$17,850.00

Direct installation cost	$6,782,475.00
ite preparation	$100,000.00
uildings	N.A.

Total Direct Cost, DC	$6,882,475.00
irect Costs	

Engineering (.10 of PEC)	$44,625.00
Field expenses (.05 of PEC)	$22,312.50
Contractor fees (.10 of PEC)	$44,625.00
Start-up (.02 of PEC)	$8,925.00
Performance test (.01 of PEC)	$4,462.50
Contingencies (.03 of PEC)	$13,387.50

Total Indirect Cost, IC	$71,400.00
'AL CAPITAL INVESTMENT = DC + IC	$7,300,125.00

Table A-1.4(b) Cost of New Intermittent Main Stack (cont.)

COPPER SMELTER ANNUALIZED COST SHEET (Main Stack)

Direct Annual Costs	Factor	Unit Cost	Total
Operating Labor			
Operator	4 hrs/stack changeover	15.77/hr *	$1,892.40
Supervisor	.15 of operator	–	$1,182.75
Maintenance			
Labor	Repair stack & ductwork	17.35/hr *	$112,500.00
Material	Replace refractory, dampers, expansion joints, fan blades, ect.	–	$75,000.00
Utilities			
Natural Gas	---	$3.50/kft^3	N.A.
Electricity	Aircraft Lights, Elevators, Ash Removal	$0.08/kWhr	$8,608.00
Total DC			$199,183.15

Indirect Annual Costs	Factor	Unit Cost	Total
Overhead	.60 of operating, supv., & maint. labor & materials	–	$69,345.09
Administrative charges	.005 of TCI	–	$36,500.63
Property Taxes	.01 of TCI	–	N.A.
Insurance	.01 of TCI	–	$73,001.25
Capital Recovery	TCI x CRF ****	–	$588,290.82
Total IC			$767,137.78

TOTAL ANNUAL COST	$966,320.93

**** CRF = i(1+i)^n/(1+i)^n−1 = 8.0586%
n = 30 yr equipment life
i = 7% interest rate

Table A-1.5(a) Cost of New Intermittent Slag Stack

CAPITAL COST DETERMINATION
Construction of Tall Stacks for Copper Smelter
Slag Stack (800 feet)

irect Costs	

Purchased equipment costs	$400,000.00
Additional ID Fan, Elevator	
Aircraft Avoidance Lights	
Ductwork, Ash Hopper	
Freight (.05 of EC)	$20,000.00

Purchased eqpmt. cost, PEC	$420,000.00
ɔirect installation costs	
Foundations & supports	$390,000.00
Construction & Materials	$5,350,000.00
Electrical (.10 of PEC)	$42,000.00
Ductwork	$320,000.00
Insulation for ductwork	$16,800.00

Direct installation cost	$6,118,800.00
ʒite preparation	$100,000.00
ʒuildings	N.A.

Total Direct Cost, DC	$6,218,800.00
direct Costs	

Engineering (.10 of PEC)	$42,000.00
Field expenses (.05 of PEC)	$21,000.00
Contractor fees (.10 of PEC)	$42,000.00
Start–up (.02 of PEC)	$8,400.00
Performance test (.01 of PEC)	$4,200.00
Contingencies (.03 of PEC)	$12,600.00

Total Indirect Cost, IC	$67,200.00
ƆTAL CAPITAL INVESTMENT = DC + IC	$6,606,000.00

Table A-1.5(b) Cost of New Intermittent Slag Stack (cont.)

COPPER SMELTER ANNUALIZED COST SHEET (Slag Stack)

Direct Annual Costs		Factor	Unit Cost	Total
Operating Labor				
	Operator	4 hrs/stack changeover	15.77/hr *	$1,892.40
	Supervisor	.15 of operator	–	$1,182.75
Maintenance				
	Labor	Repair stack & ductwork	17.35/hr *	$105,000.00
	Material	Replace refractory, dampers, expansion joints, fan blades, ect.	–	$70,000.00
Utilities				
	Natural Gas	---	$3.50/kft^3	N.A.
	Electricity	Aircraft Lights, Elevators, Ash Removal	$0.08/kWhr	$8,608.00
	Total DC			$186,683.15

Indirect Annual Costs		Factor	Unit Cost	Total
Overhead		.60 of operating, supv., & maint. labor & materials	–	$64,845.09
Administrative charges		.005 of TCI	–	$33,030.00
Property Taxes		.01 of TCI	–	N.A.
Insurance		.01 of TCI	–	$66,060.00
Capital Recovery		TCI x CRF ****	–	$532,353.78
	Total IC			$696,288.87

TOTAL ANNUAL COST	$882,972.02

**** CRF = i(1+i)^n/(1+i)^n−1 = 8.0586%
n = 30 yr equipment life
i = 7% interest rate

A.2 Case Study 2: One Source Exceeding the Endangerment Level

This case study evaluates control for a model primary lead smelting facility. There are approximately four primary lead smelters in operation in the United States. Each facility can produce between 150 and 550 tons of lead per day. Particulate matter and SO_2 are the pollutants of most concern to primary lead smelters.

The lead smelter model scenario is one which represents a great potential to exceed the 2.0 ppm endangerment level. This scenario also shows a situation where there are large numbers of exceedances of the 5-minute concern level of 0.6 ppm and few exceedances of the 3-hour and 24-hour ambient standards. Figure A-2.1 presents the modeled exceedances predicted for each SO_2 concentration level. The example illustrates situations where tighter adherence to current SIP requirements will not provide adequate protection of short-term ambient conditions. It is assumed that this model scenario is located in hilly terrain which causes complex weather conditions such as thermal inversions that tend to increase exposure problems. Due to the frequency of endangerment level concentrations, EPA and the State are requiring immediate installation of additional air pollution controls. This case study presents costs for installation of a wet scrubber to control the blast furnace gas stream.

Description of Model Plant

The model plant, depicted in Figure A-1.2, is a composite of several typical facilities and does not necessarily reflect the process of any one actual plant, however, the model is representative to actual facilities. Primary lead smelting industry profiles found in the AWMA Air Pollution Engineering Manual and AP-42[6] were used to develop the sample facility.

The process of smelting lead involves three primary steps - sintering, reduction, and refinement. The sintering stage converts sulfide ore concentrate (containing trace amounts of copper, iron, and zinc) into sinter (PbO) via a sinter machine. When the sulfur content of the sinter charge is between 5-7 percent, system operation and product quality are optimized. This optimal sulfur content is maintained by adding silica and limestone (sulfide-free fluxes) and large amounts of recycled sinter and smelter residues to the mix. The sinter machines continuous conveyor of perforated or slotted grates can be ventilated by either an updraft or downdraft system. The updraft design was chosen because it permits greater production rates, has a lower pressure drop (i.e. requires less blower capacity), requires less maintenance, and, perhaps most importantly, allows the use of a weak gas recirculation methodology. This

Figure A-2.1. Annual Exceedances for Lead Smelter Model Plant

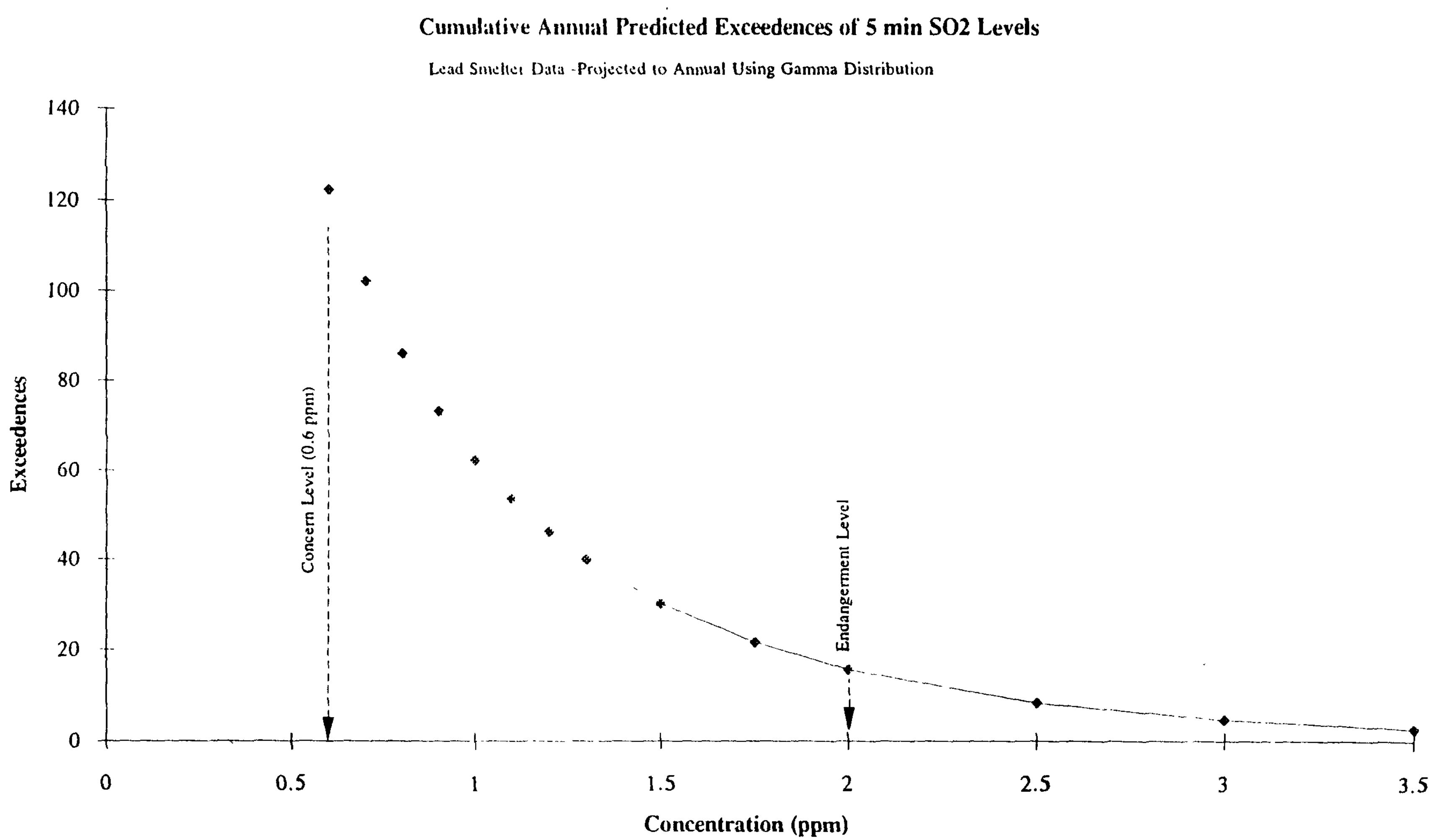
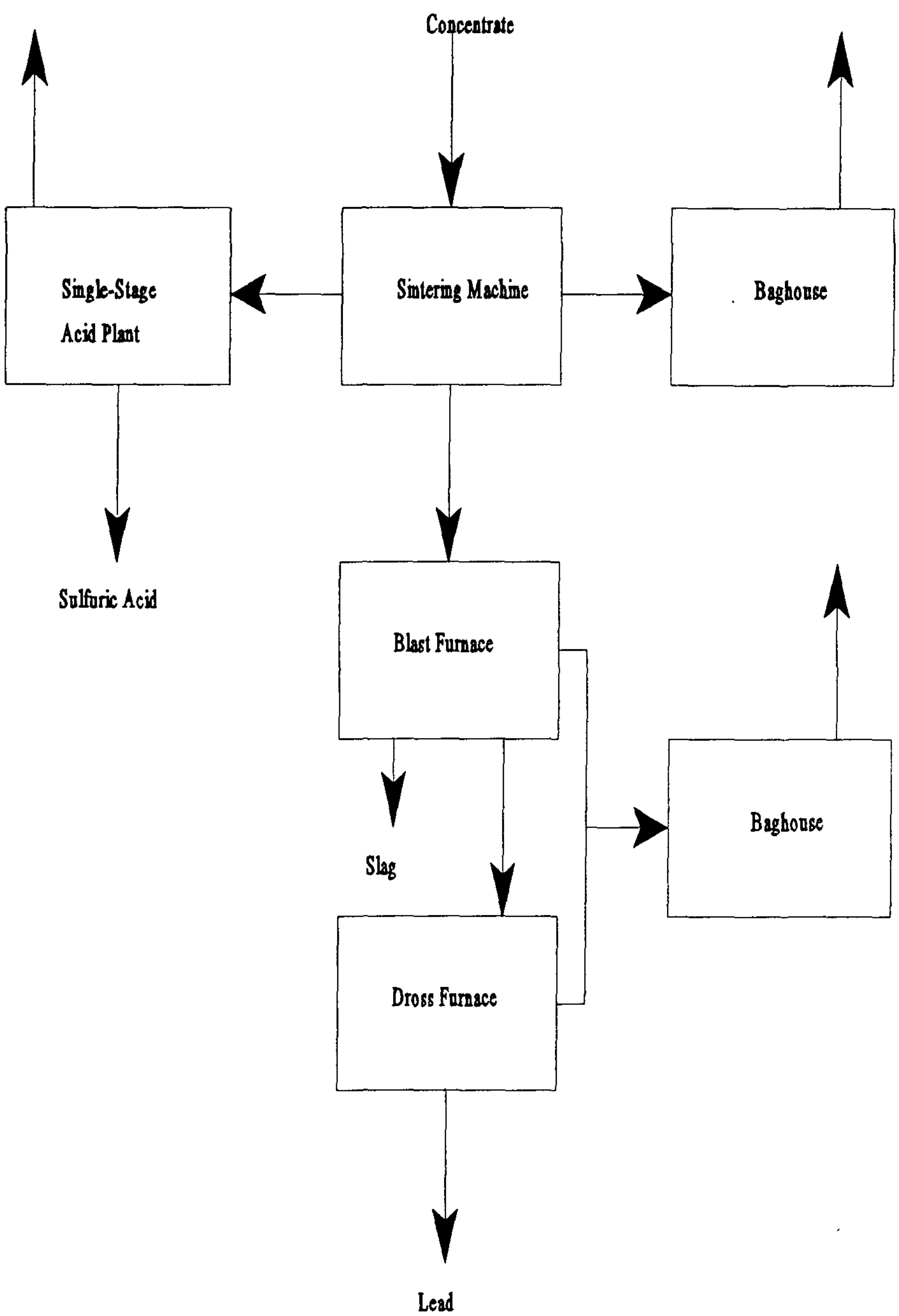


