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DRAFT

Regulatory Impact Analysis Of National Emissions Standards for Hazardous Air Pollutants for By Product Coke Oven Charging, Door Leaks, and Topside Leaks

Draft:
Regulatory Impact Analysis

for

National Emissions Standards for Hazardous Air Pollutants
for
By-Product Coke Oven Charging, Door Leaks, and Topside Leaks

Emission Standards Division

U.S. Environmental Protection Agency
Office of Air and Radiation
Office of Air Quality Planning and Standards
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EXECUTIVE SUMMARY

The Environmental Protection Agency (EPA) has developed a National Emissions Standard for Hazardous Air Pollutants (NESHAP) regulations for emissions from by-product coke oven batteries, both new and existing, under the authority of section 112(b)(1)(A) of the Clean Air Act Amendments of 1990. This decision is based on evidence from EPA and state agency studies that coke oven batteries release air pollutants that have adverse effects on both public health and welfare.

Air pollutants from coke oven batteries are emitted from charging operations, door leaks, topside leaks, and process upsets. The emissions contain benzene soluble organics (BSO) and other carcinogens such as beryllium, benzene, and arsenic. As a result, coke oven emissions were classified as a Class I carcinogen and listed as a hazardous air pollutant under the Clean Air Act in September 1984[a] with new levels of control being specified in the Clean Air Act, as amended in November 1990.

Because coke is used as an input both in traditional steel-making and in the production of iron castings in the cupolas of foundries, the market for coke actually comprises two distinctly separate markets: the market for furnace coke (used to produce steel), and the market for foundry coke (used to produce iron castings). Where possible, the impacts associated with each type of coke product is analyzed.

During the development of the regulation, the EPA entered into regulatory negotiations with industry, labor unions, states, and environmental groups. The resulting requirements for the control of emissions from coke oven batteries differs somewhat from the emission limits mandated by the CAAA. However, due to time constraints and the ever-changing aspects of a regulatory negotiation, the following analyses are based on the emission limits set by the CAAA.

The standard requires compliance with maximum achievable control technology (MACT) by 1993 and lowest achievable emission rate (LAER) by 1998. The EPA's best estimate of the total annual cost of compliance with MACT is $25 million, while LAER is anticipated to cost $46 million annually. It should be noted that the emission reductions and costs associated with LAER include those incurred by achieving MACT in 1993. The annual cost of controlling emissions from process upsets with the use of flares is $2.8 million annually.

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[a] Research Triangle Institute. Economic Analysis of Air Pollution Regulation: By-Product Coke Ovens. Final report prepared for the U.S. Environmental Protection Agency, OAQPS. Research Triangle Park, N.C. Publication No. RTI/4853-33 DR. August 1991. pp. 1-1.

Economic impacts associated with the standard are minimal with small market changes in price and quantity. The price of furnace coke is expected to increase under MACT by 0.22 percent (with a quantity decrease of 0.66 percent) and by 0.68 percent under LAER (with a quantity decrease of 2.13 percent). In the foundry coke sector, price may increase by 0.80 percent under MACT (with a quantity decrease of 1.08 percent). The price increase under LAER could reach 2.53 percent (with a quantity decrease of 2.6 percent). As with the cost estimates, the impacts associated with LAER include the impacts incurred under MACT. Only two batteries are expected to close under LAER for furnace coke, and at most, one battery would close in the foundry coke market. This assumes that the decrease in quantity produced is completely absorbed by these batteries, rather than all batteries sharing the burden of decreased production. Additionally, the small business impact is expected to be minimal. While some of the small firms will experience adverse impacts, two of these firms are expected to experience increased profits as a result of the regulation.

The benefits of reduced coke oven emissions are quantified for three benefit categories: morbidity, mortality, and household soiling. Time and resource constraints preclude quantification of all potential benefits of the regulation. These benefits are discussed qualitatively in Chapter 7. The quantified benefits associated with MACT range from \$2.8 million to \$18.0 million annually, while the benefits of LAER range from \$3.3 million to \$20.7 million annually. The monetary value of emission reductions for flares range from \$4.2 million to 26.5 million annually.

Measuring net benefits in a benefit-cost analysis is one way of determining the efficiency of a regulation. Because the benefits presented in Chapter 7 are quantified for only three benefit categories, the EPA cannot conclude that the benefits outweigh the costs of the regulation. Another method of coming to an efficient resolution to an externality is through negotiation. As mentioned previously, the EPA entered into regulatory negotiations with the affected parties to come to an efficient solution. The outcome of the negotiation is presented in Chapter 4.

CONTENTS

TABLES

FIGURES

ACRONYMS, DEFINITIONS, AND CONVERSIONS

ACRONYMS

ACCCI	American Coke and Coal Chemicals Institute
AISA	American Iron and Steel Institute
BG/EDs	Block Group/Enumeration Districts
BID	Background Information Document
BSO	Benzene Soluble Organics
CAA	Clean Air Act
CAAA	Clean Air Act Amendments of 1990
CFR	Code of Federal Regulations
CPI-U	Consumer Price Index - All Urban Consumers
EPA	Environmental Protection Agency
FR	Federal Register
HAP	Hazardous Air Pollutant
HEM	Human Exposure Model
HIS	Health Interview Survey
H_2S	Hydrogen Sulfide
IARC	International Agency for Research on Cancer
ISCLT	Industrial Source Complex Model - Long Term
LAER	Lowest Achievable Emission Rate
MACT	Maximum Achievable Control Technology
NESHAP	National Emission Standards for Hazardous Air Pollutants
OAQPS	Office of Air Quality Planning and Standards
OSHA	Occupational Safety and Health Administration

PLD	Percent Leaking Door
PLL	Percent Leaking Lids
PLO	Percent Leaking Offtakes
RAD	Restricted Activity Days
RCRA	Resource Conservation and Recovery Act
RFA	Regulatory Flexibility Act; also, Regulatory Flexibility Analysis
RIA	Regulatory Impact Analysis
RRAD	Respiratory-Related Restricted Activity Days
SHEAR	Systems Applications Human Exposure and Risk Model
SIC	Standard Industrial Classification
SIP	State Implementation Plan
SO_2	Sulfur Dioxide
TSP	Total Suspended Particulate
VOC	Volatile Organic Compound
WLD	Work Loss Days

ECONOMIC, REGULATORY, AND SCIENTIFIC TERMS

§112	Section of Title III in the CAAA that requires EPA to promulgate regulations establishing emission standards for new and existing sources of HAP emissions for By Product for Coke Ovens
1991 $	Constant (real) dollars at their fourth quarter 1991 value
Annual Costs	Annualized capital plus annual operating costs
$\mu g/m^3$	Micogram (10^{-6} gram)
Title III	The third title of the CAAA that lists the 189 HAP's to be controlled with MACT, as well as the the control of major and area sources.

UNITS AND CONVERSIONS

This report uses metric units, some of which may not be familiar to all readers. The EPA is required by Congress to use metric measurements. The following is a short guide to the units and their conversions.

Conversions To Approximate	As	Multiply by
Mg (megagram)	Ton (2,000 lb)	1.1
scm (standard cubic meter)	scf(standard cubic foot)	35.3
MJ (megajoule)	Btu (British thermal unit)	949
MW (megawatt)	Btu/second	949
kg (kilogram)	lb (pound)	2.2

CHAPTER 1

BACKGROUND

1.1 THE COKING PROCESS

Iron and steel are refined metals used for making several various products. In a series of processes, refined iron ore is manipulated to produce iron metals, which are then used in the production of steel. Coke is a chief fuel used in blast furnaces for the conversion of iron ore into iron. Coke is also used by a number of other industries, principally iron foundries, nonferrous smelters, and chemical plants.

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. It is produced in a coke oven by driving off the volatile compounds in the coal, leaving a strong residue that contains a high percentage of carbon and relatively few impurities. The particular mix of high- and low-volatile coals used, and the length of time the coal is heated determine the type of coke produced. Furnace coke, used as a fuel in blast furnaces, is produced by baking a coal mix of 10 to 30 percent low-volatile coal for 15 to 18 hours. Foundry coke, used as a fuel in the cupolas of foundries, is produced by baking a mix of 50 percent or more low-volatile coal for 25 to 30 hours[1].

The coking procedure is performed in ovens that are constructed in groups with common side walls, called batteries. A typical coke oven battery is shown in Figure 1-1. During the coking process, coal is fed into the coke oven battery (charged) 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 ammonium sulfate are recovered as part of the production process.

The cleaned gas is used to underfire the coke ovens and for fuel elsewhere in the plant[2].

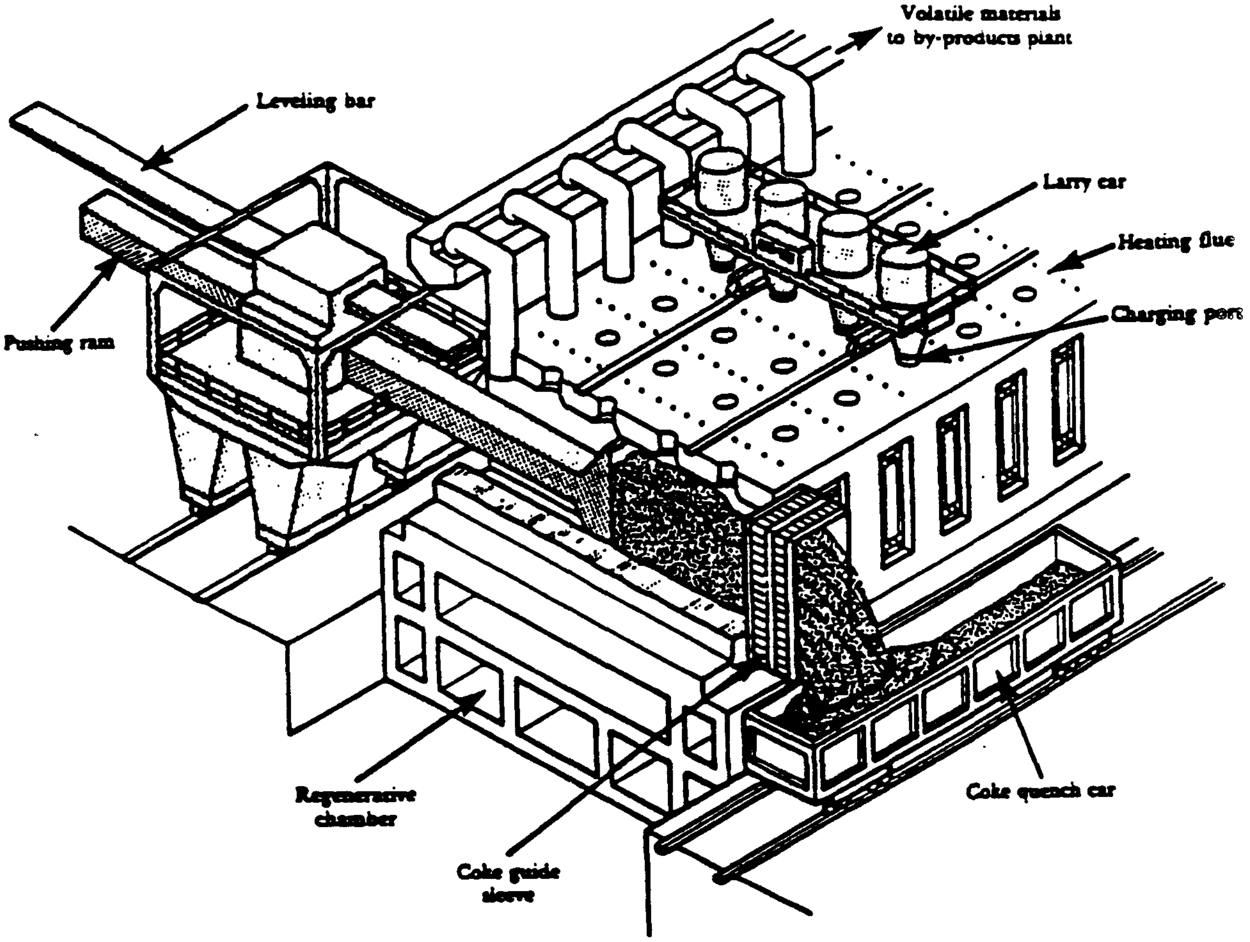

Figure 1.1[a]
A Typical Coke Oven Battery

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[a] Air Pollution Training Institute. Air Pollution Control Systems for Selected Industries. U.S. Environmental Protection Agency. Research Triangle Park, N.C. Course No. SI:431, Publication No. EPA 450/2-82-006. June 1983. pp. 10-4.

Coke oven emissions contain benzene soluble organics (BSO) and other carcinogens such as beryllium, benzene, and arsenic. In a coke battery, emissions occur from a number of locations or operations. These include the following:

- charging operations
- topside leaks[b]
- door leaks
- pushing operations
- quenching operations, and
- coke battery combustion stacks.

As a result of the pollutants contained in these emission sources, coke oven emissions were classified as a Class I carcinogen and listed as a hazardous air pollutant under the Clean Air Act in September 1984[3]. The proposed NESHAP concentrates on the control of emissions from charging operations, doors, and topsides (lids and offtakes). The remaining emission points are on the ten year bin source category list and will be considered for regulation at a later date.

1.2 LEGAL HISTORY

EPA first addressed coke ovens in the late 1970s. A standard was proposed in 1987, but it was held in abeyance due to the anticipated requirements of the CAAA. The new regulations are required by Title II of the Act, and Title III provides for a reduction in adverse effects of hazardous air pollutants from new and existing sources. Under §112 of the CAAA, EPA is required to set allowable emission limits for coke oven doors, lids, removals (offtakes), and seconds of charging[4].

1.3 STATUTORY PROVISIONS

The Clean Air Act requires standards of maximum achievable control technology (MACT) for existing sources, lowest achievable emissions rate (LAER) for existing sources, MACT for new sources, and work practices. When considering limits for MACT for existing sources, the CAAA specify that these standards are to require at a minimum that coke oven emissions not exceed 8 percent leaking doors (PLD), 1 percent leaking lids (PLL), 5 percent leaking offtakes (PLO), and 16 seconds of visible emissions per charge. In establishing the standards, the use of luting compounds to prevent door leaks and the use of nonrecovery technologies as the basis for standards for new sources have been evaluated. Existing coke oven batteries are to comply with the

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[b] Topside leaks refers to leaks from lids and offtakes.

proposed standard by December 31, 1995, and new batteries will comply with MACT for new sources upon start-up[5].

Section 112(d)(8) also requires promulgation of work practice regulations for new and existing coke oven batteries. Existing batteries must comply with the work practice regulations by November 15, 1993. The CAAA specify that the work practice regulations require, as appropriate, the use of luting compounds, if the EPA determines they are an effective means of controlling leaks, as well as door and jam cleaning practices.

Section 112(f) also requires EPA to promulgate residual risk standards in the year 2000. Coke oven batteries would be required to comply with these limits by December 31, 2003. Section 112(f) permits an owner or operator of a coke oven battery to defer meeting the residual risk limit until the year 2020 provided that the following requirements are met[6]:

- By November 15, 1993, batteries must not exceed 8 PLD, 1 PLL, 5 PLO, and 16 seconds of visible emissions per charge.

- By January 1, 1998, the batteries must meet the LAER standard that is defined for a coke oven battery that is rebuilt or replacements at a coke oven plant for an existing battery, or any subsequent revision of LAER. The Act requires that these limits may be no less stringent that 3 PLD for doors less that 6 meters tall, and 5 PLD for doors 6 meters or taller; 1 PLL; 4 PLO; and, 16 seconds of visible emissions per charge. An exclusion may be considered for emissions from doors during a period after the closing of self-sealing oven doors or the total mass emissions equivalent.

- By January 1, 2000, the owner or operator must make available to the surrounding community the results of any risk assessment performed by the EPA to determine the appropriate level of residual risk standard.

1.4 EXECUTIVE ORDER 12291

On February 17, 1981, President Reagan issued Executive Order 12291, which requires the EPA to prepare Regulatory Impact Analyses (RIA's) for all "major rules"[7]. A "major rule" consists of any regulation that is likely to result in an annual effect on the economy of $100 million or more, a major increase in costs or prices, or significant adverse effects on employment, competition, investments, productivity, innovation, or on the ability of the United States-based enterprises to compete with foreign-based enterprises in domestic or export markets[8,9]. The EPA considers the regulation for Coke Oven Emissions to be major and thus is issuing this RIA.

Along with requiring an analysis of benefits and costs, Executive Order 12291 specifies that EPA, to the extent allowed by the Clean Air Act (CAA) and court orders, demonstrate: (1) that the benefits of the Coke Oven regulation will outweigh the costs, and (2) that the maximum level of net benefits will be reached. This document reviews the need for the regulation (chapter 2), control techniques (chapter 3), regulatory options (chapter 4), costs of control (chapter 5), economic impacts (chapter 6), benefits of the regulation (chapter 7), and a comparison of the benefits and costs associated with the regulation (chapter 8).

All analyses presented in this RIA are based on the emission limits set by the CAAA. During the development of the NESHAP for Coke Ovens, the EPA entered into regulatory negotiations with industry. Because the level of control recommended by the regulatory negotiation committee was just recently reached, time and resource constraints limit the ability of re-evaluating the analyses of costs, benefits, and economic impacts based on the suggested levels of control.

In the analysis of costs associated with the emission limits set by the CAAA, all estimates were accumulated on a plant-by-plant basis and reviewed extensively by the Regulatory Negotiation Cost Work Group. To provide a summary of these costs and to avoid exposing information deemed confidential by industry, the overall costs to a plant of complying with MACT and LAER are presented as total capital and annual costs.

Monetized estimates of benefits for three of the health and welfare components are presented in Chapter 7. These benefit categories include: mortality, morbidity, and household soiling. Data, time, and resource limitations preclude a quantitative analysis for all potential benefit categories. These benefits are qualitatively discussed in Chapter 7.

1.5 GUIDE TO REFERENCES

The composition of this RIA is mostly a summary of research reports, analyses, correspondence, minutes of various meetings and hearings, policy directives, legal notices, laws, regulations, and other documents related to Coke Oven operations. The principal references are listed in the back of the chapter on the subject of interest to you. Consult these references, as well as the preambles that accompany proposal of the regulation for Coke Ovens in the Federal Register, for more details.

for Coke Ovens in the Federal Register, for more details. References are held in public dockets and are available for inspection and copying. For more information on the docket, contact:

Air Docket
Maildrop: LE-131
Waterside Mall, Rm. M-1500
401 M. Street, SW
Washington, D.C. 20460

Hours: 8:00 a.m. to 3:30 p.m.
Phone: (202) 382-7549

Refer to Docket #A-79-15 for all material relating to this regulation.

REFERENCES

1. Research Triangle Institute. Economic Analysis of Air Pollution Regulations: By-Product Coke Ovens. Final Report prepared for U.S. Environmental Protection Agency, OAQPS. Research Triangle Park, N.C. Publication No. RTI/5153-9 FR. June 1992. pp. 1-1.
2. Reference 1, pp. 1-1.
3. Reference 1, pp. 1-1.
4. U.S. Federal Register. Volume 57, Number 10, Notices. January 15, 1992. pp. 1730.
5. Reference 4, pp. 1730-1731.
6. Reference 4, pp. 1732.
7. U.S. Office of the President. Federal Regulation, Executive Order 12291. February 17, 1981.
8. U.S. Environmental Protection Agency; Office of Policy, Planning, and Evaluation; Office of Policy Analysis. Guidelines for Performing Regulatory Impact Analyses. Publication No. EPA 1230-01-84-003. December 1983 with updates through March 1988. pp. 3.
9. U.S. Office of Management and Budget. Regulatory Impact Analysis Guidance. Appendix V of Regulatory Program of the United States Government. April 1, 1988 through March 31, 1989.

CHAPTER 2

NEED FOR THE REGULATION

2.1 THE POLLUTION PROBLEM

Section 112 of the Clean Air Act defines a hazardous air pollutant as one which "in the judgement of the Administrator causes, or contributes to, air pollution which may reasonably be anticipated to result in an increase in mortality or an increase in serious irreversible, or incapacitating reversible illness"[1]. The toxic constituents of coke oven emissions include both gases and respirable particulate matter with a varying chemical composition including BSO, and other carcinogens such as beryllium, benzene, and arsenic[2]. There is, therefore, concern over the potential health risks caused by long-term exposure to particulate matter and gases contained in coke oven emissions.

As a result, the EPA listed coke oven emissions as a HAP under §112(b)(1)(A) of the Act on September 18, 1984. The passage of the Clean Air Act Amendments in November 1990 reinforced the list of HAPs. Section 112(d)(8) of the amendments specifies the actions to be taken to implement Emission Standards for Coke Ovens. The listing is supported by occupational exposure studies of coke oven workers that show statistically significant excess mortality from cancers of the respiratory tract, kidney, prostate, and all cancer sites combined. Based on the entire set of health studies, the Administrator concluded that coke oven emissions present a significant risk of cancer to the public. In addition, coke oven emissions in the presence of an air inversion also may be related to episodes of asthma, bronchitis, and other acute respiratory conditions in both children and adults[3].

Because compliance with the proposed coke oven emission regulations would be achieved through the containment of emissions in the oven rather than through the collection and removal of emissions by a pollution control device, the current level of water effluent discharges, solid waste, energy use, and noise would be unchanged[4]. Subsection 2.2.3 provides more detail on the health risks of the pollutants of coke oven emissions.

2.2 NEED FOR REGULATION

2.2.1 Market Failure

The U.S. Office of Management and Budget (OMB) directs regulatory agencies to demonstrate the need for a major rule. The regulatory impact analysis must show that market failure exists and that it cannot be resolved by measures other than Federal regulation[5]. Market failures are categorized by OMB as *externalities, natural monopolies,* or *inadequate information.* The following paragraphs address the three categories of market failure. Chapter 4 discusses the regulatory options and the requirements for a federal regulation under the CAAA of 1990.

2.2.1.1 ***Air Pollution as an Externality.*** Air pollution is an example of a negative externality. This means that, in the absence of government regulation, the decisions of generators of air pollution do not fully reflect the costs associated with the pollution. For a coke oven battery operator, pollution from coke oven emissions is a by-product that can be ignored or disposed of cheaply by venting it to the atmosphere. Other than his concerns for meeting OSHA requirements, the coke oven battery operator does not fully realize the social cost of the pollution created, and do not "internalize" the damage caused by emissions. This damage is born by society, and the receptors - the people who are adversely affected by the pollution - are not able to collect compensation to offset their costs. They cannot collect compensation because the adverse effects, like increased risks of morbidity and mortality, are by and large, non-market goods (that is, goods that are not explicitly and routinely traded in organized free markets).

Consider an example. It may be somewhat unreal, but it illustrates why air pollution is a market externality. A young man estimates that over his remaining lifetime he has a risk of getting cancer of, let's say, 4 chances in 10. A new coke oven battery is being constructed in his neighborhood, and he pessimistically calculates that the added pollution to his own environment will boost his odds of getting cancer to, say, 5 chances in 10. He walks up to the owners of the coke oven battery and offers to "sell his exposure" to the air pollution generated by the coke oven battery for a bargain basement price of just $5 a day. For his efforts he gets no more than a laugh. What's wrong? Most young men either would be unwilling to even consider such a transaction, or, if they were willing, they would not know enough about their futures and about the effects of the pollution to set such a precise price. Furthermore, even if they are willing and did have a price, they would not have any good way of coming to terms with the coke oven battery owners. The owners have little incentive to pay anything to the receptors of the air pollution. Little incentive, that is, unless government requires them to pay or to reduce the pollution.

How would it help to force coke oven batteries either to compensate the people suffering the consequences of the pollution, or simply to reduce the pollution? Where there are negative externalities like air pollution, the market price of goods and services does not fully reflect the costs borne by receptors of air pollution, generated in the course of producing the goods and services. Government regulation can be used to improve the situation. The proposed NESHAP will increase the cost of production of coke to include not only the actual production costs, but also the cost of damages to the atmosphere created from the pollution generated by coke production. This increase in cost will force coke oven battery owners and operators to reduce the amount of air pollution they emit. With the NESHAP in effect, what coke oven battery owners and operators must spend to operate may more closely approximate the full social costs of coke production. This does not, however, imply that total control is most efficient since coke producers may still choose to emit pollutants even if they are required to pay all social costs of production. Overall, if we could internalize all negative externalities in the country - including, of course, those from coking - society's allocation of resources would be improved.

2.2.1.2 ***Natural Monopoly.*** Another cause for government intervention to bring about a socially optimal allocation of resources is when a natural monopoly exists. When there are relatively few firms in an industry, due to some barrier to entry (i.e. heavy up-front capital needed to enter), these firms have a majority of the power to influence prices and quantities of the good in the market. The monopolistic power that naturally occurs in this type of market does not provide the competitive market checks and balances that are needed to ensure the best utilization of society's resources.

Because the majority of coke production (with the exception of foundry coke) is produced and used internally, it is difficult to evaluate a market for coke directly. Instead, we must look at trends in related markets, like steel, to estimate the market for coke. The steel industry, in general, is a relatively competitive market. Final products of steel are imported and exported, creating competition for market share among producers domestically and internationally. In recent years, however, the steel industry in the United States has experienced a decline in output. Technical changes in steel manufacturing in the near future will result in a decreased quantity of coke required per ton of steel produced[6]. In 1980, there were 60 plants in operation with 195 batteries. During the period from 1980 to 1991, the number of plants fell to 32, and the number of operating batteries declined by more than 50 percent, to 90 batteries[7] (additional closures are expected during the development of the NESHAP). This decreasing demand has limited the number of firms in the industry, but this does not indicate that a natural monopoly exists.

Overall, the lack of competition in the steel industry (and coke industry) is not a problem. Therefore, the proposed NESHAP is not designed to address this problem.

2.2.1.3 *Inadequate Information.* The third category of potential market failure that sometimes is used to justify government regulation is inadequate information. As stated in the Guidelines to Performing Regulatory Impact Analysis[8], the optimum level of information is not necessarily the maximum possible amount, because information, like other goods, should not be produced when the costs of doing so exceed the benefits.

It would certainly be costly to have each individual in the country to search for information on the emissions of coke ovens by travelling to each facility and gathering data. Although the amount of coke oven emissions currently placed in the atmosphere and its toxicity is not open information to the general public, the flow of information on control techniques and work practices is adequate and does not create a category of market failure under inadequate information. This information, while not provided by the producers of coke oven emissions, may be supplied by news media, consumer and environmental groups, public health agencies and similar services.

Regulatory intervention to address and information problem will not be undertaken for this NESHAP due to the lack of substantial reason to believe that private incentives to provide information are seriously inadequate. The fact that industry representatives and environmental groups are willing to negotiate throughout this regulatory process shows a fairly free-flowing rate of information.

2.2.2 Harmful Effects of Coke Oven Air Emissions

The toxic constituents of coke oven emissions include both gases and respirable particulate matter with a varying chemical composition. Historically, the greatest attention has been focused on toxic effects of the benzene soluble organic (BSO) portion of particulate matter emitted from coke ovens, because this fraction includes compounds that are known animal carcinogens. In addition, beryllium, benzene, and arsenic are known carcinogens emitted from coke ovens. There is also concern over the potential health risks caused by long-term exposure to trace metals (e.g. cadmium, chromium, lead, and nickel) and gases (e.g. hydrogen sulfide, carbon monoxide, nitric oxide and sulfur dioxide) contained in the coke oven emissions[9].

As mentioned earlier, the listing of coke oven emissions as a hazardous air pollutant under §112 of the Act is supported by occupational exposure studies of coke oven workers that show statistically significant excess mortality from cancers of the respiratory tract, kidney, and prostate, and all cancer sites combined. There is sufficient evidence for carcinogenicity in humans and experimental animals for the International Agency for Research on Cancer (IARC) to classify coke oven emissions as Category 1, meaning that this mixture is carcinogenic to humans[10].

2.3 CONSEQUENCES OF REGULATION

2.3.1 Consequences if EPA's Emission Reduction Objectives are Met

2.3.1.1 *Allocation of Resources.* There will be improved allocation of resources associated with coke production. Specifically, more of the costs of the harmful effects of coke production will be internalized by coke oven plants. This, in turn, will affect consumers' decisions on whether, where, how, and how much of a product produced using coke (i.e. iron and steel products) to use. To the extent these newly-internalized costs are then passed along to these consumers, and to the extent these people are free to buy as much or as little of the products of coke as they wish, they will purchase less (relative to their purchases of other competing services). If this same process of internalizing negative externalities occurs throughout the entire coke producing industry, an economically optimal situation is approached. This is the situation when the marginal cost of the resources devoted to coke production equals the marginal value of the products to the people who are using the products produced using coke. There are many "ifs" in this chain of events. It is easy to cite situations where the air pollution control costs will not ripple through as suggested here and effect decisions by the consumers of coke-produced products. Nevertheless, in the aggregate and in the long run, the proposed NESHAP will move society toward this economically optimal situation.

2.3.1.2 *Emissions Reductions and Air Quality.* Under the proposed standard, it is estimated that emissions of coke oven air pollutants will be reduced by 66 percent per year under MACT and by 84 percent per year under LAER. For more information on this topic, refer to Chapter 7 on the benefits of the regulation. Air quality will improve, however, this analysis does not translate emission reductions into ambient air quality improvements.

2.3.1.3 *Costs, Benefits, and Economic Impacts.* The national annual cost of emission control under MACT will increase by approximately $25 to $33 million by 1995. The estimated annual cost of emission control under LAER is $46 to $57 million by 1998. Expected benefits include reduced risks for mortality, morbidity, and other adverse health and welfare effects from lower levels of VOC emission reductions (Reference: Chapters 7 and 8). The resulting NESHAP will create relatively small market changes in price and quantity, and result in , at most, two battery closures. Additionally, the impacts on small coke producers is minimal (Reference: Chapter 6).

2.3.1.4 ***Water Quality, Solid Waste, and Energy Impacts.*** As previously mentioned, because compliance with the proposed coke oven emission regulations would be achieved through the containment of emissions in the oven rather than through the collections and removal of emissions by a pollution control device, the current level of water effluent discharges, solid waste, and noise would be unchanged[11]. A minor increase in energy use may occur from the coke by-product removal. This impact, however, is insignificant and is not considered in the analyses that follow.

2.3.1.5 *Technological Innovation.* Section 112 of the CAA regulations serve to disseminate both pollution control and coke oven battery technology, and to stimulate further technological development. Coke oven facility constructors have the freedom to seek the most economical way to comply with standards. The proposed NESHAP may promote the sharing of technology with other countries, and probably will open new directions of research in coke production technology.

2.3.1.6 *State Regulation and New Source Review.* State regulatory programs will be strengthened. The NESHAP will be delegated to the states for enforcement. Assuming states do not pull resources from other programs to handle their enlarged responsibilities, there will be a natural strengthening of state air pollution control staffs. Recognition that the NESHAP is effectively reducing emissions will expedite the state process of reviewing applications for new coke oven batteries and issuing permits for their construction and operation. There will be less controversy involved. Finally, state regulations will be uniform, and the disadvantages of the piecemeal approach to emission regulation will be avoided.

2.3.2 Consequences if EPA's Emission Reduction Objectives are *not* Met

The most obvious consequence of failure to meet EPA's emission reduction objectives would be emissions reductions and benefits that are not as large as EPA is projecting. However, costs are not likely to be as large either. Whether it is noncompliance from ignorance or error, or from willful intent, or simply slow compliance due to owners and/or operators exercising legal delays, poor compliance can save some resources money. Unless states respond by pouring more resources into enforcement, then poor compliance could bring with it smaller aggregate nationwide control costs. EPA has not included an allowance for poor compliance in its estimates of emissions reductions. This is because the potential effects of poor compliance are expected to be minor.

If the emission control devices degraded rapidly over time or in some other way did not function as expected, there could be a misallocation of resources. This situation is very unlikely because the NESHAP is based on demonstrated technology. Other ways the regulation could fail are conceivable.

REFERENCES

1. U.S. Congress. The Clean Air Act of 1970, § 112.

2. Research Triangle Institute. Economic Analysis of Air Pollution Regulations: By-Product Coke Ovens. Final Report prepared for U.S. Environmental Protection Agency, OAQPS. RTI Project No. 5153-9 FR. June 1992. pp. 4.1-4.5.

3. U.S. Congress. The Clean Air Act, as amended. Title III, §112. November 15, 1990.

4. Federal Register. Volume 52, No. 78; 40 CFR Part 61. U.S. Environmental Protection Agency. April 23, 1987. pp. 13586-13686.

5. U.S. Office of Management and Budget. Regulatory Impact Analysis Guidance. Appendix V of Regulatory Program of the United States Government. April 1, 1988 through March 31, 1989.

6. Reference 2, pp. 2-1.

7. Reference 2, pp. 3-7.

8. U.S. Environmental Protection Agency; Office of Policy, Planning, and Evaluation; Office of Policy Analysis. Guidelines for Performing Regulatory Impact Analyses. Publication No. EPA 1230-01-84-003. December 1983 with updates through march 1988. pp.

9. Reference 4, pp. 13587.

10. Reference 4, pp. 13587.

11. Reference 4, pp. 13596

CHAPTER 3

CONTROL TECHNIQUES

This chapter discusses the technology for control of emissions from wet-coal charging, oven door leaks, and topside leaks during coking.

3.1 TECHNOLOGY FOR THE CONTROL OF EMISSIONS FROM CHARGING

Charging practices have been altered by past efforts of regulatory agencies and coke oven operators to reduce emissions. In the past, the most common procedure was to isolate the gas-collection system from the oven and charge the coal into the red-hot ovens simultaneously through three to five charging holes in the top of the oven. When the moist coal entered the hot oven, it displaced the air. This displacement and the immediate gasification of moisture and volatile components of the coal caused the oven pressure to rise sharply. Because the gas-collection system was blocked off, the only escape for the smoke, hydrocarbons, gases, and steam was to the atmosphere through any opening. Techniques to control these emissions are discussed in this section.