Figure A-2.2. Lead Smelter Model Plant Process Diagram



recirculation design permits more efficient and more economical use of control methods, such as sulfuric-acid-recovery devices.

Reduction of lead is done in a blast furnace. The feed material to the blast furnace is sinter (80-90 percent of charge) and metallurgical coke (8-14 percent of charge) which is reduced to lead bullion and slag. SO_2 emissions from the blast furnace are a function of residual lead sulfide and lead sulfate content as well as the amount of sulfur captured by constituents of the slag, particularly copper.

A preliminary refining process of cooling and heating the rough lead bullion in kettles (drossing) is performed to remove metals from the lead. Sulfur-bearing materials, zinc, and/or aluminum are mixed with the rough lead bullion to facilitate the removal of copper. The final refinement of the lead consists of a series of five steps that further remove metals from the lead. The result is 99.990 - 99.999 percent pure lead that is cast into 10 lbs "pigs."

The model plant utilizes a dual-gas-stream system to capture a highly concentrated (5-7 percent SO_2), or strong stream, from the feed end of the machine, and a weak stream (< 2 percent) pulled from the discharge end of the machine. The weak stream is recirculated back through the feed bed where it might otherwise be vented to the atmosphere after particulate removal. Recirculation will reduce the production capacity, allow for more convenient and cost-effective SO_2 removal and recovery, and increase particulate generation at the discharge end of the machine.

Because the smelting process produces such a concentrated form of SO_2 from the sintering machine, many lead smelters find it profitable to produce sulfuric acid from the off gas and sell the acid commercially. Sulfuric acid is produced through a contact process which uses a vanadium-based catalyst to turn the SO_2 into SO_3. The SO_3 is then reacted with water to produce the sulfuric acid. Before the SO_2 from the sintering process can be converted to SO_3, the off gases must be cleaned and dried using electrostatic precipitators and a drying tower. The SO_3 is sent to an absorbing tower where the SO_3 is absorbed by strong sulfuric acid and water is added to keep the acid concentration at 98 to 99 percent. The model facility uses a single stage sulfuric acid plant to remove SO_2 from the sintering machine. The removal efficiency is estimated at 96.5 percent.

The reduction stage will eliminate approximately 15 percent of the total amount of sulfur found in the original ore concentrate (versus 85 percent eliminated by sintering) with one half in the form of SO_2 and the other half in the slag. The concentration of SO_2 is dependent upon the amount of dilution air introduced into the effluent gas stream. The SO_2 emissions from the reduction process consist of emissions from the blast furnace. The reduction and drossing process emissions are ducted to a baghouse and vented to a stack. It is assumed that there is no SO_2 control is used for this stream. Table A-2.1 summarizes the SO_2 emissions from the model facility.

Costs of Control

Exceedances of the endangerment level promoted quick action by EPA and the State. Although there are exceedances of the 3 and 24-hour standards, compliance with the standards would occur by other methods that would not solve the short-term problem. For this reason, the entire cost of control has been attributed to the short-term rule. However, the additional controls will also reduce ambient concentrations of SO_2 to a level that should eliminate 3 and 24-hour exceedances.

Table A-2.1.
Estimated SO_2 Emissions From Model Primary Lead Smelter

Process	Throughput* (tons produced)	AP-42 Emission Factor (lb/ton lead)	Control** Efficiency (percent)	Emissions (tons per year)
Sintering Machine	100,000	550	96.5	962.5
Blast Furnace	100,000	45	0	2,250.0
Totals				3,212.5

* A rough average of facility throughput data presented in "Background Information for New Source Performance Standards: Primary Copper, Zinc, and Lead Smelters, Volume I."
** From AP-42

The proposed method of SO_2 emission control is the addition of a packed bed scrubber to the blast furnace exhaust. Applying scrubbers to a previously uncontrolled source is much more cost effective than adding equipment to processes which have controls. Scrubbers are commonly used for SO_2 control and can achieve a control efficiency of 95 percent. For a throughput of 100,000 tons per year, this added control would remove 2,137.5 tons of SO_2 being emitted from the reduction process. This reduction in emissions could potentially result in the control of two thirds of the SO_2 previously emitted, a reduction that will was demonstrated to eliminate 0.6 ppm exceedances. The costs of adding this scrubber and of performing the rollback modeling are detailed in Table A-2.2. Modeling costs are based on an assumed initial cost of $100,000 that would not need to be repeated for a 5-year period annualized (24.39 percent capital recovery factor) to $24,390.

The capital cost of installing a double contact sulfuric acid scrubber is estimated to be $181,652. Cost estimates were done using one of the twenty "CO$T-AIR" spreadsheet developed by EPA's Office of Air Quality Planning and Standards to estimate the costs of installing and operating several different types of air pollution control equipment. Annualized costs were estimated to be $317,819 for a primary lead smelting facility with an average throughput of 100,000 tons per year. Assuming a $317,819 annualized cost and an added removal of 2137.5 tons of SO_2 per year, the cost of SO_2 emission reduction is $149.16 per ton. The detailed capital and annualized costs estimated by the "CO$T-AIR" program are presented in Table A-2.2

Table A-2.2.
Case 2: Cost of Control (1993 dollars)

Affected Unit	**Capital Cost**	**Annualized Cost**
Double Contact Scrubber	$0.18 million	$0.32 million
Rollback Modeling	$0.1 million	$0.024 million
Total	$0.28 million	$0.344 million

Summary

Lead smelters have a large number of instances where they exceed the 0.6 ppm ambient concentration level that is considered a "level of concern". In order to prevent these short-term exceedances, it is proposed that a packed bed scrubber will be installed on the blast furnace. The reduction stage is often not controlled for SO_2 emissions and it is believed that this would have a significant positive impact on local short-term SO_2 levels. Emission modeling, costing approximately $60,000 per year per facility is necessary to verify any impacts of this strategy. It is estimated that this option would have a saved cost, per ton of SO_2, of $149.16.