Investigations have revealed that successful control of these emissions is often more dependent on adherence to specified work practices and operating procedures than on the design of charging equipment. Consequently, the following discussion will concentrate on these procedures as well as required equipment modifications. The one control system (or procedure) used at present is stage charging.

3.1.1 Stage Charging

Stage charging was first developed in England in the 1950's and was more recently applied in the United States. Although there are necessary equipment requirements, these do not include conventional air pollution control devices such fabric filters, electrostatic precipitators, and scrubbers.

Stage charging is the ordered pouring of coal into the oven so that, regardless of coal flow, a consistent exit space is maintained for gas. The larry car hoppers are discharged in an ordered sequence so that an open tunnelhead is maintained at the top of the oven until the last hopper is discharged. Emissions are effectively contained in the ovens and collecting mains by steam aspiration, and they are exhausted through the regular gas handling equipment.[1] Successful stage charging is dependent on many factors such as equipment design, maintenance, and operating procedures. Each factor is significant; failure in only one area can negate all the money and effort expended in the other areas.

3.1.1.1 ***Description of Stage Charging.*** Stage charging is primarily an operating technique based on a predetermined sequence for simultaneously charging coal from one or two larry car hoppers into the incandescent ovens. The ovens are maintained under a slight negative pressure by applying steam aspiration in the goosenecks of the offtake. The assembly that comprises the standpipe and gooseneck is often called the offtake or ascension pipe. The stage charging technique is uncomplicated but requires close attention to detail. The most important aspects of stage charging are good aspiration and the operating crew's strict adherence to specific charging and leveling practices.[2]

Perhaps the most important ingredient of a good stage charge is adequate aspiration from the oven. In essence, a slightly negative pressure must be maintained at every open charging port throughout the entire charge. Steam is the common aspiration fluid, although it has been reported that liquor sprays can achieve stronger aspiration.[3] Other advantages reported for the liquor sprays are less frequent cleaning of nozzles and less steam, condensate, and heat in the effluent from the mains. However, aspiration efficiency of steam and liquor sprays is sensitive to the flow and pressure maintained at the nozzles. Steam pressures and nozzle sizes necessary for adequate aspiration vary from plant to plant depending on factors such as offtake design and amount of air leakage into the oven. To ensure adequate aspiration, the stream nozzles require frequent inspection and cleaning.

The rate at which gases can be aspirated from an oven must be limited. Too high a rate can pull an excessive amount of coal dust into the collecting mains. Therefore, aspiration systems are carefully designed to provide just enough draft on the oven to prevent emissions during the charging cycle.

Timely removal and replacement of the lids on the charging ports is crucial to good stage charging. For this, both manual or automated methods can be used. The most common manual method uses hydraulically operated electromagnets.[4] Either method can be effective, although the automated system may reduce the incidence of improper alignment of the lids. Any mechanical system must allow the lids to be moved individually.

Another necessary aid used to minimize emissions is a seal which closes the opening between the leveler bar and the chuck door when the bar is in the oven. As previously discussed, any air that enters the oven thwarts the aspiration system. A seal, commonly referred to as a leveler boot, can be used throughout the charge to preclude any air intrusion at the chuck door. To operate without air leakage, the leveler bar is extended to the chuck door opening the seal before initiating the charge. The opening remains sealed until the leveler bar is retracted at the end of the charge.

Even with an adequate flow of the aspirating fluid through clean nozzles, the system may fail if the standpipes and goosenecks do not provide a clear passage for the gases to flow from the oven. During the coking cycle, carbon deposits reduce the cross-sectional area of the standpipes and goosenecks. Well-controlled stage charging can be achieved only if these deposits are removed before every charge as a routine part of the charging process.

Carbon deposits on the roof of the oven must be removed before every charge to ensure unimpeded gas flow across the top of the oven. This roof carbon is removed by blades that are mounted on the top of the pusher ram and that scrape the carbon off as the coke is pushed. Sometimes high-pressure air jets mounted at the top of the ram are used to provide better cleaning. Even if all other forms of emission control are operating perfectly, failure to remove excessive roof carbon may result in poor emission control.[5]

Another essential factor to good emission control is to ensure that the entire length of the oven is under vacuum. On a new plant, this condition can best be achieved with two mains, standpipes, and aspiration systems. One main is placed at each end of the ovens. If the coal blocks the open space at the top of the oven each side of the blockage will remain under vacuum.

An obvious design consideration is the amount of coal in each hopper of the larry car. This amount is predetermined so that the coal dumped from all but the last hopper will peak below the "coal line." The amount of coal placed in each hopper depends on the size of the oven, the number of charging holes, and the angle of repose assumed by the coal. This angle of repose is influenced by the bulk density of the coal, oil additives, moisture content, and the particle size to which the coal is ground. The amount placed in each hopper varies from plant to plant, depending on the three factors mentioned earlier.

Just before charging the coal, the larry car must be accurately aligned over the charging holes. Poor alignment can result in spillage of coal on the top of the battery where the coal is heated and excess emissions are produced. A poor fit between the drop sleeves and charging hole permits excessive air leakage into the oven. Air drawn into the oven may overpower the aspiration system. When the gas volume exceeds the capability of the aspiration system, pressure will rise elsewhere in the oven, and emissions may escape to the atmosphere.

Stage charging achieves a marked reduction in emissions by aspiration of air into the by-products system from points where otherwise pollutant gases and smoke are emitted. The aspiration steam and the inspired air significantly affect the by-product plant. Furthermore, aspiration can cause coal fines to be entrained into the by-product system. The steam increases the wastewater load, the air increases the density and reduces the heating value of the coke oven gas, and the coal fines tend to reduce the acceptability of the coal-tar pitch to the manufacturers of carbon or synthetic graphite electrodes, a major end use. Careful attention to the selection of nozzle dimensions and steam pressure, coupled with adherence to procedures which avoid needless air leakage into the system, can usually decrease the problem of coal fines. The primary cooler system usually removes tar "sludge" containing the coarser coal particles.[6]

3.1.1.2 Optimizing Stage Charging. Optimizing stage charging generally is a function of the performance of the battery workers, particularly the battery top workers. A detailed, written procedure, an effective training program, and coordination of the battery top worker's activity are required. A few of the important worker job functions are listed below:

* Inspection and cleaning of the gooseneck.

* Prompt lid replacement.

* Prompt luting of lids.

* Turning the aspiration system on and off.

* Observing the position of drop sleeves.

* Spotting the larry car.

* Notifying the larry car operator if the car is improperly spotted.

* Continuing a program of cleaning and maintenance.

* Consistently following operating procedures.

A study of a specific battery's operation would aid in developing an optimum written procedure and effective training program. In addition, such a study may reveal minor equipment modifications that are peculiar to that specific battery and may dramatically improve control. For example, CF&I discovered that altering the steam nozzles improved aspiration for their particular case. The company also discovered that constructing a platform for inspecting goosenecks improved the gooseneck inspection and cleaning procedure. Worker coordination, training, and communication were also improved.[7]

3.2 TECHNOLOGY FOR THE CONTROL OF DOOR LEAKS

Because charging takes only a few minutes, while coking continues for many hours, it might seem that door leaks are a much more serious and pervasive problem than charging emissions. However, outward leakage from any given door (2 per oven in a battery of perhaps 50 ovens) may occur near the beginning of the cycle and inward leakage may occur later. Inward leakage of air affects the utility of the coke oven gas; therefore, coke oven operators were concerned about door leakage before most regulatory agencies were formed.

Control techniques for coke oven door emissions may be separated into four basic categories:

- Oven door seal technology,
- Pressure differential devices,
- Hoods and sheds over doors, and
- Operating and maintenance procedures.

The first category relies on the principle of producing a resistance to the flow of gases out of the coke oven. This resistance may be produced by a metal-to-metal (or hard) seal, a resilient soft seal, or a luted seal. Small cracks and defects in the seal permit pollutants to escape from the coke oven early in the cycle. The magnitude of the oven door seal leak is determined by three factors: (1) size of the opening, (2) the pressure drop between the oven and the atmosphere, and (3) the composition of the emission.

The effectiveness of a pressure differential control device depends on the ability of the device to reduce or reverse the pressure differential across any defects in the door seal. These systems either provide a channel to permit gases evolved at the bottom of the oven to escape to the collecting main or provide external pressure on the seal through the use of steam or inert gases.

Oven door emissions to the atmosphere also can be reduced by collection of the leaking gases and particulates and subsequent removal of these pollutants from the air stream. A suction hood above each door with a wet electrostatic precipitator for fume removal is an example of this type of system.

Other control techniques rely on operating and maintenance procedures rather than only hardware. Operating procedures for emission reduction could include changes in the oven cycle times and temperatures, the amount and placement of each charge, and any adjustments of the end-door while the oven is on line. Maintenance procedures include routine inspection, replacement, and repair of control devices and doors.

Performance of the control techniques for doors is expressed in terms of visible emissions as percent leaking doors (PLD). The number of doors leaking is divided by the total number of doors and then multiplied by 100 to obtain the PLD. The chuck door is not counted as a separate door but is considered as part of the pusherside door.

3.2.1 Oven Door Seal Technology

Oven door seals can be divided into three subsets: hard seals, soft seals, and luted seals. Hard seals contain the oven gas by pressing a metallic strip against the oven jamb. To obtain uniform pressure, the metallic strip has adjustable screws, springs, or cams. Soft seals are resilient and they permit the seal to conform to the shape of the door jambs to seal in the gas. Luting is a water-based dispersion of clay and other materials which flow to seal the door. The oven heat evaporates the water and the luting composition dries in position. A combination of hard and soft seals sometimes is used in pressure-differential devices such as the prechamber door.

Hard seals rely on the principle of self-sealing. Emissions that contain steam, volatile oils, and tars pass through small defects in the sealing surface. The tars condense and seal the small openings after the steam content is reduced. The time required for self-sealing varies with oven pressures and gap size in the door.

Hard seals are commonly used in the production of metallurgical coke. The major types of industrial seals used in the United States are the Koppers and the Wilputte seals, named for their manufacturers.

Luting, which is one of the oldest coke oven control technologies, is used commercially on many foundry batteries and on a few furnace batteries. Hand-luted doors are sealed by trowelling a luting mixture into a V-shaped opening between the metal door frame and a roll formed steel shape (door jamb) on the end of the oven. The luting is a mixture of clay, coke breeze, and water, which dries and seals the gap between the door jamb and the door. The carbonaceous material is added to reduce shrinkage and cracking upon curing.

Some advantages of luting are that there are no leaks when it is properly applied, and luted doors are less costly to maintain than self-sealing doors. However, the luting mixture is applied manually and workers may be exposed to fumes during the 5 minutes required to lute a door. Another concern is that the luting can crack because of the mild combustion explosion from the coal first entering the oven. Reluting may be required after charging to avoid uncontrolled fires if cracks develop or the luting is jarred loose. The removal and disposal of luting material does not represent a major problem because it is recyclable.

Luting is particularly interesting because it represents an emission control technology that has the potential for eliminating almost all door leaks. Unfortunately, the lack of fully developed luting formulations and the absence of proven luted door technology for high production rate metallurgical coking have limited widespread adoption. Although luting has been used for foundry coking with 30-hour cycle times, the faster cycle time for metallurgical coking (18 hr) would require additional manpower, new equipment, and solutions to material handling problems.

3.2.2 Modern Hard Seals

Currently available major emission control techniques are based on hard seals. Self-sealing doors with hard seals invariably have a small clearance between the sealing surface and the jamb, and tar in the escaping gas ultimately plugs these small gaps. The time needed to plug the gap depends on the size of the gap, the temperature of the seal, the pressure in the oven, and other factors. Leaks cannot be prevented solely by metal-to-metal contact without plastic (irreversible) deformation of the metal.

A few coke oven doors have been observed to be completely free of visible emissions during the entire process.[8] One hundred percent control of visible emissions can be obtained with Koppers doors when new seals, well-adjusted doors, and relatively straight and clean jambs are used. However, the performance often begins to deteriorate in less than 6 months.

Effective sealing is inhibited by several factors, including distortion and damage to jambs, doors, sealing strips, and adjusting hardware.[9] Most of the components of the oven's end-door assembly are tightly constrained; consequently, when the assembly is heated, stresses result because gross distortions are prevented. Thermal cycling under these constrained conditions causes thermal warping of the metal components. Occasional temperature excursions and fires from leaking doors also cause warping, because plastic deformation occurs at temperatures of 500°C or higher. Although no metal-to-metal contact without plastic deformation will prevent leaks, this very deformation can lead to long-term problems in maintaining close tolerances on sealing surfaces.

3.2.3 Other Hard Seals

There are several other types of hard seals. One is the Ikio seal (oven door). The Ikio oven door, a Japanese technology, is similar to a modified Wilputte oven door. However, rather than the knife edge holder being welded to the door diaphragm or sealing plate as in the Wilputte door, the Ikio oven door has a flexible sealing plate which is welded directly onto the knife edges. Another difference is that the Ikio door has springs which can be moved forward and backward up to 15 mm (0.6 in) and are positioned 300 mm (12 in) apart along the sides of the oven door, unlike the adjustable screws used with the Wilputte door. This unique construction is claimed to seal in the gas completely.

A second type of hard seal is the Battelle seal, developed by the Battelle Columbus Laboratories in association with AISI and the EPA. The seal is retrofittable both to Wilputte and Koppers enclosure systems. The concept behind this seal is to provide a seal which is highly flexible in the direction perpendicular to the face of the jamb. The design stress levels are below the allowable stress for the high-temperature material. If these objectives are achieved, the seal will conform to a badly distorted jamb without taking a permanent set at the normal operating temperatures.

A third type of hard seal has been used commercially in Japan since the mid-1970's. This gas-sealed door technology as practiced at the Kamiashi Works includes use of a luting mixture on the exterior sealing surface edge and use of gas pressure to prevent leakage.[10] The gas used is nontoxic, nonexplosive, noncombustible, and generally available to all coke plants. Details of the seal design, gas type, and gas distribution system are confidential.

In practice, the gas supply to each door is turned on after the push is complete and the door has been reinstalled. Gas is injected in the oven chamber at 200 kPa (30 psi).[11] While the oven is charging, workers rap the knock-type seal to force the sealing edge into residual tar deposits and effect a partial seal. As points of leakage are identified, a luting mixture composed of mortar and coke breeze is spread along the exterior edge of the seal. The amount of luting mixture applied is very small in comparison to the amount used in hand-luted door practice. The worker can hold the supply of luting mixture in a pan that fits the palm of his hand. Reluting is practiced as necessary to prevent obvious leaks.

3.2.4 Saturn Doors

The Saturn door is a flexible door technology that includes several features different from those of conventional doors and seals:

- Flexibility: The door and doorplug are constructed in two or three sections, which allows the doors to flex (either in the concave or convex direction) more than the rigid conventional doors to conform to warped jambs with an outward or inward bow.
- The seal: The door seal is constructed of Inconel^{R}, which is a durable, heat-resistant alloy that is flexible and easily repaired. The seal is mounted on a flexible diaphragm plate.
- Leaf springs: Pressure is maintained on the seal by leaf springs that provide continuous force around the door perimeter instead of the point loading of plungers (spaced at 10 to 20 cm [4 to 8 in] intervals) used on conventional doors.

A major advantage of the Saturn door is in seal maintenance because the seal can be relatively easily repaired at the plant by replacing a damaged seal section or filling in place. Conventional doors generally are sent to outside contractors for seal replacement and repairs, and these repairs are usually more extensive and expensive. Another advantage is that the door can be more easily adjusted to conform to the deflections of warped jambs. The use of leaf springs instead of numerous spring-loaded plungers also improves seal performance by providing a uniform and continuous pressure on the seal against the jamb. This eliminates the need for manual adjustment of numerous spring-loaded plungers, which may result in too much or too little pressure on the seal.[12]

As of 1988, the only complete set of Saturn doors in place was on a 6-meter battery with 60 ovens. (Single experimental doors were being evaluated in trials at several other coke plants.) This battery had several structural design problems and also had a leakage problem from warped jambs. The design problems were being remedied, and all of the jambs on the battery were being replaced. The design problems and warped jambs were unrelated to the installation or indicated emission performance of the Saturn doors. Fifty-eight observations of door leaks conducted on the doors showed an overall average of 4.5 PLD and an upper 95 percent confidence level of 7 PLD (based on a three-run average).

While the use of Saturn door technology could require the replacement of existing doors with the new flexible doors, no major modifications to existing door machines are expected. The capital cost (as of 1988) for a new door for short ovens ranged from about $10,000 to $12,000 per door and about $160,000 each for a door or jamb cleaner. For a typical 60-oven battery, the capital cost for the doors was about $1.3 million, and the cost of door and jamb cleaners added about $0.64 million for a total of about $2 million per short battery. For a tall (6 meter) battery with 60 ovens, the capital cost rose to $3.2 million, $2 million for the doors and $1.2 million for the cleaners.[13]

3.3 OTHER CONTROL TECHNIQUES

There are several other techniques for the control of emissions from door leaks. Emphasis is given here on work practice controls, fume collection, design modifications, promising technology that is in the trial stage, and proven technology that is receiving greater notice.

3.3.1 Operating and Maintenance Procedures

The avoidance of leakage greatly depends on good operating practices and maintenance. One factor in emissions control is provision of the best possible work environment for the operators. In one reference (Graham and Kirk), good operating and maintenance practices were advocated: "In some ways it is the easiest method, probably the least expensive, the most effective, and justifiably on many occasions 'the best practical means' of controlling the pollution."[14]

Good operation requires the removal of deposits from the sealing edge and the jamb. Cleaning is perhaps the most burdensome task of the coking process, and workers tend to overlook the hard-to-reach sections on high oven doors. The task of manual cleaning is more difficult on the taller ovens than on the short ovens, and there is a greater tendency to not clean the oven thoroughly.

For a long time, coke plant operators have recognized that large, unchecked leaks may cause fires and damage the seal and buckstays beyond repair. The cleaning of the metal surfaces which come into contact should emphasize the removal of encrustations and particulate deposits which can cause gaps that allow leaks.

Cleaning the doors and jambs to the bare metal does not always provide additional benefits. It has been reported that excessive leakage always resulted when the operators scraped the jambs to bare metal.[15] With Wilputte doors, a thin film of tar should remain after cleaning to aid in sealing gaps between the knife edge and jamb.

The seal on hard coke oven doors should be maintained so that they meet a maximum gap specification. Typical gap specifications are 0.005 to 0.008 cm (0.002 to 0.003 in). The use of temperature-resistant materials and seals designed to provide uniform sealing pressures can reduce much of the maintenance effort necessary to meet the specifications.

3.3.2 <u>Effects of Process Variables</u>

Oven pressure is a process variable which can be used to moderate emissions because flow through small leaks is proportional to the pressure differential. A disadvantage of using low overhead pressure as a control technique is that low oven pressures have been reported to cause severe damage to the oven wall brickwork.[16] Also, oxygen that is introduced into the oven at the later stages of the coking cycle by the low pressures causes soot formation that can block the ascension pipes and lower the quality of the coke oven gas.

Temperature effects of the process variables damage the door components and increase emissions. The major drawback to lowering the coke to minimize thermal damage is the resulting increase in cycle time and decrease in coking capacity. Decreasing the coke temperature from 1,000°C to 800°C could conceivably reduce capacity by one-half. The temperature change could also alter the composition of the by-product gas.

3.3.3 <u>Startup, Shutdown, Upsets, and Breakdowns</u>

The emission rate from coke oven doors during startup and shutdown operations is expected to be lower than during normal operations. One reason for the lower emission rate is that the initial heatup or shutdown of a battery requires 5 to 7 weeks; therefore, shutdowns are very infrequent and are undertaken only as a last resort. Also, the coking rate is much slower during a heatup or shutdown because of lower coking temperatures. This slow coking rate results in a slower evolution of gases, lower oven pressures, and consequently fewer and smaller leaks. An oven is probably in better condition during an initial heatup, because repairs are usually performed during a shutdown.

Process upsets that affect oven pressures have a significant impact on door emissions. For example, the pressure regulating valve, usually located in the crossover main between the collecting main and suction main, controls the collecting main pressure and consequently affects oven pressure. If this valve malfunctioned, the oven pressure could increase and cause an increase in door leaks. Dirty standpipes and goosenecks may plug during the coking cycle and cause excessive pressures to build up in the oven. This plugging problem is remedied by regular, periodic cleaning. The pressure in the bottom of the oven may also be increased if the door's gas channel or vented plug fouls because of accumulation of carbon deposits. Upsets like this may be avoided by regular inspection, maintenance, and cleaning.

Another factor that may cause a process upset is the introduction of a high-moisture or high-volatile coal into the oven. The rapid evolution of these additional volatiles at the beginning of the coking cycle may increase the oven pressure and initially increase leaks and door sealing time.

3.3.4 Door Controls for Tall Ovens

The metal-to-metal seal technology that was previously discussed applied to tall (6-meter) ovens. However, a review of the available data indicates that these tall ovens do not control door leaks as well as the smaller ovens. Among the explanations for this phenomenon is the increased potential for leak occurrence (by a factor of two) because of the larger door perimeter where the sealing edge must contact the jamb. In addition, the oven pressure at the bottom of a 6-meter door is greater than on smaller doors for batteries operating at the same collecting main pressure. Also, when dry coal is charged, the resulting pressure surges may increase leaks.

3.3.5 Thompson Non-Recovery Coke Ovens

This non-recovery design was developed by B. Ray Thompson more than 30 years ago. The process has been operational for over 20 years. The Thompson design is used at only one location in the United States, the Jewell Coke and Coal Company facility in Vansant, Virginia. Similar to by-product coke ovens, Thompson non-recovery coke ovens use heat to produce coke. The pushing and quenching of the coke is also similar to the same steps at by-product coke ovens. Thompson coke ovens, however are not designed to recover the chemical by-products from the raw coke oven gas as is done at most coke plants. Instead, the raw coke oven gas is burned to provide the energy for coking, and excess heat is used to generate steam. The coking cycle is 24 hours rather than 18 hours which is typical for by-product ovens.

During coking, the raw coke oven gas is removed from the ovens by a natural draft (exhausters are not required), which maintains negative pressure in the ovens. This is the exact opposite of how a by-product oven operates. The non-recovery ovens have two basic emission points, the vents to the atmosphere and the doors during charging. No lids or offtakes are present. There are no leaking door emissions. No pollution controls are needed on the stack at the plant; however, ovens constructed in nonattainment areas may need to consider controls for sulfur dioxide and particulate matter.

The Thompson non-recovery coke oven does not have to be pushed and charged in a special sequence as is done at by-product batteries. Instead, the ovens are pushed sequentially, and the charging is performed in one shift, which results in lower manpower requirements. This type of coke oven is not affected by this NESHAP.

3.4 TECHNOLOGY FOR THE CONTROL OF TOPSIDE LEAKS (CHARGING PORT LIDS AND STANDPIPES)

3.4.1 Description of Technology

Topside leaks occur around the rims of charging port and standpipe lids; standpipes can also leak at their bases or through other cracks. These leaks are primarily controlled by proper maintenance and operating procedures which include:

* Replacement of warped lids,

* Cleaning carbon deposits or other obstructions from the mating surfaces of lids or their seals,

* Patching or replacing cracked standpipes,

* Sealing lids after a charge or whenever necessary with a luting mixture, and

* Sealing cracks at the base of a standpipe with the same luting compounds.

Luting mixtures are generally prepared by plant personnel according to formulas developed by each plant. The consistency (or thickness) of the mixture is adjusted to suit different applications. Charging port lids are relatively horizontal; therefore, a thinner mixture can be used to seal them. Standpipe lids come in a variety of positions; those that are not horizontal require a thicker mixture to prevent runoff. Careful application of lute is necessary to prevent a buildup of residue which can cause standpipes to burn out. The buildup must be removed from sealing surfaces when lids are opened, to prevent poor sealing when the lids are closed again.

Some equipment designs may reduce the effort required to keep leaks sealed. Heavier lids or better sealing edges may reduce leaks. Automatic lid lifters can rotate charging-hole lids after they are sealed to provide a better seal. Even with such equipment, manual effort will still be required to seal leaks.

Because there are many places where leaks can develop, keeping all charging lid and standpipe leaks sealed is a continuous job. In essence, success in controlling these emissions is directly related to the amount of manpower and the dedication of the employees. The number of topside workers required for effective emission control depends on several factors, such as the job assignment, number of ovens, cycle time, and extent of automation. In general, a battery may have a work force of 4 lidsmen if automatic lid lifters are used or 8 lidsmen if the lid lifting is performed manually.[17] For some batteries, the larry car operator or helper seals standpipe caps; on other batteries the lidsmen perform this function.

3.4.2 Performance for Topside Leaks Control

Mass emission measurements are not available to indicate emission control performance for methods of reducing topside leaks. However, measurement of visible emissions is possible and provides a good indicator of performance for all emissions. Emissions are controlled by sealing the leaks or plugging the holes. If the hole is plugged so that fine particles that make the emissions visible cannot escape, then all emissions, including the carcinogens, are controlled effectively. The emissions from topside leaks for an entire battery are measured by counting the number of leaks that are visible and expressing this number as a percentage of total potential leaks. Each charging port and each standpipe is considered to be a potential source of one leak.

As explained in the previous section, the primary technique used to reduce the number of topside leaks is luting. With this simple technique of sealing holes that allow coke oven emissions to escape to the atmosphere, it is plausible that the number of leaks depends on the effort applied to luting. Greater effort can be achieved by making luting a prime responsibility of topside workers. Additional manpower may be required to carry out this responsibility. The emission control performance increases proportionally with the diligence of workers in watching for leaks and promptly sealing them.

Data on offtake leaks at Kaiser Steel's Fontana, California batteries show the effect of additional manpower at one plant. This plant noted 35 to 56 percent fewer leaks for the seven batteries over a 3 month period when one employee per battery per shift was responsible for luting topside leaks and tending to lid removal and replacement.[18] The level of effort provided was sufficient to lower the average PLO below the local requirement of 10 PLO.

Leaks in battery mains on a well maintained battery will occur infrequently. If battery mains are closely watched by plant operators, preventive maintenance and prompt repair of leaks will allow them to be maintained without leaks.

3.5 Flares

Flaring is an open combustion process in which the oxygen necessary for combustion is provided by the air around the flame. The organic compounds to be combusted are piped to a remote, usually elevated, location and burned in an open flame in the open air using a specially designed burner tip, auxiliary fuel, and sometimes steam or air to promote mixing for nearly complete (98 percent minimum) destruction of combustibles. Good combustion in a flare is governed by flame temperature, residence time of organic species in the combustion zone, turbulent mixing of the organic species to complete the oxidation reaction, and the amount of oxygen available for free radical formation. Combustion is complete if all combustibles (i.e., VOC's) are converted to CO^2 and water, while incomplete combustion results in some of the VOC's being unaltered or converted to other organic compounds such as aldehydes or acids.

Flares are generally categorized in two ways: 1) by the height of the flare tip (i.e., ground-level or elevated), and 2) by the method of enhancing mixing at the flare tip (i.e., steam-assisted, air-assisted, pressure-assisted, or unassisted). Elevating the flare can prevent potentially dangerous conditions at ground level where the open flame is located near a process unit. Further, the products of combustion can be dispersed above working areas to reduce the effects of noise, heat radiation, smoke, and objectionable odors.

In most flares, combustion occurs by means of a diffusion flame. A diffusion flame is one in which air diffuses across the boundary of the fuel/combustion product stream toward the center of the fuel flow, forming the envelope of a combustible gas mixture around a core of fuel gas. This mixture, on ignition, establishes a stable flame zone around the gas core above the burner tip. This inner gas core is heated by diffusion of hot combustion products from the flame zone.

Cracking can occur with the formation of small hot particles of carbon that give the flame its characteristic luminosity.[19] If there is an oxygen deficiency and if the carbon particles are cooled to below their ignition temperature, smoking occurs. In large diffusion flames, combustion product vortices can form around burning portions of the gas and shut off the supply of oxygen. This localized instability causes flame flickering, which can be accompanied by soot formation.

3.5.1 Applicability

Flares can be dedicated to almost any VOC stream, and can handle fluctuations in VOC concentration, flow rate, heating value, and inerts content. Flaring is appropriate for continuous, batch, and variable flow vent stream applications.

Some streams, such as those containing halogenated or sulfur-containing compounds, are usually not flared because they corrode the flare tip or cause formation of secondary pollutants (such as acid gases or sulfur dioxide). If these vent types are to be controlled by combustion, thermal incineration, followed by scrubbing to remove the acid gases, is the preferred method.[20]

The majority of chemical have existing flare systems designed to relieve emergency process upsets that require release of large volumes of gas. Often, large diameter flares designed to handle emergency releases are also used to control continuous vent streams from various process operations. Typically in refineries, many vent streams are combined in a common gas header to fuel boilers and process heaters. However, excess gases, fluctuations in flow rate in the fuel gas line, and emergency releases are sometimes sent to a flare.

3.5.2 Efficiency

Five factors affecting flare combustion efficiency are vent gas flammability, auto-ignition temperature, heat content of the vent stream, density, and flame zone mixing.

The flammability limits of the vent stream influence ignition stability and flame extinction. Flammability limits are the stoichiometric composition limits (maximum and minimum) of an oxygen-fuel mixture that will burn indefinitely at given conditions of temperature and pressure without further ignition. In other words, gases must be within their flammability limits to burn. If these limits are narrow, the interior of the flame may have insufficient air for the mixture to burn. Fuels, such as hydrogen, with wide limits of flammability are therefore easier to combust.

The auto-ignition temperature of a vent stream affects combustion because gas mixtures must be at a sufficient temperature and concentration to burn. A gas with a low auto-ignition temperature will ignite more easily than a gas with a high auto-ignition temperature.

The heat content of the vent stream is a measure of the heat available from the combustion of the VOC in the vent stream. The heat content of the vent stream affects the flame structure and stability. A gas with a lower heat content produces a cooler flame that does not favor combustion kinetics and is more easily extinguished. The lower flame temperature will also reduce buoyant forces, which reduces mixing.

The density of the vent stream also affects the structure and stability of the flame through the effect on buoyancy and mixing. By design, the velocity in many flares is very low; therefore, most of the flame structure is developed through buoyant forces as a result of combustion. Lighter gases therefore tend to burn better. In addition to burner tip design, the density also affects the minimum purge gas required to prevent flashback, with lighter gases requiring more purge.[21]

Poor mixing at the flare tip or poor flare maintenance can cause smoking (particulate matter release). Vent streams with high carbon-to-hydrogen ratios (> 0.35) have a greater tendency to smoke and require better mixing to burn smokelessly.[22] For this reason, one generic steam-to-vent-stream ratio is not appropriate for all vent streams. The steam required depends on the vent stream carbon-to-hydrogen ratio. A high ratio requires more steam to prevent a smoking flare.

The efficiency of a flare in reducing VOC emissions can be variable. For example, smoking flares are far less efficient than properly operated and maintained flares. Flares have been shown to have high VOC destruction efficiencies, under proper operating conditions. Up to 99.7 percent combustion efficiency can be achieved.

3.5.3 Types of Flares

3.5.3.1 Steam-Assisted Flares

Steam-assisted flares are single burner tips, elevated above ground level for safety reasons, that burn the vented gas in essentially a diffusion flame. They reportedly account for the majority of the flames installed in most industries today.[23] To ensure an adequate air supply and good mixing, this type of flare system injects steam into the combustion zone to promote turbulence for mixing and to induce air into the flame.

3.5.3.2 Air-Assisted Flares

Air-assisted flares use forced air to provide the combustion air and the mixing required for smokeless operation. These flares are built with a spider-shaped burner (with many small gas orifices) located inside but near the top of a steel cylinder two feet or more in diameter. Combustion air is provided by a fan in the bottom of the cylinder, and the amount of combustion air can be varied by varying the fan speed. The primary advantage air-assisted flares provide is that they can be used in the absence of steam.

3.5.3.3 Non-Assisted Flares

The non-assisted flare is just a flare tip without any auxiliary provision for enhancing the mixing of air into its flame. Its use is limited essentially to gas streams that have a low heat content and a low carbon/hydrogen ratio that burn readily without producing smoke.[24] These streams require less air for complete combustion, have lower combustion temperatures that minimize cracking reactions, and are more resistant to cracking.

3.5.3.4 Pressure-Assisted Flares

This type of flare use vent stream pressure to promote mixing at the burner tip. If sufficient vent stream pressure is available, these flares can be applied to streams previously requiring steam or air assist for smokeless operation. Pressure-assisted flares generally have the burner arrangement at ground level, and consequently, must be located in a remote area of the plant where there is plenty of space available. They have multiple burner heads that are staged to operate based on the quantity of gas being released. The size, design, number, and group arrangement of the burner heads depend on the vent gas characteristics.

3.5.3.5 Enclosed Ground Flares

The burner heads of an enclosed flare are inside a shell that is insulated. This shell reduces noise, luminosity, and heat radiation and provides wind protection. A high nozzle pressure drop is usually adequate to provide the mixing necessary for smokeless operation and air or steam assist is not required. In this context, enclosed flares can be considered a special class of pressure-assisted or non-assisted flares. Enclosed flares are always at ground level.

Enclosed flares generally have less capacity than open flares and are used to combust continuous, constant flow vent streams, although reliable and efficient operation can be attained over a wide range of design capacity. Stable combustion can be obtained with lower heat content vent gases than is possible with open flare designs, probably due to their isolation from wind effects.[25]

REFERENCES

1. Clark, F.M. Stage Charging on a Single Collector Main Battery: A Total System Concept. Paper Presented at the 1973 Iron and Steelmaking Conference.

2. Coke Oven Emissions from Wet-Coal Charged By-Product Coke Oven Batteries-Background Information for Proposed Standards. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 27711. EPA-450/3-85-028a. April 1987. p. 4-2.

3. Barnes, T.M., H.W. Lownie, Jr., and J. Varga, Jr. Control of Coke Oven Emissions. American Iron and Steel Institute. December 31, 1973. p. 24-25.

4. Reference 2. p. 4-6.

5. Reference 2. p. 4-9.

6. VanOsdell, D.W., et al. Research Triangle Institute trip report to U.S. Steel, Fairfield, Conn. October 27, 1977.

7. Oliver, J.F. and J.T. Lane. Control of Visible Emissions at CF&I's Coke Plant - Pueblo, Colorado. Journal of the Air Pollution Control Association. <u>29</u> (9): September 1979.pp. 920-925.

8. Lownie, Jr. , H.W. and A.O. Hoffman. A Research Approach to Coke-Oven End-Closure Problems. Ironmaking Proceedings, <u>35</u>, 109(1976).

9. Reference 8.

10. Telecon. Jablin, R. with Feiser, Art, A.F. Industries. July 10, 1978.

11. Reference 10.

12. U.S. Environmental Protection Agency. National Emission Standards for Hazardous Air Pollutants; Coke Oven Emissions from Wet-Coal Charged By-Product Coke Oven Batteries. 53 FR 251, December 30, 1988, Washington, DC. U.S. Government Printing Office. January 1989.

13. Reference 12.

14. Graham, J.P. and B.P. Kirk. Problems of Coke-Oven Air-Pollution Control. The Metals Society. London. p. 82-100.

15. Proposed Interim Report on Development of Concepts for Improving Coke-Oven Door Seals. Summary of Task 4: Pre-Engineering Analysis Evaluations and Recommendations. Battelle Columbus Laboratories. March 1978.

16. Lownie, H.W., et al. Study of Concepts for Minimizing Emissions from Coke-Oven Door Seals. EPA-690/2-75-064. July 1975.

17. Reference 2. p. 4-88.

18. Draft of Standards Support and Environmental Impact Statement Volume I: Proposed National Emission Standard By-Product Coke Oven Wet Coal Charging and Topside Leaks. Emission Standards and Engineering Division. U.S. EPA. p. 4-61.

19. U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards. Research Triangle Park, North Carolina. OAQPS Control Cost Manual, Fourth Edition. January 1990. p. 7-5.

20. Reactor Processes in SOCMI -- Background Information for Proposed Standards. U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards. Research Triangle Park, North Carolina. Preliminary Draft. EPA Publication No. 450/3-90-016a. June 1990.

21. Letter from David Shore (Flaregas Corp., Spring Valley, NY) to William M. Vatavuk (U.S. EPA, OAQPS, RTP, NC). October 3, 1990.

22. Reference 20.

23. Guide for Pressure-Relieving and Depressuring Systems. Refining Department, API Recommended Practice 521, Second Edition. September 1982.

24. Reference 21.

25. Kalcevic, V. (IT Enviroscience). "Control Device Evaluation Flares and the Use of Emissions as Fuels," Organic Chemical Manufacturing Volume 4. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina. EPA Publication No. 450/3-80-026. December 1980. Report 4.

CHAPTER 4

REGULATORY OPTIONS

4.1 INTRODUCTION

The EPA listed coke oven emissions as a hazardous air pollutant on September 18, 1984. This listing decision was followed by proposal of a NESHAP for the control of coke oven emissions from wet-coal charged batteries.[1] These proposed standards were not promulgated because Congress revisited the issue during development and passage of the CAAA of 1990. The CAAA establish specific requirements for the development of regulations governing coke oven emissions. Under §112(d)(8), EPA must promulgate standards based on maximum achievable control technology (MACT) for new and existing coke oven batteries by December 31, 1992. In addition, §112(i)(8) instructs EPA to promulgate standards that reflect the lowest achievable emissions rate (LAER), as defined by §171 of the Act, by December 31, 1992. If the LAER standard is not promulgated, the Act specifies limits that will automatically go into effect January 1, 1998. The EPA must also promulgate work practice regulations and residual risk standards.

EPA's option for regulation is to set MACT and LAER standards at least as stringent as the limits outlined in the CAAA. The first section of this chapter describes these limits. In the development of the NESHAP for coke ovens, the EPA entered into regulatory negotiations with industry, labor unions, states, and environmental groups to develop a satisfactory regulation that is more stringent than the limits outlined in the CAAA. The second section of this chapter discusses some of the history and the results of the regulatory negotiations.

4.2 LIMITS IN CLEAN AIR ACT

Emission reductions for coke oven batteries are to be phased in over a twenty-seven year period. This period spans from 1993 to 2020 with the implementation of MACT, LAER, and residual risk standards.

4.2.1 Requirements for MACT, LAER, and Residual Risk Standards

By definition in the CAA, MACT is the best demonstrated control technology or practices used by the coke oven industry. New sources that must meet MACT requirements must meet emission-reduction standards as strict as those achieved by the best-controlled similar sources. Existing sources must at least meet the average emission limitation achieved by the best performing 12 percent of existing sources. For coke ovens, the CAAA require at a minimum that batteries will not exceed 8 PLD, 1 PLL, 5 PLO, and 16 seconds of visible emissions per charge.[2]

LAER, as defined by §171 of the CAAA, is the rate of emissions for any source which reflects:[3]

(1) the most stringent emission reduction which is contained in a SIP, unless the source demonstrates such levels are unachievable, or

(2) the most stringent level of control achieved in practice by such a category (or class) of source.

The default limitations set by LAER are to reflect at least 3 PLD, 1 PLL, 4 PLO, and 16 seconds of visible emissions per charge.

Within six years after the date of enactment of the CAAA, the EPA is to investigate and report to Congress the methods of calculating any remaining risk to public health from emissions of coke oven batteries subject to regulation. The EPA must also report the public health significance of such remaining risks, and the available technology and methods for the reduction of such risks along with an estimation of the costs associated with further reductions. In addition, an evaluation is to be conducted on the actual health effects with respect to persons living in the vicinity of sources, and provide recommendations as to legislation regarding such remaining risk.[4] From this report, residual risk standards will be implemented.

4.2.2 Timing of Coke Oven Provisions in the CAAA

Technology-based emission standards for coke oven batteries must be established by December 31, 1992. Coke oven owners and operators have two options for meeting their Clean Air Act obligations. The first requires coke oven batteries to meet MACT requirements by the end of 1995 and residual risk emission standards by 2003. Owner/operators of coke ovens seeking an extension of the residual risk requirements must meet a special 8 PLD standard by 1993. By 1998, these coke ovens must meet the standard of LAER set by EPA. Any coke oven that does not meet this standard in 1998 must meet the residual risk standard by 2003 or cease operations. Those coke ovens that meet the 1993 and 1998 standards will be granted the residual risk extension to 2020[5].

4.3 REGULATORY NEGOTIATION

During the spring and summer of 1991, EPA met with representatives of the industry, labor unions, states, and environmental groups to discuss available data to be used as the basis of the new regulations. A workshop format was used to explore and clarify the varying viewpoints. Following these informal discussions, EPA announced its intention to establish a committee to negotiate a new approach for the control of coke oven emissions and conducted formal meetings and informal workshops over the next several months to identify and resolve the many issues associated with the regulation.

At the final negotiating session, the Committee members conceptually resolved all outstanding major issues and decided to reach final agreement after reviewing and concurring on the draft preamble and regulation describing in detail the scope, application, and impacts.

4.3.1 Source Categories

A foundry battery is defined as a battery that is not owned or operated by an integrated steel producer, and had an annual capacity less than 1.25 million megagrams per year. The Committee agreed that the standard for door leaks at foundry coke producers should be slightly less stringent than the LAER door leak standard for other coke oven batteries.

A new source is a stationary source for which construction commences after the date of proposal. Any coke oven battery for which construction is begun at a plant site (where no batteries previously existed) after the date of proposal in the Federal Register would be subject to the emission limitations for new sources included in the proposed standards. This type of construction is termed "greenfield" construction. In addition, the construction of a new battery or the reconstruction of an existing battery that results in an expansion in capacity of an existing coke plant would subject such a battery to the emission limitations for new sources. The emission limitations for new sources are based on the emission control performance achieved by nonrecovery coke oven batteries.

Batteries that are completely reconstructed on the same site as an existing battery without an increase in the coke plant capacity are called "padup rebuilds", and new batteries that replace existing batteries without increasing plant capacity are called "brownfield" construction. Padup rebuild and brownfield batteries are considered existing and are subject to the LAER limits for as long as the battery is on the extension track.

Distinctions were made for door leaks on short batteries (batteries with ovens less than 6 m in height) and tall batteries (batteries with ovens 6 m or more in height) with a slightly less stringent standard for coke oven doors on tall batteries because they are more difficult to control.

4.3.2 Emission Limitations Set by MACT & LAER

The Committee agreed to use the recently-collected data from self monitoring and State or local agency inspections to assess control levels that have been achieved and to develop the emission limits. The Committee also concluded that the rolling 30-day limit should be based on an upper confidence level of 99.7 percent. In addition, agreement was reached that the emission limits effective in November 1993 for batteries on the risk extension track would be converted to 30-day average limits at the 99.7 percent confidence level. Although several options for the level of control of coke oven emissions were considered during the months of the regulatory negotiations, the limitations described in Table 4-1 are the resulting levels agreed upon by the regulatory negotiation committee.

MACT limits. For existing by-product batteries not seeking a compliance date extension, the limits to be met by December 31, 1995 and January 1, 2003 are in the first two columns of Table 4-1.

MACT for new source limitations are based on levels achieved by nonrecovery batteries with 0.0 PLD, 0.0 PLL, 0.0 PLO, and 34 seconds per charge.

LAER limits. The negotiated limits for batteries seeking a compliance date extension require that leaks must follow the last three columns of Table 4-1 with compliance dates of November 15, 1993, January 1, 1998, January 1, 2010, and then residual risk standards in 2020.

The Act provides that at any time prior to January 1, 1998, an owner or operator may elect to comply with residual risk standards by the required date rather than comply with the LAER and revised LAER standards and compliance dates. However, the owner or operator would be legally bound to comply with the residual risk standards as of January 1, 2003. If EPA has not promulgated industrywide residual risk standards by that time, the Agency must promulgate residual risk standards for those batteries that choose to meet residual risk standards by 2003. (Work to develop the residual risk standards has not yet begun.)

TABLE 4-1. PROPOSED LIMITS FOR EXISTING BY-PRODUCT BATTERIES

	MACT LIMITS		LAER EXTENSION TRACK		
	12/31/95	Beyond 2003 (must meet residual risk)	11/15/93 (CAA Limits)	1/1/98	1/1/10
LIDS PLL	0.6	0.6	0.83	0.4	0.4
OFFTAKES PLO	3.0	3.0	4.2	2.5	2.5
CHARGING (log) s/charge	12	12	12	12	12
<u>DOORS</u> PLD					
TALL	6.0	5.5	7.0	4.3	4.0
SHORT	5.5	5.0	7.0	3.8	3.3
FOUNDRY	5.5	5.0	7.0	4.3	4.0

4.3.3 Process Upsets

During periods of short process upsets or when a catastrophic failure occurs (such as an exhauster malfunction, or electrical failure), raw coke oven gas is vented directly to the atmosphere. Such an event can release tons of organic compounds in a short period of time. Ignitors can be installed on the coke oven batteries to flare the gas when it is bypassed. Combustion in a flare destroys the organic compounds in the gas and also converts highly-toxic hydrogen sulfide (H_2S) to less toxic sulfur dioxide (SO_2).[6]

Only 16 of the 82 batteries currently in this industry control these emissions. Although information from a manufacturer indicates flares can achieve 99.5 percent control, a conservative estimate of 95 percent control is expected from the installation of flares on coke oven batteries. The regulatory negotiation committee agreed to install flares on currently uncontrolled batteries.

4.3.4 Work Practices

The proposed work practice standards would require the owner or operator of an existing or new coke oven battery to develop a written plan describing emission control work practices to be implemented for each battery. The plan, required by November 15, 1993, must include provisions for training and procedures for controlling emissions from coke oven doors, charging operations, topside port lids, and offtake system(s). Compliance with such work practices is November 15, 1993.

4.4 ECONOMIC INCENTIVES: A MARKET-BASED APPROACH TO THE CONTROL OF COKE OVEN EMISSIONS

An alternative approach to the control of coke oven emissions could be established using economic incentive strategies. When designed properly, these market based approaches act to harness the marketplace to work for the environment. Such strategies influence, rather than dictate producer and consumer behavior, in order to achieve environmental goals. Such environmental goals are achieved with the most flexibility and at the least cost to society.

Several types or categories of economic incentive strategies exist, including fees, subsidies, and emissions trading. Fee programs establish and collect a fee on emissions, providing a direct economic incentive for emitters to decrease emissions to the point where the cost of abating emissions equals the fee. Similarly, subsidy programs provide a direct incentive for emitters to decrease emissions by providing subsidy payments for emission reductions beyond some baseline. Emissions trading allows sources with low abatement cost alternatives to trade or sell emission allowances to higher abatement cost alternatives so that the cost of meeting a given total level of abatement is minimized[7].

Legal constraints imposed by Title III of the CAAA severely limit the usefulness of economic incentive strategies for reducing HAP emissions. Because Title III requires the implementation of MACT, sources have little or no choice as to the type or level of control they implement, except perhaps if the source controls beyond the requirements set for doors, lids and offtakes. In the development of the coke ovens NESHAP, the regulatory negotiations acted as a means for industry to express the desired level of control. Plus, the costs associated with compliance with the default levels of control were based on input by each battery operator. Thus some flexibility in control techniques has been considered in the analysis of costs. However, this form of providing flexibility to the industry does not constitute an incentive to reduce pollution. Overall, the applicability of economic incentive programs for the coke oven NESHAP is very limited.

REFERENCES

1. U.S. Federal Register. Volume 52, No. 78;40 CFR Part 61. U.S. Environmental Protection Agency. April 23, 1987. pg. 13586.

2. U.S. Congress. The Clean Air Act, as Amended. Title III, Section 112(d)(8)(C). November 1990.

3. Reference 2, Section 171(3).

4. Reference 2, Section 112(f).

5. Commerce Clearinghouse, Inc. Clean Air Act - Law and Explanation. Chicago, Illinois. Prepared for the U.S. Environmental Protection Agency. Research Triangle Park, N.C. pp.35-39.

6. Research Triangle Institute. Preliminary Assessment of Bypassed Coke Oven Gas: Evaluation of Emissions and Controls. Prepared for U.S. Environmental Protection Agency. March, 1992.

7. U.S. Environmental Protection Agency; Office of Air Quality Planning and Standards. Draft Regulatory Impact Analysis for the NESHAP for Source Categories: Organic Hazardous Air Pollutants from Synthetic Organic Chemical Manufacturing Industry and Seven Other Source Categories. Publication No. EPA-450/3-92-009. February 1992. pp. 5-11, 5-12.

CHAPTER 5

COST ANALYSIS

5.1 INTRODUCTION

This chapter summarizes the cost analysis that was performed to estimate the cost of the NESHAP for coke oven emissions. Additional details are provided in the appendices. Appendix A is a battery-by-battery listing of the major cost elements, which were identified in many cases by representatives from the coke plant. Appendix B lists the estimated costs for each battery. The cost estimates are based on achieving the "default" emission limits given in the Clean Air Act amendments.

5.1.1 Approach

The approach used for the cost analysis was developed with the assistance of a Cost Work Group that was formed by the Regulatory Negotiation Committee for the coke oven NESHAP.[1] The Work Group consisted of representatives from EPA, individual coke plants, the American Iron and Steel Institute (AISI), the American Coke and Coal Chemicals Institute (ACCCI), the United Steelworkers of America, environmental groups, and consultants for the industry and union.

Based on suggestions from the Work Group, a draft approach was written and costs were estimated for each battery using a generic approach.[2] Several categories of batteries were identified based on the current emission control performance, extent of repairs needed, and other factors. Cost functions were developed for each class of battery, and each of the 82 batteries was assigned to one of the different cost classifications. The cost functions were then applied to each battery to estimate costs.

A major difficulty in performing an accurate cost analysis is that no one knows exactly what each coke oven battery must do (in terms of additional labor, new equipment, and repairs) to meet the upcoming coke oven regulation. There is much variation among existing batteries in terms of battery condition, remaining useful life, and current emission control capability. Consequently, the generic or model battery approach may result in an inaccurate estimate (either too high or too low) for a specific battery. However, the approach provides a range of costs for different types of batteries from the various cost categories. In addition, the total nationwide cost estimate should be reasonable if the proper distribution of battery types is used in the generic approach, even if every battery is not assigned to the proper cost category.

To improve the generic approach, preliminary estimates generated by EPA were sent to the individual coke plants by the trade associations for review and comment. After reviewing the estimates provided for their batteries, many individual plants provided alternative estimates of the additional expenses that they anticipated in the next few years. Other companies commented that the generic approach provided a reasonable estimate for their plant, and a few companies offered no additional comments. The comments received on the cost estimates from individual companies were summarized and discussed in a meeting of the Cost Work Group on March 9, 1992.[3] In addition, revisions were discussed for the generic approach that was used to estimate costs for batteries that did not provide specific cost data. Many specific recommendations were incorporated into the cost estimates presented in this analysis.

The cost report was revised based on the extensive review and comments received from the industry representatives. The site-specific cost data were included, and revisions were made to the generic approach. A final cost report was prepared and distributed to members of the Cost Work Group.[4] The cost report is the primary reference for the information presented in this chapter.

There is uncertainty as to the stringency of the regulation, including the numerical emission limits, the format of the standard, and how it will be enforced (because the negotiations are still underway). Consequently, the Work Group concluded that the cost analysis at this point should be based on the emission limits written into the Clean Air Act Amendments of 1990 as the least stringent that can be promulgated for maximum achievable control technology (MACT) and lowest achievable emission rate (LAER).

5.1.2 Issues and Assumptions

The individuals who provided battery-specific estimates of costs cautioned that their estimates were preliminary at this point, and that no commitment had been made to implement the capital or other improvements that were described. For some of these estimates, there was difficulty in separating items directly attributable to the NESHAP from those attributable to other factors. For example, some of the planned expenditures may be attributable to a current regulation that is already as stringent as the anticipated NESHAP. In other cases, extensive repairs planned for batteries that are old and in poor condition may have been needed in the near future to continue operating, even if the NESHAP were not in place. Another issue is the cost of ancillary equipment that might be replaced if extensive repairs are undertaken. A discussion is provided below for these issues and how they are handled in this analysis.

For this analysis, two costs estimates were developed to characterize the potential costs attributable to the NESHAP. The first estimate is EPA's best estimate of the costs that could be attributable to the standard, and the second estimate includes essentially all of the items identified by the company as potentially attributable to the standard. Major differences in the estimates are described below:

(a) The EPA estimate does not include the costs to meet current regulations that may be as stringent as the NESHAP. For example, several batteries have current regulations (State implementation plans or consent decrees) that limit percent leaking lids and offtakes to 1 and 5 percent, respectively, based on any single observation. This analysis assumes that the MACT limits are 1 percent leaking lids and 5 percent leaking offtakes based on the average of three runs. For the industry estimate, these costs are included as provided by the company.

(b) The EPA estimate does not include the cost of through-wall repairs because these repairs are required for other reasons, including the proper operation of the battery and to meet emission limits for combustion stacks. These costs are included in the industry estimate.

(c) Some batteries estimated millions of dollars in costs for extensive repairs to meet either the November 1993 limits or the MACT limits (December 1995). In addition, some of these batteries are projected to be completely rebuilt to meet LAER. The EPA cost estimate includes a portion of the rebuild cost. (The portion of the rebuild cost attributed to the standard is determined in the economic impact analysis, which considers factors such as the remaining useful life of the battery and the declining demand for coke.) The industry estimate includes both the extensive repairs followed by the rebuild in a few years.

(d) No additional costs are estimated for the Acme Steel batteries to meet MACT for door leaks in the EPA estimate. A total of 21 observations over 7 years shows exemplary control for percent leaking doors. Cost estimates provided by the company are included in the industry estimate.

(e) One company estimated that jambs will be replaced every 8 years on one of their batteries because of their past history and because of the NESHAP. For the industry estimate, this cost was annualized over 8 years. For the EPA estimate, a 20-year lifetime was used for the annualization.

One issue discussed by the Work Group concerned whether the NESHAP might "trigger" an early rebuild of some batteries. The LAER standard increases the stringency of the standard for percent leaking doors, which could require some extensive repairs on batteries that are not in good condition. These batteries may require extensive repairs to their entire end-closure system, including brickwork, jambs, doors, and seals. If extensive repairs are required for one part of the battery, the owner may choose to rebuild the entire battery for economic reasons. The issue is how much, if any, of the rebuild cost is attributable to the NESHAP. The cost of a complete rebuild is several times more costly than extensive repairs to improve door leak control. For this analysis, the cost of rebuilding batteries is apportioned to the NESHAP based on the estimated remaining life of the battery. Consequently, this represents the cost of rebuilding a battery earlier than it would otherwise have been rebuilt. The apportionment of rebuild cost and estimates of nationwide costs are provided in the economic impacts analysis, which also considers the declining demand for coke and other factors.

Another issue is related to equipment for other operations that might be upgraded as part of the rebuild. The estimated rebuild cost that was used included upgraded or new equipment used to operate the battery, primarily for items that might be related to emission control. For example, the costs included door machines, door and jamb cleaners, larry cars, pusher machines, and door spotting devices. The rebuild cost did not include extensive repairs to or replacement of ancillary operations, such as the by-product recovery plant, coke and coal handling equipment, and wastewater treatment.

Each coke battery has a choice of two compliance "tracks", and the choice of tracks may have a significant effect on costs. For example, a battery nearing the end of its useful life might be a candidate for the MACT route, which requires meeting MACT by December 31, 1995, and then meeting a risk standard by 2003. This battery would not have to meet the more stringent LAER standard in 1998, and a decision to rebuild or shut down might be postponed until 2003. For this analysis, only two coke batteries were identified by the company as probable candidates for the "MACT only" track. Other plants are still evaluating options, including a choice to meet the requirements of both regulatory tracks until the requirements of a risk-based standard are known. This analysis takes a somewhat worst-case approach by assuming that all batteries (with the 2 exceptions identified) will incur the MACT costs by November 1993 and all will incur the LAER costs by 1998.

Costs were not included for Bethlehem Steel's plant at Sparrows Point, MD. This plant shut down in 1991, and the company has not announced any plans to rebuild the batteries. Costs also are not included for the batteries at Inland Steel. The company has announced that Battery 11 will be shut down in 1992, and the remaining batteries will be closed before the end of 1994. There are no announced plans to rebuild these batteries.

5.2 MACT COSTS

The costs associated with MACT are given in Appendix B for each battery and show that the total capital cost ranges from $66 to $100 million. The total annualized cost is estimated to range from $25 to $33 million per year. The following sections summarize the basic components of cost used in the estimates.

5.2.1 Lids and Offtakes

Control costs associated with the NESHAP are estimated for batteries with current emission limits greater than 1 percent leaking lids (PLL) and 5 percent leaking offtakes (PLO). These current regulations are enforced as limits that are not to be exceeded for any single observation. A total of 74 batteries have emission limits greater than 1 PLL, and approximately 45 batteries have emission limits greater than 5 PLO.[5]

The estimated cost for batteries with current limits higher than 1 PLL and 5 PLO is based on adding one additional person per battery unit per shift to locate and seal leaking lids and offtakes. Labor costs are estimated as $25/hour, including benefits, or approximately $220,000 per year for each battery unit.[6,7] If improvement in control is required for only one of the two emission points, the increased labor is estimated as 0.5 persons per shift.

5.2.2 Charging

The Cost Work Group suggested that MACT for charging may require certain single main batteries (those without jumper pipes) to make extensive modifications to the larry car and charging operation with a cost on the order of \$600,000. A review of available data (based primarily on a 1979 report)[8] indicated that approximately 44 out of 82 batteries have a single collecting main. However, most of these batteries already have jumper pipes to perform stage charging properly and to meet current State regulations for charging.

Single main batteries with the least stringent current limits for charging were investigated more closely. A total of 20 single main batteries have current limits that are higher than 25 seconds per charge. Five of these batteries are in the rebuild category, and the previous approach assumed that these batteries would install upgraded or new larry cars at that time. Reviewers pointed out that these batteries that might be rebuilt would likely incur costs to meet the MACT charging standard before rebuilding the battery to meet LAER limits at a later date. Consequently, the cost analysis was revised to include estimates for upgrading the charging system to meet MACT, even if the battery is expected to be rebuilt before 1998.[9]

5.2.3 Doors

The additional cost for the control of percent leaking doors (PLD) to meet the MACT limits is based on the cost of increased cycling of doors through the door repair shop. This cost is estimated as \$440/oven per year for an improvement of 1 PLD.[10] However, this cost function is used only to estimate the cost to improve to an average of 5.7 PLD (which is the long-term average associated with a 3-run limit of 8 PLD). Capital improvements may be required for some batteries to achieve much lower levels for PLD. Several individual plants identified specific capital expenditures they expected to make to meet MACT. When specific information was provided by the company on capital expenditures for MACT, these costs were included in the analysis.

The improvement in control that would be required was estimated two ways. For the first case, the current performance was based on visible emissions data available for each battery. For the second case, each battery was assumed to be meeting its current regulation 95 percent of the time. The two approaches yielded essentially the same estimates for nationwide costs, even though the estimates for specific batteries were different. The annualized cost was estimated as \$3.4 million per year based on the performance data and \$3.2 million per year based on the current regulation (i.e., assuming that batteries are meeting their current regulations 95 percent of the time).[11]

5.2.4 Monitoring

For visible emission monitoring, the analysis assumes that the cost of monitoring (above that currently performed) will include 4 hours per battery per day at $25 per hour. Many batteries currently perform daily visible emissions monitoring and may incur no additional monitoring cost. The total of 4 hours includes 0.5 hours to inspect for leaking doors, lids, and offtakes; 2.5 hours to observe 5 consecutive charges; and 1 hour of travel time for the inspector.

5.3 LAER COSTS

LAER cost estimates are given for each battery in Appendix B. The total capital cost, excluding complete rebuilds, is estimated to range from $150 to $240 million. The total annualized cost ranges from $46 to $57 million per year, again excluding the annualized cost of rebuilds. The capital cost of rebuilds that may be triggered early was estimated as $709 million, and a portion of this cost will be attributed to the NESHAP in the economic analysis.

The cost estimates for LAER are based on a more stringent door standard. In addition, the control costs incurred under MACT for lids, offtakes, and charging will be continued under LAER. For this analysis, several categories were developed to estimate the costs to meet LAER limits for batteries that did not provide specific information. These categories are described below[12]. Site-specific cost information was received for most coke oven batteries from company representatives. Consequently, the generic categories described in this section were used only when the company representatives did not provide alternative estimates for their specific batteries. Appendix A provides a battery-by-battery listing of the specific cost components supplied by the industry, and for those cases when site-specific information was not given, the generic category assigned to the battery is given.

Category A - Batteries with hand-luted doors: Assume that additional control is provided for these batteries by adding an additional person per battery unit per shift to aid in locating and luting leaks. The estimated labor cost at $25 per hour (for 24 hours per day and 365 days per year) is $220,000/yr.

Category B - Batteries Currently Subject to a Standard of 5 PLD: Several batteries are currently subject to a standard of 5 PLD, based on any single observation and usually excluding 2 leaks. This standard has been applied to new or rebuilt batteries; consequently, these batteries are not expected to require major rebuilding or new doors and jambs. The cost estimate for these batteries assumes an additional person per battery unit per shift to locate and seal leaks (at $220,000/yr) and the material cost of sodium silicate ($56,000/yr) for a total cost of $276,000/yr.

Category C - **Batteries Consistently Averaging 2 to 4 PLD:** Batteries that are currently averaging 2 to 4 PLD are expected to require only a marginal improvement in control to meet LAER limits. The cost estimate for these batteries assumes an additional person per battery unit per shift to locate and seal leaks (at $220,000/yr) and the material cost of sodium silicate ($56,000/yr) for a total cost of $276,000/yr.

Category D - **Batteries Averaging 4 to 6 PLD:** Assume that these batteries will require an additional person for each battery unit per shift to locate and seal leaks and that sodium silicate will be used as a supplemental sealant ($276,000/yr as described above). Also include automatic door and jamb cleaners on the coke side of short batteries ($700,000). Most tall batteries have automatic cleaners. Assume that half of the tall batteries will rebuild their existing cleaners ($400,000) and the other half will install new cleaners ($1.4 million) on both sides of the battery with a midrange cost of $0.9 million.

Category E - **Batteries Averaging 7 to 10 PLD:** Assume that batteries in this category will require extensive repairs or a partial rebuild to achieve the LAER limit for doors. The cost estimate includes jamb and end flue repairs, new doors, 10 percent spare doors, new jambs, automatic door and jamb cleaners on the coke side of short batteries and both sides of tall batteries, and a spotting device for improved door placement. Also assume that these batteries will require an additional person for each battery unit per shift to locate and seal leaks, and that sodium silicate will be used.

Commenters noted that some batteries may choose to perform through-wall repairs when the end flue repairs are made. If through-wall repairs are needed, they would probably be performed to maintain the proper operation of the battery and to meet existing regulations for the battery's combustion stack. However, industry commenters have argued that when repairs or modifications are made to meet the LAER limits, plants may also perform through-wall repairs at the same time. Consequently, the LAER limits may trigger these repairs earlier than they normally would be performed. For this analysis, assume that half of the batteries will perform through-wall repairs at a cost of $12.5 million per battery (from the Struthers' cost report)[13]. Capital costs are given in Table 5-1 for the case without through-wall repairs. Through-wall repairs will be distributed across all batteries in this category at $6.3 million each and will be included in the industry cost estimate. The cost of through-wall repairs will be annualized over a 10-year lifetime.

TABLE 5-1. CAPITAL COST ELEMENTS FOR CATEGORY E

Item	Unit	Cost for 4 m	Cost for 6 m
Jamb and end flue repairs	oven	$62,400	$119,000
New doors (installed)	oven	24,600	28,600
Spare doors (10%)	oven	2,200	2,600
New jambs (installed)	oven	23,000	27,000
Jamb cleaner[a]	each	450,000	550,000
Door cleaner[a]	each	250,000	350,000
Spotting device	each	50,000	50,000

[a] Assume that new door cleaners ($250,000) and new jamb cleaners ($450,000) will be installed on the cokeside of short batteries (less than 6 meters). Tall batteries (6 meters) generally already have automatic cleaners. Assume that half of the tall batteries will install new cleaners on both the pusher side and coke side ($1.4 million), and assume that the other half will have their existing cleaners rebuilt ($400,000) with a midrange cost of $900,000.

- Cost for short batteries = $750,000 + 112,000 (no. ovens)
- Cost for tall batteries = $950,000 + 177,000 (no. ovens).

Category F - **<u>Batteries Averaging over 10 PLD</u>:** Assume that batteries averaging over 10 PLD must be rebuilt earlier than planned because of the 1998 LAER limit. Include the cost of a pad up rebuild, automatic door and jamb cleaners on the coke side (both sides for tall batteries), spotting devices, and new or refurbished larry car, pusher machine, and door machines. For this analysis assume that half of these machines will be refurbished and that the other half will be replaced by new equipment. For tall batteries that already have automatic cleaners, assume that half will be refurbished and half replaced by new cleaners. Also assume that these batteries will require an additional person for each battery unit per shift to locate and seal leaks with sodium silicate ($276,000/yr). Also include $10 million for repairing or refurbishing the by-product plant. The capital cost of a padup rebuild is given in Table 5-2.

TABLE 5-2. CAPITAL COST ELEMENTS FOR CATEGORY F - REBUILD

Item	Unit	Cost for 4 m	Cost for 6 m
Padup rebuild	oven	$790,000	$1,056,000
Jamb cleaner(s)[a]	each	450,000	550,000
Door cleaner(s)[a]	each	250,000	350,000
Spotting device	two	100,000	100,000
Larry car[b]	each	1,150,000	1,800,000
Pusher[b]	each	2,250,000	2,800,000
Door machines[b]	two	2,200,000	2,800,000
Repairs to by-product plant[c]	plant	10,000,000	10,000,000

[a] Assume that new door and jamb cleaners will be installed on the cokeside of short batteries (less than 6 meters). Tall batteries (6 meters) generally already have automatic cleaners. Assume that half of the tall batteries will install new cleaners on both the pusher side and coke side, and assume that the other half will have their existing cleaners rebuilt.

[b] Assume that half of the batteries will install new door machines, larry cars, and pusher machines. Assume that the other half will rebuild existing equipment. Use the midrange cost.

[c] Cost for the by-product plant will be used only in the study of capital availability.

- Cost for short batteries:
  $6,400,000 + 790,000 (no. ovens)

- Cost for tall batteries:
  $8,400,000 + 1,056,000 (no. ovens)

5.4 PROCESS UPSETS

The venting of raw coke oven gas to the atmosphere from process upsets seldom occurs. However, the magnitude of effects from the emissions from a process failure could potentially be significant due to the amount released in a short period of time. Currently, twenty percent of existing batteries have installed flares to control emissions from process upsets.