Table A-2.3(a) Cost of Wet Scrubber System

TOTAL ANNUAL COST SPREADSHEET PROGRAM--WET IMPINGEMENT SCRUBBERS [1]
(Total flowrates > 77,000 acfm)

COST BASE DATE: June 1988 [2]

VAPCCI (Third Quarter 1995): [3]		115

INPUT PARAMETERS

-- Inlet stream flowrate (acfm):		51260
-- Inlet flowrate/unit (acfm):		25630
-- ' ' ' ' -2nd iteration:		25630
-- Number of units:		2
-- Inlet stream temperature (oF):		135
-- Inlet moisture content (fractional):		0.20
-- Inlet absolute humidity (lb/lb b.d.a.): [4]		0.155
-- Inlet water flowrate (lb/min):		212.4
-- Saturation formula parameters: [5]		
	Slope, B:	3.335
	Intercept, A:	9.405000E-09
-- Saturation absolute humidity (lb/lb b.d.a.):		0.1520
-- Saturation enthalpy temperature term (oF):[6]		144.9
-- Saturation temperature (oF):		145.0
-- Inlet dust loading (gr/dscf):		3.00
-- Overall control efficiency (fractional):		1
-- Overall penetration (fractional):		0
-- Number of stages (trays):		3
-- Scrubber liquid solids content (lb/lb H2O):		0.11
-- Liquid/gas (L/G) ratio (gpm/1000 acfm):		2.5
-- Material of construction (see list below):[7]		1

DESIGN PARAMETERS

-- Scrubber pressure drop (in. w.c.):	4.50
-- Inlet air flowrate (dscfm): [8]	18264
-- Inlet (= outlet) air flowrate (lb/min):	1369.0
-- Outlet water flowrate (lb/min):	208.1
-- Outlet total stream flowrate (acfm):	25956
-- Scrubber liquid bleed rate (gpm):	8.112
-- Scrubber evaporation rate (gpm):	-0.52
-- Scrubber liquid makeup rate (gpm):	7.59

Table A-2.3(b) Cost of Wet Scrubber System

CAPITAL COSTS

Equipment Costs ($):	
-- Scrubber, one-stage: [9]	0
" two-stage:	0
" three-stage:	61,618
-- Total scrubber (base):	61,618
" " (escalated):	80,598
-- Other (auxiliaries, e.g.):	0
-- Total equipment:	80,598
Purchased Equipment Cost ($):	95,106
Total Capital Investment ($):	181,652

ANNUAL COST INPUTS

Operating factor (hr/yr):	8000
Operating labor rate ($/hr):	12.96
Maintenance labor rate ($/hr):	14.26
Operating labor factor (hr/sh):	8
Maintenance labor factor (hr/sh):	1.50
Electricity price ($/kWhr):	0.059
Chemicals price ($/ton):	0
Process water price ($/1000 gal):	0.20
Wastewater treatment ($/1000 gal):	3.80
Overhead rate (fractional):	0.60
Annual interest rate (fractional):	7%
Control system life (years):	10
Capital recovery factor (system):	0.1424
Taxes, insurance, admin. factor:	0.04

ANNUAL COSTS

Item	Cost ($/yr)	Wt. Fact.	W.F.(cond.)
Operating labor	103,680	0.326	----
Supervisory labor	15,552	0.049	----
Maintenance labor	21,384	0.067	----
Maintenance materials	21,384	0.067	----
Electricity	9,965	0.031	----
Chemicals	0	0.000	----
Process water	729	0.002	----
Wastewater treatment	14,796	0.047	----
Overhead	97,200	0.306	0.816
Taxes, insurance, administrative	7,266	0.023	----
Capital recovery	25,863	0.081	0.104
Total Annual Cost ($/yr)	317,819	1.000	1.000

Table A-2.3(c) Cost of Wet Scrubber System

Notes:

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[1] Data used to develop this program were taken from 'Estimating Costs of Air Pollution Control' (CRC Press/Lewis Publishers, 1990).

[2] Base equipment costs reflect this date.

[3] VAPCCI = Vatavuk Air Pollution Control Cost Index (for wet scrubbers) corresponding to year and quarter shown. Base equipment cost, purchased equipment cost, and total capital investment have been escalated to this date via the VAPCCI and control equipment vendor data.

[4] Program calculates from the inlet moisture content.

[5] By assumption, the saturation humidity (hs)-temperature (ts) curve is a power function, of the form: hs = A*(ts)^B.

[6] To obtain the saturation temperature, iterate on the saturation humidity. Continue iterating until the saturation temperature and the saturation enthalpy term are approximately equal.

[7] Enter one of the following numbers: carbon steel--'1'; coated carbon steel--'1.25'; fiberglass-reinforced plastic (FRP) or polyvinyl chloride (PVC)--'2.0'.

[8] Measured at 70 oF and 1 atmosphere.

[9] Equipment cost is a function of the number of scrubber stages. Cost does NOT include fans, pumps, or other auxiliaries.

A.3. <u>Case Study 3: One source impacting a local community and school-aged children</u>

The fifth case study looks at control of elevated emissions of SO_2 resulting from pulping activities at a paper mill. At this paper mill, pulp digestion produces SO_2 that is emitted at the end of the batch operation. This venting of SO_2 lasts only a short duration, but can produce substantial concentrations of SO_2. The model facility for this case study is located in a small town in the Midwest. The location of this facility in a populated area produced complaints of shortness of breath during these emissions periods. EPA and the State reacted to these complaints with a monitoring program. As the results of this monitoring effort confirmed the relationship between the digester operation and elevated SO_2 concentrations, the monitoring effort was followed by requirements for control of the SO_2 emissions. This case study evaluates the costs of using scrubbers to control these emissions. Although the scrubbers have a high capital cost, modifications to the process, coupled with installation of the scrubbers effectively eliminated these conditions of elevated SO_2 concentrations.

Description of Source

The main source of short-term SO_2 emissions is an acid sulfite pulping digester. In the typical acid sulfite process, sulfurous acid is used along with a bisulfite such as ammonium, magnesium, calcium, or ammonium to digest wood fiber under elevated temperature and pressure. For the purposes of this case study, the facility is assumed to be similar to the magnesium process unit shown in Figure A-3.1. While other pulping activities (such as Kraft pulping) emit reduced sulfur products, sulfite pulping produces substantial amounts of SO_2. The major source of SO_2 is venting of the digester at the end of the batch operation when process gas is vented to the atmosphere. This venting occurs through a blow tank. Process chemicals are recovered at the end of the digester batch; brown stock washers associated with recovery of process chemicals also produce some emissions. At the model plant, approximately 2,100 pounds of SO_2 is normally vented in three cycles taking approximately 15 minutes each. This venting takes place at the end of a digestion cycle that takes approximately every 10 hours. There are three digesters that operate in a sequential batch mode so that a venting occurs approximately every 3.5 hours.

This concentrated venting over a short period of time has resulted in frequent complaints from the public and has resulted in complaints of shortness of breath from a nearby elementary school. During the period of 2 years the state agency recorded complaints on several different occasions of strong odors and

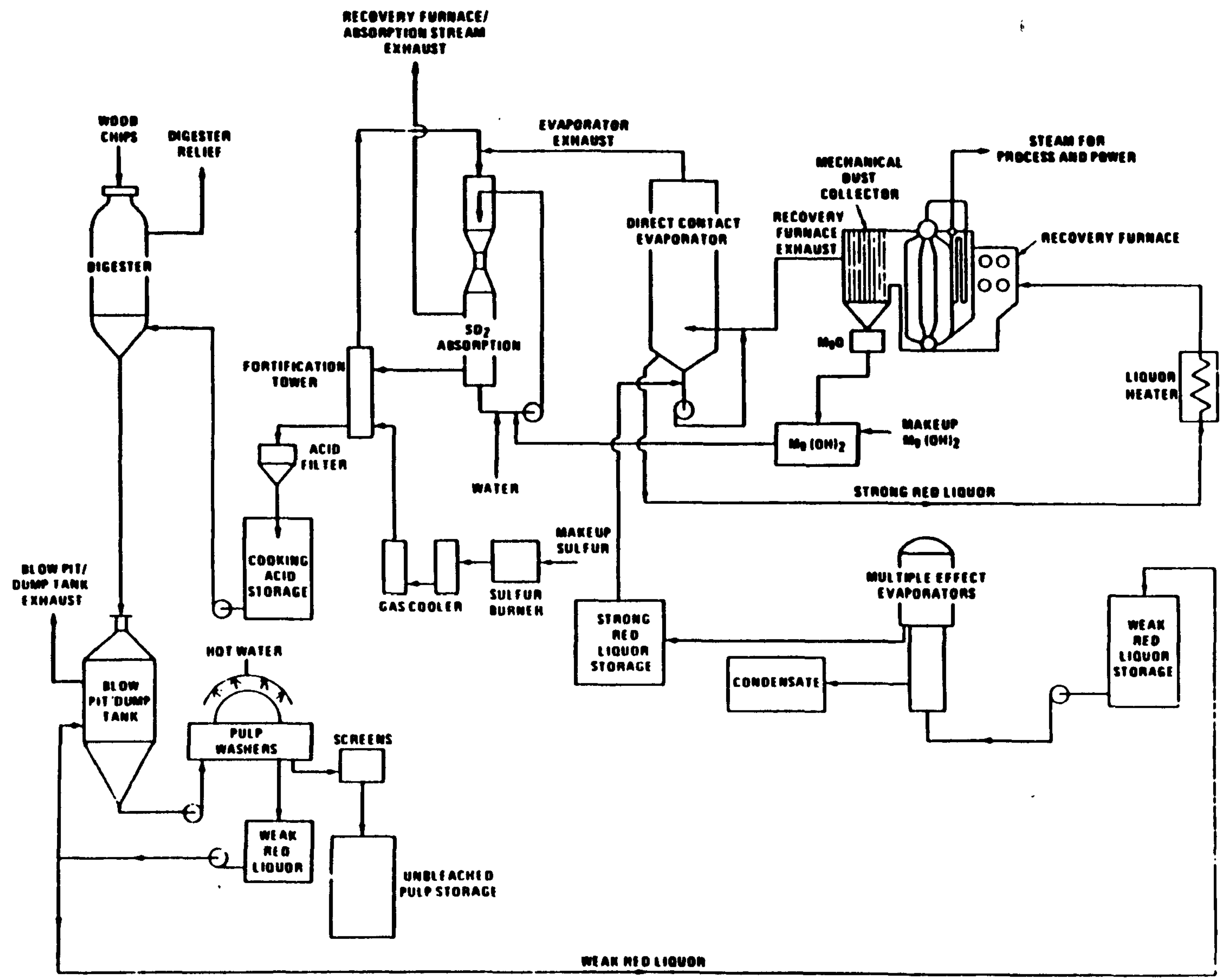


Figure A-3.1. Process Flow Diagram for Model Paper Mill

symptoms of painful breathing. The strong odors are likely to result from reduced sulfur compounds and are not associated with the short-term health impacts of SO_2 under investigation in this study. These complaints were reported by several residents and school officials regarding exposure in close proximity to the mill.

In response to these complaints, the EPA initiated a special monitoring program. The average annual number of SO_2 concentrations over values associated with short-term SO_2 health impacts are resulting from this monitoring program are summarized in Figure A-3.2. Due to the high number of exceedances of both the 0.6 ppm level of concern and the 2.0 ppm endangerment level, EPA and the State determined to take prompt action.

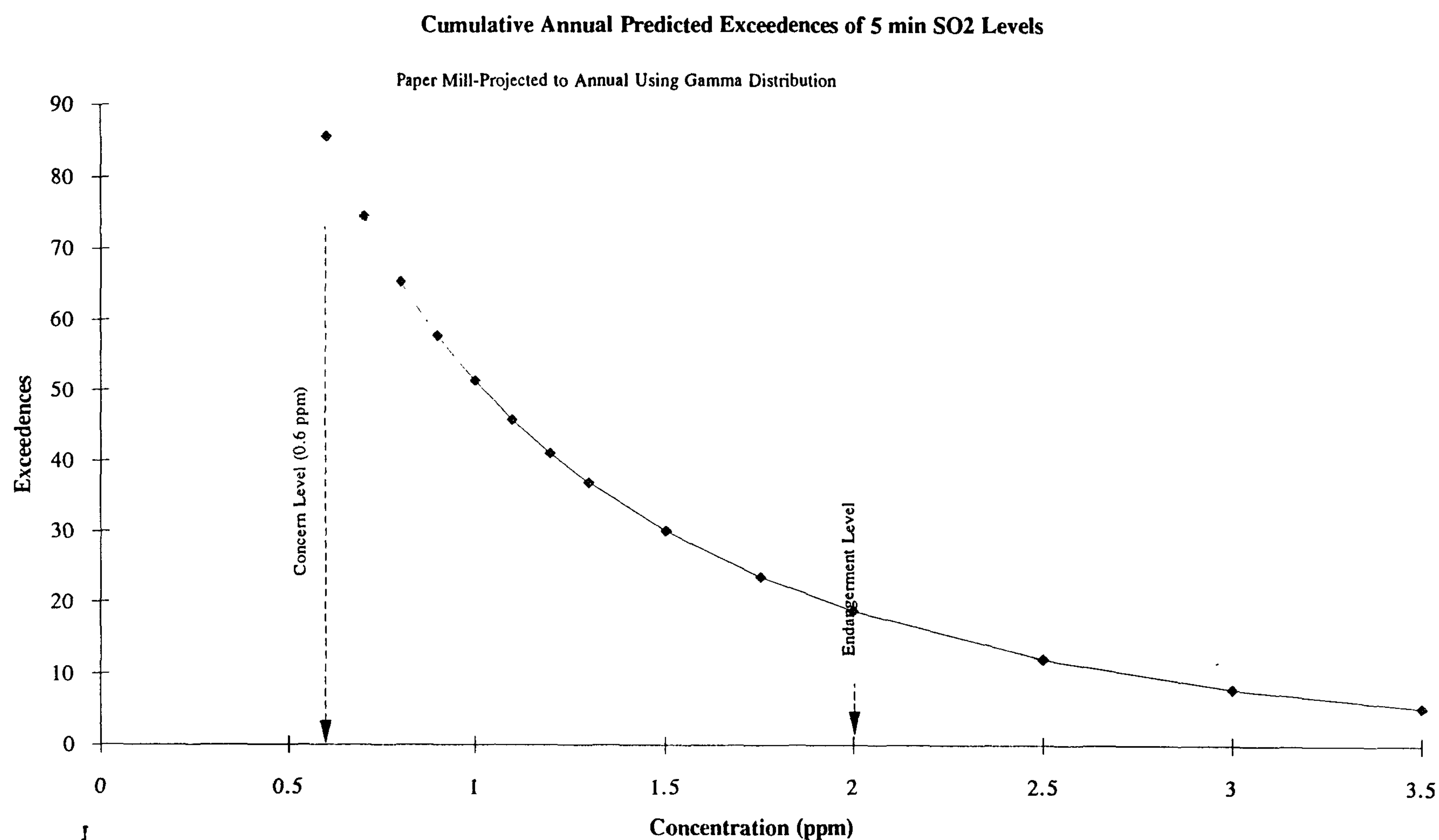
As EPA, the State, and the facility all agreed that the only substantial source of SO_2 was the venting from the digester, it was determined that these emissions would need to be controlled. A limited set of screening level dispersion modeling runs were performed by EPA to determine the effect of add-on controls. Using an estimated 95 percent control effectiveness for the SO_2 reduction resulting from addition of a scrubber, this screening modeling showed that air quality would meet the 0.6 ppm level of concern. The addition of air pollution control equipment was determined to be the only alternative that would eliminate air quality problems.

The addition of air pollution controls resulted in a substantial decrease in SO_2 emissions. The new emissions limitations negotiated between the facility and the regulators established 35 lbs./hour and 50 lbs. over any 2-hour period as the new emissions limits after installation of controls. As the digester tank blows can cover more than 1-hour period, the emission reduction was calculated over the 2-hour period as a 97.6 percent reduction in SO_2 emissions. As this was better than the 95 percent emissions reduction calculated by the model, this level of control was deemed to be adequate The overall emissions reduction resulting from control was calculated as 2,050 lbs. per blow. Averaging this over the 3.5 hour batch cycle, the average emissions reduction is 585 lbs. per hour. Using an estimated 7,000 hours per year of operation, an annual emissions reduction of 2,048 tons per year of SO_2 is achieved.

Costs of Control

As none of the monitored exceedances of the 5-minute standard resulted in exceedances of NAAQS, the entire cost of additional controls will be attributed to the IL program. The costs of the screening modeling performed by EPA were minimal and are not detailed in the overall costs. This leaves the costs of the scrubber as the only costs for correction of this problem. In order to effectively install controls, the digester needed to

Figure A-3.2. Annual Exceedances for Paper Mill Example



be substantially rebuilt. The reconstruction of the digester and installation of a wet scrubber to control SO_2 had a capital cost of $9.2 million. This control device resulted in an emissions reduction of over 97.6 percent of the SO_2 previously emitted. The annualized costs of the entire project are estimated to be $1.15 million. The capital and annualized costs of this project are presented in Table A-3.1.

Table A-3.1.
Case 3: Cost of Control (1993 dollars)

Affected Unit	**Capital Cost**	**Annualized Cost**
Double Contact Scrubber Costs	$1.99 million	$0.68 million
Overall Project Costs Including Digester Retrofit & Scrubber	$9.45 million	$1.15 million
Total	$9.45 million	$1.15 million

The annualized cost of operation is combined with the estimated emissions reductions to provide a cost effectiveness estimate for control. This cost effectiveness estimate is provided in Table A-3.2. OAQPS control equipment cost models were used to estimate an approximate capital and annual cost of control, this information is presented in Tables A-3.3 and A-3.4.

Table A-3.2. Cost Effectiveness of Control

Tons of SO_2 Emissions Reduced per Year	Annualized Cost of Control in Thousands of Dollars	Cost Per Ton Reduced (dollars per ton)
2,048 tons	$ 1,150	$562

Table A-3.3(a) Scrubber Costs

TOTAL ANNUAL COST SPREADSHEET PROGRAM--WET IMPINGEMENT SCRUBBERS [1]
(Total flowrates > 77,000 acfm)

COST BASE DATE: June 1988 [2]

VAPCCI (Third Quarter 1995): [3]		115
INPUT PARAMETERS		
-- Inlet stream flowrate (acfm):		275000
-- Inlet flowrate/unit (acfm):		91667
-- ' ' ' ' -2nd iteration:		68750
-- Number of units:		6
-- Inlet stream temperature (oF):		300
-- Inlet moisture content (fractional):		0.20
-- Inlet absolute humidity (lb/lb b.d.a.): [4]		0.155
-- Inlet water flowrate (lb/min):		446.1
-- Saturation formula parameters: [5]		
	Slope, B:	3.335
	Intercept,A:	9.405000E-09
-- Saturation absolute humidity (lb/lb b.d.a.):		0.2006
-- Saturation enthalpy temperature term (oF):[6]		157.8
-- Saturation temperature (oF):		157.6
-- Inlet dust loading (gr/dscf):		3.00
-- Overall control efficiency (fractional):		1
-- Overall penetration (fractional):		0
-- Number of stages (trays):		3
-- Scrubber liquid solids content (lb/lb H2O):		0.11
-- Liquid/gas (L/G) ratio (gpm/1000 acfm):		2.5
-- Material of construction (see list below):[7]		2
DESIGN PARAMETERS		
-- Scrubber pressure drop (in. w.c.):		4.50
-- Inlet air flowrate (dscfm): [8]		38355
-- Inlet (= outlet) air flowrate (lb/min):		2874.9
-- Outlet water flowrate (lb/min):		576.7
-- Outlet total stream flowrate (acfm):		59141
-- Scrubber liquid bleed rate (gpm):		17.036
-- Scrubber evaporation rate (gpm):		15.68
-- Scrubber liquid makeup rate (gpm):		32.71

Table A-3.3(b) Scrubber Costs

CAPITAL COSTS

Equipment Costs ($):	
-- Scrubber, one-stage: [9]	0
" two-stage:	0
" three-stage:	674,929
-- Total scrubber (base):	674,929
' ' (escalated):	882,828
-- Other (auxiliaries, e.g.):	0
-- Total equipment:	882,828
Purchased Equipment Cost ($):	1,041,737
Total Capital Investment ($):	1,989,718

ANNUAL COST INPUTS

Operating factor (hr/yr):	8000
Operating labor rate ($/hr):	13
Maintenance labor rate ($/hr):	14.26
Operating labor factor (hr/sh):	8
Maintenance labor factor (hr/sh):	2
Electricity price ($/kWhr):	0
Chemicals price ($/ton):	0
Process water price ($/1000 gal):	0.20
Wastewater treatment ($/1000 gal):	3.80
Overhead rate (fractional):	0.60
Annual interest rate (fractional):	0
Control system life (years):	10
Capital recovery factor (system):	0.1424
Taxes, insurance, admin. factor:	0

ANNUAL COSTS

Item	Cost ($/yr)	Wt. Fact.	W.F.(cond.)
Operating labor	103,680	0.153	----
Supervisory labor	15,552	0.023	----
Maintenance labor	21,384	0.031	----
Maintenance materials	21,384	0.031	----
Electricity	22,706	0.033	----
Chemicals	0	0.000	----
Process water	3,141	0.005	----
Wastewater treatment	31,073	0.046	----
Overhead	97,200	0.143	0.382
Taxes, insurance, administrative	79,589	0.117	----
Capital recovery	283,291	0.417	0.534
Total Annual Cost ($/yr)	678,999	1.000	1.000

Table A-3.4(a) Project Costs

CAPITAL COST SHEET

ect Costs		

ırchased equipment costs		$2,000,000.00
Additional ID Fan, Elevator		
Aircraft Avoidance Lights		
Ductwork, Ash Hopper		
Freight (.05 of EC)		$100,000.00

	Purchased eqpmt. cost, PEC	$2,100,000.00
irect installation costs		
Foundations & supports		$500,000.00
Construction & Materials		$5,900,000.00
Electrical (.10 of PEC)		$210,000.00
Ductwork		$320,000.00
Insulation for ductwork		$84,000.00

	Direct installation cost	$7,014,000.00
ite preparation		$100,000.00
uildings		N.A.