Although the data on the bypassing of raw coke oven gas are limited, annual emissions and the cost of control are estimated from data obtained from EPA Region III and from the Allegheny County (Pennsylvania) Air Pollution Control Agency on the frequency, duration, and mass emissions associated with these bypass events. Data on three coke oven plants (19 batteries) in the Pittsburgh, PA. area indicate the average battery vented for a total of 4.1 hours per year (hrs/yr).[15] The more serious episodes of venting for 37 hours (on average) are believed to occur infrequently. For this analysis, venting from a serious malfunction is assumed to occur once every 10 years, which yields an annual rate of 3.7 hrs/yr. Adding the infrequent (but long) events to the average obtained from Allegheny County for short episodes yields an annual venting rate of 7.8 hrs/yr per battery.

It is estimated from this that current nationwide bypass BSO emissions are 470 Mg/yr, which results in a level that is higher than the baseline level of emissions from charging and leaks from doors, lids, and offtakes. When MACT and LAER limits are applied (using the limits written into the CAA), the bypassed emissions dwarf the emissions from the NESHAP sources.[16]

ChemTech consultants estimated the installed cost of a flare system for a coke oven battery is $100,000 to $200,000 per flare, with two flares per battery (one on each end of the battery). The upper end of the range is for some batteries that may require additional structural support to install the flare system or to provide the ducting required to carry the gas to the flare. The company suggested a midrange value of $150,000 per flare or $300,000 per battery as a reasonable estimate.[17]

Operating costs are minimal. The gas used for the pilot flame is negligible, and the only labor requirement is to steam clean the pilot system once per week. The labor cost, based on one hour per flare (two hours per battery) and $25 per hour, is $2,600 per year. The life of a flare system is estimated as at least 10 years and probably closer to 20 years. A midrange value of 15 years is used for the cost analysis.

As a result, it is estimated that for the 66 batteries required to install flares, the total capital cost is $20 million. Total annual cost is estimated to be 2.8 million per year.

REFERENCES

1. More information on the Regulatory Negotiation Committee for coke ovens can be found in 57 FR 1730 (January 15, 1992); 57 FR 4025 (February 3, 1992); 57 FR 5267 (February 13, 1992); and 57 FR 6830 (February 28, 1992).

2. Revised Approach for the Coke Oven NESHAP Cost Analysis. Draft distributed for review and comment. February 11, 1992.

3. Coke Oven Cost Work Group Teleconference. Memo from D. Bell, EPA, to Cost Work Group. March 3, 1992.

4. Cost Analysis for the Coke Oven NESHAP. Transmitted by Amanda Agnew, EPA, to Cost Work Group. April 20, 1992. 34 pages.

5. Reference 4, p. 27-28.

6. Cost Implications for the Coking Industry to Meet the Clean Air Act Amendments of 1990. Prepared by Struthers Corporation for the American Iron and Steel Institute and the American Coke and Coal Chemicals Institute. November 1991. Section X of Appendices.

7. Forbes Magazine. January 8, 1990. p.40-42.

8. Technical Approach for a Coke Production Cost Model. PEDCo Environmental, Inc. EPA Contract No. 68-02-3071. December 1979, p. 38-50.

9. Reference 4, p. 6.

10. Reference 4, p. 7, 17.

11. Reference 4, p. 7-8.

12. Reference 4, p. 8-12.

13. Reference 6, Figure 2.

14. Reference 4, p. 12-16.

15. Research Triangle Institute. Preliminary Assessment of Bypassed Coke Oven Gas: Evaluation of Emissions and Controls. Prepared for U.S. Environmental Protection Agency. March, 1992. pg. 4.

16. Reference 15, pp. 1-2.

17. Reference 15, pg. 5.

CHAPTER 6

ECONOMIC IMPACTS

6.1 INTRODUCTION

Analyzing the economic impacts of the control levels specified by the CAAA requires describing the baseline conditions in the market for coke. Then, changes in the markets for coke that result from the regulation can be quantified, and their impacts estimated. To accomplish this, we first profile the market for coke at baseline (in the absence of the emission standard). Then, we use a mathematical simulation model to estimate the changes in those markets resulting from the costs of complying with the emission standard.

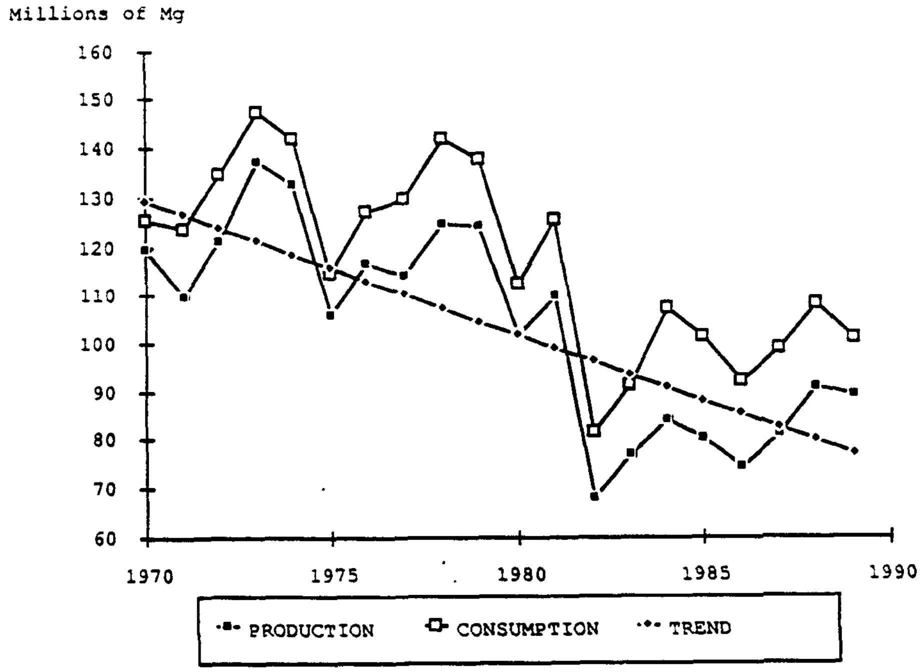
As mentioned previously, coke is used as an input both in traditional steel-making and in the production of iron castings in the cupolas of foundries. Because the physical properties required of coke used to produce steel differ from those required of coke used to produce iron castings, the market for coke actually comprises two distinctly separate markets: the market for furnace coke, used to produce steel, and the market for foundry coke, used to produce iron castings. Thus, conditions in the steel industry determine the demand for furnace coke, while conditions in the iron castings industry determine the demand for foundry coke.

6.2 THE DOMESTIC DEMAND FOR FURNACE COKE, DERIVED FROM THE DEMAND FOR STEEL

Because the demand for furnace coke depends on the quantity of steel produced, recent developments in the steel industry have had a profound impact on the demand for furnace coke. Overall U.S. steel output has declined in the past 20 years, and technical changes in steel manufacturing will result in a decreased quantity of furnace coke required per ton of steel produced. The following sections describe trends in the quantity of raw steel produced in the U.S. and trends in the types of steel-making technologies employed.

6.2.1 Quantity of Raw Steel Produced

Trends for U.S. steel production and consumption for the period 1979-1989 are presented in Figure 6-1. Although in some years, consumption and production increased from the previous year's level, the general trend is downward. Table 6-1 shows trends in steel production, consumption, and trade. The decline of the last 20 years reflects in part the reduction in steel intensity typical of developed economies, which are less involved in infrastructure construction. The change in production and consumption was also due to a fundamental change in the pattern of steel consumption in the U.S. For example, steel use in automobile production has fallen because of substitution of other materials, especially plastics and aluminum, for steel, and because of the general reduction in size of American cars. Also over the past 20 years, supply-side factors have resulted in U.S. steel producers having production costs that are high relative to those of their foreign competitors. The forecast for the domestic steel industry predicts a slight decline in production. Total coke-using steel production is predicted to be 52.8 million Mg in 1995 and 52.7 million Mg in 2000.[1] Because furnace coke consumption depends on coke-using steel production, furnace coke consumption will likely also decline in the future.



Source: American Iron and Steel Institute (AISI). *Annual Statistical Reports*. 1973, 1974, 1978, 1983, 1984, 1989.

Figure 6-1. Total Steel Production and Consumption in the U.S., 1970-1989.

6.2.2 Trends in Steel-Making Technology

Historically, vertical integration ensured that steel mills had a reliable supply of all the raw materials necessary to their production. Until the 1930s, the traditional method of steel-making, which starts with iron ore, was the only method. The steel-making firms, therefore, depended on adequate supplies of iron ore, coal for coking, and limestone for fluxing to guarantee adequate supplies of pig iron or "hot metal," without which their steel-making could not go forward. Changes in the mix of technologies used to produce steel, particularly the increasing use of electric air furnaces (EAFs), have reduced the need for such integration. Figure 6-2 shows the changing shares of total steel production over the last 20 years for the three main steel-making technologies: open hearth furnaces (OHF), basic oxygen furnaces (BOF), and EAFs.

The OHF was the dominant furnace type for nearly a century, but it has now virtually disappeared, replaced in integrated steel manufacturing by the BOF. Pig iron is melted and refined in these furnaces and transformed into steel. The molten steel is formed into ingots, which are in turn shaped in the primary mill into blooms, billets, or slabs, or put through a continuous casting process that forms them directly into these semi-finished forms. Finally, in the rolling mills, the steel is finished and turned into sheets, wire, rods, or structural forms, for example. Much of the recent investment in the integrated steel sector has been the introduction of continuous casting facilities into the plants.

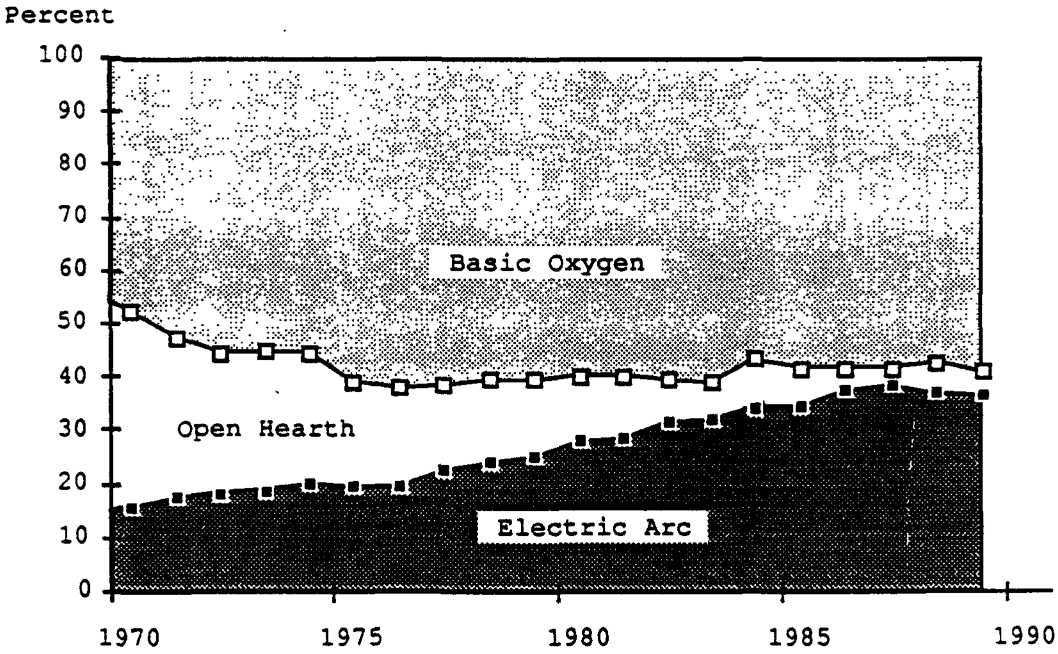
Another steel-making technology, the EAF, uses scrap steel and electricity as inputs and does not require coke, iron ore, or limestone; therefore the steel-maker does not depend on these raw material supplies. Although EAFs have been in existence since the 1930s, rapid improvements in design during the 1960s increased their profitability. EAFs do not require the massive investment that integrated traditional plants do and have, therefore, given rise to "minimills," which have much smaller average capacity than traditional steel mills. EAFs have accounted for a growing share of total steel production (see Figure 6-2). The quantity of domestic raw steel produced using this technology increased steadily from 1970 to 1989, during a period when total domestic raw steel production was falling. Thus, their share of domestic raw steel production has increased. In 1970, EAFs accounted for 15.3 percent of domestic raw steel production. EAFs produced 27.9 percent of domestic raw steel in 1980 and 35.9 percent in 1989.

Because of continuing technological developments, the steel-making technologies that do not require coke are expected to continue to increase their share of production. New EAF technologies are being developed that can produce a wider variety of steels at lower costs than conventional EAFs, and several new

TABLE 6-1. QUANTITY OF STEEL PRODUCED DOMESTICALLY, IMPORTS, AND EXPORTS OF STEEL (10^3 Mg)

Year	Quantity of Steel Produced Domestically	Quantity of Steel Imported	Quantity of Steel Exported	Apparent Supply of Steel
1970	119,558	12,149	6,412	125,295
1971	109,494	16,640	2,570	123,564
1972	121,128	16,074	2,612	134,590
1973	137,090	13,773	3,684	147,179
1974	132,473	14,518	5,303	141,688
1975	106,038	10,920	2,685	114,273
1976	116,364	12,986	2,413	126,937
1977	113,939	17,552	1,821	129,670
1978	124,574	19,214	2,202	141,585
1979	123,946	15,925	2,562	137,309
1980	101,668	14,086	3,728	112,026
1981	109,844	18,089	2,640	125,293
1982	67,797	15,148	1,675	81,270
1983	76,924	15,518	1,090	91,352
1984	84,115	23,785	891	107,009
1985	80,235	22,051	847	101,439
1986	74,186	18,811	845	92,152
1987	81,046	18,558	1,026	98,578
1988	90,840	18,992	1,881	107,951
1989	89,040	15,746	4,162	100,624

Source: AISI. *Annual Statistical Report.* 1973, 1974, 1978, 1983, 1984,1989.



Source: AISI. *Annual Statistical Reports.* 1973-1989.

Figure 6-2. Share of Steel Production by Technology

EAFs are under construction. In addition, the AISI, along with the Department of Energy, is developing a direct steel-making process that involves pre-reduction of iron ore pellets. The Japanese are developing a similar process.[2] These processes will eliminate the intermediate step of using a blast furnace to produce iron and thus will not require coke.

The industry is also investigating technical changes that reduce the quantity of coke used per ton of iron produced in blast furnaces, so that even when blast furnaces are still used, furnace coke consumption is reduced. Such technical changes include direct injection of pulverized or granulated coal into blast furnaces.[3]

Figure 6-3 depicts the effects of these trends on the consumption of furnace coke. As the domestic demand for furnace coke decreases from D_1 to D_2, the quantity produced, Q, falls to Q_2. At the same time, the price per megagram of coke falls from P_1 to P_2.

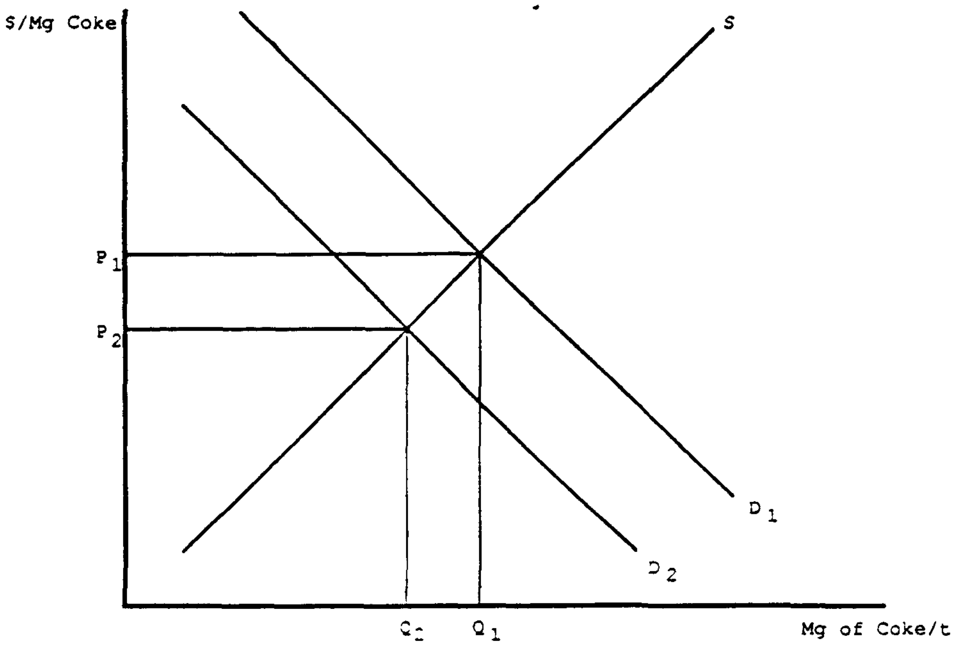


Figure 6-3. Effects of Decreased Steel Production and Changing Steel-Making and Iron-Making Technologies on the Market for Furnace Coke

In addition to domestic demand for furnace coke, another source of demand for domestically produced furnace coke is demand from outside the U.S. Coke exports are small relative to domestic consumption. As shown in Table 6-2, export consumption of furnace coke declined over the period from 1970 to 1989, averaging 1.3 million Mg in the 1970s and 0.98 million Mg during the 1980s. In 1989, furnace coke exports were 0.99 million Mg.[4]

6.2.3 Domestic Consumption of Furnace Coke

Domestic consumption of furnace coke is approximated by the "apparent consumption" of furnace coke. Apparent consumption is computed by subtracting exports of furnace coke from domestic production, then adding imports of furnace coke. This calculation yields the amount of furnace coke produced or imported during a given year available for use in the U.S. (It may differ from actual use because some of the coke produced may go into inventory, while some of the coke consumed may come out of inventory.) Historical data on furnace coke production are not available; instead, data on coke production by integrated ("captive") coke producers are used. A relatively small quantity of furnace coke (less than 3 million Mg in 1992) is produced by merchant producers--independent businesses that specialize in coke production. Merchant coke producers sell their coke rather than using it on site. For this analysis, data on the apparent consumption of furnace coke are computed using captive coke production rather than total furnace coke production as the starting point. Thus, our estimate of apparent furnace coke consumption, shown in Table 6-2, underestimates total apparent furnace coke consumption by the amount of merchant furnace coke production.

6.2.4 The Demand for Foundry Coke Derived from the Demand for Iron Castings

Approximately 90 percent of all manufactured goods and almost all industrial machines currently produced in the U.S. contain some type of cast metal.[5] Castings with very different physical properties can be produced by varying the composition of the melted metal, varying the temperature to which the metal is heated, and varying the cooling time for the castings produced.[6]

Three types of furnaces are commonly used to melt the metals used to produce iron castings: cupolas, EAFs, and induction furnaces. Of these three furnace types, only cupolas, which resemble miniature blast furnaces, require using foundry coke. Foundry coke is used in the initial stage of casting production to melt scrap iron and steel into a liquid that can be poured into prepared molds and allowed to cool and harden.

According to Robert Eppich, Vice President of Technology of the American Foundrymen's Society, only gray iron, ductile iron, and malleable iron castings ever require coke as an input. Because malleable iron castings make up less than 4 percent of the total tonnage of these types of castings produced each year and most of the molten metal used for malleable iron castings is melted in induction furnaces, demand for foundry coke is essentially a function of the demand for gray and ductile iron castings. Approximately 60 percent of the gray and ductile iron castings produced nationwide are produced with metals melted in cupolas using foundry coke as an input.[7] Although this analysis assumes a constant ratio of foundry coke production to gray and

TABLE 6-2. FURNACE COKE PRODUCTION IN CAPTIVE BATTERIES, EXPORTS, IMPORTS, AND APPARENT CONSUMPTION (10^3 Mg)

Year	Captive Coke Production	Exports	Imports	Apparent Consumption
1970[a]	54,308	2,285	139	52,162
1971[a]	46,452	1,372	158	45,238
1972[a]	49,298	1,120	168	48,346
1973[a]	52,932	1,268	980	52,644
1974[a]	50,573	1,162	3,218	52,629
1975[a]	47,071	1,157	1,654	47,568
1976[a]	48,514	1,195	1,192	48,511
1977[b]	44,899	1,127	1,663	45,435
1978[b]	40,755	630	5,202	45,327
1979[b]	43,630	1,309	3,613	45,934
1980[c]	38,090	1,883	599	36,806
1981[c]	35,366	1,064	479	34,781
1982[c]	23,067	903	109	22,273
1983[c]	20,505	605	32	19,932
1984[c]	24,355	950	529	23,934
1985[c]	22,886	1,020	525	22,391
1986[c]	20,228	913	299	19,614
1987[c]	22,260	522	838	22,576
1988[c]	25,942	994	2,444	27,392
1989[c]	26,550	986	2,101	27,665
1990	22,916	520	695	23,091

[a] The quantities of coke production, exports, imports, and consumption are calculated from the values reported in U.S. Department of the Interior, Bureau of Mines. *Mineral Industry Surveys*. Washington, DC. 1970-1976.

[b] The quantities of coke production, exports, imports, and consumption are calculated from the values reported in U.S. Department of Energy, Energy Information Administration. *Coke and Coal Chemicals Report*. Washington, DC. 1977-1980.

[c] The quantities of coke production, exports, imports, and consumption are calculated from the values reported in U.S. Department of Energy, Energy Information Administration. *Quarterly Coal Report*. Washington, DC. 1982-1990.

ductile iron castings production, some observers believe that competitive forces and stringent environmental regulations are encouraging foundries to increase their use of electric induction ovens, which are believed to be more flexible, more energy efficient, and cleaner than cupolas.[8]

Demand for iron castings depends on demand for the finished products that contain them. This condition is particularly true of castings sold to the automotive, machinery manufacturing, and transportation industries. Demand in these industries is greatly affected by fluctuations in industrial activity, business and consumer spending, and the strength of the dollar.[9] Increased substitution of alternative materials for iron castings also influences total demand for castings. For example, in the market for automobiles, an 8 percent reduction in iron and steel castings per vehicle was predicted to occur between 1989 and 1992.[10]

The quantity of foundry coke consumed each year in the U.S. is small relative to the quantity of furnace coke consumed. (In 1990, U.S. foundry coke consumption was less than 4 percent of total domestic furnace coke consumption.) Foundry coke is a specialized of breakage during transportation and other quality concerns, such as the higher sulphur content of foreign-made coke, importing foundry coke is not practical.[11] Although some foundry coke may be exported from the U.S. to Canada and Mexico,[12] foundry coke exports cannot be reliably distinguished from furnace coke exports in the records kept by the U.S. Department of Commerce. For this reason this analysis assumed all internationally traded coke is furnace coke.

Unlike the integrated steel firms producing furnace coke, merchant coke producers sell their coke rather than using it on site. They are much smaller businesses than the integrated steel producers that produce the majority of furnace coke. The average battery capacity of foundry coke producers is only 152 Mg per year, much less than the average furnace coke battery capacity of 378 Mg per year.

Foundries producing ferrous castings in the U.S. suffered serious cutbacks in production during the early 1980s as a result of the combined effects of a slumping U.S. economy, fierce international competition, and higher costs of production brought on by stricter environmental regulations.[13] Total production of ferrous castings in 1986 fell to about half the level recorded in 1978. Almost half of the foundries, representing over a third of U.S. production capacity operating in 1980, closed down during that period.

6.3 COKE PRODUCTION

Regulation of coke oven emissions required in the Clean Air Act Amendments will affect the costs of coke production. Both fuel, so substitution opportunities are severely limited. Because captive coke and merchant coke producers will be affected by the candidate NESHAP regulating coke oven emissions. To analyze the impacts of the NESHAP, the following sections identify and characterize coke producers, analyze coke production trends, and evaluate the variable inputs to the production process.

6.3.1 The Coke Production Process

A small positive back-pressure maintained on the oven prevents air from leaking into the ovens during coking. During coking, raw coke oven gas is removed through an offtake system composed of standpipes and other piping to a central collecting main. By-products such as coal tar, ammonia, and light oil (benzene, toluene, xylene) are removed from the coke oven gas in the by-product recovery plant. The cleaned coke oven gas is used to underfire the coke ovens, and excess gas is used in other parts of the plant. At the end of the coking cycle, doors on each end of the oven are removed, and the coke is pushed from the oven into a special railroad car (quench car). The incandescent coke is carried to a quench tower where it is deluged with water for cooling.[14]

Air pollutants may be emitted from several sources during this process. First, if the oven doors warp or fail to seal properly, they may leak. Second, if the lids over the charging ports do not seal properly, emissions may occur there. Finally, the offtake system that recovers the coke oven gas may leak. The candidate NESHAP specifies the maximum allowable percentages of each of these sources at a plant permitted to release emissions.

6.3.2 Profile of Coke Producers

As noted in Section 6.2, both the producers and consumers of coke are part of SIC code 3312, Blast Furnaces and Steel Mills. Almost all of the furnace coke produced in integrated steel plants is used on site. Blast furnace operators typically prefer coke that is sized between 0.75 and 3 inches. Smaller coke fragments, called breeze, are used either as fuel in steel mill boiler houses to generate steam or to assist in ore agglomeration as a fuel in the sintering process.[15] Captive furnace coke plants, part of vertically integrated steel mills, produce most of the domestically produced coke. Merchant coke producers produce a small percentage of furnace coke; however, they produce all of the foundry coke produced in the U.S.

6.3.2.1 *Captive Coke Producers.* Almost 90 percent of domestically produced blast furnace coke is produced by captive furnace coke plants that are part of vertically integrated steel mills. These steel mills include most, if not all, of the following:

- plants that produce coke,
- plants that process iron ore,
- plants that combine the coke and iron ore to produce pig iron,
- plants that use the pig iron to produce raw steel, and

- plants that use the raw steel to produce semi-finished and finished shapes.

6.3.2.2 ***Merchant Coke Producers*** About 11.5 percent of domestic blast furnace production capacity is in the merchant sector. Merchant coke producers are smaller, independent companies that rely solely on the sale of coke and coke by-products to generate revenue. Merchant furnace coke producers sell their coke to the large steel companies and sell the by-products of coking to coal chemical refineries. One merchant furnace producer, Jewel Coke and Coal, uses a nonrecovery coking process and relies entirely on coke sales for survival. This NESHAP applies only to by-product coke facilities; therefore, the non-recovery production process used by Jewel Coke and Coal is not affected.

All of the foundry coke produced in the U.S. is made by merchant producers. Foundries require coke that is sized at 3 inches or greater. Only about 70 to 75 percent of the coke produced by merchant foundry producers meets this requirement and is sold to iron foundries. The remaining 25 to 30 percent of coke produced by foundry producers is sized between 0.75 and 3 inches and is sold at reduced prices to producers of sugar, mineral wool, and other non-metallurgic commodities.[16] Merchant coke producers have no use for coke breeze.

Although much of it never reaches a foundry cupola, we refer to all coke products by merchant foundry producers as foundry coke. The two columns labeled "Foundry Coke" and "Other Coke" in Table 6-3 should therefore be added together to represent what we refer to as foundry coke production.

Table 6-3 lists the plants in operation in 1992, their location, batteries, coke type, and production capacity. These data reveal systematic differences between captive and merchant coke plants. Merchant coke plants tend to be smaller than captive coke plants; they tend to have a smaller number of batteries per plant; and the individual batteries tend to be smaller than those of captive coke producers. For example, three of the 11 merchant coke plants have only one battery, and the largest number of merchant batteries at a single plant is five. Merchant coke plants have an average of 2.45 batteries per plant, with an average annual production capacity of 169,000 Mg per battery. Captive coke plants, on the other hand, average 3.1 batteries per plant, with an average production capacity of 340,000 Mg per year. The largest captive producer in 1991 was the U.S. Steel (USX) furnace coke production site in Clairton, Pennsylvania, which has 12 batteries and a capacity of approximately 4,030,000 Mg of coke per year.

TABLE 6-3. COKE PRODUCERS IN THE UNITED STATES

Plant Name	Address	Blast Furnace Battery Capacity (10^3 Mg)	Foundry Battery Capacity (10^3 Mg)	Other Battery Capacity (10^3 Mg)
MERCHANT PRODUCERS				
ABC	Tarrant, AL		317	128
			63	25
			73	29
Citizens Gas	Indianapolis, IN		83	34
			75	31
		245	82	
Empire	Holt, AL		70	28
			35	14
Erie	Erie, PA		58	19
			89	29
Jewell Coke and Coal[a]	Vasant, VA	221		
		153		
		111		
		153		
Koppers	Woodward, AL	161		
		128		
		252	97	
		55		
New Boston	Portsmouth, OH	341		
Shenango	Pittsburgh, PA	301		
		151		
Sloss	Birmingham, AL	111		
		111	119	48
			127	52
Toledo	Toledo, OH		188	62
Tonawanda	Buffalo, NY			
TOTAL MERCHANT CAPACITY		1,953	1,476	499
CAPTIVE PRODUCERS				
Acme Steel	Chicago, IL	226		
		226		
Armco	Middleton, OH	466		
		466		
		316		
Armco	Ashland, KY	305		
		528		
Bethlehem Steel	Bethlehem, PA	200		
		200		
		591		
Bethlehem Steel	Burns Harbon, IN	809		
		664		
Bethlehem Steel	Lackawana, NY	340		
		340		
Geneva Steel	Provo, UT	223		
		120		
		211		
		188		

(continued)

TABLE 6-3. COKE PRODUCERS IN THE UNITED STATES (CONTINUED)

Plant Name	Address	Blast Furnace Battery Capacity (10^3 Mg)	Foundry Battery Capacity (10^3 Mg)	Other Battery Capacity (10^3 Mg)
CAPTIVE PRODUCERS (continued)				
Gulf States Steel	Gadsden, AL	268		
		268		
Inland Steel	E. Chicago, IN	131		
		223		
		224		
		281		
		482		
LTV	Pittsburgh, PA	256		
		256		
		289		
		289		
LTV	S. Chicago, IL	382		
LTV	Warren, OH	558		
LTV	Cleveland, OH	447		
		248		
National Steel	Granite City, IL	248		
		250		
National Steel	Detroit, MI	250		
Sharon Steel	Monessen, PA	795		
		212		
U.S. Steel	Clairton, PA	105		
		760		
		260		
		260		
		260		
		260		
		260		
		260		
		270		
		270		
		270		
		450		
U.S. Steel	Gary, IN	450		
		700		
		680		
		250		
Wheeling-Pittsburgh	Steubenville, WV	250		
		151		
		151		
		163		
		782		
Total Captive Capacity		20,038		
Total Capacity		21,991	1,476	499

[a] All of Jewell Coke and Coal's batteries use a non-recovery coking process. These batteries will not be affected by the candidate NESHAP.

6.3.3 Historical Coke Production Trends

As already mentioned, the number of coke plants, the number of batteries, and the total amount of coke produced have decreased over the last decade. In 1980, 60 coke plant locations had a total of 195 batteries. This total included 20 merchant coke plant locations with 47 batteries and 40 furnace coke plant locations with 148 batteries. Total production for these batteries in 1980 was approximately 48 million Mg of coke.

During the period from 1980 to February of 1992, the number of plants fell to 30, and the number of operating batteries present at coke plants declined by more than 50 percent, to 86 batteries. During this period, at least one new coke battery was constructed and several batteries were modified. Total coke production, shown in Table 6-4, fell from about 48 million Mg in 1979 to about 26.3 million Mg in 1990. Production generally declined from 1980 to 1986, then rebounded slightly between 1986 and 1989. At its lowest level, in 1986, coke production fell to 23.2 million Mg, less than 50 percent of 1980 coke production. Coke production gradually increased from 1986 to 1989 to about 30 million Mg, approximately 62 percent of 1980 coke production, before falling once more in 1990 to 26.3 million Mg per year. As shown in the list of coke producers, the most recent information indicates that the total capacity of batteries present in February 1992 is 23.9 million Mg.

TABLE 6-4. HISTORY OF U.S. COKE PRODUCTION (10^3 Mg)

Year	Merchant Plant	Captive Plant	Total Production
1970[a]	5,377	54,308	59,685
1971[a]	5,061	46,452	51,513
1972[a]	5,115	49,298	54,413
1973[a]	4,792	52,932	57,724
1974[a]	4,642	50,573	55,215
1975[a]	4,290	47,071	51,361
1976[a]	3,966	48,514	52,480
1977[b]	3,336	44,899	48,235
1978[b]	3,097	40,755	43,852
1979[b]	4,500	43,630	48,130
1980[b]	3,848	38,090	41,938
1981[c]	3,531	35,366	38,897
1982[c]	2,492	23,067	25,559
1983[c]	2,957	20,505	23,462
1984[c]	3,427	24,355	27,782
1985[c]	3,160	22,886	26,046
1986[c]	2,990	20,228	23,218
1987[c]	3,228	22,260	25,488
1988[c]	3,516	25,942	29,458
1989[c]	3,464	26,550	30,014
1990[c]	3,400	22,916	26,316

[a] The quantities of coke production are calculated from the values reported in U.S. Department of the Interior, Bureau of Mines. *Mineral Industry Surveys*. Washington, DC. 1970-1976.

[b] The quantities of coke production are calculated from the values reported in U.S. Department of Energy, Energy Information Administration. *Coke and Coal Chemicals Report*. Washington, DC. 1977-1980.

[c] The quantities of coke production are calculated from the values reported in U.S. Department of Energy, Energy Information Administration. *Quarterly Coal Report*. Washington, DC. 1982-1990.

6.3.4 Inputs in Coke Production

Production of coke requires only a few variable inputs: high- and low-volatile coals, energy, and labor. These are combined with capital equipment (the coke oven batteries) whose quantity is fixed in the short run. The marginal cost of producing a megagram of coke, therefore, is the marginal cost of the coal, energy, and labor required to produce it. The baseline marginal cost of the ovens themselves is zero, because they are already in place. This analysis concentrates on two inputs, coal and labor.