	Total Direct Cost, DC	$7,114,000.00
direct Costs		

Engineering (.10 of PEC)		$210,000.00
Field expenses (.05 of PEC)		$105,000.00
Contractor fees (.10 of PEC)		$210,000.00
Start–up (.02 of PEC)		$42,000.00
Performance test (.01 of PEC)		$21,000.00
Contingencies (.03 of PEC)		$63,000.00

	Total Indirect Cost, IC	$336,000.00
		======
		IC + SP + Bldg.
OTAL CAPITAL INVESTMENT = DC + IC		$9,450,000.00

Table A-3.4(b) Project Costs

Direct Annual Costs	Factor	Unit Cost	Total
Operating Labor			
Operator	6hrs/day;360days/year	$12/hr	$25,920.00
Supervisor	.15 of operator	–	$3,888.00
Maintenance			
Labor	3hrs/day;360days/yr	$13.20/hr	$14,256.00
Material	same as labor costs	–	$14,256.00
Utilities			
Natural Gas		$3.50/kft^3	N.A.
Electricity		$0.08/kWhr	$148,614.72
Total DC			$206,934.72

Indirect Annual Costs	Factor	Unit Cost	Total
Overhead	.60 of operating, supv., & maint. labor & materials	–	$34,992.00
Administrative charges	.02 of TCI	–	$47,250.00
Property Taxes	.01 of TCI	–	N.A.
Insurance	.01 of TCI	–	$94,500.00
Capital Recovery	TCI x CRF ****	–	$761,541.51
Total IC			$938,283.51
TOTAL ANNUAL COST			$1,145,218.23

**** CRF = i(1+i)^n/(1+i)^n−1 = 8.0586%
n = 30 yr equipment life
i = 7% interest rate

A.4 Case Study 4: One Source Impacting Multiple Communities

This case study involves a hypothetical area with a petroleum refinery that has historical SO_2 emissions problems. Numerous complaints have been received from several citizens from the area around the refinery of health problems including asthma and respiratory difficulties, burning eyes, and throats. In the past getting action from such a source has been complex and difficult. Large facilities often have massive political clout and impressive legal forces behind them making them extremely powerful against the state. Sometimes citizens from several states are affected by the emissions of one facility therefore requiring the cooperation and coordination among numerous states. Several facilities, including the model facility in this study, have long histories of conflict with state regulations. This case study will investigate a facility's use of an Operations and Maintenance (O&M) approach coupled with Continuous Emissions Monitoring (CEMs) as described in Case Study 2, to reduce excessive short-term SO_2 emissions. In addition to O&M activities to eliminate current problems with excess emissions, additional controls will be needed to ensure public protection from elevated short-term SO_2 concentrations. This case study includes installation of controls on a catalytic cracking unit that currently is uncontrolled.

Description of Source

This case study involves a localized area that intersects several states and EPA regions. It is a highly industrialized area with mostly "smoke stack" type sources. It contains an oil refinery which emits large quantities of SO_2. In the hypothetical situation a combination of frequent air inversions and the existence of a downwind population makes it imperative that the facility minimize emissions to avoid adverse impacts on the local population.

The model refinery described in this case study converts crude oil into various combustion fuels. The difficulty resides in the fact that crude oil contains sulfur that has the potential to contaminate the environment. The facility process over 200,000 barrels of crude oil per day which is considered fairly large.

The refining process requires the use of several pieces of equipment that produce SO_2. The primary source of SO_2 emissions is from a large Fluid Catalytic Cracking Unit (FCC) used to convert complex hydrocarbons into blending stocks and fuel oils. The large FCC unit was built before the implementation of an NSPS and therefore was allowed to emit a much higher limit of SO_2 than would be allowable today, as well as operate without a pollution control device. Annual allowable emissions from this unit are 2300 lb/hr. This "grandfathered" unit has an emission limit of 2000 ppm (see Table A-4.1) whereas, the NSPS for newer catalytic cracking units limits emission is 250 ppm SO_2. As a result, this unit is the largest single source of SO_2 in the area.

The refinery operates a CO boiler that (as mentioned in Case Study 2) takes flue gas from the FCC units that are steeped

Table A-4.1.
Emissions for Refinery in Case Study 4

Unit	NSPS Emission (ppm)	Annual Allowable SO_2 Emission (lb/hr)	Annual Allowabl e SO_2 Emission (TPY)
Sulfur Recovery Unit 1 + Sulfur Recovery Unit 2 (SRU)	250	86 (50+35)	376.68
Reduced Crude Conversion System (RCC)	250	1200	5256
Fluid Catalytic Cracking Unit (FCC)	2000	2300	10074

with SO_2 and CO. The CO boiler takes the offgases, combusts them to produce process steam. A fluidized bed boiler into which limestone is injected removes sulfur oxides.

Fuel oils must be hydrotreated in order to remove sulfur in order to be sold commercially. Desulfurizing feed is mixed with hydrogen in a catalyst reactor. In this process sulfur is reduced to H_2S. The H_2S is then sent through a sulfur recovery unit where it is turned into commercial grade sulfur that sold to recover some of the operating costs.

The model refinery also operates two Claus Sulfur Recovery Units (SRUs). The SRUs take off-gases put out by the FCC units and convert it into elemental sulfur which can then be sold commercially (this process is presented in detail in Case Study 2). Operation of this equipment results in emissions of SO_2,

H_2S, and other VOCs. The SRUs spike H_2S levels in the atmosphere. The SRUs at the facility have a 99.7 removal efficiency rate for sulfur.

The facility also employs a Shell Claus Offgas Treating (SCOT) unit. This equipment allows for the removal of sulfur compounds from the SRU tail gas before its incineration. The compounds are then converted to H_2S, which is then recycled back into the SRU.

A Reduced Crude Conversion System (RCC) that is used is similar in function as the FCC unit, but it is designed to process heavier feeds using a mixture of fresh catalyst and equilibrium catalyst from the FCC. The unit processes heavy vacuum gas oils, #3 crude unit bottoms, and #1 refinery lube plant vacuum unit bottoms into light gases, gasoline, and cyclic oils. As with the FCC unit, the catalyst is coked in the cracking reaction. Sulfur is released in this reaction but as in the FCC unit it is removed with limestone in fluidizing beds.

Baseline Conditions

The current 24-hour and 3-hour SO_2 NAAQS are usually met using existing control equipment. The facility is required to notify state officials when these levels are exceeded. As of 1993 the facility has been required to purchase and operate a 24-hour video system which allows regulators to constantly monitor its happenings. Ongoing exceedances of the current NAAQS are believed to result from process upsets. The facility has installed Continuous Emissions Monitors (CEMs) on all four of the major SO_2 emitting units. The state has required an effective notification procedure to be implemented at the refinery which would result in swift notification of federal, state, and local agencies in the occurrence of an emissions release. Under the requirements of the facility's permit, the State has required a maintenance plan to eliminate excess emissions. Although this additional O&M should reduce short-term SO_2 problems, it will not be sufficient enough to eliminate them. As this O&M plan has been required under the existing SIP to meet NAAQS, its costs are not part of the IL program burden. It is assumed that improvements in O&M will, however, provide benefit by reducing the frequency of short-term exceedances.

Monitoring Data

Presently, the model facility is assumed to have drastically reduced 3-hour and 24-hour SO_2 standard violations. The facility has improved control equipment designed to lower SO_2 pollution emitted from their processes. Specifically, the addition of the SRUs has decreased NAAQS violations drastically. The use of the SCOT unit which is 99.7 percent effective at removing SO_2-has aided the facility's attempts of lowering SO_2 emissions. The facility is currently hydrotreating off gases with desulfurizing feed which greatly decreases emissions of sulfurous compounds. Violations of both 3-hour and 24-hour SO_2 standards still exist, but they are very infrequent.

The area surrounding the model plant still suffers from excessive short-term concentrations of SO_2 resulting from process upsets and generally high emissions from one uncontrolled unit. Figure A-4.1 shows the cumulative annual predicted exceedances of 5-minute SO_2 levels of the IL program. In order to rectify the situation a plan is developed which results in the establishment of 5-minute emission limits for SO_2 sources used by the refinery including:

1) In depth modeling of short-term (5-minute) average data which would be used in establishing a 5-minute emissions limit. The collection of such data will require the construction of a meteorological station in the vicinity of the refinery. Obtain at least 2 years of meteorological data for comparison to monitoring data and use in dispersion models to show post-SIP emissions.

2) Use any existing monitoring stations around the refinery to also obtain 2 years of short-term monitoring data along with meteorological data.

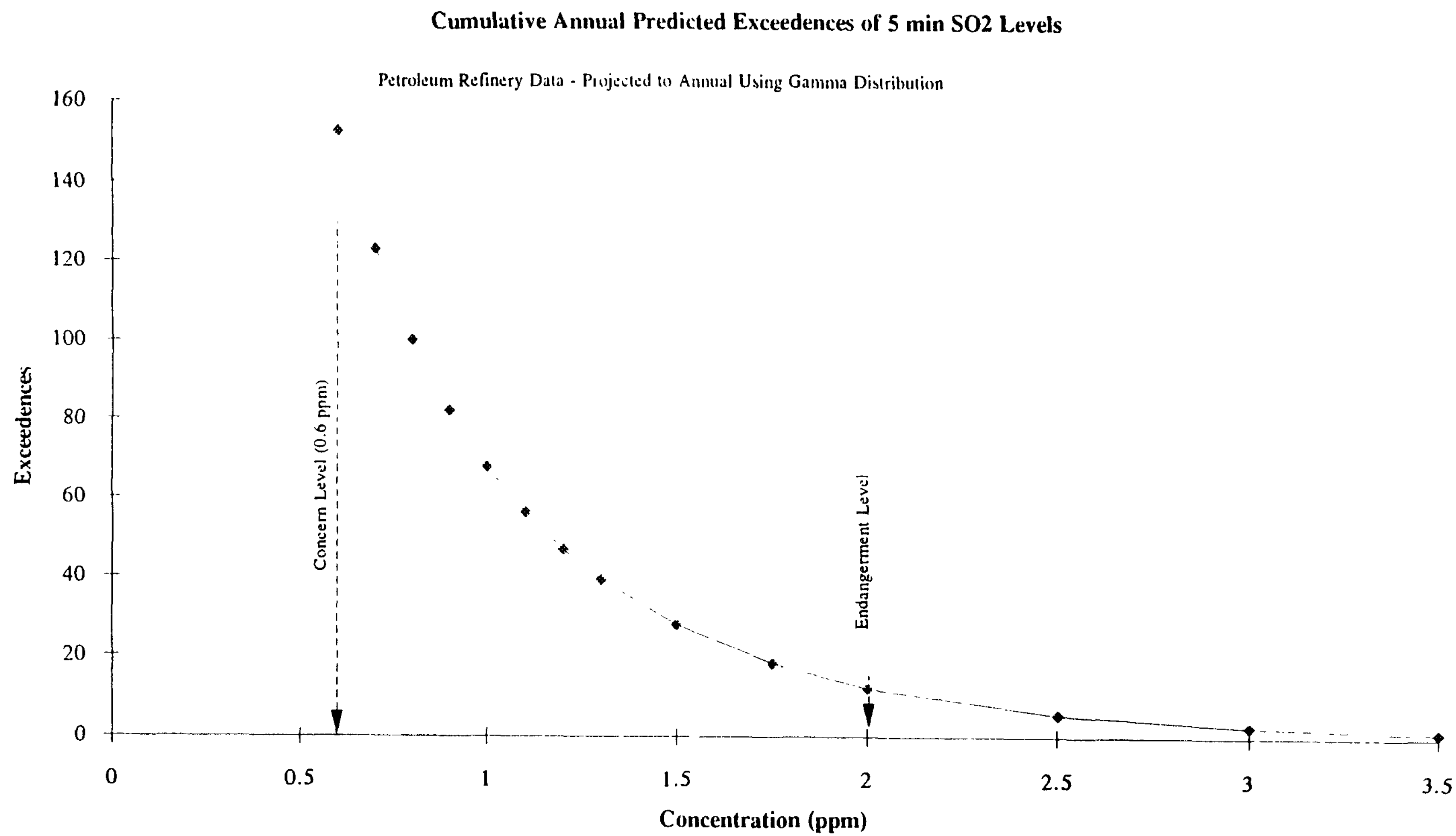
3) Appropriate 5-minute emissions limits should be determined for the refinery from the rollback modeling using the meteorological data. The modeled concentrations will be compared to actual measured concentrations to ensure validity in the modeling process.