6.3.4.1 *Coal.* Two principal markets exist for U.S. coal:

- the market for boiler fuel--coal that is burned for its energy content, and

- the market for "metallurgical coal"--coal that is pyrolyzed and reduced to coke for use by the iron and steel industry.

This analysis evaluates the market for metallurgical coal. The quantity of metallurgical coal traded has declined as the quantity of coke produced and consumed has declined. Domestic consumption of metallurgical coal is now half of the 1977 level and currently accounts for only 5 percent of total U.S. coal consumption.[17] The average price of coal receipts at coke plants in 1989 was $52.57 per Mg.[18]

6.3.4.2 ***Labor.*** Unfortunately, employment data for the by-product coke sector are not available. Because coke-making is only a part of the Blast Furnace and Steel Mill industry, employment in the by-product coke industry is only a portion of the total industry employment. However, Harry Kokkinis, an industry analyst with Locker Associates, and Monty Stuart, Supervisor of Environmental Affairs and Technical Programs for Bethlehem Steel, provided estimates of the number of workers employed in coke production on a per-battery basis within the steel industry.[19,20] Because the batteries for which the estimates were made were of different sizes, with larger batteries requiring fewer man-hours per unit of output, our estimate of 1.2 man-hours per Mg of coke produced, which is a weighted average of the two estimates, might overstate employment levels in larger facilities and understate them for smaller batteries. Using this ratio of 1.2 man-hours of labor per megagram of coke production and assuming that the industry average of 41 hours of labor per worker per week applies to workers engaged in coke production, we estimate total employment in captive furnace coke production in 1992 in the U.S. to be 11,278 workers.

Our estimate of employment in coke production for the merchant sector relies on 1990 survey data gathered by the American Coke and Coal Chemicals Institute (ACCCI), a trade association of merchant coke producers.[21] ACCCI represents merchant furnace coke producers as well as all U.S. foundry coke producers. According to the information supplied by ACCCI, the 27 coke batteries at 11 merchant plants producing coke employed 2,530 production workers. This figure corresponds to 1.586 man-hours per Mg of coke produced in the merchant sector.

6.4 BASELINE CONDITIONS IN THE MARKETS FOR FURNACE AND FOUNDRY COKE

The producers and consumers of coke interact to define the baseline conditions in the markets for furnace and foundry coke. Together, they determine the price and quantity of coke consumed. The baseline conditions form the setting in which the impacts are projected resulting from the emissions standards.

6.4.1 The Markets for Furnace and Foundry Coke

Both furnace and foundry coke are intermediate goods. That is, they are produced to be used as inputs into the production of other goods. Furnace coke is used to produce iron in blast furnaces, which in turn is used to make steel. Foundry coke is used to melt iron for castings. Thus, the demand for the two types of coke is derived from the demand for the goods they are used to produce.

On the supply side of the market for furnace coke are domestic suppliers and imports of furnace coke. As discussed previously, two very different types of U.S. companies produce furnace coke: integrated steel producers and merchant coke producers. Foundry coke is supplied exclusively by merchant producers. Because importing foundry coke is not practical, domestic merchant producers are the only suppliers of foundry coke.

As described earlier, most furnace coke is produced by the same facilities that use it to produce iron. These producers are, in general, vertically integrated steel mills that combine coke production, iron ore processing, iron production, and steel production and finishing. Historical data on the quantity of furnace coke produced by such captive coke plants are available from the Department of Energy's *Quarterly Coal Report*. The total furnace coke production estimate published in the *Quarterly Coal Report* actually represents integrated firms' furnace coke production and does not include furnace coke production by merchant coke producers. The estimate of total furnace coke production in 1990 is, therefore, the sum of furnace coke produced by coke batteries within integrated steel companies and the estimated quantity of furnace coke produced by merchant furnace coke producers. This estimate of total furnace coke production is 24.4 million Mg.

Although much of the furnace coke produced in the U.S. is consumed by different branches of the same large corporations that produce it and is, therefore, not for sale, the National Energy Information Center within the Department of Energy has years 1949 through 1985 from a wide range of previously published sources. The Producer Price Index for furnace coke (SIC code 3212#11111) was used to update this time series, producing an estimate of $90.44 per Mg for the equilibrium price of furnace coke in 1990.

Foundry coke, unlike most furnace coke, is produced for sale by independently owned and operated companies for which coke production represents the primary revenue source. The quantity of foundry coke produced in 1990 is defined for this analysis as the quantity of coke produced by merchant coke producers specializing in foundry coke production in 1990. A quantity of 1.92 M Mg is estimated by subtracting the estimated amount of merchant foundry coke production in 1990 from the total merchant coke production.

The equilibrium published price of foundry coke in 1990 was estimated by comparing recent and historical price information obtained from several foundry coke producers and traders[22-27] with published price indices from the Department of Commerce. The prices for foundry coke produced by these facilities ranged from $160.50 to $161.00 per Mg for 1990. This analysis selects $160.50 as the 1990 published price of foundry coke. This price represents an official asking price; the actual prices realized may be $15.00 to $20.00 lower than producers' published prices.[28]

6.4.2 **The Baseline: Projected Conditions in the Markets for Coke**

The emissions standards evaluated here will take effect during the period 1990 to 2000. To assess their impacts, several projections of yearly furnace coke consumption and yearly foundry coke production were developed to represent estimated baseline conditions. Each of these baseline scenarios reflects different assumptions regarding future production levels of coke-using steel and gray and ductile iron castings, in the absence of the regulation.

The year 1990 is the latest year for which historical data on coke and steel production are available. To model the baseline market conditions for coke production that follow, these data were combined with projections of coke-using steel production, furnace coke consumption, and foundry coke production. In addition, adjustments were made to reflect changes in coke production capacity that have occurred since 1990.

Table 6-3, discussed previously, shows batteries present at plants producing coke in February 1992 and identifies, for each, the type of coke produced and its production capacity. We updated this information for this analysis and verified the capacities with coke experts and the facilities themselves. Sixty-nine furnace coke batteries at 24 plants had a production capacity of 21.9 million Mg of coke per year, while 14 foundry coke batteries at 8 plants had an annual production capacity of 1.5 million Mg of foundry coke and 0.5 million Mg of other coke, for a total annual coke production capacity of 23.9 million Mg. (One battery at Citizens' Coke in Indianapolis, Indiana, is counted twice in these figures, because it produces both furnace and foundry coke.)

Baseline aggregate data are available for 1990, but analysis of regulatory impacts should include only those plants and batteries still operational in February 1992. Several coke batteries were shut down during 1990 and 1991. For the analysis, the capacity of batteries present in 1992 was summed and compared with estimated coke production. For the furnace sector, capacity is less than estimated coke production for 1990.[a] Therefore furnace coke production is set equal to the summed battery capacities, with the assumption that imports of coke will increase sufficiently so that estimated coke consumption will remain unchanged. Foundry coke production in 1990 was only slightly higher than the 1992 summed capacity of batteries producing foundry coke. Therefore to estimate each foundry battery's output, each battery is assumed to produce enough so that their summed production just equals estimated foundry production for 1990.

6.4.2.1 *1993 and 1998 Furnace and Foundry Coke Production Projections as Baseline*

In the furnace sector, the relationship between historical captive coke consumption within the steel industry and coke-using steel production was estimated. Similarly, using time-series data and regression analysis we estimated a statistically significant relationship between historical merchant coke production and coke-using gray and ductile iron castings production. Then, the coefficients determined by our regression analysis of these historical relationships, along with projections made by others of future steel and castings production levels, combine to estimate future captive and merchant coke production levels. To estimate future furnace and foundry coke production levels based on these projections of future captive and merchant coke production, we subtracted the estimated production of the three merchant furnace coke producers from the coke production projected for merchant coke production and added it to the projected coke production for the captive sector.

6.4.2.2.1 ***Projected Furnace Coke Consumption.*** The baseline scenario projects furnace coke consumption based on a forecast of coke-using steel production, using a relationship estimated using regression analysis. Using time-series data for the years 1970 to 1989, coke consumption was estimated to be a linear function of the production of coke-using steel and the ratio of coke consumption to coke-using steel. The values of these variables for the years 1970 to 1989 appear in Table 6-5.

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[a] For simplicity, the Citizens' Coke battery that produces both furnace and foundry coke is assumed to produce only furnace coke. Data on capacity from the facility indicate that this battery has a capacity of 245 Mg of furnace coke and 82 Mg of foundry coke. Foundry coke takes approximately 1.5 times as long per cycle to produce as furnace coke. Thus, we estimate that the battery's furnace coke capacity is 245 + (1.5)*82 = 368 Mg of furnace coke.

TABLE 6-5. DATA USED IN FORECASTING FURNACE COKE CONSUMPTION

Year	Coke Consumption (000 Mg)	Coke-Using Steel Production (000 Mg)	Ratio of Captive Furnace Coke Production to Coke-Using Steel Production
1970	52,162	101,229	0.568
1971	45,238	90,456	0.556
1972	48,346	99,564	0.537
1973	52,644	111,855	0.513
1974	52,629	106,410	0.538
1975	47,568	85,420	0.607
1976	48,511	93,989	0.558
1977	45,435	88,592	0.551
1978	45,327	95,267	0.508
1979	45,934	93,104	0.542
1980	36,806	73,335	0.554
1981	34,781	78,803	0.486
1982	22,273	46,745	0.530
1983	19,932	52,728	0.434
1984	23,934	55,598	0.492
1985	22,391	53,012	0.482
1986	19,614	46,559	0.486
1987	22,576	50,147	0.515
1988	27,392	57,344	0.539
1989	27,665	57,082	0.545

The regression was based on the equation

$$\text{COKECONS} = \beta_0 + \beta_1\text{STEEL} + \beta_2\text{RATIO}$$

where

COKECONS = the quantity of furnace coke consumed in captive plants

STEEL = the quantity of coke-using (BOF and OH) steel produced

RATIO = the ratio of coke consumption to coke-using steel production

β_0 represents the intercept term; β_1 and β_2 are the coefficients for the explanatory variables. Correcting for serial correlation was necessary. Table 6-6 displays the regression results. All of the explanatory variables are significantly different from zero and have the expected signs. Furthermore, the account for nearly all of the variation in coke production.

Captive coke consumption is estimated to be 27.0 million Mg in 1993 and 26.3 million Mg in 1998 (see Table 6-7). This forecast is consistent with the historical trend.

TABLE 6-6. REGRESSION ANALYSIS OF FURNACE COKE CONSUMPTION IN CAPTIVE FACILITIES

Variable	Coefficient	T-Statistic
Intercept	-35,205	-16.539[a]
STEEL	0.4937	54.232[a]
RATIO	65,078	17.294
Adjusted R^2	0.9951	

[a] Denotes significance at the 1 percent level.

TABLE 6-7. PROJECTED PRODUCTION OF COKE-USING STEEL AND FURNACE COKE CONSUMPTION: 1990 THROUGH 2010

Year	Projected Production of Coke-Using Steel (10^3 Mg)	Projected Total Furnace Coke Consumption (10^3 Mg)
1991	55,635	27,730
1992	54,918	27,376
1993	54,202	27,022
1994	53,487	26,669
1995	52,773	26,317
1996	52,751	26,306
1997	52,730	26,295
1998	52,708	26,284
1999	52,686	26,274
2000	52,665	26,263
2001	52,337	26,121
2002	52,090	25,979
2003	51,805	25,839
2004	51,521	25,699
2005	51,239	25,559
2006	50,959	25,421
2007	50,680	25,283
2008	50,403	25,146
2009	50,127	25,010
2010	49,853	24,875

6.4.2.2.2 *Projected Foundry Coke Production.* The model projects foundry coke production as a function of gray and ductile iron castings production. The model assumes that foundry coke is not exported or imported, and that foundry coke added to inventory exactly equals coke consumed out of inventory.

Approximately 60 percent of all gray and ductile iron castings are made with iron melted in cupolas, for which foundry coke is an important input. We estimated the baseline quantities of foundry coke for the years 1991 through 2000 using regression analysis. Using time-series data for the years 1970 to 1989, merchant coke production was estimated to be a linear function of time, the production of gray and ductile iron castings, and the ratio of coke consumption to coke-using castings. The values of these variables for the years 1970 to 1989 appear in Table 6-8.

TABLE 6-8. DATA USED IN FORECASTING MERCHANT COKE PRODUCTION

Year	Merchant Coke Production (10^3 Mg)	Total Gray and Ductile Iron Castings Shipment (10^6 Mg)	Time Trend	Ratio of Merchant Coke Production to Coke-Using Castings Shipments (%)
1970	5,377	12.67	1	385.72
1971	5,061	13.29	2	346.17
1972	5,115	13.91	3	334.31
1973	4,792	15.50	4	281.06
1974	4,642	14.24	5	296.42
1975	4,290	11.28	6	345.69
1976	3,966	12.88	7	279.89
1977	3,336	13.74	8	220.78
1978	3,097	14.65	9	192.12
1979	4,500	14.00	10	292.21
1980	3,848	10.73	11	326.10
1981	3,531	10.73	12	299.24
1982	2,492	7.46	13	303.53
1983	2,957	8.41	14	319.68
1984	3,427	9.56	15	325.76
1985	3,160	9.11	16	315.37
1986	2,990	7.57	17	358.94
1987	3,228	7.83	18	374.91
1988	3,516	8.41	19	380.11
1989	3,464	6.81	20	462.48

The regression was based on the equation

$$\text{MERCPROD} = \beta_0 + \beta_1\text{CASTINGS} + \beta_2\text{TIME} + \beta_3\text{RATIO}$$

where

MERCPROD = the quantity of merchant coke produced

CASTINGS = the quantity of coke-using (gray and ductile) iron castings produced

TIME = a linear time trend

RATIO = the ratio of merchant coke consumption to coke-using castings production

β_0 represents the intercept term; β_1, β_2, and β_3 are the coefficients for the explanatory variables. We used the ordinary least squares technique; correcting for serial correlation was not necessary. We present the regression results in Table 6-9. Each of the explanatory variables is significant and has the expected sign. As was the case in the model of the furnace sector, the explanatory variables account for nearly all of the variation in coke production.

TABLE 6-9. REGRESSION ANALYSIS OF MERCHANT COKE PRODUCTION

Variable	Coefficient	T-Statistic
Intercept	-2,326.15	-3.621[a]
CASTINGS	246,370	8.861[a]
TIME	-42.225	-3.410[a]
RATIO	11.158	13.610[a]
Adjusted R^2	0.9656	
Durbin-Watson	1.606	
F-statistic	178.911	

[a] Denotes significance at the 1 percent level.

The analysis examines two very different projections of future gray and ductile iron castings production. One of these projections, obtained from the Department of Commerce, forecasts a reversal of the historical downward trend in castings shipments during the period between 1990 and 2000. This forecast, which predicts a 76 percent increase in gray and ductile iron castings shipments over recorded 1989 levels by the year 2000, is based on the belief that iron castings exports will increase markedly over the next decade because of a persistently weak dollar and free-trade agreements with Canada and Mexico.[29] The other forecast, prepared for the years 1991 to 2001 by Stratecasts, projects a 30 percent increase in shipments of U.S. gray and ductile iron castings over the recorded 1989 level by the year 2000.[b]

After consulting industry experts (many of whom consider even the Stratecasts forecast overly optimistic), the more moderate Stratecasts forecast of castings production was selected to develop our baseline scenario for the foundry sector and extended to the year 2010 using the average annual projected rate of change in castings production. The ratio of merchant coke consumption to coke-using iron castings production was assumed to remain constant at the 1989 level. Forecasts of the explanatory variables for the years 1990 through 2010, combined with the regression coefficients, allow a prediction of merchant coke production for those years. Table 6-10 shows the forecast values for coke-using castings production and total merchant coke production over the period 1990 through 2010.

As indicated earlier, the projection of foundry coke production was derived by subtracting the estimated production of the three merchant furnace coke producers from the projected total merchant coke production. Historical data are available only for merchant coke production.

6.4.3 Baseline Costs of Coke Production, 1990

Using the estimated 1990 baseline unit production cost (or average total cost [ATC]) for each battery present in 1991 as presented in Chapter 5, each site's batteries were grouped in order of increasing average variable cost per megagram of coke produced. This organization reflects the assumption that if a plant were going to reduce production, output would be reduced at the highest unit-cost battery first, then the next highest, and so forth. We computed total plant production costs and calculated the marginal costs (MCs) by computing the additional cost per megagram of coke produced resulting from the operation of each battery. Each battery's baseline "supply price" was then determined.

Using baseline supply price for each battery in each market, baseline supply functions for the furnace and foundry coke markets were then constructed by ranking the batteries in each industry in order of increasing supply price. These supply functions were statistically smoothed using econometric methods.

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[b] This forecast was provided by Citizen Gas and Coke Utility, a client of Stratecasts, Inc. It is used here with permission from Kenneth Kirgin, president of Stratecasts, Inc.

TABLE 6-10. PROJECTED PRODUCTION OF CASTINGS AND FOUNDRY COKE: 1990 THROUGH 2020

Year	Projected Gray and Ductile Iron Castings Shipments (10^3 Mg)	Projected Production of Merchange Coke (10^3 Mg)	Projected Production of Foundry Coke (10^3 Mg)
1991	7,530.00	3,946	1,452
1992	8,160.91	4,075	1,581
1993	8,808.18	4,208	1,714
1994	9,512.73	4,357	1,863
1995	9,161.82	4,219	1,725
1996	8,422.73	3,977	1,483
1997	8,832.73	4,046	1,552
1998	9,552.73	4,198	1,704
1999	9,160.91	4,050	1,556
2000	8,920.91	3,943	1,449
2001	8,348.18	3,745	1,251
2002	8,452.33	3,731	1,237
2003	8,560.25	3,718	1,224
2004	8,672.05	3,706	1,212
2005	8,787.85	3,696	1,202
2006	8,907.77	3,686	1,192
2007	9,031.93	3,677	1,183
2008	9,160.46	3,670	1,176
2009	9,293.49	3,664	1,170
2010	9,431.15	3,659	1,165

6.5 COSTS OF THE REGULATION

6.5.1 Components of Compliance Costs

The development of compliance costs for both the MACT and LAER control levels are discussed in Chapter 5. As with the cost estimates this analysis assumes the level of control specified in the 1990 Amendments. With the cooperation of the facilities providing current performance and current emissions limits, EPA defined the actions that would be required at each battery to achieve the specified limits and estimated corresponding battery-specific MACT compliance costs.

The activities required to meet the LAER standard range from using additional labor to locate and seal leaks to rebuilding batteries from the pad up. The net cost of making the capital investments associated with these rebuilds earlier than would otherwise have been necessary is attributed to the regulation. Therefore, battery life expectancy is an integral part of computing the compliance costs for batteries estimated to require rebuilding. We describe our formula for estimating battery life expectancy later in this section.

6.5.1.1 *Expected Rebuild Date.*The first step in computing this element of the battery's compliance cost is estimating when each battery may be expected to be rebuilt in the absence of the regulation.

Coke batteries do not have an infinite life span. The expected rebuild date depends on the age of the battery, the maintenance history of the battery, its initial design, and many other factors. These factors are difficult to quantify; therefore, the expected rebuild date is modeled as a function of battery age only.

Engineers typically estimate the expected life of a battery to be between 20 and 40 years. In the absence of LAER, all batteries presently operating would have been rebuilt either before or after 1998. Properly assessing the additional costs of the proposed regulation for each battery requires estimating the expected rebuild date of existing batteries. Then, the net cost of rebuilding the battery earlier than would otherwise have been required is attributed to the regulation. In addition, the costs of rebuilding should not be attributed to the LAER regulation for any batteries that are expected to rebuild before 1998 for reasons unrelated to the regulation.

The expected rebuild date for an existing battery is based on the assumption that battery life expectancy is normally distributed across the population. Comments received from industry and from Mr. Bindu Madhava at Davy/Still Otto, a battery building firm, indicate that 6-meter batteries built before 1980 had structural problems that resulted in their having a shorter lifespan than other batteries.[30] Based on these comments, we split the distribution of batteries in existence in 1992 into two groups: 6-meter batteries built before 1980 and all others.

Statistical properties of a normal distribution allow for estimating the expected rebuild date if the mean and standard deviation are known. The mean and standard deviation of current battery age distributions, and engineering estimates of battery life,[31] suggest a mean age at which batteries would be rebuilt of 18 years for the old 6-meter batteries and 35 years for all other batteries. The standard deviations of the distributions of battery life expectancy were assumed to be the same as the standard deviations of the distributions of present battery age: 4 years for the old 6-meter batteries and 13 years for all other batteries.

After determining the assumed characteristics of the distributions of battery life expectancy, we computed the expected rebuild date of each existing battery. As with human life expectancy, the life expectancy of an existing battery is not the mean of the distribution of battery life expectancy. Rather, it depends on the characteristics of the distribution and on the current age of the existing battery. The older a battery currently is, the older it is expected to be when it is rebuilt.

Thus, the expected rebuild date for each battery was estimated statistically[a] using a technique described by Johnson and Kotz.[32] The estimation is conditional on the present age of the battery. For example, if an analysis required predicting the life expectancy of a brand new battery, the mean life expectancy provides the most reasonable estimation because no additional information is available. However, if an analysis required predicting the life expectancy for a battery that is presently 28 years old, an age greater than the mean of the distribution would be predicted, because that battery has already survived for many years. Thus, the expected rebuild date is conditional on the battery's current age.

Figure 6-4 highlights this example. A normal distribution with a mean of 35 and a standard deviation of 13 illustrates the distribution of life expectancy of most coke batteries. The "x" represents a battery that is presently 28 years old. Any estimate of the life expectancy of that battery would be bounded by its present age. The bold line in Figure 6-4 indicates the portion of the normal curve to be evaluated. Thus, the expected lifespan of a battery is based on a truncated normal distribution. For this particular battery, the expected lifespan is 41 years. It would then be expected to be rebuilt in 13 years, or in 2004.

After estimating each battery's expected rebuild date, we compared it with 1998 to determine the number of years in which that battery would have to be rebuilt prematurely as a result of the LAER standard. The cost of LAER assigned to the regulation is only the net cost of rebuilding early.

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[a] The computation is as follows. The expected value of X in a single-sided truncated normal distribution is

$$E[X] = m + \frac{Z\left(\frac{A-m}{\sigma}\right)}{1 - X\left(\frac{A-m}{\sigma}\right)} \cdot \sigma$$

where
m = the mean of the distribution
A = the lower truncation point (i.e., current age of battery)
σ = the standard deviation of the distribution
X = the probability density function

$$Z = \frac{1}{\sqrt{2\pi}} \cdot \left(\frac{1}{\sqrt{e}}\right)^{-\frac{1}{2}\left(\frac{A-m}{\sigma}\right)^2}$$

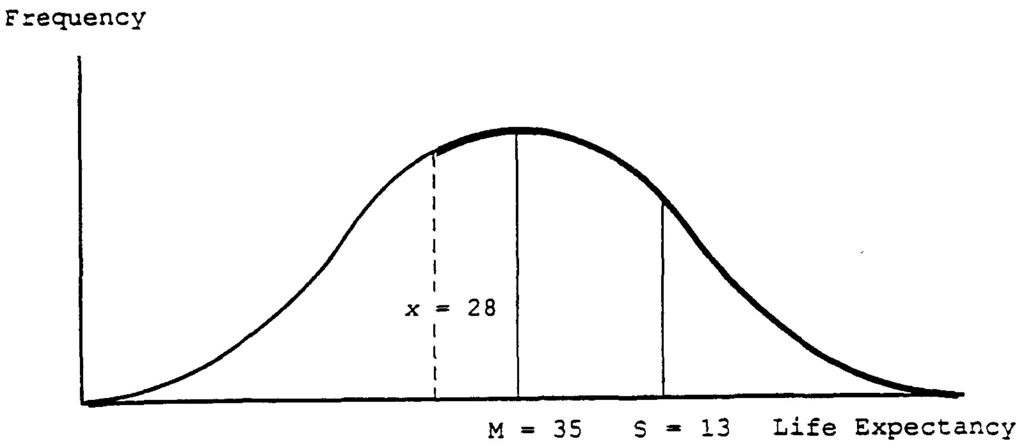

Figure 6-4. Example of Truncated Normal Distribution

6.5.2 Calculating Compliance Costs

Using the data on capital and operating costs combined with costs associated with early rebuilds allowed calculation of compliance costs. For the MACT scenario, the capital portion of the cost was annualized using a 10 percent discount rate. The number of years that these costs are discounted depends on the type of cost. The equipment associated with using sodium silicate was annualized over 10 years; the new doors and jambs and the automatic cleaners were annualized over 20 years. We computed the annualized value using a capital recovery factor, which spreads out the capital payment over that time span. Any annual operating costs were then added to the annualized value of the capital cost.

Computing the compliance costs associated with LAER was more complex because the cost of rebuilding that would have been incurred in the absence of the regulation was subtracted from the full cost of the regulation. This task was accomplished by computing the present value of the payment stream in the year in which the battery would have been rebuilt. Then the present value of that sum was computed for 1998 and subtracted from the capital cost of the regulation that would be incurred in 1998.

An example helps illustrate this computation. Suppose that a particular battery is 15 years old in year 0, and its life expectancy is 35 years. Further suppose that the capital cost of rebuilding is $25 million. Without the regulation, this battery would have been rebuilt in year 20. Therefore, the annualized value of the capital costs over the 15 years between year 20 and year 35 would have been incurred without the regulation.

Annualizing the rebuild cost of $25 million over 35 years at 10 percent yields an annual value of $2.4 million. The present value of the stream of payments of $2.4 million for years 20 to 35 is computed using a present value interest factor for an annuity (PVIFA).[a] This value amounts to $18.25 million and represents the value in year 20 of that stream of annualized costs. The present value of $18.25 million in year 0 (1998) is $2.7 million, which is computed using a present value interest factor (PVIF).[b] The $2.7 million represents the present value in year 0 of the cost that would have been incurred without the regulation. The $2.7 million is subtracted from the $25 million to compute the net cost of rebuilding the battery in 1998. The result is $22.3 million, which represents the capital cost of the regulation for this battery.

After computing the net capital cost of rebuild for LAER, the net rebuild cost, annualized over 35 years at 10 percent, was added to this amount to the other annualized components of LAER, plus recurrent elements of the MACT costs, to compute the total annual cost of LAER.

After computing total annual compliance costs for each battery under MACT and LAER, we computed unit compliance costs for each battery by dividing the total annual compliance costs for the battery by the battery's estimated output in 1991. Each battery's unit cost of compliance was added to its baseline marginal cost of coke production to compute the battery's marginal cost of coke production, or supply price, with the regulation in effect.

The following section describes the results of our analysis based on our primary scenario, described as follows:

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[a] The formula for computing the PVIFA is

$$\frac{1 - \frac{1}{(1 + r)^N}}{r}$$

where
r is the interest rate, and
N is the number of years.

[b] The formula for computing the PVIF is

$(1 + r)^{-N}$

where
r is the interest rate
N is the number of years

- Furnace coke consumption will vary over the period 1991 to 2010 as a result of variations in the production of steel.

- Foundry coke production and consumption will vary over the period 1991 to 2010 as a result of changes in the production of gray and ductile iron castings.

- Batteries' expected rebuild date depends on their current age and type of battery.

- Sufficient resources will be available to permit facilities to make whatever changes are required to achieve the emissions control levels.

- Compliance costs of MACT and LAER reflect EPA's cost estimates.

6.5.3 <u>Availability of Resources</u>

One of the assumptions of our analysis is that the companies will be able to obtain whatever resources are required to enable them to meet the control levels. Most of the costs associated with meeting the minimum MACT limits are operating costs; we do not anticipate a resource availability problem for most facilities meeting MACT. However, this may not be the case for alterations that facilities may choose to implement to meet LAER. The resources that may provide constraints to companies' repairs and rebuilds are:

- bricks for rebuilds,

- expert labor for repairs and rebuilds, and

- funding to finance capital expenditures.

We estimate that ten batteries operating in 1992 will be rebuilt before 1998. Information from engineering firms that specialize in coke-oven construction indicates that bricks for rebuilding a given battery are specialized, take 6 to 9 months to make, and must be imported. The one American brick manufacturer makes bricks only for repairs at present. Mr. Bindu Madhava of Davy/Still Otto estimated that the maximum number of batteries that can be rebuilt worldwide annually is five, and that a maximum of five batteries in the U.S. could be rebuilt before 1998.[33] Mr. Jim Eriser of ICF-Kaiser Engineering agreed that a maximum of five U.S. batteries could be rebuilt by 1998 and added that the total length of time for a rebuild, from design through "first push," is 2 to 3 years.[34]

In addition to the possible shortage of brick, the availability of engineering experts and specialized brick-layers may present problems. Several firms specialize in battery rebuilds, but they prefer to work on only one or two batteries at a time.[35]

Finally, capital availability is questionable: will companies be able to obtain financing to make the capital expenditures they feel will be necessary to achieve the control levels? EPA has addressed this question in a separate study. Preliminary results from that analysis indicate that the larger, integrated producers will be able to obtain capital funding. Of the merchant coke producers, only Indianapolis Coke (Citizens' Gas and Coke Utility) provided data for a capital availability study. Their data indicated that capital would be available for their repairs. Data for the smaller, independent merchant coke producers are not publicly available, so no analysis was done for them. Therefore, we do not know whether capital availability will be a problem for them. For the companies for which data are available, however, the EPA draft analysis indicated that capital would be available to make needed repairs.[36]

6.6 ECONOMIC IMPACTS

Imposing emission controls on coke ovens will increase the cost of producing coke. This regulation, in turn, will affect the markets for factors of production used to produce coke and for products that use coke as a factor of production. In addition, the markets for the by-products of the coke-making process will be affected. This section discusses qualitatively the effects anticipated as a result of the emissions controls, describes the model used to estimate the quantitative impacts of the emissions controls, and finally discusses the impacts projected by the model.

6.6.1 Qualitative Analysis of Expected Impacts

Economic theory allows us to predict the qualitative changes that will result in the market for coke and other affected markets as a result of the new control emissions, which will increase the cost of producing coke. The additional costs of production include:

- the cost of additional labor required to monitor and repair leaks,
- the cost of any materials employed in repairing the leaks, and
- the annualized cost of any capital equipment that must be installed or replaced to comply with the emission standard.

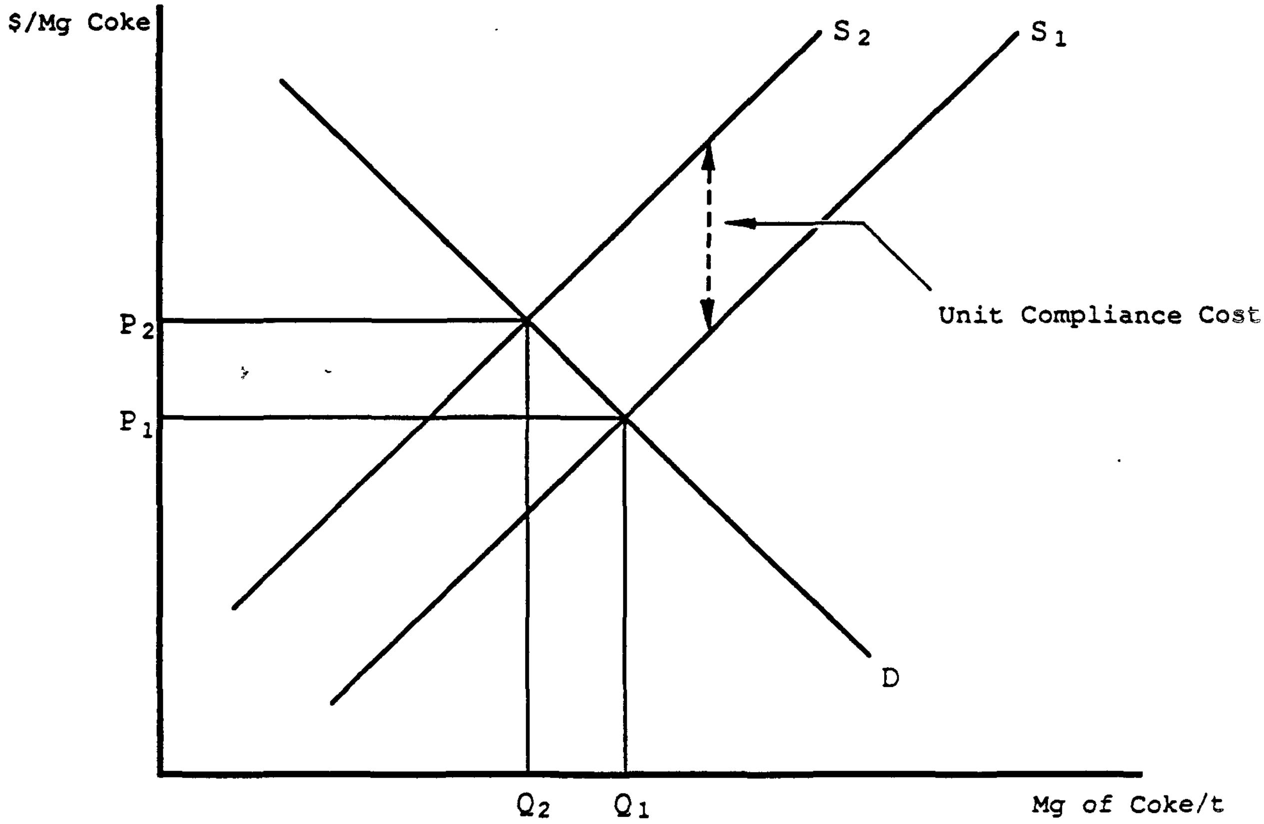
Each regulated facility's average total cost of production, or cost per megagram of coke produced, will increase. This increase, in turn, will raise the supply price each facility will accept for the coke produced by its batteries. As shown in Figure 6-5, this increase is reflected in an upward shift in the market supply curves in the furnace coke and foundry coke markets. Because the industry supply curve shifts upward, the equilibrium market price for coke also increases, and the equilibrium market quantity decreases relative to the situation without the emissions standard.