4) Modeling will be used to determine if there is a need for dry scrubbing of the FCC unit. A dry scrubber device added to the unit would possibly reduce SO_2 emissions by 95 percent thereby eliminating short-term NAAQS violations (3 hrs).

Costs Associated with the IL Progarm

After the 5-minute emissions are established, O&M (Operations and Maintenance) techniques will be required to eliminate exceedances of the IL program. As mentioned in Case Study A-2, O&M practices are relatively cost effective. The refinery is obligated to report any exceedances of the 5-minute standard, explain why it occurred, and describe what they plan to do in the future to be sure it does not happen again. This type of system will require extra costs in monitoring and recording these costs are presented in Table A-4.2. and are developed on the same basis as those in Table A-2.4.

Figure A-4.1. Annual Number of 5-Minute Exceedances Prior to SIP Controls



Currently the hypothetical refinery is using a CEMS to monitor source emissions hourly. This means that no new additional equipment will be necessary to comply with the IL program requirements. The present monitors are capable of sampling continuously and producing concentrations as needed. These concentrations are taken from the monitor and recorded by strip charts or digital data loggers. The charts would not need to be modified, but they would need to be read more often. This would lead to increased labor expenses for the facility. The digital loggers could still be used, but they would need to be reprogrammed to take 5-minute average readings along with the current 3-hour and 24-hour readings.

Five-minute averages for stack flow, stack temperature, stack concentrations, and calculated emissions requirements would increase the facilities burden, as well as the increased monitoring, reading, and validating the additional data gathered.

The addition of the dry scrubber device onto the "grandfathered" FCC unit will be a substantial cost burden. Table A-4.2. details the capital and annual costs for the purchasing and installation of such equipment for the refinery. For a predicted emission reduction of 95 percent, or 9,570 tons per year SO_2, the annual cost of $2,189,021.76 results in a cost of $228.74 per ton of SO_2 emission reduction. The additional costs for improved O&M are needed to meet existing SIP requirements and are, therefore, not attributed to the IL program. It should be noted that the FCC unit addition is the only item presented in the costs in this case study and that ICR provides national O&M costs and effort is not duplicated for this report. A modeling demonstration has been included in the costs to represent dispersion modeling conducted to demonstrate the adequacy of the proposed controls to reduce levels to no more that 1 exceedance hour of 0.6 ppm over any 5-minute period. The modeling was estimated to cost $100,000 and was assumed to not need to be repeated any more frequently than 5 years. Therefore this cost was capitalized over 5 years using a capital recovery factor of 24.39 percent for an annual cost of $24,390.

Table A-4.2. Case 4: Cost of Control (1993 dollars)		
Affected Unit	**Capital Cost**	**Annualized Cost**
Dry Scrubber	$20.4 million	$2.19 million
Additional CEM Activity for One Unit (see Table B.4.)	none	$0.01 million (290 hours @33.75)
Dispersion Modeling	$0.1 million	$0.024 million
Total	$20.5 million	$2.224 million

Summary

Though the facility in this case study is fictitious, it is intended to be representative of actual facilities. As with actual facilities, if proper equipment controls are placed on emission sources then subsequent control costs, operations and maintenance, can be at a minimal. The total estimated costs to the model source is estimated to be $228.74 per ton of SO_2 emission reduction. For a 95 percent reduction of SO2 emissions an annual cost of $2,189,021.76 cost of air pollution control would be incurred for the addition of the dry scrubber to the FCC unit. The additional costs resulting from modeling and reporting do not provide emissions reductions and were not included in the cost per ton reduced. However, their cost is relatively small and including these costs makes the overall annual cost of elimination of short-term SO_2 problems $2.224 millions. The new unit addition would provide some benefit in reducing the number of 3- and 24-hour standard exceedances for the model facility. Coupled with the required O&M improvements to minimize excess emissions, modeling demonstrated compliance with the NAAQS and the IL program.

Table A-4.3(a)
Costs for Addition of Dry Scrubber Device

Direct Costs	
Purchased equipment costs	$10,000,000.00
Additional ID Fan, Elevator	
Aircraft Avoidance Lights	
Ductwork, Ash Hopper	
Freight (.05 of EC)	$500,000.00
Purchased eqpmt. cost, PEC	$10,500,000.00
Direct installation costs	
Foundations & supports	$500,000.00
Construction & Materials	$5,900,000.00
Electrical (.10 of PEC)	$1,050,000.00
Ductwork	$320,000.00
Insulation for ductwork	$420,000.00
Direct installation cost	$8,190,000.00
Site preparation	$100,000.00
Buildings	N.A.
Total Direct Cost, DC	$8,290,000.00
Indirect Costs	
Engineering (.10 of PEC)	$1,050,000.00
Field expenses (.05 of PEC)	$525,000.00
Contractor fees (.10 of PEC)	$1,050,000.00
Start-up (.02 of PEC)	$210,000.00
Performance test (.01 of PEC)	$105,000.00
Contingencies (.03 of PEC)	$315,000.00
Total Indirect Cost, IC	$1,680,000.00
TOTAL CAPITAL INVESTMENT = DC + IC	$20,370,000.00

Table A-4.3 (b)
Costs for Addition of Dry Scrubber Device

ct Annual Costs	Factor	Unit Cost	Total
erating Labor			
Operator	6hrs/day;360days/year	$12/hr	$25,920.00
Supervisor	.15 of operator	–	$3,888.00
intenance			
Labor	3hrs/day;360days/yr	$13.20/hr	$14,256.00
Material	same as labor costs	–	$14,256.00
ities			
Natural Gas		$3.50/kft ^ 3	N.A.
Electricity		$0.08/kWhr	$148,614.72
Total DC			$206,934.72

ect Annual Costs	Factor	Unit Cost	Total
erhead	.60 of operating, supv., & maint. labor & materials	–	$34,992.00
ministrative charges	.02 of TCI	–	$101,850.00
)perty Taxes	.01 of TCI	–	N.A.
urance	.01 of TCI	–	$203,700.00
pital Recovery	TCI x CRF ****	–	$1,641,545.04
Total IC			$1,982,087.04
'AL ANNUAL COST			$2,189,021.76

**** CRF = i(1+i) ^ n/(1+i) ^ n−1 = 8.0586%
n = 30 yr equipment life
i = 7% interest rate

A.5. Case Study 5: Multiple Sources Affecting a Local Community

The next case study involves a hypothetical area containing several SO_2 sources that when combined, contribute to concentrations greater than the 5-minute concern level of 0.6 ppm. In the majority of the case studies, little or no overlap of the current 3-hour and 24-hour National Ambient Air Quality Standards (NAAQS) with 5-minute exceedances is anticipated. However, in this case study current State Implementation Plan (SIP) efforts to meet the NAAQS will form the basis of the effort to control 5-minute concentrations. In order to meet the existing NAAQS, O&M activities and emissions controls coupled with CEMs limits have been put in place. The CEMs will be used to demonstrate continuous compliance with emissions standards. While the current effort was designed to meet current NAAQS, this effort will assist in lowering short-term emission peaks and reducing the frequency of exceedances of 5-minute SO_2 concentrations.

Description of Sources

The facilities that are located in close proximity and contribute to the 5-minute problem, include two oil refineries, two sulfur recovery facilities, and a coal burning power plant. A description of the model plants associated with these facilities is provided below.

Oil Refineries: The two refineries in the area refine approximately 50,000 barrels of crude oil per day, which classifies them as medium in size. The refining process turns crude oil into various petroleum products including liquefied petroleum gas, gasoline, kerosene, jet fuel, diesel fuel, fuel oils and lubricating oils. Refining operations consist of separation operations, conversion processes and petroleum product treatments. These three processes are responsible for splitting crude oil into its various components, recombining them into useful fuels and lubricants and then treating and blending them to stabilize and enhance the performance characteristics of the final petroleum products.

Separation processes involve atmospheric and vacuum distillation of the crude oil into various petroleum fractions. These fractions are then broken down or combined to form various products through the conversion process. Some conversion processes are cracking and coking to break large molecules into smaller ones; isomerization and reforming to rearrange molecular structures of compounds; and polymerization and alkylation to combine smaller molecules into larger ones. Treatment processes are used to remove impurities from the petroleum products. Treatments include deasphalting, hydrodesulfurization, hydrotreating, chemical sweetening and acid gas removal.

Sources of emissions from petroleum refineries are generally the volatile petroleum products or the combustion sources, which results from sulfur existing as an impurity in the crude oil. Process heaters and boilers at the two facilities run off of oil and fuel gas and as such are the largest contributor to SO_2 emissions at these sources. The sulfur content of the fuel oils for the two refineries varies between 3 and 6 percent by weight. Primary sources of SO_2 emissions from the refineries are the fluid catalytic cracking (FCC) unit, carbon monoxide (CO) boilers and the coker CO boilers.

The FCC units use catalysts and high temperatures to convert complex hydrocarbons into blending stocks and fuel oils. A gas/oil stream entering the FCC is heated and fed into a catalytic reactor, where the cracking reaction occurs. The reactor vapors are then sent to fractionation columns where they continue to be processed. The pores of the catalyst are covered with hydrocarbons, sulfur, nitrogen, and trace metals. The spent catalyst is then stripped of the entrained impurities in a catalyst regenerator. Hot combustion air and steam strippers remove the hydrocarbons and the off-gases are removed from the regenerator by a flue. The flue gas which is rich in CO and SO_2 is then sent to a CO boiler which combusts the reactor off gases to generate process steam. SO_2 and other pollutants are vented from the CO boiler stack to the atmosphere.

The coking unit uses high temperature treatments of heavy residual oils to produce light hydrocarbon products and petroleum coke. The coke particles are burned in a combustor. The off-gases which contain SO_2 from the combustor are sent to the CO boiler where they are burned along with supplemental fuel oil.

As part of the fuel treatment process, fuel oils are hydrotreated to remove sulfur before they are marketed. The hydrotreatment process mixes the oil feed with hydrogen in a catalyst reactor. A byproduct of the hydrotreatment is sulfuric acid (H_2S), ammonia, nickel and volatile organic constituents (VOCs). The H_2S is sent to a local sulfur recovery facility to turn it into elemental sulfur to be sold commercially.