The changes in the market for coke resulting from the regulation give rise to changes in related markets. The increased price of coke, for example, increases the cost of producing steel, which shifts upward the supply curve for steel produced using coke. Because the supply curve for this type of steel has increased, the equilibrium price of coke-using steel will increase, and the equilibrium quantity of steel will decrease. The demand for EAF steel will increase, as some steel users substitute EAF steel for coke-using steel, which is now relatively more expensive. In addition, the increased cost of domestically produced steel is expected to result in increased imports of steel.

Similarly, because the quantity of coke produced is expected to decrease as a result of the regulation, demand for the coal and labor used to produce it will decrease. This result is reflected in a downward shift in the demand curves for these inputs. Because the demand for the inputs has decreased, their equilibrium prices and quantities are expected to fall as a result of the regulation. Because coke-making represents a small share of the total markets for coal and labor, large changes in the prices of these inputs are not expected. In the model used to simulate these market responses, the prices of coal and labor are assumed to be unaffected by the regulation.

6.6.2 The Economic Impacts Estimation Model

The impacts of the NESHAP were estimated using a model that simulates its effects on the markets for labor, coal, coke (including imports and exports of coke), and steel (including imports and exports of steel). In this model, separate sectors represent furnace coke and foundry coke production. In the furnace sector, production relationships are specified that relate furnace coke consumption to steel production. Other expressions describe the relationships between domestically produced steel and coke and imports and exports of those commodities. Additional expressions describe the relationship between steel produced using coke and steel produced using an EAF, which are assumed to be close but not perfect substitutes for one another. Figure 6-6 depicts the markets simulated by the furnace sector model and shows the commodities for which changed prices and quantities are estimated. The foundry sector of the model is simpler, containing expressions for quantities of coal



S_1 shows supply of coke without regulation. P_1 and Q_1 show market equilibrium price and quantity of coke without the regulation.

S_2 shows supply of coke with regulation. S_2 is vertically greater than S_1 by the amount of the unit compliance cost for each battery. P_2 and Q_2 show equilibrium price and quantity for coke with the regulation (a single control option shown).

Figure 6-5. Effect of Control Options on Market for Coke

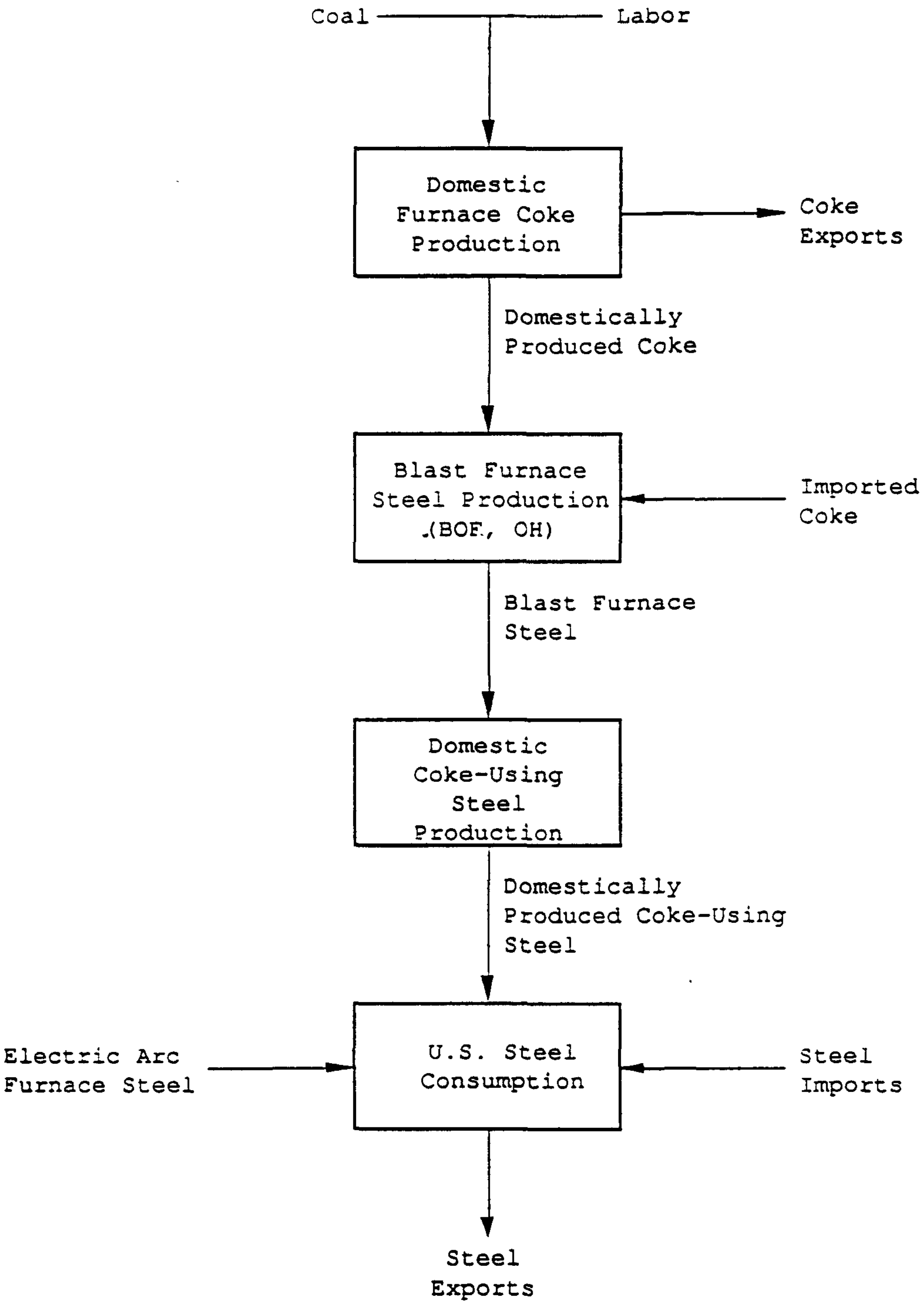


Figure 6-6. Markets and Commodities in the Furnace Sector of the Coke Ovens NESHAP Economic Impacts Model

and labor used to produce foundry coke, the demand for foundry coke, and the supply of foundry coke.

The analysis of the standards given in the 1990 Amendments to the Clean Air Act used this model, together with projected baseline conditions in the affected industries, to quantitatively evaluate the relative impacts of the estimated compliance costs resulting from the emissions controls.

We provide the parameter estimates required for the impact estimation model in Table 6-11. Some of these parameters were adopted directly from an earlier study performed to analyze the effects of the emissions controls contained in the 1987 NESHAP proposal. These parameters include elasticities of demand, which are parameter estimates resulting from regression analyses in an econometric analysis of the steel industry.[37] Conversations with foundry producers suggest that the elasticity of demand for foundry coke estimated for the 1987 analysis may be too low. This elasticity measures the percentage increase (decrease) in the quantity of foundry coke demanded in response to a 1 percent

TABLE 6-11. PARAMETER ESTIMATES FOR THE FURNACE AND FOUNDRY COKE IMPACTS MODEL, 1993 BASELINE

Parameter	Value
Demand Elasticities	
Furnace coke imports	9.93
Steel exports	-1.69
Steel imports	1.51
Steel consumption	-1.86
Foundry coke exports	0.00
Foundry coke consumption	-1.03
Coke steel, price of EAF steel	0.6
EAF steel, price of coke steel	1.0
Supply Elasticities	
Furnace coke	0.77
Foundry coke	2.03
Other steel inputs	1.00
EAF steel	1.20
Substitution Elasticities	
Furnace coke, other steel inputs	0.10
Cost Shares	
Furnace coke in coke-using steel	8.41%
Other steel inputs in coke-using steel	91.59%
Market Shares	
Furnace coke production/furnace coke consumption	79.69%
Furnace coke imports/furnace coke consumption	22.23%
Furnace coke exports/furnace coke consumption	1.92%
Coke-using steel in steel production	61.71%
EAF steel in steel production	38.29%
Steel production/steel consumption	87.03%
Steel imports/steel consumption	17.48%
Steel exports/steel consumption	4.50%
Foundry coke production/foundry consumption	100.00%

decrease (increase) in the price of foundry coke. A higher elasticity estimate would mean that foundry producers are less able to pass cost increases along to customers; a given increase in cost would result in a larger decrease in quantity of coke produced and a smaller increase in its price. Attempts to re-estimate the elasticity econometrically failed to produce statistically significant results, so the old elasticity estimate was used.

Other parameters such as cost shares, output shares, or market shares were re-calculated based on the 1989 conditions in the affected markets. Still other parameters, such as the cross-price elasticities of demand for coke-using steel and EAF steel and the elasticity of substitution in production of coke-using steel between coke and other steel inputs, were assumed, based on expectations of these relationships.

Estimating the elasticities of supply in the two coke markets requires first constructing supply curves in those markets by sorting the batteries by increasing supply price, reflecting the assumption that they would be taken out of production, if at all, in order of "highest cost first." This sorting process enabled construction of industry supply curves for furnace and foundry coke. These supply curves relate the supply price of coke to the total quantity of coke that would be supplied in the market at each price. Finally, log-linear regressions computed the elasticities of supply in the furnace coke and foundry coke markets. The coefficient b in the following equation is the elasticity of supply:

$$\ln(Q\ \text{coke}) = a + b \bullet \ln(P\ \text{coke}) + u_i$$

where

Q coke = the cumulative quantity of coke produced,

P coke = the supply price of coke including compliance costs,

u_i = an error term reflecting the unexplained variation in the quantity of coke produced.

The model uses these parameters and the percentage increase in cost resulting from the controls to calculate percentage changes in the prices and quantities of the commodities shown in Figure 6-6 that result from each control level. The direct result of implementing the controls is to increase the supply price at which a given quantity of coke will be offered by each battery. The increase in the supply price resulting from the regulation, estimated by computing the average unit compliance cost as a percentage of the average baseline supply price, provides the exogenous shock that motivates the model.

6.6.3 Implementing the Impacts Estimation Procedure

The model described above, combined with our projected baseline, described above, determines the estimated impacts of the MACT and LAER standards. In general, facilities under analysis are expected to choose to meet the minimum MACT standards in 1993 and to implement LAER controls in 1998. Thus, a projected 1993 baseline was constructed against which the impacts of the MACT controls can be measured.

6.6.3.1 ***Estimating the Impacts of MACT in 1993.*** First, 1993 coke production in each of the sectors was estimated. We projected total furnace coke consumption as a function of coke-using steel production. Projected furnace coke consumption in 1993 exceeds furnace coke capacity currently present. For the furnace sector, therefore, all batteries still present in 1993 are assumed to produce at capacity. (One facility informed EPA that a furnace coke battery would be closed during 1992. Consequently, this battery was omitted from the analysis.) We projected total merchant coke production as a function of gray and ductile iron castings production, then projected total foundry coke production by subtracting the 1992 quantity of furnace coke produced by merchant facilities. Each foundry battery's coke production was projected by multiplying its capacity by a scaling factor so that the sum of all the foundry batteries' output exactly equaled projected foundry coke production. The scaling factor used was the ratio of total projected foundry coke production in 1993 to the summed capacities of foundry coke batteries projected to be present in 1993.

Then, assuming that production relationships remained unchanged, coal and labor use in 1993 was estimated based on 1993 projected coke production. Furnace coke imports were adjusted to make up the difference between coke production and coke consumption plus coke exports. We assumed furnace coke exports were constant. Because this analysis assumed that the process of producing coke-using steel remains unchanged, the quantity of other steel inputs used to produce coke-using steel (iron ore was used as a proxy for all other inputs used) was adjusted to maintain its 1990 relationship to coke-using steel production. Coke-using steel production was changed to reflect the projected quantity in 1993. EAF steel production was assumed to remain constant at 1990 levels, as were imports and exports of steel and all baseline prices.

Each battery's unit cost (cost per megagram) of complying with MACT controls was computed by dividing the battery's annualized cost of compliance by the battery's estimated output. Adding the battery unit cost of compliance to the baseline supply price yielded the battery's supply price of coke with the controls in place.

The model computes the changes in certain prices and quantities, relative to the baseline conditions in those markets. These relative changes result from an exogenous change in one of the interrelated markets. In this case, compliance with the emissions controls will increase the cost of supplying coke, resulting in an upward shift in the supply curves for both furnace and foundry coke (see Figure 6-5). The model uses this upward shift from the compliance cost analysis to quantify the exogenous shock to which the affected markets respond.

The supply-shift parameter that measures the percentage increase in coke production costs resulting from the standard was calculated by dividing the average cost of compliance by the average baseline cost. These parameters were entered into the impacts estimation model, and the model simulated the response of affected markets to this exogenous shock. The market interaction of supply and demand in the coke markets results in higher prices for both furnace and foundry coke and a smaller quantity of coke produced. The quantity of coke-using steel produced falls, because its production is now more costly, and its price rises. The quantity of EAF steel produced increases, because some steel users substitute EAF steel for coke-using steel. Imports of both coke and steel are expected to increase, because they are now relatively less expensive than their domestically produced counterparts. Finally, the markets for the inputs used to produce coke and for the steel whose production uses coke will also be affected, and the model predicts decreases in their quantities as well.

6.6.3.2 ***Estimating the Impacts of LAER in 1998.*** Estimating the impacts of the LAER controls assumed to be adopted by all coke producers in 1998 first involves estimating the baseline conditions in 1998. The projected baseline quantities of furnace coke consumed, foundry coke, and coke-using steel produced in 1998 were used to determine the 1998 baseline in the absence of the regulation. EPA has been informed that four batteries will close in 1994; these batteries were included in the production estimate for the 1993 analysis but are deleted for the 1998 analysis.

As was the case for the 1993 baseline, the summed capacities of the furnace batteries expected to be present in 1998 are less than projected furnace coke consumption; therefore, all furnace coke batteries present in 1998 are assumed to produce at capacity. Their summed capacity determines estimated furnace coke production at baseline. Furnace coke imports are projected to make up the difference between furnace coke consumption and furnace coke production plus exports. Estimated foundry coke production exceeds projected foundry coke production in 1998. Therefore, we scaled each foundry battery's production again so that the summed outputs of all batteries exactly equal total projected production.

Then, the LAER unit compliance costs were added to the baseline supply price for the batteries present in each sector, the data were sorted by this resulting supply price with compliance cost, and elasticities of supply and exogenous shift parameters were computed for each cost scenario. (See Section 6.6.2 for a more detailed description of this process.)

The resulting parameters, entered into the impacts estimation model, result in the same types of decreases in quantities and increases in prices as occurred under MACT. But, unlike MACT, several batteries are estimated to close as a result of the LAER standard.

6.6.4 Results of the Market Impact Estimation Model

As described above, the model uses a shift parameter that measures the percentage increase in the marginal supply price of coke in each market resulting from complying with the emissions controls. This supply-shift parameter provides an exogenous shock to the interrelated markets for coke, coal, labor, and steel. The model uses a system of simultaneous equations to estimate the resulting percentage changes in the equilibrium prices and quantities in those markets.

6.6.4.1 ***Impacts of MACT Standard, 1993.*** Table 6-12 depicts the baseline conditions projected for 1993. These conditions reflect a moderate decline in steel and coke production during the period 1989-1993. The economic impacts assessment model produces impact measures that are described in terms of percentage changes in the prices and quantities traded in the affected markets. These percentage changes can be combined with baseline information about these markets to predict the absolute changes in prices and quantities and the levels of prices and quantities that would result with the control levels in place. Finally, the estimated changes in quantity of coke produced can be used to determine whether any batteries may be shut down as a result of the regulation.

6.6.4.1.1 ***Percentage Changes in Quantities and Prices.*** Table 6-13 shows the percentage changes in the prices and quantities in affected markets resulting from the MACT control level. The changes in the equilibrium prices and quantities are expected to be small. Furnace coke production is predicted to decline by 0.66 percent, while the price of coke increases by 0.22 percent. Furnace coke imports are projected to increase by nearly 2.21 percent, so that overall furnace coke consumption decreases by only 0.03 percent. The production of coke-using steel is estimated to fall by 0.01 percent and its price to increase by 0.01 percent. Overall, domestic steel production and consumption are projected to fall by at most 0.01 percent.

In the foundry sector, changes are also expected to be small. Foundry coke production is expected to fall by 1.08

TABLE 6-12. BASELINE PRICES AND QUANTITIES IN AFFECTED MARKETS, 1993

	Price[a]	Quantity[b]
Furnace Coke Sector		
Coal	54.08	28,194
Labor	16.21	12,121
Furnace coke produced	90.88	21,535
Furnace coke imported	90.88	6,007
Furnace coke exported	90.88	520
Furnace coke consumed	90.88	27,022
Other steel inputs (iron ore)	32.78	73,067
Domestic coke-using steel produced	538.76	54,202
Electric arc furnace steel produced	538.76	33,628
Total domestic steel produced	538.76	87,830
Steel imported	538.76	17,637
Steel exported	538.76	4,546
Steel consumed	538.76	100,921
Foundry Coke Sector		
Coal	51.79	4,048
Labor	16.21	1,261
Foundry coke produced	160.50	1,714
Foundry coke consumed	160.50	1,714

[a] Units are 1991 \$/Mg except for labor. Labor's price is in 1991 \$/hour.
[b] Units are 10^3 Mg except for labor. Labor is measured in jobs.

TABLE 6-13. PERCENTAGE CHANGES IN PRICES AND QUANTITIES IN AFFECTED MARKETS UNDER MACT MINIMUM CONTROL LEVEL, 1993

	Price (%)	Quantity (%)
Furnace Coke Sector		
Coal	0.00	-0.66
Labor	0.00	-0.66
Furnace coke produced	0.22	-0.66
Furnace coke imported		2.21
Furnace coke exported		0.00
Furnace coke consumed		-0.03
Other steel inputs (iron ore)	-0.01	-0.01
Domestic coke-using steel produced	0.01	-0.01
Electric arc furnace steel produced	0.00	0.00
Total domestic steel produced	0.01	-0.01
Steel imported		0.01
Steel exported		-0.01
Steel consumed		-0.00
Foundry Coke Sector		
Coal	0.00	-1.08
Labor	0.00	-1.08
Foundry coke produced	1.05	-1.08
Foundry coke consumed		

percent. With no change in foundry exports, this corresponds to a decrease in domestic foundry consumption of 1.05 percent. As noted above, we suspect that the estimated elasticity of demand is too low. If in fact the elasticity of demand is -2 instead of -1.03, the percentage changes in quantity of foundry coke produced and consumed are somewhat larger: -1.59 percent. The price of foundry coke, on the other hand, would increase by only 0.80 percent under these conditions.

Thus, the MACT controls projected to take effect in 1993 are expected to reduce the quantity of coke produced by at most approximately one percent. Relative impacts on steel are even smaller.

6.6.4.1.2 ***Absolute Changes in Quantities and Prices.*** Table 6-14 shows the absolute changes in the quantities and prices in the affected markets, computed by combining the percentage changes shown in Table 6-13 and the baseline prices and quantities shown in Table 6-12. Under MACT, furnace coke production is projected to decrease by about 142,000 Mg. Imports of furnace coke increase by 133,000 Mg, so consumption of furnace coke decreases by only 9,000 Mg. The price of furnace coke is projected to increase by $0.20 per Mg. Iron ore use is projected to decrease by 8,000 Mg, and its price to decline by $0.06 per Mg. As a result of these changes, relatively small changes also occur in the market for steel. The price of steel increases by about $0.03 per Mg, and steel production using pig iron from blast furnaces is expected to decrease by 7,000 Mg. Electric arc steel production increases by 1,000 Mg, so total domestic steel production decreases by 6,000 Mg. Exports decrease slightly and

TABLE 6-14. CHANGES IN PRICES AND QUANTITIES IN AFFECTED MARKETS UNDER MACT MINIMUM CONTROL LEVEL, 1993

	Price[a]	Quantity[b]
Furnace Coke Sector		
Coal	0.00	-186
Labor	0.00	-80
Furnace coke produced	0.20	-142
Furnace coke imported		133
Furnace coke exported		0
Furnace coke consumed		-9
Other steel inputs (iron ore)	-0.06	-8
Domestic coke-using steel produced	0.04	-7
Electric arc furnace steel produced	0.01	1
Total domestic steel produced	0.03	-6
Steel imported		2
Steel exported		-0
Steel consumed		-4
Foundry Coke Sector		
Coal	0.00	-44
Labor	0.00	-14
Foundry coke produced	1.68	-19
Foundry coke consumed		-19

[a] Units are 1991 $/Mg except for labor. Labor's price is in 1991 $/hour.
[b] Units are 10^3 Mg except for labor. Labor is measured in jobs.

imports increase slightly. Steel consumption is projected to decrease by 4,000 Mg.

Foundry coke incurs relatively small impacts under MACT. Production and consumption of foundry coke decrease by about 19,000 Mg, while prices for foundry coke increase by $1.71 per Mg. If the elasticity of demand is -2 instead of -1.03, the quantity produced and consumed would decrease by 27,000 Mg, while the price would increase by $1.28 per Mg.

6.6.4.1.3 ***New Prices and Quantities.*** Table 6-15 shows the resulting prices and quantities in each of the affected markets under MACT, computed by combining the absolute changes in Table 6-14 with the baseline quantities and prices shown in Table 6-12.

TABLE 6-15. NEW PRICES AND QUANTITIES IN AFFECTED MARKETS UNDER MACT MINIMUM CONTROL LEVEL, 1993

	Price[a]	Quantity[b]
Furnace Coke Sector		
Coal	54.08	28,008
Labor	16.21	12,041
Furnace coke produced	91.08	21,393
Furnace coke imported		6,140
Furnace coke exported		520
Furnace coke consumed		27,013
Other steel inputs (iron ore)	32.72	73,059
Domestic coke-using steel produced	538.80	54,195
Electric arc furnace steel produced	538.77	33,629
Total domestic steel produced	538.79	87,824
Steel imported		17,639
Steel exported		4,546
Steel consumed		100,917
Foundry Coke Sector		
Coal	51.79	4,004
Labor	16.21	1,247
Foundry coke produced	162.18	1,695
Foundry coke consumed		1,695

[a] Units are 1991 $/Mg except for labor. Labor's price is in 1991 $/hour.
[b] Units are 10^3 Mg except for labor. Labor is measured in jobs.

Under MACT, furnace coke production falls to 21.4 million Mg, and the price increases to $91.08 per Mg. Furnace coke imports increase to 6.1 million Mg, and furnace coke consumption falls to 27.0 million Mg. Steel production using pig iron decreases to 54.2 million Mg, and total steel production decreases to 87.8 million Mg. The price of steel remains approximately $539 per Mg.

In the foundry coke market, under MACT, the quantity of coke produced falls to 1.70 million Mg, while the price increases to $162.18 per Mg. Foundry coke consumption falls to 1.70 million

Mg. If the elasticity of demand were -2 instead of -1.03, the quantity of foundry coke produced and consumed would decrease to 1.69 million Mg, and its price would increase to approximately $161.78 per Mg.

6.6.4.2 *Impacts of LAER Standard, 1998.* The baseline against which the impacts of LAER were measured was constructed as described in Section 6.6.3.2. Table 6-16 shows this 1998 baseline. Then, adding unit compliance costs to baseline supply price and sorted the data by the resulting supply price with compliance costs produced supply curves with the LAER standard in place. Exogenous shift parameters were computed, and these parameters were input into the model. The model then simulated the response to the implementation of LAER controls in 1998 in the interrelated markets for coke and steel.

TABLE 6-16. BASELINE PRICES AND QUANTITIES IN AFFECTED MARKETS, 1998

	Price[a]	Quantity[b]
Furnace Coke Sector		
Coal	54.08	27,070
Labor	16.21	11,637
Furnace coke produced	91.08	20,676
Furnace coke imported	91.08	6,128
Furnace coke exported	91.08	520
Furnace coke consumed	91.08	26,284
Other steel inputs (iron ore)	32.72	70,694
Domestic coke-using steel produced	538.80	52,708
Electric arc furnace steel produced	538.77	33,629
Total domestic steel produced	538.79	86,337
Steel imported	538.79	17,636
Steel exported	538.79	4,456
Steel consumed	538.79	99,427
Foundry Coke Sector		
Coal	51.79	4,084
Labor	16.21	1,254
Foundry coke produced	162.18	1,703
Foundry coke consumed	162.18	1,704

[a] Units are 1991 $/Mg except for labor. Labor's price is in 1991 $/hour.
[b] Units are 10^3 Mg except for labor. Labor is measured in jobs.

6.6.4.2.1 *Percentage Changes in Quantities and Prices.* Table 6-17 shows the percentage changes in the prices and quantities in affected markets resulting from the LAER control level. In the furnace coke sector, we estimate that the quantity of coke produced will decrease by 2.13 percent. This decrease is

TABLE 6-17. PERCENTAGE CHANGES IN PRICES AND QUANTITIES IN AFFECTED MARKETS UNDER LAER CONTROL LEVEL, 1998

	Price[a] (%)	Quantity[b] (%)
Furnace Coke Sector		
Coal	0.00	-2.13
Labor	0.00	-2.13
Furnace coke produced	0.00	-2.13
Furnace coke imported	0.68	6.74
Furnace coke exported		0.00
Furnace coke consumed		-0.11
Other steel inputs (iron ore)	-0.04	-0.04
Domestic coke-using steel produced	0.02	-0.04
Electric arc furnace steel produced	0.01	0.01
Total domestic steel produced	0.02	-0.02
Steel imported		0.03
Steel exported		-0.03
Steel consumed		-0.01
Foundry Coke Sector		
Coal	0.00	-2.60
Labor	0.00	-2.60
Foundry coke produced	2.53	-2.60
Foundry coke consumed		-2.60

accompanied by a 0.68 percent increase in the price of furnace coke. Because imports of furnace coke are projected to increase by 6.74 percent, the overall quantity of furnace coke consumed falls by only 0.11 percent. A small decrease in the quantity of coke-using steel produced (0.04 percent) combines with small increases in EAF steel production (0.01 percent) and steel imports (0.03 percent) and results in a 0.01 percent decrease in steel consumed in the U.S.

Relative impacts in the foundry coke sector are larger. Foundry coke production and consumption are projected to fall by 2.60 percent in the main scenario and price would increase by 2.53 percent. If the elasticity of demand for foundry coke is actually -2 instead of -1.03, the quantity of foundry coke produced and consumed would decrease by 3.84 percent. In that case, the price would increase by only 1.92 percent.

6.6.4.2.2. ***Absolute Changes in Quantities and Prices.*** Table 6-18 shows the absolute changes in the quantities and prices in the affected markets attributable to LAER, computed by combining the percentage changes shown in Table 6-17 and the baseline prices and quantities shown in Table 6-16. Furnace coke production is projected to fall by 441,000 Mg. Imports of furnace coke are projected to increase by 413,000 Mg, so furnace coke consumption decreases by only 28,000 Mg. The price of furnace coke is projected to increase by $0.62 per Mg. Small decreases in the production of coke-using steel and total steel combine with small increases in EAF production and steel imports

TABLE 6-18. CHANGES IN PRICES AND QUANTITIES IN AFFECTED MARKETS UNDER LAER CONTROL LEVEL, 1998

	Price[a]	Quantity[b]
Furnace Coke Sector		
Coal	0.00	-577
Labor	0.00	-248
Furnace coke produced	0.62	-441
Furnace coke imported		413
Furnace coke exported		0
Furnace coke consumed		-28
Other steel inputs (iron ore)	-0.19	-25
Domestic coke-using steel produced	0.13	-22
Electric arc furnace steel produced	0.04	3
Total domestic steel produced	0.10	-19
Steel imported		5
Steel exported		-1
Steel consumed		-12
Foundry Coke Sector		-106
Coal	0.00	-33
Labor	0.00	-44
Foundry coke produced	4.10	-44
Foundry coke consumed		

[a] Units are 1991 $/Mg except for labor. Labor's price is in 1991 $/hour.
[b] Units are 10^3 Mg except for labor. Labor is measured in jobs.

to result in a projected decrease in steel consumption of 12,000 Mg. The price of various types of steel is projected to increase by $0.04 to $0.13 per Mg.

Production and consumption of foundry coke decrease by about 44,000 Mg in our main scenario, while prices for foundry coke increase by $4.10 per Mg. If, on the other hand, the elasticity of demand for foundry coke is -2 instead of -1.03, foundry coke production and consumption would decrease by 65,000 Mg, and the price would increase by only $3.10 per Mg.

6.6.4.3 ***New Prices and Quantities.*** Table 6-19 shows the resulting prices and quantities in each of the affected markets under each of the control levels, computed by combining the absolute changes in Table 6-18 with the baseline quantities and prices shown in Table 6-16.

Production of furnace coke is projected to fall to 20.2 million Mg. Imports of furnace coke are expected to increase to 6.5 million Mg, so that furnace coke consumption falls to 26.3 million Mg. The price of furnace coke is expected to increase to $91.70 per Mg. Only small adjustments are projected to take place in the markets for steel. Coke-using steel produced decreases to 52.7 million Mg, while EAF production increases to

TABLE 6-19. NEW PRICES AND QUANTITIES IN AFFECTED MARKETS UNDER LAER CONTROL LEVEL, 1998

	Price[a]	Quantity[b]
Furnace Coke Sector		
Coal	54.08	26,492
Labor	16.21	11,389
Furnace coke produced	91.70	20,235
Furnace coke imported		6,541
Furnace coke exported		520
Furnace coke consumed		26,256
Other steel inputs (iron ore)	32.53	70,669
Domestic coke-using steel produced	538.93	52,686
Electric arc furnace steel produced	538.81	33,632
Total domestic steel produced	538.89	86,318
Steel imported		17,641
Steel exported		4,545
Steel consumed		99,415
Foundry Coke Sector		
Coal	51.79	3,977
Labor	16.21	1,221
Foundry coke produced	166.28	1,660
Foundry coke consumed		1,660

[a] Units are 1991 $/Mg except for labor. Labor's price is in 1991 $/hour.
[b] Units are 10^3 Mg except for labor. Labor is measured in jobs.

33.6 million Mg. Total domestic steel production decreases to 86.3 million Mg, while steel consumption in the U.S. falls to 99.4 million Mg. The new prices of different types of steel range from $538.81 to $538.93 per Mg.

In the foundry coke market, production and consumption fall to 1.66 million Mg, while the price increases to $166.28 per Mg. Under the scenario where the elasticity of demand is higher, the quantity of foundry coke falls to 1.64 million Mg, while the price increases to only $164.88 per Mg.

6.6.4.4 *Battery Closures.* The decreases in coke production that result under the MACT standard and under both cost scenarios for the LAER standard may result in the closure of some coke batteries. This analysis measures closures in terms of the average-sized battery in each sector. That is, the change in production is compared with the size of the average battery in each sector. If the change in production exceeded 50 percent of the output of an "average" battery, one battery closure would occur. In so doing, we assumed that one battery would make all the adjustment in quantity. Possibly the adjustment in quantity would be spread over many operating batteries, and no batteries would close.

Under MACT, the reduction in coke production can be accomplished by reducing the output of a single average furnace coke battery and a single foundry coke battery, with no batteries being required to close. Under LAER, two furnace batteries are projected to close. If the elasticity of demand for foundry coke is -1.03, no batteries would close. The projected decrease in foundry coke production could be accompanied by reducing the output of one average foundry battery. If, on the other hand, the elasticity of demand is -1.75 or greater (in absolute value), one foundry battery is projected to close.

This projection must be interpreted in the context of the projected decline in furnace coke consumption and foundry production at baseline. These adjustments are projected to result from the expected decrease in furnace coke consumption and foundry coke production in the absence of this regulation. Over the period from 1990 to 2010, furnace coke consumption is projected to decline by 2.86 million Mg. During the same period, foundry coke production is projected to decline by 0.29 million Mg, resulting in the closure of batteries. EPA has been informed by industry that five batteries at one facility will be shut down by 1998. Two other batteries at two facilities are not expected to meet LAER and may close by 2003. These closures, which have not been attributed by their owners to this regulation, far outnumber the closures attributed to the NESHAP in this analysis.

6.6.5 Evaluation of Small Business Impacts

The Clean Air Act requires that economic impacts on small businesses be investigated and that significantly adverse impacts be mitigated. The first step in such an investigation is to identify small businesses owning affected facilities. The Small Business Administration's definition of "small business" for each SIC Code is given in 13 CFR Part 121. For SIC code 3312, Blast Furnaces and Steel Mills, small firms are those with less than 1000 employees. Data were obtained about numbers of employees from Dun and Bradstreet's DUNS Market Identifiers[38] and from telephone conversations with some of the affected facilities.[39-45] Of the companies owning coke plants in operation in 1991, only four are small. Three of these are foundry coke producers:

- Erie Coke,
- Toledo Coke, and
- Tonawanda Coke.

The other small company, New Boston Coke, is a furnace producer. All are merchant coke producers. The three foundry coke producers are all owned by one individual; but even if they are treated as one firm, it would qualify as a small firm.

One measure of a "significant" impact is whether compliance costs exceed 1 percent of baseline production costs. At the minimum MACT control level, estimated cost of compliance exceeds 1 percent of estimated baseline production costs for two of the four small companies. Under LAER, compliance costs exceed 1 percent of baseline costs for all four. For one of the small companies, estimated LAER compliance costs exceed 10 percent of estimated baseline costs of production. This criterion, therefore, indicates that significant impacts will occur as a result of the candidate NESHAP.

This conclusion must be interpreted in the context of the effect of the regulation on the firms' revenues. One of the four small firms is estimated to be unprofitable at baseline. It is projected to become more unprofitable in the MACT and LAER analyses. The other three small businesses are believed to be profitable at baseline. They continue to be profitable under both the MACT and LAER scenarios, although one that is thought to be extremely profitable at baseline is expected to be somewhat less profitable with the controls in place. The other two small businesses are expected to increase their profitability under LAER.

The market prices for furnace and foundry coke are projected to increase as a result of the regulation. This will result in higher revenues for the facilities that continue in production with the regulation in place. The firms that own these facilities will suffer adverse impacts only if their increased revenues do not exceed the increased production costs arising from complying with the emissions controls. Under MACT, three of the small firms are expected to incur compliance costs exceeding the increase in revenue they are projected to receive. Under LAER, two small businesses are expected to incur compliance costs exceeding the increase in revenues predicted by the model. Although one firm is expected to lose approximately $1.2 million more under LAER relative to its baseline positions, it will continue to be profitable under LAER. However, the other small firm is expected to lose $1.6 million and may become more unprofitable under LAER than it is currently.

The other two small firms are expected to experience profits that increase by $650,000 and $800,000 as a result of the regulation. This result occurs because market price is projected to increase by more than their costs of control. These firms are projected to be more profitable with the controls in place than at baseline, so we do not believe they will be adversely affected by the controls. Because only a small absolute number of small firms (two) is projected to incur significant adverse impacts as a result of the standard, a formal Regulatory Flexibility Analysis is not required.

6.6.6 Indirect Impacts

In addition to the impacts projected by the model, there are additional impacts that may result from the regulation. Such impacts include the effects of decreased coke production on the markets for the by-products of coke ovens, impacts on communities of plant closures, and additional costs incurred by companies when facilities are closed. Although it is beyond the scope of this study to analyze these impacts quantitatively, they are discussed qualitatively in this section.

6.6.6.1 *Impacts on By-Product Markets.* The projected decreases in coke production are expected to be associated with decreased production of coke by-products. The by-products of carbonizing coal to make coke include gas, gas liquor, light oils and tar. By-product yields are a function of the volatility of the coals carbonized. Because the production of foundry coke requires using a less volatile coal mixture than does the production of furnace coke, carbonizing coal for foundry coke production yields more coke (foundry coke and "other" coke) and fewer by-products than for furnace coke production. Carbonization of 1 Mg of dry coal to produce furnace (foundry) coke yields approximately 0.7 Mg (0.8 Mg) of coke, 12,100 (10,450) cubic feet of gas, 35 (15) gallons of gas liquor, 4 (2.5) gallons of light oils, and 9 (5) gallons of coal tar.[46,47] By-product yields for both types of coke production will vary with the different recovery methods and different carbonization temperatures.

About 40 percent of the coke gas produced is used to underfire the coke ovens that produce it. In integrated steel plants virtually all of the excess gas produced is used for fuel in other steps of the steel-making process. Foundry coke producers generally use what they can of the excess gas, and attempt to sell the remainder. Several foundry coke producers simply burn their excess gas to dispose of it.[48] Coke gas is not as volatile as natural gas. It typically only has about 500 Btu per cubic foot compared to 1,000 Btu per cubic foot for natural gas.[49] Those coke producers that use or sell their excess gas could significantly affect local energy market conditions if they stopped producing the coke gas that currently provides for their own or others' energy needs. Other down-stream products that use coke gas distillates include synthetic resins, adhesives, anti-freeze, insecticides, explosives, pharmaceuticals, and fertilizers.[50]

Gas liquor is used in the production of fertilizers, explosives, and pyridine tar bases, which are inputs to the production of many products including dyestuffs, latex adhesives, pharmaceuticals, solvents, and many others.[51]

Light oils derived from carbonizing coal are used to produce hundreds of products ranging from aspirin, flavorings, detergents, and deodorants to poison gas, herbicides, photographic chemicals, and saccharin.[52] Light oils produced in coking make up about 10 percent of the U.S. market supply.[53]

The by-product markets that would be most significantly affected by a reduction in the amount of coke produced in by-product recovery plants are the market for coal tar and its down-stream products. Coal carbonization is the only available source of coal tar. Coal tar is used to make creosote oils, the most widely used and efficient products for preserving wood.[54] Coal tar is also refined to produce tars and pitch used for roofing, road surfacing, sidewalk composition, waterproofing, insulation, and many other uses. It is distilled to extract other chemicals such as naphthalene that is used to produce products ranging from mothballs and insect repellents to solvents, detergents, fabric dyes, inks, and paints.[55]

6.6.6.2 *Community Impacts*. When a facility is closed, the workers employed there generally become unemployed. Under MACT, we project that employment will fall by 96 workers at furnace and foundry coke facilities. No facility closures are projected, so these changes in employment may be interpreted as temporary layoffs associated with reductions in output at facilities that remain open. Under LAER, we project the closure of two furnace batteries, with an associated reduction in employment of 279 workers. (Information from industry indicates that as many as 500 workers may be displaced by the closing of two batteries.) In the foundry sector, we project the closure of at most one battery. In our main scenario, there are no closures, but output reductions are associated with a decrease in employment of 37 workers. In our alternative scenario, however, output falls by more than 50 percent of the capacity of the average foundry battery; this might result in a closure. Our model predicts a decrease in employment of only 59 workers, but if a battery were closed, that might result in the displacement of as much as 250 workers.

When workers become unemployed, their incomes fall and they spend less money in the local community. This situation in turn reduces the incomes of others in the community, who in turn spend less. If a large enough number of workers are displaced due to the original closure, additional workers in the community may lose their jobs. Thus, the immediate impact of the regulation is to reduce employment and income by the amount of the displaced coke-oven workers. This reduction will generally result in further reductions elsewhere in the community. For industries that produce final goods, multipliers are computed by the Department of Commerce that estimate the ultimate change in employment and income that will result from the original decrease in employment due to the facility closure. Because coke is an intermediate good, we are unable to use these multipliers to estimate the total change in employment and income that will result. Although we are unable to quantify it, we recognize that the total change in community employment and income will be somewhat higher than the direct change resulting from the closure.

6.6.6.3 *Additional Costs of Closure.* When a battery shuts down, the facility avoids the costs associated with coke production at that battery. They also avoid the costs associated with achieving any regulations that apply to the battery. The facility also incurs costs associated with shutting down the battery. These costs include personnel costs, the costs of cleaning up the site, and the costs of foregone sales of coke by-products.

Estimates of employee-related costs of coke battery closures were provided by Harry Kokkinis of Locker Associates and Monty Stuart of Bethlehem Steel. Mr. Kokkinis defined employee costs as the costs of paying early retirement benefits, retiree health insurance, and supplemental unemployment benefits to displaced workers. Assuming that half of the workers who would lose their jobs due to a premature battery closure would be over the age of 55 and therefore eligible for early retirement, Mr. Kokkinis estimated the total cost per job lost due to a battery closing earlier than expected to be about $60,000. Mr. Stuart estimated the total cost per employee of permanently closing any Bethlehem facility to be $100,000. This figure is the combined cost of cash outlays to the employee pension fund and to the individual employee required as the result of closing a facility permanently.

Mr. Stuart also provided an estimate of the cost of the site remediation activities for a typical by-product recovery coke plant required to comply with RCRA standards for continuing releases and corrective action in the event of the permanent closure of a hypothetical steel mill. The estimate was taken from a study conducted for AISI by REMCOR, Inc., in 1989. The size, in terms of production capacity, of the hypothetical coke plant for which costs were estimated was 1,090,909 Mg of furnace coke per year. The REMCOR estimate of the total capital cost of site remediation was $15,100,000. The REMCOR estimate for annual operating and maintenance costs during the clean-up period was $210,000 per year (all costs were estimated in 1989 dollars).

Our estimate of the revenues foregone because of foregone by-product sales resulting from a reduction in coke production depends on

- the unit prices of the individual by-products,
- the amount that production is reduced, and
- the type of coke facing the reduction in production.

The thermal value of 1,000 cubic foot of coke gas is approximately 0.5 decatherms. The going rate for 1 decatherm of energy in January, 1992, was $2.60. The price of coal tar is approximately $0.45 per gallon, and the price of light oils is about $0.32 per gallon. We do not believe that any net cost accrues to foregone sales of ammonia, the primary by-product derived from gas liquor, because the cost of properly disposing of this by-product is as high as the sale price. Based on the estimated by-product yields from carbonization of 1 Mg of coal to produce furnace (foundry) coke presented in Section 6.6.6.1, we estimate the foregone revenue per megagram reduction of furnace (foundry) coke produced to be $21.58 ($16.64).[56]

This amount represents the gross revenue loss per megagram reduction in coke produced rather than the net revenues loss. The processing and marketing of by-products result in costs, which are also foregone when by-product production decreases. We do not have estimates of these by-product production costs, so we cannot compare the decrease in revenues to the decrease in costs. It is likely, however, that net revenue from by-product sales will decrease due to decreases in coke production.

6.7 CONCLUSIONS

The aggregate impacts of this regulation on affected markets, even at the more stringent control level, are not very large. No batteries are expected to close as a result of MACT, and only two or three are expected to close as a result of LAER. This impact must be evaluated in the context of current conditions in the coke industry. Although coke production has recovered slightly in the last few years, a general downward trend in coke production and coke consumption by steel-makers, accompanied by the shutting down of coke batteries, is evident. (More than half the batteries in existence in 1979 had shut down by 1991.) Many batteries presently operating are old and will need to be replaced within the next 10 years or so, unless technology can be developed to extend their lives beyond 35 years (40 percent of the batteries in North America fall into this category, according to the International Iron and Steel Institute).[57] A declining quantity of coke consumption is projected over the period 1990 through 2000, due largely to a decline in projected coke-using steel production. This analysis assumes that the ratio of coke consumption to coke-using steel production will remain constant throughout the period. For several reasons, this may not be the case.

The shortage of investment capital, the considerable cost of building coke ovens, and the increasing cost of meeting antipollution laws are

> *some of the reasons why the industry throughout the world is developing and evaluating alternative methods to reduce coke requirements and possibly*

> *eliminate the need entirely. These developments include the use of pulverized or granulated coal injection into blast furnaces, with or without oxygen injection, and direct iron ore smelting with coal. Other developments are formed coke that uses less costly noncoking coals and heat-recovery coke-making.*[58]

Indeed, Inland Steel is expected to install a new nonrecovery process for coke-making with cogeneration of electricity that is expected to have much lower emissions than conventional by-product recovery coke-making. In Europe, producers are developing a smelting/reduction process that eliminates the need for coke and provides a degree of continuity between the iron-making and steel-making production processes.[59] Other influences suggesting lower coke demands include the direct reduction iron-making and the direct steel-making methods discussed in Section 6.2.

Thus, technological developments in the steel industry suggest that the demand for coke, relative to other steel-making inputs, may fall over time, as coke-saving technical changes are adopted by steel producers. If trends involving the substitution of other materials, such as plastics and ceramics, for steel continue, the demand for steel may continue to decrease, resulting in even lower demand for coke than projected.

Therefore, the regulation may at most accelerate the reductions in coke production that are occurring as a result of the changing conditions in the markets for iron and steel. Quantitatively, the impact of the regulation will probably be small relative to the influence of technical and economic changes presently occurring in the industry. Only two or three batteries are predicted to cease production as a result of the LAER standard, and only two small firms are projected to incur significant adverse economic impacts.

REFERENCES

1. DRI/McGraw-Hill Steel Industry Review, Long-Term Steel Industry Outlook and Iron and Steel Castings Shipments, Fourth Quarter 1991. Obtained from Charles L. Bell, U.S. Department of Commerce, Office of Basic Industries.

2. Labee, C.L., and N.L. Samways. Developments in the Iron and Steel Industry, U.S. and Canada - 1990. *Iron and Steel Engineer,* February 1991, p. D-22.

3. Reference 2.

4. U.S. Department of Energy, Energy Information Administration Quarterly Coal Report. 1989.

5. Douglas, John. Electrifying the Foundry Fire. *EPRI Journal,* October/November 1991.

6. U.S. Steel. The Making, Shaping, and Treating of Steel, 9th Edition. Pittsburgh. 1971.

7. Telecon. Eppich, Robert, American Foundryman's Society, with Robert Cushman, Research Triangle Institute. January 8 and 9, 1992.

8. Reference 5.

9. Duggan, Brian. U.S. Industrial Outlook 1991--Metals. September 1990.

10. Duggan, Brian. U.S. Industrial Outlook 1990--Ferrous Metals. September 1989.

11. Reference 7.

12. Telecon. Engle, Mark, American Coke and Coal Chemicals Institute, Washington, DC, with Cushman, Robert, Research Triangle Institute. January 15, 1992.

13. Reference 7.

14. U.S. Steel. The Making, Shaping, and Treating of Steel, 10th Edition. Pittsburgh, Association of Iron and Steel Engineers. 1985.

15. Reference 6.

16. Telecon. Dusel, Martin, Indianapolis Coke (Citizens' Gas and Coke Utility) with Cushman, Robert, Research Triangle Institute. March 3, 1992.

17. U.S. Department of Commerce. U.S. Industrial Outlook, Coal. Washington, DC. 1990.

18. U.S. Department of Energy, Energy Information Agency Quarterly Coal Report. 1990.

19. Telecon. Kokkinis, Harry, Locker Associates with Cushman, Robert, Research Triangle Institute. January 17, 1992.

20. Stuart, L.M. Bethlehem Steel Corporation. Letter to Robert Cushman, Research Triangle Institute, describing costs of coke battery closure. January 20, 1992.

21. American Coke and Coal Chemicals Institute (ACCCI), Employment Survey, Table 2. Provided by David Ailor, ACCCI, 1992.

22. Telecon. Brown, M., ABC Coke, with Sarmiento, Rhythm, Research Triangle Institute. March 6, 1991.

23. Telecon. Erie Coke, Erie, PA, with Sarmiento, Rhythm, Research Triangle Institute. March 6 and March 11, 1991.

24. Telecon. Landsell, M., Sloss Industries, Birmingham, AL, with Sarmiento, Rhythm, Research Triangle Institute. March 6 and March 8, 1991.

25. Telecon. Citizens' Gas, Indianapolis, IN, with Sarmiento, Rhythm, Research Triangle Institute. March 11, 1991.

26. Frazier, Richard M., Hickman, Williams, and Company. Written communication with Robert Cushman, Research Triangle Institute, detailing historical Indianapolis foundry coke price increases. December 31, 1991.

27. Pearson, John M., ABC Coke, Birmingham, AL. Written communication with Robert Cushman, Research Triangle Institute, including an 11-year history of published prices and estimated actual foundry coke prices for ABC Coke. January 31, 1992.

28. Reference 27.

29. Reference 1.

30. Telecon. Madhava, Bindu, Davy/Still Otto, with Cushman, Robert, Research Triangle Institute. January 20 and 22, 1992.

31. PEDCo Environmental, Inc. Revised Technical Approach for a Coke Production Cost Model. Prepared for U.S. Environmental Protection Agency. January 1991.

32. Johnson, Norman L., and Samuel Kotz. Continuous Univariate Distributions, Vol. 1. New York, John Wiley & Sons, 1970.

33. Reference 30.

34. Telecon. Eriser, Jim, ICF-Kaiser Engineering with Cushman, Robert, Research Triangle Institute. January 20, 1992.

35. Reference 34.

36. U.S. Environmental Protection Agency/Industrial Economics, Inc. Coke Ovens Capital Availability Analysis. Draft Memorandum. March 6, 1992.

37. Ramachandran, V. An Econometric Model of the U.S. Steel Industry. Draft Report. Research Triangle Institute. Research Triangle Park, NC. April 1981.

38. Dun and Bradstreet. DUNS Market Identifiers. February 1991. Online computerized database.

39. Telecon. Ailor, D., and Engle, M., American Coke and Coal Chemicals Institute, with Heller, Katherine, Sarmiento, Rhythm, and Curtis-Powell, Sandra, March 15, 1991.

40. Telecon. Hall, D., Koppers Industries, Woodward, AL, with Sarmiento, Rhythm, Research Triangle Institute. March 5, March 6, and March 11, 1991.

41. Reference 24.

42. Telecon. Webb, K., Terre Haute Coke, Terre Haute, IN, with Sarmiento, Rhythm, Research Triangle Institute. March 6, 1991.

43. Telecon. Seals, M., Empire Coke, Holt, AL, with Sarmmiento Rhythm, Research Triangle Institute. March 8, 1991.

44. Reference 23.

45. Reference 22.

46. Reference 16.

47. Reference 6.

48. Reference 16.

49. Reference 16.

50. Koppers Industries. Products Derived from Coal and Coal Products Tree. Information Pamphlets provided by Don Sweet. 1992.

51. Reference 50.

52. Reference 50.

53. Telecon. Lung, Henry, U.S. Steel (USX), with Cushman, Robert, Research Triangle Institute. March 18, 1992.

54. Telecon. Sweet, Don, Koppers Industries, with Cushman, Robert, Research Triangle Institute. March 13, 1992.

55. Reference 50.

56. Reference 16.

57. Reference 2.

58. Reference 2.

59. Reference 2.

CHAPTER 7

BENEFITS ANALYSIS

7.1 INTRODUCTION

This chapter presents analyses of the potential benefits associated with the National Emission Standards for Coke Oven Batteries. Benefits represent the improvement in society's well-being as a result of improved air quality. Total benefits are comprised of both use and non-use values. Use values are the values associated with an individual's desire to avoid his or her own exposure to an environmental risk; non-use values are values an individual may have for lowering the level of risk that is unrelated to his or her own exposure. This chapter presents monetized estimates of benefits for parts of three of the health and welfare components of use value associated with various levels of coke oven emission reductions: mortality, morbidity, and household soiling. The estimated benefits represent the incremental improvement from a baseline level of coke oven emissions that reflects current operating practice to compliance with the CAAA default limits of emission control. Data, time and resource limitations preclude a quantitative analysis for all potential benefit categories, therefore total benefits are understated. However, other components of total benefits are qualitatively discussed.

7.2 POLLUTANTS

Coke production results in the release of chemically-complex emissions to the atmosphere. Coke oven emissions are comprised of both gases and respirable particulate matter. The particulate fraction contains polycyclic organic matter, aromatic compounds (e.g. benzene, toluene), trace metals (e.g. arsenic, lead, chromium), and inorganic gases (e.g. nitric oxide, carbon monoxide, hydrogen sulfide), some compounds of which are known human carcinogens. The condensed particulates are within the respirable size range.

Table 7-1 presents the relative composition of coke oven gas based on an analysis conducted at USX Clairton.[1] Per ton of coal, almost 60% by weight of the coke oven gas is water vapor while approximately 37% of the coke oven gas is composed of carbon monoxide, heavy hydrocarbons, benzene, hydrogen, carbon dioxide, ethylene, and ethane. The remaining 3% of coke oven gas is composed of compounds such as napthalene, hydrogen sulfide, hydrogen cyanide, ammonia, toluene, and xylene. It should be noted that this analysis does not cover the trace elements that are simultaneously emitted such as arsenic, beryllium, cadmium, chromium, cobalt, iron, lead, nickel, selenium and mercury.

7.3 ENVIRONMENTAL BENEFITS

The release of hazardous compounds to the atmosphere as a result of coke production can adversely impact human health and welfare. Coke oven emissions may accelerate the onset of mortality and increase the incidence of acute and chronic morbidity. Reductions in coke oven emissions as a result of regulation will improve ambient air quality and in turn reduce the incidence of adverse health and welfare effects. The health and welfare improvements are the direct benefits of these environmental regulations.

7.4 METHODOLOGY

Ideally, the estimation of potential economic benefits would be accomplished using data, assumptions, and modeling techniques specifically developed for the analytic objective. However, time and resource constraints prevent this approach. Therefore, benefit estimates are based upon existing studies that may be applied to the health and welfare impacts from coke oven emissions. The following discussion outlines the steps involved in this benefit assessment.

7.4.1 Identification of Potential Benefit Categories

Table 7-2 illustrates the range of potential physical effects categories that may result from coke oven emission control strategies. For this analysis, benefits resulting from the control of coke oven emissions can be derived for both benzene soluble organics (BSO)(i.e., the organic component of coke oven emissions that is soluble in benzene) and particulate matter (PM).

TABLE 7-1
COMPOSITION OF COKE OVEN GAS

COMPOUND	% OF COKE OVEN GAS
Water Vapor	57.5
Methane	14.3
Carbon Monoxide	5.8
Heavy Hydrocarbons	4.2
Hydrogen	4.1
Benzene	2.7
Carbon Dioxide	2.5
Ethylene	2.1
Ethane	1.4
Napthalene	.8
Hydrogen Sulfide	.8
Ammonia	.8
Nitrogen	.8
Propylene	.4
Butene	.4
Hydrogen Cyanide	.3
Toluene	.2
Carbon	.2
Propane	.1
Butane	.1
Pentene	.1
Tar Acids	.1
Tar Bases	.1
Solvents	.1
Tar Abs Oil	.1
Acetylene	.05
Xylene	.02

* Coke oven gas analysis conducted at USX Clairton.[1] Analysis does not consider trace elements that are also emitted. These are the following: arsenic, beryllium, cadmium, chromium, cobalt, iron, lead, nickel, selenium, mercury.

TABLE 7-2.
POTENTIAL PHYSICAL EFFECTS CATEGORIES FOR COKE OVENS NESHAP

	BSO	PM
Human Health Effects		
Mortality Due to Chronic Exposure	*	
Mortality Due to Acute Exposure		
Morbidity Due to Chronic Exposure		
Morbidity Due to Acute Exposure		*
Reduced Activity Days		
Human Welfare Effects		
Worker Productivity Losses		
Odors		
Non-Human Biological Effects		
Agriculture		
Forestry		
Recreational/Commercial Fishing		
Ecosystem		
Soiling & Materials Damage		
Residential/Commercial/Industrial Facilities		*
Miscellaneous Materials		

* - Quantitatively estimated for this analysis.

7.4.2 Identification of Concentration-Response Functions Appropriate for Benefit Estimation

All identified studies are screened on the basis of several criteria, the most important of which are analytic quality and potential for extrapolation of estimates for benefit analysis (e.g. requisite air quality data available). As a result of this screening analysis, monetized estimates of benefits are provided for three benefit categories.

Emission controls will reduce ambient concentrations of the hazardous compounds contained in coke oven emissions. This analysis quantitatively estimates mortality benefits from reductions in ambient BSO concentrations (used as a surrogate measure for the carcinogenic component of coke oven emissions) and acute morbidity and household soiling benefits from reductions in ambient particulate matter concentrations. It is not possible, however, to quantify the other potential benefit categories presented in Table 7-2. For example, BSO and particulate coke oven emissions may have additional adverse health and welfare impacts (e.g., ecosystem, forestry, agricultural, and recreational and commercial fishing effects) for which there is no dose-response data.

There may be additional benefits that result from the reduction of hazardous compounds not covered by BSO or particulate matter benefits. For instance, some of the inorganic gases such as ammonia and hydrogen sulfide that escape during the coking process may contribute to an odor problem in the vicinity of coke plants. Additionally, trace metal emissions (e.g., lead, nickel, arsenic, and cadmium) may enter the aquatic environment via atmospheric deposition, locally impacting aquatic ecosystems.

7.4.3 Development of Benefit Estimates

Benefit estimates are developed using the identified concentration-response functions and the air quality improvements predicted for each regulatory option. Figure 7-1 illustrates the process of benefit estimate development.

The first step is to identify the magnitude of the ambient air quality improvement that is estimated to occur in each area and year. This is the improvement achieved due to implementation of a particular coke oven emission control measure, relative to a baseline situation that reflects existing controls.

The selected concentration-response functions are then used to determine the health and welfare improvements that may occur as a result of the improvement in ambient air quality for each area and year for which there is air quality improvement.

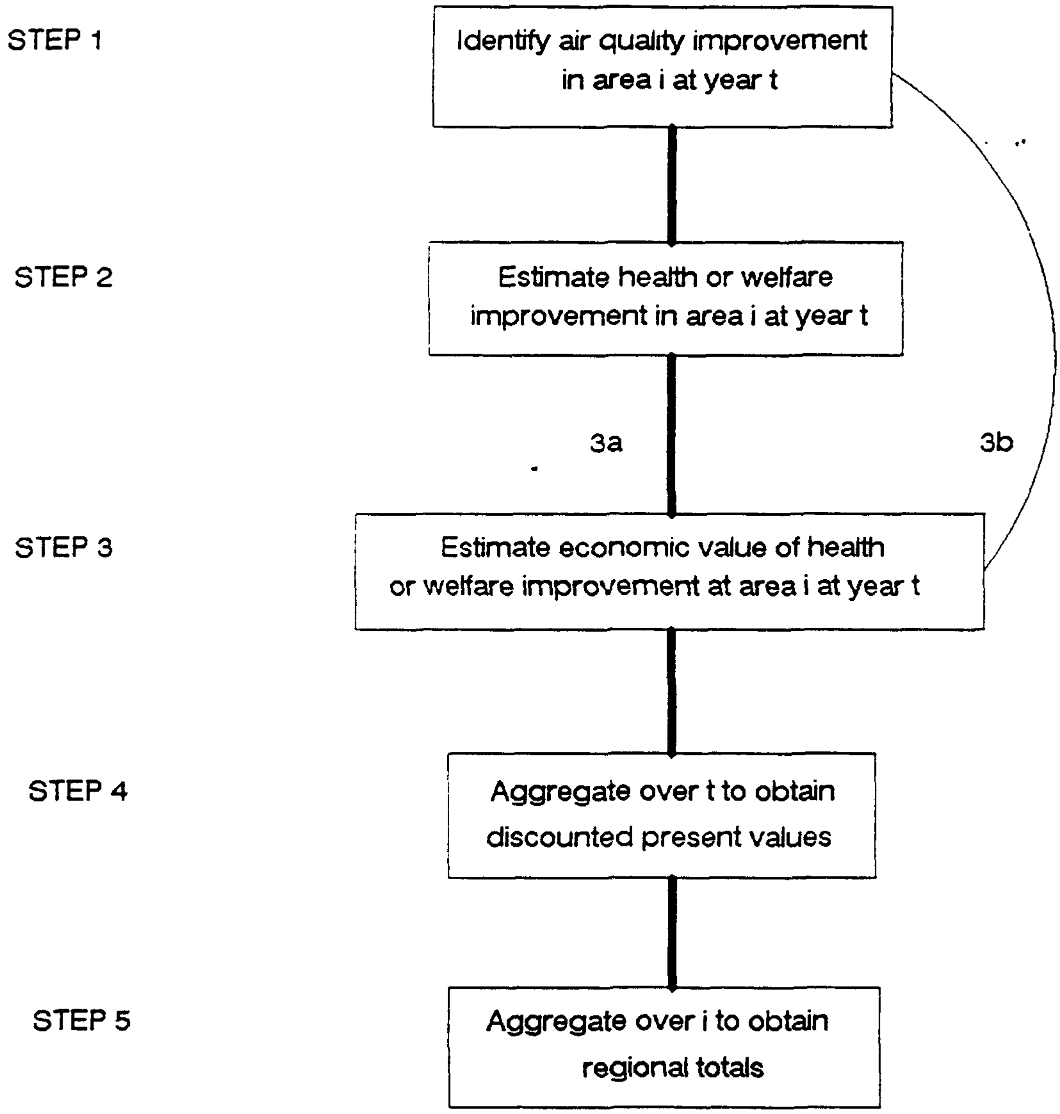


Figure 7-1. Benefits estimation process for an individual study.

Consideration of mitigating and averting behavior is important in determining the extent of population exposure to a hazardous compound and in turn estimating health effect incidence. For example, over time individuals may choose to move away from areas surrounding coke oven plants to escape the adverse effects of coke oven emissions. To the extent that this is the case, comparison of population data over time may capture this migration effect.

The third step is to impute an economic value to the estimated changes in health and welfare (step 3a). It is also possible to estimate economic values directly from the air quality improvement for some classes of benefits (step 3b) such as household soiling.

Benefit estimates are next discounted over a specified time period such that results are in present value terms and then summed across geographic area according to regulatory alternative.

7.4.4 Aggregation to Total Incremental Benefits

Benefit estimates for each of the effects categories are summed by regulatory alternative. These benefit estimates should represent total benefits associated with achieving each of the proposed levels of control versus present new and existing source control requirements. Benefit estimates reflecting the incremental change in emissions achieved through each of the alternative emission standards are required inputs to correctly analyze the total incremental benefits and costs of each regulatory alternative.

7.5 DATA

7.5.1 Air Quality Data

The Industrial Source Complex Model-Long Term (ISCLT) was used to estimate ambient concentrations of BSO around 28 coke oven plants. The ISCLT model was set to the "regulatory mode" and the source type was set to "volume source" in an urban setting with flat terrain[2]. Each plant was assumed to have just one oven 10 meters on a side and 5 meters high. An initial plume width was set based on width and height of a single oven. All emissions were assumed to exit from this one structure. In this study, the ISCLT model calculated long-term concentrations which were based on several years of meteorological observations. The output, concentration profiles in a polar grid coordinate system centered at each plant, were designed for direct input into the exposure model. The polar grid extended from 200 meters out to 50 km for 16 different radial directions.

Particulate matter concentration profiles were obtained by extrapolation from ambient BSO concentrations. Ambient BSO concentrations were multiplied by the ratio of total suspended particulates to BSO (2.3) to yield ambient TSP concentrations[3].

7.5.2 Demographic Information

Public exposure was estimated using data from the 1980 population census. However, enough data from the 1990 census were available to derive correction factors to adjust exposure results to reflect population changes between 1980 and 1990. The adjustment process had little impact on the benefit estimates because there was only a slight increase in population in the counties affected by the coke oven emissions. In 1980 the population in the 159 affected counties was 34 million; by 1990 the population had increased by only 40,000.

The morbidity benefit estimates require two additional pieces of information: household income and the percentage of population that is employed. Household income was obtained from the 1990 Census. Because the 1990 Census labor participation rate has not been released, the Commerce Department's OBERS projections of employment growth, combined with 1980 Census and 1986 Survey of Current Population data were used as a basis for extrapolating the labor participation rate by county[4].

All monetary values in this chapter are in 1991 dollars. The Consumer Price Index - All Urban Consumers (CPI-U) was used to adjust prices where needed.

7.6 EXPOSURE ASSESSMENT

The Human Exposure Model (HEM) was used to derive quantitative expressions of public exposure to ambient concentrations of BSO and TSP. The BSO and TSP concentration profiles obtained from the ISCLT model were used as input data (see section 7.5). Because county-specific data was required to run the PM morbidity and household soiling benefits models, a specialized version of the HEM, called the Systems Applications Human Exposure and Risk Model (SHEAR) option, was selected for this study[5]. The HEM-SHEAR model contains the 1980 U.S. census data by block group/enumeration districts (BG/EDs). As described above, 1980 population was adjusted to 1990 population through multiplication by a population growth factor. All people grouped by BG/ED were defined as living at the approximate center of the BG/ED area. Average exposure concentrations for BSO and TSP were calculated by estimating the BSO and TSP concentrations at the center of the BG/ED area and multiplying that concentration by the number of people in that BG/ED. These products of people and pollutant concentrations were summed over all BG/EDs in each county to yield total exposure to both BSO and TSP.

7.7 QUANTIFIED BENEFIT ESTIMATION

The following section outlines the studies selected to estimate the benefits of coke oven emission standards. The section also discusses the application of these studies to the analysis and provides benefit estimates for mortality, morbidity and household soiling. Benefits have been calculated in 1991 dollars.

7.7.1 Mortality Due to BSO Exposure

7.7.1.1 *Study Selection.* According to EPA's "Carcinogen Assessment of Coke Oven Emissions", coke oven emissions are carcinogenic to humans. Due to the complex chemical composition of coke oven emissions, the benzene soluble organics (BSO) fraction is used as a surrogate measurement for coke oven emissions when conducting exposure analysis and cancer risk assessment. EPA has calculated a unit risk estimate for BSO that defines the relationship between exposure to coke oven emissions and respiratory cancer risk (assumed to be linear). The unit risk estimate is the lifetime risk associated with a lifetime (70 year) exposure to an average unit concentration of the pollutant. The unit risk factor was derived from human epidemiological data collected from coke oven and steel workers exposed to coke oven emissions. Positive epidemiologic studies are generally treated as the most conclusive evidence for a particular disease. Additionally, the unit risk factor reflects an upper bound estimate of cancer risk.

7.7.1.2 *Application.* The HEM-SHEAR model was used to estimate cancer risk estimates associated with each coke oven plant. BSO risk estimates were calculated by multiplying the BSO exposure products (obtained from the exposure assessment) by the unit risk estimate and dividing by 70. The unit risk estimate for BSO is 6.2×10^{-4} per 1 $\mu g/m^3$. Multiplying the exposure products by the unit risk estimate provides the number of cancer cases expected over a lifetime. Thus, division of lifetime cancer cases by 70 years yields an estimate of the number of cancer cases per year.

7.7.1.3 *Valuation.* The value of a change in mortality rates is measured through the value of a change in mortality risk. The value of risk reduction has been estimated in studies[6] that examine the wage premia required by workers to accept risky jobs. These studies reveal that workers require approximately an additional $100 to $700 annually (1983 $) to accept an additional mortality risk of 1×10^{-4}. This is equivalent to $1.6 to $8.5 million per statistical life saved (1986 $).

In this analysis, mortality benefits are presented in 1991 dollars as low, mean, and high estimates reflecting values of

$1.6 million, $4.4 million, and $8.5 million (1986 $) per statistical life saved respectively.

7.7.2 Acute Morbidity due to Particulate Matter (PM) Exposure

7.7.2.1 *Study Selection.* A cross-sectional microepidemiological study by Ostro[7] was used to estimate the particulate matter benefits associated with each of the coke oven emission control options. The Ostro study focused on broad health end points that relate work loss and restricted activity days due to respiratory disease to fine particulate concentrations. The PM Staff Paper[8] states that this study provides strong qualitative support for a relationship between current PM levels and restricted activity in adults.