<u>Sulfur Recovery Facilities</u>: The sulfur recovery facility uses a Claus sulfur recovery unit (SRU) to extract the sulfur from the refinery off-gases. The sulfur recovery facility is located adjacent to one of the refineries and handles only waste gas from

this refinery, and is classified as medium in size. Within the SRU, part of the H_2S is oxidized to form SO_2. The remaining part of the H_2S reacts with the SO_2 to form elemental sulfur as shown below.

$$2H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O + Heat$$
$$2H_2S + SO_2 \rightarrow 3S + 2H_2O + Heat$$

The product gases of the reaction are sent to a waste heat boiler. The gases then pass through a condenser where elemental sulfur is removed. The gas stream is then reheated and sent to a catalytic reactor where the H_2S and SO_2 reaction continues. The reactor condenser process is repeated twice to remove as much of the sulfur as possible from the off gases. Off-gases of this process contain SO_2, H_2S, other reduced sulfur compounds and VOCs.

Coal-Fired Power Plant: The power plant in this area uses a 165 MW coal-fired utility boiler, which is classified as small in size. The power plant burns an average of 88 tons of coal per hour with a peak of 110 tons per hour during peak winter months. As the coal is combusted SO_2 is emitted from a 350 foot tall stack.

Cogeneration Facility: Within the area is also a cogeneration facility that burns petroleum coke from one of the refineries and produces process steam for use within the refinery to replace high sulfur fuel oil. The cogeneration facility produces SO_2 from the coke burning operations.

Baseline Conditions

Existing emission limits for SO_2 are intended to prevent exceedances of the 3-hour and 24-hour SO_2 NAAQS. Major sources of emissions from each facility have specific emission limits, while the remaining sources, such as valves, vents and flanges, are required to use appropriate maintenance, repair and operating practices.

Along with the emission limits are additional requirements for facilities during meteorological situations that prevent dispersion of SO_2 emissions. These requirements have supplemental emission limitations when calculated buoyancy fluxes are below a certain level. When these meteorological conditions exist, emissions of SO_2 are required to be reduced so that ground level concentrations do not exceed the standards due to reduced pollutant dispersion from the lower buoyancy fluxes.

In order to assure compliance with the emission limitations for the sources in the area, the regulatory agency instituted several monitoring and reporting requirements for the local SO_2 sources.

Each source which has a 3 or 24-hour emission limit is required to install and maintain a CEM. The CEM must record at least 90 percent of the operating time for that source.

Monitoring Data

The close proximity of the sources has produced continued violations of the 24-hour SO_2 standard. The frequency of these violations has been low, with an average of about 3 violations per year. Violations of the 3-hour standard have occurred, however, they are less frequent. Previous SIP efforts have not eliminated violations, so the regulatory agency required the installation of CEMs on all of the major SO_2 sources coupled with emissions limitations tied to 3-hour and 24-hour emissions standards. Dispersion modeling was used to establish new emissions limitations for each facility that will be verified through CEM monitoring. These new emissions limits are predicted to eliminate NAAQS violations.

Prior to the installation of CEMs, monitoring data indicate an average of 32 exceedances of the short-term standard of 0.6 ppm for 5 minutes out of an hour. After installation of the CEMs, data show twelve violations of the concern level. Thus, it has been assumed that the current SIP strategy will not eliminate 5-minute exceedances.

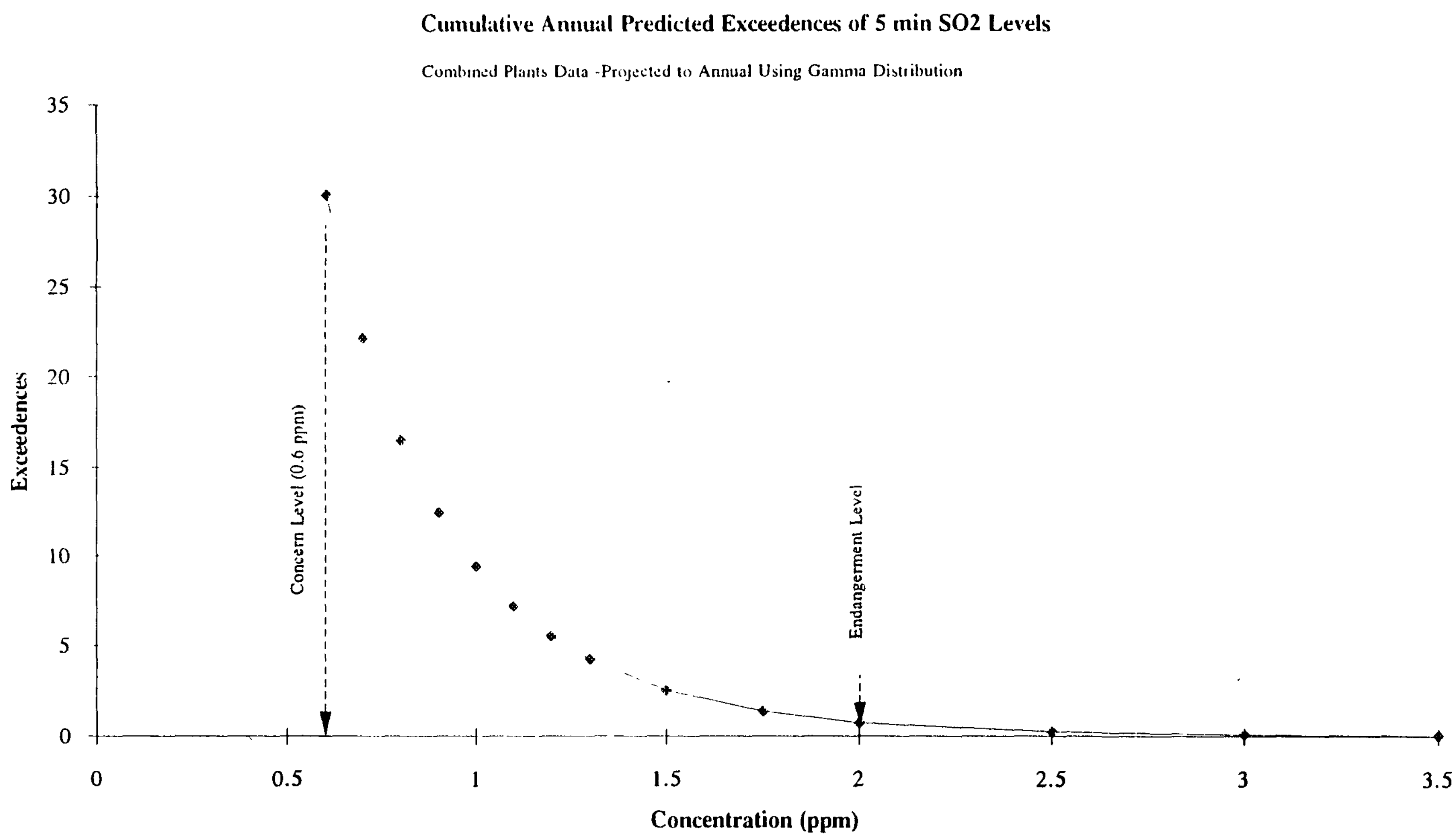
To address the 5-minute problem, a working group is established representing the State and the regulated facilities. A plan is developed in response to the State's prediction of continued exceedances of 5-minute levels. The major elements of the plan are:

1) Recalibrate the meteorological station to obtain 2 years of 5-minute average data for use in establishing short-term emissions limits.

2) Use existing monitoring stations to obtain 2 years of short-term monitoring data concurrent with meteorological data, to help identify those conditions producing high short-term SO_2 concentrations.

3) Current information indicates that short-term events result from stagnant conditions occurring during winter weather. These conditions are fairly rare; typical high wind speeds in the area are sufficient to produce adequate dispersion for avoidance of short-term exceedances. The design plan will, therefore, focus on establishing

Figure A-5.1. Annual Number of 5-Minute Exceedances Prior to SIP Controls



intermittent emissions limits.

4) An analysis will be performed to determine total SO2 reduction required in aggregate for the area to determine suitable emission limits for the sources.

5) The Acid Rain Emissions Trading Program is being used as a model for achieving desired emissions reductions during these stagnant conditions. The State will allocate allowances to each source to achieve the aggregate SO_2 reductions necessary to eliminate the 5-minute problem.

Overall, the State will use the meteorological and monitoring data to establish periods of the year when intermittent control are required to prevent 5-minute bursts of SO_2. During these periods of the year, the sources can use a trading program to reduct the combined effect of 5-minute SO_2 emissions at the lowest cost. In the program, sources use a variety of control methods that are viable under the IL program. Activities such as temporarily scaling back production rates at sulfur recovery facilities, or use of lower sulfur coal at the power plant represent substantially more cost effective approaches to control than requiring additional controls at the refineries. It is assumed that the refineries are business competitors, and therefore, unlikely to trade. However, the sulfur recovery facilities are dependant on refinery operation and would be likely to scale back operation provided that they were compensated (allowances purchased) for their efforts. The power plant could also conceivably sell allowances based on demand on the grid (ability to lower production) and on their ability to utilize cleaner fuels.

Costs Associated with the IL Program

Costs to Regulated Facilities: To meet the SIP requirements, facilities within the area are already monitoring their emissions on an hourly basis. For the IL program, monitors will sample continuously and are capable of producing the concentrations as needed. The concentration data from the monitors is recorded by either strip charts or by digital data loggers. Strip charts would not have to be modified but would have to be read more often. The digital data loggers would have to be reprogrammed to report 5-minute averages in addition to the 3 and 24-hour averages. Because, no new or additional equipment is anticipated to comply with the monitoring requirements of the IL program. All costs related to purchase of CEMS and the activities to meet the SIP are assumed to be baseline costs and are not included as additional costs imposed by the IL program.

Facilities would incur an increased burden due to the additional amount of reporting due to the 5-minute continuous monitoring requirements. Five minute averages for stack flow, stack temperature, stack concentrations, and calculated emissions would be required in addition to the current reporting requirements. Additional effort will be required to validate the added amount of monitoring data that would be collected. Once collected, this information will need to be reported to the State. The costs of this additional reporting are assumed to be similar to the incremental reporting burden costs developed for the continuous air monitoring (CAM) Rule[7,8]. These costs assume 0.5 hours of new record keeping per pollutant point for 260 days per year; an additional 0.5 hours twice a year is the assumed burden for transmitting this information to the State. As three parameters are being recorded (flow, temperature, and concentration), these burdens are multiplied by three assuming the burden is similar to tracking three different pollutants. This produces an annual incremental burden of 393 hours per year for each of the process units identified in Table A-5.1. The CAM Rule regulatory impact assessment (RIA) identifies this task as being carried out by an employee with a burdened hourly pay scale of $40.00. The annualized cost of the incremental burden of the 5-minute monitoring effort is calculated to be $15,720 per regulated stack. With 11 stacks in the area, this totals to $172,920 per year.

In this case study, it is assumed that the final benefit of implementing the current SIP efforts to achieve the 3-hour and 24-hour standards has not yet been fully determined. Sufficient information is not available at the onset of the program to fully define the emissions reductions needed to meet short-term ambient concentration goals. The final benefit of implementation of the current SIP efforts to achieve the 3-hour and 24-hour standards has not yet been fully determined. However, two roll-back scenarios have been developed to account for the costs of reducing emissions beyond the current SIP efforts to meet 5-minute standards. These rollback scenarios assume that either a 10 percent or 20 percent increase in emissions reduction will be required beyond the SIP required 3-hour limits in Table A-5.1. The costs of a linear reduction (rollback) of 10 percent and 20 percent of the remaining emissions were estimated based on the market based cost per ton of emissions reductions is indicated by the SO_2 Allowance Trading Program. A cost of $270 per ton reduced was used to estimate the cost of control[9]. As previously mentioned, the number of exceedances of the 5-minute standard has decreased to approximately 12 per year based on current information. As this data represents a limited set of observations, 25 days per year has been used in the roll-back model to represent the number of annual days during which emissions will need to be lowered and trading will occur.

<u>Costs to Regulatory Agencies</u>: Costs for increased ambient and

meteorological monitoring efforts are not included in the case studies, these costs are documented nationally in the Information Collection Request (ICR) memo that is submitted to the docket in support of the modeling requirements contained in the proposal of CFR Part 58. The cost estimates in this case study reflect the additional reporting requirements the regulatory agency will have to review and expend added effort to insure compliance with the new requirements associated with expending man-hours for compliance audits of the facilities, reviews of source tests and compliance reports and for the preparation and review on monitoring protocols. Manpower hours were determined on a per source unit, a per facility and an overall fixed cost basis for the various tasks necessary to carry out the enforcement of the short-term emission limit. Table A-5.2 demonstrates that the added work loads for the local regulatory agency totals to 953.3 hours per year and $32,173.88.

Summary

The total estimated cost to the affected sources was estimated to be between $210,855 and $248,890 per year depending on the amount of emissions reduction required to eliminate the few remaining elevated short-term SO_2 values. The cost of monitoring and reporting may somewhat overestimate the reporting burden due to the fact that the facilities are already required to report on longer term basis. However, the overall cost of reporting developed for the Enhanced Monitoring Rule RIA was considered the best estimate available. The overall burden of this case study on both the affected sources and the permitting agency combined is estimated to be between $243,029 and $280,964 per year.

Table A-5.1.
Case 5: Cost of Control (1993 dollars)

	10% Rollback Reduction (tons/day)	20% Rollback Reduction (tons/day)	Cost per Ton Reduced	Number of Days Requiring Control	Annual Monitoring & Reporting Cost for Stacks ($15,720/stack)	Total Costs
Cost of Emissions Reductions (10%)	5.62		$270	25	$172,920	$210,855
Cost of Emissions Reductions (20%)		11.24	$270	25	$172,920	$248,890

Table A-5.2.
Annual Burden Cost for Report Review and Compliance Assurance

Agency Tasks	Hours per Unit	Hours per Facility	Fixed Cost Hours	Units	Facilities	Total Hours	Hourly Rate	Total
Audits	25.6	-	120	11	5	401.6	$33.75	$13,554.00
Source Test Review	18.6	-	40	11	5	244.6	$33.75	$8,255.25
Compliance Reports	6.1	-	40	11	5	107.1	$33.75	$3,614.63
Protocol Preparation	-	40	-	11	5	200	$33.75	$6,750.00
Total	50.3	40	200	-	-	953.3	-	$32,173.88

A.6 Case Study 6: Several Sources with Exceedances at Night

The case studies presented to this point have demonstrated some situations in which there was a need for implementation of the IL program and have discussed the costs associated with implementation. In the two case studies that follow, the regulatory authorities (State or local agencies) investigate situations where exceedances of the concern level are known, but as a result of a simplified risk assessment, they have determined that the risks associated with the violations were not significant enough to warrant action under the IL program.

In this case study, monitor data is evaluated for an area with three coke oven facilities in close proximity to each other. The area is part of a metropolitan statistical area (MSA) and is officially designated as a nonattainment area for the SO_2 NAAQS. However, due to a consistent record of attaining the 3-hour, 24-hour, and annual NAAQS, the regulatory authority has requested the EPA to redesignate the area to attainment. Because of the potential to be redesignated to attainment, the regulatory authority has devoted 10 monitors to evaluate SO2 emissions in the area. Eight of the monitors are located around the coke oven facilities, five of which have reported measurements in excess of 0.60 ppm over a 5-minute period.

Coke Oven Production Process and Emissions

Iron and steel are refined metals used for making several various products. In a series of processes, refined iron ore is manipulated in blast furnaces to produce iron metals, which are then used in the production of steel. Coke is the chief fuel used in blast furnaces for the conversion of iron ore into iron metals. Coke is a metallurgical coal that has been baked into a charcoal-like substance that burns more evenly and has more structural strength than coal.

The coking procedure is performed in ovens that are constructed in groups with common side-walls, called batteries. During the coking process, coal is fed into the coke oven battery through ports at the top of the oven, which are then covered with lids. The coal is then heated in the absence of air in specially designed refractory chambers. Volatile material is driven off in the form of raw coke oven gas and then piped through an offtake system (for distillation and separation), where valuable by-products such as phenols, naphthalene, benzene, toluene, and ammonia are recovered as part of the production process[10].

After valuable by-products are removed from the coke oven gas, the remaining products could be fed to a desulfurization plant to reduce the sulfur contained in the gas to levels acceptable for fuel use. The sulfur in coke oven gas exists as H_2S and organic sulfur compounds (primarily carbon disulfide, CS_2, and carbonyl sulfide, COS). A fairly typical coking coal might contain about 1 percent sulfur, and about half of the sulfur remains in the coke after carbonization. Perhaps 95 percent by volume of the sulfur in the coke oven gas is in the form of H_2S; of the remainder, CS_2 accounts for 3.5 percent and COS for 1.5 percent[11]. When coke oven gas that has not been desulfurized is burned as a fuel, sulfur is emitted as SO_2. Desulfurization has a long history, as sulfur was once removed from gas for residential fuel use by contact with iron oxide, or through the absorption of acidic gases in a basic solution or oxidizing solution. With the advent of natural gas in the 1950's, desulfurization became much less common and is now only practiced at larger facilities.

Monitoring Data

In the analysis that follows, ten monitors in the area are used to evaluate 5-minute ambient concentrations of SO_2 around three coke oven facilities. The first facility is a small entity that operates one by-product recovery coke battery with less than 75 ovens, and produces approximately 20 MMCF of coke oven gas (COG) per day. The second facility, which is moderate in size, has five coke batteries with more than 300 ovens, and produces approximately 60 MMCF of COG per day. The third facility is considered large in the industry because it has 10 coke oven batteries with more than 800 ovens that produce approximately 200 MMCF of COG per day. All of the facilities have desulfurization plants for the recovery of H_2S for processing and future sale.

Although there is only one recorded violation of the NAAQS in the past 4 years, the regulatory authority is aware of the potential to exceed 0.60 ppm SO_2 over a 5-minute period around these sources, especially if the desulfurization plant has a malfunction or is shut-down. For example, one facility reported that malfunctions caused the desulfurization plant to shut-down for 251 days in 1 year[a], which increases SO_2 emissions by 10 times during periods of plant operation. In an evaluation of the 5-minute problem, the regulatory authority collected monitored data for the years of 1993 and 1994, which is summarized in Table A-6.1 below. Overall, the concentrations varied in severity from 0.60 to 1.0 ppm (with a majority of exceedances occurring around

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[a] Note that data does not exist to indicate the number of days of operation of the facility. It is possible that the source shut-down all operations including the desulfurization plant for long periods of time during the year.

Table A-6.1: Summary of Monitored
5-Minute Data: 1993-1994

Monitor	No. of 5-min. blocks with exceedances*	Number of hours with exceedances	Number of hours w/o desulfurization	Max 5-min. Value (ppm)	Time of max value reading
1	27	13	6	0.84	4-5 a.m.
2	29	8	3	1.00	4-5 a.m.
3	7	3	3	0.87	4-5 a.m.
4	3	3	2	0.77	11pm-12am
5	2	2	0	0.80	12am-1am
Totals	68	29	14		

*Note: Although violation of the IL program is measured as an exceedance occurring in any 5-minute block of an hour and only 1 hour can be recorded as a violation, this column provides information on the number of multiple exceedances of 0.60 ppm that could occur in an hour.

0.80 ppm). As the table demonstrates, over a 2-year period there were 68 measurements that exceeded the 0.60 ppm concern level. These measurements occurred in a total of 29 hours. Fourteen of the hours that recorded exceedances did not have desulfurization plants in operation at the facilities which would impact the monitor.

With this information and the knowledge that a significant portion of the 1.3 million people living in the area could be affected by the 5-minute exceedances, the regulatory authority decided examine the data more closely to determine if the level of risk to the population warranted action under the IL program. As part of the investigation, the regulatory authority discovered that approximately 55 percent of the hours with exceedances (16 out of 29) were between the times of 11:00 p.m. and 5:00 a.m., while nearly 80 percent of the exceedance hours (23 out of 29) occurred between 9:00 p.m. and 6:00 a.m. In addition, the regulatory authority was not aware of any citizen complaints pertaining to a short-term exposure of SO_2. As a result, the regulatory authority concluded that the public health risk from exposures of concern, that an asthmatic individual would encounter peak SO_2 concentrations while outside and engaged in moderate exercise, is very low due to time of day when these peaks occur. This assessment was reinforced by the absence of complaints about pollution-related breathing difficulties. Based on this assessment of very low public health risk, the regulatory authority concluded that action under the IL program was not warranted. However, the monitored data would continue to be evaluated quarterly to ensure that public health risk did not increase significantly. Copies of the evaluation were provided to the three sources, as well as community environmental groups.

While there would not be any control costs associated with this case study because no remedial action was taken, there would be a minimal cost to the regulatory authority associated with conducting the risk analysis and the quarterly review of the monitoring data. The EPA estimates these costs to range between a tenth of a man year to a fourth of a man year. In addition, it is assumed that the monitoring costs are negligible since the monitoring sites and operations where established to support redesignation of the area to attainment for the NAAQS.

A.7 <u>Case Study 7: One Source Impacting a Rural Community:</u>

This case study evaluates the impact of a single source on a rural community with a total population of less than 1,000. The source is a coal-fired utility power plant that is moderate in size (500 GW) which is located on flat terrain. The State contacted the source regarding the potential for the regulatory authority to begin a risk assessment of 5-minute peaks of SO_2. In response to the notice, the source provided monitor data to the State that indicated the existence of 5-minute peaks that exceed 0.60 ppm. Over a 1-year period the source's monitor that was located 3.8 km from the plant measured a total of 10 short-term peaks, with the majority of the peaks at concentrations near 0.60, but a few of the exceedances reached 0.80 ppm. Additional information provided by the source indicated that the duration of the peaks lasted less than 5-minutes (i.e., 1 to 2 minutes) because of the flat terrain of the area and the quick dispersion of emissions.

Based on this information and the history of the source being in compliance with the SO_2 NAAQS, the State decided that the risk to public health in the area was low and that no further investigation was necessary.

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