Ostro analyzed six years of individual data from the National Center for Health Statistics Health Interview Survey (HIS) to examine the relationship between air pollution and morbidity. Ostro's sample included all adults age 18 to 65 from 49 metropolitan areas for which pollution data and HIS sample data were available. The sample contained approximately 12,000 adults for each of the six years from 1976 through 1981.

Three measures of morbidity were used in Ostro's analysis: work loss days (WLD), restricted activity days (RAD), and respiratory-related restricted activity days (RRAD). Information on these morbidity measures was obtained in response to a survey question asking the individual how many days did illness in the previous two weeks prevent him/her from working or participating in his/her usual activities.

The concentration-response functions estimated by Ostro regressed a measure of the individual's acute WLD, RAD, or RRAD against a measure of ambient particulate matter concentration, the individual's personal and economic characteristics, and temperature. The measure of particulate matter was a two-week average lagged to represent the two-week exposure period prior to the study period. In addition to the PM measure, the independent variables included the individual's age, sex, race, education, family income, marital status, existence of a chronic condition, quarter of the survey, and average two-week minimum temperature. The concentration-response functions that included WLD as the dependent variable controlled for paid sick leave and whether the individual worked in a blue or white collar job. In addition to the basic set of variables, the RAD and RRAD concentration-response functions included a variable reflecting whether or not the restricted activity occurred on work time versus leisure time.

7.7.2.2 *Application.* For this analysis, the concentration-response function for TSP and RRAD's was used. Average ambient total suspended particulate concentrations and the exposed population on the county level obtained from HEM are used to calculate the baseline number of work loss days, reduced activity days, and direct medical expenses resulting from current levels of coke oven emissions. This study cannot be used to estimate benefits for a reduction in pain and suffering prior and subsequent to the receipt of medical care, therefore these values may underestimate morbidity benefits.

7.7.2.3 ***Valuation.*** In this analysis, the cost-of-illness approach is used to approximate willingness to pay to avoid morbidity effects. A reduction in the number of work loss days is valued at the average daily wage rate. A reduced activity day is valued at one-half the average daily wage rate. Direct medical expenditures are calculated for acute respiratory conditions only. The range of benefit estimates presented reflects variability around the regression coefficient of the dose-response equation (mean ± 2 standard deviations).

7.7.3 Household Soiling

7.7.3.1 ***Study Selection.*** The 24 Standard Metropolitan Statistical Areas longitudinal study by Mathtech[9] was used to measure household soiling benefits resulting from reductions in the particulate component of coke oven emissions. In this model, benefits are estimated directly from air quality changes without first measuring physical damage. Adverse effects of pollutants are reflected in changes in market demand and supply relationships. Household behavior in terms of soiling perception, cleaning activity, and expenditures to maintain a given degree of cleanliness is estimated econometrically.

7.7.3.2 ***Application.*** The inputs to the household soiling model are 1990 economic and socio-demographic data such as product prices and household income. Background TSP concentrations were obtained from EPA's National Air Quality and Emissions Trend Report, 1988[10] which reports annual arithmetic mean PM10 levels by city. PM10 values were divided by 0.55 to recover the equivalent annual arithmetic mean TSP. Baseline levels of household soiling due to current levels of coke oven emissions were calculated from the model. These benefits represent soiling occurring in the household sector only and do not cover the commercial, industrial, and governmental sectors. Therefore, this analysis may underestimate the total benefits of reduced soiling. The range of benefit estimates presented reflects variability around the regression coefficient of the econometric function (mean ± 2 standard deviations).

7.8 FINDINGS FOR MACT AND LAER COMPLIANCE

The coke oven NESHAP will result in the control of emissions from doors, topside and charging at 28 coke oven plants. Exposure modeling results of current levels of coke oven emissions reveal that 23 million people are exposed to the toxic emissions released from these facilities. The cancer risk assessment indicates that there are approximately 1.8 excess cancer cases per year due to baseline levels of coke oven emissions. Similarly, current levels of coke oven emissions are estimated to annually contribute 2,200 additional work loss days, 13,000 additional reduced activity days, and an extra $103,000 (1991 $) in direct medical expenses. Table 7-3 summarizes these statistics.

These damages resulting from current levels of coke oven emissions can be monetized. As presented in Table 7-4, the monetary value of estimated mortality, morbidity, and household soiling effects in the absence of the proposed coke oven NESHAP range from $3.4 million to $21.4 million (1991 $) annually.

Compliance with the MACT requirements (66% control from baseline) results in benefits of $2.8 million to $18.0 million that are annualized for the five year time period 1993 - 1998 at a 10 percent interest rate. This benefit estimate considers all batteries that must meet MACT for the LAER track and the two Armco batteries that are expected to follow the MACT track. See Table 7-5 for a summary of these results.

Compliance with the LAER requirements (90% control from baseline inclusive of 66% MACT control) results in annualized benefits fo $3.3 million to $20.7 million for the 15 year time period 1998 - 2013. See Table 7-6 for a summary of these results.

TABLE 7-3. EFFECTS OF BASELINE LEVELS OF COKE OVEN EMISSIONS FROM DOORS, TOPSIDE, AND CHARGING

Number of Coke Oven Plants Subject to NESHAP	28
Number of People currently exposed[a]	23 Million
Maximum Individual Mortality Risk	1.6×10^{-2}
Expected Annual Excess Mortality	1.8
Number of Work Loss Days	2,200
Number of Reduced Activity Days / Year	13,000
Annual Direct Medical Expenses	$103,000 (1991$)

NOTE:
[a] Underestimate because some counties are impacted by more than one coke oven plant. The exposure model calculates exposure levels at the sub-county level. In order to avoid double counting, "Number of People Currently Exposed" is the sum of the largest population in each county that is affected by any one plant. This underestimates the total exposed population in any county where one plant affects certain people, and other plants affect additional people.

TABLE 7-4. ESTIMATED MONETARY VALUE OF DAMAGES DUE TO BASELINE LEVELS OF COKE OVEN EMISSIONS FROM DOORS, TOPSIDE, AND CHARGING

	Lower Bound	Mean Estimate	Upper Bound
ANNUAL VALUE (1991 $)			
Excess Mortality	$3.3 Million	$9.1 Million	$17.6 Million
Excess Morbidity	$11,000	$1.6 Million	$3.4 Million
Soiling	$47,000	$223,000	$440,000
TOTAL	$3.4 Million	$10.9 Million	$21.4 Million

TABLE 7-5. ESTIMATED MONETARY VALUE OF COMPLIANCE WITH MACT REQUIREMENTS*

(66% Control of Baseline Emissions)

	Lower Bound	Mean Estimate	Upper Bound
ANNUAL VALUE (1991 $)			
Excess Mortality	$2.8 Million	$7.6 Million	$14.7 Million
Excess Morbidity	$8,700	$1.3 Million	$2.9 Million
Soiling	$39,000	$186,000	$366,000
TOTAL	$2.8 Million	$9.1 Million	$18.0 Million

* Due to incomplete coverage of effects categories, monetized benefits may be understated.

Note:

- Annualized benefits for time period 1993 - 1998.
- Analysis considers 2 Armco batteries reported to follow MACT track.

TABLE 7-6. ESTIMATED MONETARY VALUE OF COMPLIANCE WITH LAER REQUIREMENTS*

(90% Control of Baseline Emissions)

	Lower Bound	Mean Estimate	Upper Bound
ANNUAL VALUE (1991 $)			
Excess Mortality	$3.2 Million	$8.8 Million	$17.0 Million
Excess Morbidity	$10,000	$1.5 Million	$3.3 Million
Soiling	$45,000	$216,000	$424,000
TOTAL	$3.3 Million	$10.5 Million	$20.7 Million

* Due to incomplete coverage of effects categories, monetized benefits may be understated.

Note:

- Annualized benefits for time period 1998 - 2013.
- Analysis excludes 2 Armco batteries reported to follow MACT track.

7.9 PROCESS UPSETS

As stated in Chapter 4, in addition to reducing emissions to meet MACT and LAER, compliance with the Coke Oven NESHAP will require plants to install flares to control emissions for process upsets. While the occurrence of process upsets is considered infrequent, the effects of the emissions can be significant in that the amount of pollutants released in a short period of time could result in acute exposures to toxic compounds including known human carcinogens.

It was estimated in Chapter 5 that 470 Mg of BSO is emitted nationwide each year from bypassed coke oven gases during process upsets. In addition to BSO, many other pollutants not included in this total would be controlled by the use of flares. These pollutants include low molecular weight volatile organics (e.g., benzene, toluene) and inorganic gases (e.g., carbon monoxide, sulfur dioxide) some of which are extremely toxic (e.g., hydrogen sulfide, ammonia).

It is possible to estimate some of the benefits of coke oven emission reductions achieved by flares by transferring the monetized benefit per Mg value determined from the coke oven analysis described earlier in this chapter. This benefit value represents the per unit value of decreased mortality from exposure to BSO and decreased morbidity and household soiling from particulate matter exposure. Other benefit categories are not captured by this value.

For this analysis, the Clairton and Gary US Steel facilities were excluded as flares have already been installed at these batteries. By dividing total monetized benefits for the remaining 26 facilities by total BSO emission reductions for those 26 facilities, an average estimate of benefits per Mg of BSO reduced can be obtained ($8,298 to $52,477 per Mg BSO (1991 $)). The installation of flares to control process upset releases is assumed to be 95 percent efficient. The benefit per Mg range is transferred and applied to the flares scenario and then multiplied by 95% control efficiency [($8,298 to $52,477) * 470 Mg of BSO emitted annually from process upsets * .95]. The total benefit range is annualized over the 15 year analytic time period to be consistent with the cost analysis. Total benefits range from $4.2 million to $26.5 million (1991 $). Table 7-7 summarizes these results.

TABLE 7-7. ESTIMATED MONETARY VALUE OF EMISSION REDUCTIONS FOR FLARES*

(95% Control of Baseline Emissions)

	Lower Bound	Mean Estimate	Upper Bound
ANNUAL VALUE (1991 $)			
TOTAL	$4.2 Million	$13.2 Million	$26.5 Million

* Due to incomplete coverage of effects categories, monetized benefits may be understated.

Note:

- Monetized benefit estimates annualized over 15 year time period 1993 - 2008.

7.10 NON-QUANTIFIED BENEFITS

As described in the preceding sections, the quantitative component of this benefit assessment covers cancer mortality due to coke oven emission exposure and acute morbidity and household soiling from particulate matter exposure. However, there are many other potential benefit categories that are not covered by this analysis because of significant data gaps. The following discussion qualitatively describes some of these other benefit categories that may apply to the coke oven regulation.

7.10.1 Cancer Mortality of Coke Oven Workers

Absent from this analysis is the benefit of mortality risk reduction for coke oven workers. These individuals would typically experience the highest exposures to coke oven emissions due to working proximity to coke oven battery doors and lids. Emission reductions achieved through this regulation would in turn decrease worker mortality risk if all other variables remain constant.

7.10.2 Non-cancer Mortality and Morbidity Due to Exposure to Non-BSO or Non-PM Related Compounds

Benzene soluble organics and the particulate matter components of coke oven emissions do not include all of the toxic volatile organics, all of the inorganic gases, or all of the trace metals that are also emitted from the coking process. Many of these compounds have associated adverse non-cancer health effects. For instance, carbon monoxide (CO) is 5.8% of coke oven gas. CO brings about oxygen deficiency in the blood thus having detrimental effects on the cardiovascular, central nervous, pulmonary, and other body systems. Exposures to high concentrations of CO could lead to death. Ammonia is a serious skin, eye and membrane irritant. Ammonia releases resulted in the second greatest number of injuries and deaths of all chemicals in the acute hazard database. Hydrogen sulfide is fatal at high concentrations, causing pulmonary edêma and eye and respiratory tract irritation. This compound is the leading cause of accidental death in the workplace. Adverse health effects from exposure to toxic metals ranges from brain and kidney damage (mercury) to teratogenic effects (lead).

7.10.3 Adverse Environmental Impacts

There is scant information specifically on the environmental impacts of coke oven emissions. However, there is data available indirectly linking coke oven emissions with adverse environmental effects such as information regarding the transport and deposition of hazardous air pollutants from areas in which coke ovens operate. For instance, atmospheric loading is estimated to account for approximately 80 - 90% of all pollutant inputs to the upper Great Lakes, an area considered relatively pristine and with few major sources of toxics. Similarly, short-range atmospheric deposition is thought to be responsible for 90 - 99% of lead inputs to the mid-lower Chesapeake Bay. Both of these areas contain coke and steel production facilities that may be contributing to toxic inputs to the two water bodies.[11]

A number of the chemical constituents of coke oven emissions have a high potential to bioconcentrate and are also quite persistent in the environment.[12] Ambient concentrations of these compounds may be directly toxic to organisms while atmospheric deposition of these compounds to land may have direct impacts on individual terrestrial organisms and ecosystems as a whole.

It has also been shown that atmospheric deposition of hazardous air pollutants, some of which are found in coke oven emissions, contributes to adverse aquatic ecosystem effects. Through the process of biomagnification, persistent compounds accumulate in toxic concentrations in the tissues of species high on the food chain leading to adverse impacts on wildlife and, through subsequent ingestion of contaminated fish or waterfowl, adverse health effects in humans. These adverse effects may pose significant impacts on recreational and commercial fishing industries.[13]

Although there is indirect evidence that coke oven emissions are hazardous to the environment, it is unclear the extent to which coke oven emissions contribute to adverse environmental impacts and the degree to which this regulation will mitigate these effects.

REFERENCES

1. Memorandum from Elizabeth M. Ackerman, U.S. EPA Region III, to Amanda Agnew, U.S. EPA, OAQPS, April 8, 1991.

2. U.S. Environmental Protection Agency. Industrial Source Complex Dispersion Model User's Guide, Second Edition (revised), Volume I. EPA-450/4-88-002a. December 1987.

3. Memorandum from Marvin Branscome, Research Triangle Institute, to Amanda Agnew, U.S. EPA, OAQPS, March 27, 1992.

4. U.S. Department of Commerce, Bureau of Economic Analysis. 1985 OBERS BEA Regional Projections. 1985.

5. U.S. Environmental Protection Agency. User's Manual for the Human Exposure Model (HEM). EPA-450/5-86-001. June 1986.

6. Fisher, A., Chestnut, L. and Violette, D. "The Value of Reducing Risks of Death: A Note on New Evidence", *Journal of Policy Analysis and Management* 8(1), 1989, pp. 88-100.

7. Ostro, Bart D. "Air Pollution and Morbidity Revisited: A Specification Test." *Journal of Environmental Economics and Management* 14(1), 1987, pp. 87-98.

8. U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards. Review of the National Ambient Air Quality Standards for Particulate Matter: Assessment of Scientific and Technical Information. OAQPS Staff Paper. EPA-450/5-82-001. Research Triangle Park, NC. January 1982.

9. MathTech, Inc. Benefits Analysis of Alternative Secondary National Ambient Air Quality Standards for Sulfur Dioxide and Total Suspended Particulates. Final report prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC. 1982.

10. U.S. Environmental Protection Agency. National Air Quality and Emissions Trends Report, 1988. EPA 450/4-4-90-002, March, 1990.

11. ICF, Inc. Atmospheric Deposition of Toxic Chemicals to Surface Waters: Identification and Summary of Recent Literature. Draft Report. Prepared for Office of Air Quality Planning and Standards, U.S. EPA, Research Triangle Park, NC August 1991.

12. ICF, Inc. Focus Chemicals for the Clean Air Act Amendments Great Waters Study. Draft Report. Prepared for Office of Air Quality Planning and Standards, U.S. EPA, Research Triangle Park, NC. August 1991.

13. Environment Canada. Toxic Chemicals in the Great Lakes and Associated Effects. Toronto, Ontario. March 1991.

CHAPTER 8

BENEFIT-COST ANALYSIS

8.1 INTRODUCTION

This chapter presents a comparison of the incremental benefits and incremental costs of the coke oven MACT and LAER limits mandated in the CAAA and the flares requirement. Additionally, the chapter discusses the rationale for the proposed regulatory action.

In the course of internalizing the air pollution externality, air quality regulations bring about a reallocation of resources within the economy that affect society's well-being. The cost of reducing coke oven emissions is reflected in the production, distribution, and consumption of products affected by the proposed Coke Oven NESHAP. This additional cost is in contrast to the improvement in society's well-being from a cleaner environment and concomitant reductions in adverse health and welfare effects. Benefit-cost analysis is one vehicle that provides a consistent framework for the evaluation of the economic effects of alternative regulatory policies.

The efficiency criterion is one measure of the desirability of the resource allocation (the optimum level of pollution abatement) resulting from the coke oven NESHAP. An allocatively efficient regulation maximizes the positive net benefits to society, which yields the optimal level of pollution control. For this decision rule, the preferred regulatory option would be the alternative that maximizes positive net benefits. However, in addition to economic considerations, other factors, such as political or statutory constraints, play a role in the decision making process. Therefore the allocatively efficient regulatory option is not always selected.

8.2 COMPARISON OF QUANTIFIED BENEFITS AND COSTS FOR COKE OVEN DOORS, TOPSIDE, AND CHARGING MACT AND LAER REQUIREMENTS

Table 8-1 presents net quantified benefits for the MACT and LAER requirements mandated by the CAAA assuming 64 batteries follow the LAER track and two batteries follow the MACT track. A range of benefit estimates is used that reflects the lower bound, mean estimate, and upper bound annual values as presented in Chapter 7. The cost data used are EPA's annualized point estimates for both the MACT ($25 million) and LAER ($46 million) compliance tracks. Monetized benefits presented in the table do not include the impact of the non-quantified benefits discussed in Chapter 7.

The nationwide annual costs minus quantified benefits of implementing the MACT standards for doors, topside and charging are -$7.0 to -$22.2 million. The nationwide annual costs minus quantified benefits of implementing the doors, topside, and charging LAER standard are -$25.3 million to -$42.7 million. Recognize that incomplete coverage of benefits precludes a definitive statement on the allocative efficiency aspects of these two requirements.

TABLE 8-1. TOTAL ANNUAL COSTS, BENEFITS*, AND NET BENEFITS OF COKE OVEN MACT AND LAER REQUIREMENTS (1991 $)

	MACT	LAER
ANNUAL COST	$25 million	$46 million
ANNUAL BENEFIT*		
Low	$2.8 million	$3.3 million
Mean	$9.1 million	$10.5 million
High	$18.0 million	$20.7 million
QUANTIFIED BENEFITS MINUS COST		
Low	($22.2 million)	($42.7 million)
Mean	($15.9 million)	($35.5 million)
High	($7.0 million)	($25.3 million)

* Quantified benefits only; benefits coverage is incomplete.

8.3 COMPARISON OF QUANTIFIED BENEFITS AND COSTS FOR COKE OVEN FLARE CONTROL

The nationwide cost for installation, operation and maintenance of flares for coke oven batteries at 26 facilities is estimated to be $2.8 million annually (1991 $). Net benefits (quantified benefits minus cost) for the coke oven flare requirement are positive. They range from $1.4 million to $23.7 million annually (1991 $). This suggests an improvement in society's well-being on allocative efficiency grounds despite incomplete quantification of the benefits. See Table 8-2 for a summary of these results.

TABLE 8-2. TOTAL ANNUAL COSTS, BENEFITS*, AND NET BENEFITS FOR COKE OVEN FLARE REQUIREMENTS (1991 $)

		FLARES - 95% CONTROL
ANNUAL COST		$2.8 million
ANNUAL BENEFIT*	Low	$4.2 million
	Mean	$13.2 million
	High	$26.5 million
QUANTIFIED BENEFIT MINUS COST*	Low	$1.4 million
	Mean	$10.4 million
	High	$23.7 million

* Quantified benefits only; benefits coverage is incomplete.

Note: Costs and benefits annualized over 15 year time period 1993 - 2008.

8.4 RATIONALE FOR THE PROPOSED REGULATORY ACTION

As discussed in Chapter 2, there are alternative ways to internalize a negative externality. Economists acting as third parties could assess the benefits and costs of regulations in an attempt to identify the optimum level of pollution control for the regulation. Alternatively, parties directly affected by the negative externality could negotiate and develop the regulation to reduce air pollution.

This more direct approach of negotiation is sometimes preferred on economic efficiency grounds. This is especially the case when identification of affected parties is not difficult and the transactions costs of their participation in the negotiations is modest.

The EPA entered into regulatory negotiations with industry, environmental groups, and state agencies in the development of the proposed coke oven regulation. The CAAA set default limits of 3 PLD, 1 PLL, 4 PLO, and 16 seconds charging, and required for the MACT track, MACT compliance by 1995 or for the LAER track MACT compliance by 1993 and LAER compliance by 1998. Regulatory negotiations resulted in decisions on control levels that differ somewhat from the default limits for doors, topside, and charging (See Chapter 4).

8.5 CONCLUSIONS

Estimates of potential quantified benefits, costs, and net benefits for the Coke Oven doors, topside, and charging MACT and LAER requirements are presented in Table 8-1. The upper bound of quantified benefits do not outweigh the costs associated with this component of the regulation. Because the benefits were quantified for only three benefit categories, EPA cannot conclude that net benefits are necessarily negative (net cost). The net cost as reflected in this analysis could be reduced, however, if some portion of the non-quantified benefits presented in Chapter 7 were quantified. For example, reductions in adverse human welfare effects (worker productivity losses and odors) and non-human biological effects (agriculture, forestry, recreational/commercial fishing and ecosystem impacts) could potentially yield higher benefit estimates if quantified.

There are other potential benefit categories associated with the particulate matter component of coke oven emissions beyond acute morbidity and household soiling such as chronic morbidity, industrial and commercial sector soiling and materials damage, and ecosystem impacts.

There are other compounds that are emitted by coke ovens, yet are not covered by BSO or PM, that are highly toxic to humans and the environment. Due to lack of data, the benefits of controlling compounds such as hydrogen sulfide, benzene, ammonia, and the trace metals have not been included in this analysis.

Estimates of quantified benefits, costs, and net benefits for compliance with the flares requirement are presented in Table 8-2. Annual benefits outweigh annual costs by a factor of 1.5 to 9.5.

Major conclusions of this analysis:

- With incomplete coverage of the benefits, the allocative efficiency aspects of the MACT and LAER requirements are indeterminant:
  - complete coverage of benefits (i.e., quantification of all benefit categories) may or may not result in positive net benefits
  - The ratios of monetized benefits to the costs for doors, topside, and charging MACT requirements range from .11:1 to .72:1.
  - The ratios of monetized benefits to the costs for doors, topside, and charging LAER requirements range from .07:1 to .45:1.

- Despite incomplete coverage of the benefits, compliance with the coke oven flare requirement results in allocative efficiency gains.
  - Net benefits for the flares requirement are positive.
  - The ratios of monetized benefits to estimated costs for flares range from 2:1 to 10:1.

APPENDIX A

COST COMPONENTS FOR EACH BATTERY

APPENDIX A.

COSTS COMPONENTS FOR EACH BATTERY

This appendix identifies cost components provided by specific plants through the American Iron and Steel Institute and the American Coke and Coal Chemicals Institute. For plants that did not provide alternative information, the generic category used is identified for each battery. This information is documented in the report for the Cost Work Group.[14]

1. **ABC Coke:** The company plans to install a spare larry car for Battery A. (This cost was not attributed to the NESHAP.) For LAER, Battery A was placed in Category E and Batteries 5 and 6 were placed in Category A.

2. **Acme Steel:** To meet MACT, the plant plans to install new doors, a door cleaner, improved door spotting equipment, new offtake caps, larry car modifications, and additional training with a total estimated cost of $3.9 million. If the company chooses to meet the LAER limits; they estimate an additional cost of $0.6 million for jamb cleaners and improved back pressure controls.

[Note: Door leak data for this plant show that the two batteries have averaged 0.6 and 0.8 PLD from 21 observations over 7 years. Consequently, this plant may already be able to meet the MACT and LAER limits for percent leaking doors.]

3. **Armco, Middletown, OH:** The company plans to meet MACT in 1995 for Battery 3 at a cost of $19 million. This cost includes the installation of modified doors, replacement of one-third of the jambs and buckstays, ceramic welding behind jambs, anti-hourglassing modifications, resetting one-third of the charging hole castings, new standpipe valves, a new larry car, rebuild of existing larry car for use as a spare, upgrade pusher, new door machine, rebuild of existing door machine, new quench car, new backpressure controls, and by-product plant modifications. Batteries 1 and 2 were placed in Category F (rebuild) for LAER.

4. **Armco, Ashland, KY:** The company plans to meet MACT in 1995 for Battery 3 at a cost of $17.5 million. This cost includes the installation of new doors, new jambs, replacement of 12 buckstays, anti-hourglassing modifications, reset charging hole castings, new and rebuilt larry cars, upgrade pusher, new and rebuilt door machines, new quench car, door cleaner, and new steam aspiration. To meet LAER with Battery 3, the company plans

to spend $16.5 million over the next few years for new doors, jambs, upgraded or new equipment, and repairs. An additional $30 to $35 million will probably be needed for through-wall and end flue repairs around the year 2000.

5. **Bethlehem Steel, Bethlehem, PA:** MACT costs for Battery A include new drop sleeves ($200,000) and new slip joints for the offtakes ($800,000). MACT costs for Batteries 2 and 3 include new slip joints ($1 million) and the conversion of the pusher side self-sealing doors to hand-luted doors ($4 million). For LAER, 120 new jambs will be installed on Battery A ($3 million). Batteries 2 and 3 will probably need to be rebuilt to meet LAER.

[NOTE: The costs for drop sleeves and slip joints may be associated with meeting the current regulations for offtakes and charging, which are as stringent as the default MACT limits. These costs are included in the industry estimate and are not included in the EPA estimate as directly attributable to the NESHAP.]

6. Bethlehem Steel, Burns Harbor, IN: The costs for these two batteries to meet MACT includes replacement/repair of standpipes ($2.4 million), larry car modifications ($300,000), gooseneck cleaners ($200,000), new jamb cleaners and improved door cleaners ($2 million), jamb replacement ($1.1 million), new door seals ($2 million), buckstay replacement on Battery 2 ($6.3 million), and additional door repair capability/equipment ($3.5 million). These batteries will probably be rebuilt to meet LAER.

[NOTE: The MACT capital investment must be recovered in 5 years (the capital recovery factor is 0.264 at 10 percent), which results in an annualized cost of $5 million/yr for this plant to meet MACT. In addition, this plant may be rebuilt to meet LAER. Only the rebuild cost is used in the EPA estimate and both costs are used in the industry estimate.]

7. Bethlehem Steel, Lackawanna, NY: To meet MACT, these two batteries will require larry car modifications ($750,000), new door seals ($500,000), new door plugs ($1.6 million), and improved back pressure control ($500,000). To meet LAER, new doors, new jambs, and automatic door and jamb cleaners may be required.

8. Citizens Gas and Coke: Batteries E and H may require larry car modifications to meet MACT for charging. Battery 1 is placed in Category B and Batteries E and H are placed in Category A for LAER costs. An automatic door cleaner is planned for the coke side of Batteries E and H.

9. **Empire Coke:** The costs to meet MACT include an additional person per shift, modifications to the larry car ($750,000), exhauster ($200,000), and an additional person for monitoring. For LAER, an additional person per shift would be required.

10. **Erie Coke:** These batteries are assigned to Category A for LAER costs. In addition, 3 to 4 walls must be repaired at a cost of $25,000 to $50,000 each.

11. **Geneva Steel:** These batteries are assigned to Category C for LAER costs.

12. **Gulf States Steel:** To meet MACT, the company expects to install a new larry car ($4 million), repair/replace doors ($1.5 million), and hire 5 new people. For LAER, these batteries were assigned to Category F.

13. **Inland Steel:** Batteries 6, 7, 9, and 10 will shut down in 1994, and Battery 11 will shut down in 1992. No costs are attributed to the NESHAP.

14. **Koppers:** The estimated cost to meet MACT includes $400,000/yr for operating labor, $200,000/yr for door maintenance labor, $100,000 for improved back pressure control, and $350,000 for updating equipment. These batteries are placed in Category A for LAER costs.

15. **LTV, Cleveland, OH:** Battery 6 is assigned to Category E and Battery 7 is assigned to Category F for LAER costs.

16. **LTV, Pittsburgh, PA:** These batteries are assigned to Category E for LAER costs. The cost of coke side door and jamb cleaners should be estimated as $5 to 7 million because of site-specific conditions (insufficient structural support for the cleaners).

17. **LTV, Chicago:** No costs are estimated for this battery to meet LAER (it is among the best-performing tall batteries for the control of door leaks).

18. **LTV, Warren, OH:** This battery is assigned to Category D for LAER costs.

19. **National Steel, Ecorse, MI:** This battery is assigned to Category B for LAER costs.

20. **National Steel, Granite City, IL:** Battery A is assigned to Category D and Battery B is assigned to Category B for LAER costs.

21. **New Boston Coke:** To meet MACT, the company expects to replace offtakes ($1.4 million), install a new steam system and jumper pipes ($2 million), and install new doors and jambs ($2 million). The costs to meet LAER include a new jamb cleaner ($450,000), door cleaner ($250,000), spotting device ($50,000), and jamb/end flue repairs ($2 million).

22. **Sharon Steel:** These batteries are assigned to Category C for LAER costs.

23. **Shenango:** One person per shift is added for topside leaks for Battery 4. Battery 1 is assigned to Category B and Battery 4 is assigned to Category A for LAER costs.

24. **Sloss Industries:** These batteries are assigned to Category D for LAER costs.

25. **Toledo Coke:** This battery is assigned to Category F for LAER costs.

26. **Tonawanda Coke:** This battery is assigned to Category B for LAER costs.

27. **USX, Clairton, PA:** For LAER, include automatic door and jamb cleaners on the coke side, the replacement of 50 percent of the jambs, and additional labor for the use of a supplemental sealant for Batteries 1, 2, 3, 7, 8, 9, and 19. For Batteries 13, 14, 15, 20, and B, assign Category B. In addition, include coke side door and jamb cleaners on Batteries 13, 14, 15, and 20.

28. **USX, Gary, IN:** Batteries 5 and 7 are assigned to Category D and Batteries 2 and 3 are assigned to Category E for LAER costs.

29. **Wheeling-Pittsburgh:** To meet MACT for doors on Batteries 1, 2, and 3, add 2 new door machines and automatic door cleaners. Also include automatic lid replacement for the last lid. To estimate LAER costs, assign Batteries 1, 2, and 3 to Category D. For Battery 8, include replacement of jambs and rehabilitation of doors at $18 million every 8 years as LAER costs. The company plans to spend $10.5 million to replace half of the jambs and to install water-sealed standpipe caps as part of their current operation. The cost for jambs is annualized over 8 years for the industry estimate and over 20 years for the EPA estimate.

30. **Bethlehem Steel, Sparrows Point, MD:** These batteries are shut down and are not included in the cost analysis.

APPENDIX B

COST ESTIMATES FOR EACH BATTERY

TABLE B-1. SUMMARY OF MACT COSTS (1991 DOLLARS)

					MACT COSTS - EPA			MACT COSTS INDUSTRY		
No.	PLANT	BATTERY	NUMBER OF BATTER UNITS	AVERAGE PERCENT LEAKING DOORS	OPRTNG	CAPITA	TOTAL ANNUAL	OPRTNG	CAPITA	TOTAL ANNUAL
1	ABC Coke, Tarrant, AL	A	1.0	3.6	2.6E+05	0.0E+00	2.6E+05	2.6E+05	3.1E+06	6.2E+05
		5	0.5	6.2	1.5E+05	0.0E+00	1.5E+05	1.5E+05	0.0E+00	1.5E+05
		6	0.5	6.2	1.5E+05	0.0E+00	1.5E+05	1.5E+05	0.0E+00	1.5E+05
2	Acme Steel, Chicago, IL	1	0.5	0.6	1.5E+05	0.0E+00	1.5E+05	1.5E+05	2.0E+06	3.8E+05
		2	0.5	0.8	1.5E+05	0.0E+00	1.5E+05	1.5E+05	2.0E+06	3.8E+05
3	Armco Inc., Middletown, OH	1	0.5	15.5	3.9E+05	0.0E+00	3.9E+05	2.7E+05	0.0E+00	2.7E+05
		2	0.5	15.5	3.9E+05	0.0E+00	3.9E+05	2.7E+05	0.0E+00	2.7E+05
		3	1.0	8.7	3.6E+05	1.9E+07	3.4E+06	3.2E+05	1.9E+07	3.4E+06
4	Armco Inc., Ashland, KY	3	1.0	18.0	6.7E+05	1.8E+07	3.5E+06	2.6E+05	1.8E+07	3.1E+06
		4	1.0	16.0	4.6E+05	0.0E+00	4.6E+05	1.5E+05	0.0E+00	1.5E+05
5	Bethlehem Steel, Bethlehem, PA	A	1.0	5.7	1.5E+05	0.0E+00	1.5E+05	2.1E+05	1.0E+06	3.3E+05
		2	0.5	5.2	9.1E+04	2.0E+06	6.2E+05	1.7E+05	2.5E+06	8.3E+05
		3	0.5	5.1	9.1E+04	2.0E+06	6.2E+05	1.7E+05	2.5E+06	8.3E+05
6	Bethlehem Steel, Burns Harbor, IN	1	1.0	8.6	3.6E+05	0.0E+00	3.6E+05	3.8E+05	6.3E+06	2.0E+06
		2	1.0	9.7	4.0E+05	0.0E+00	4.0E+05	3.8E+05	1.2E+07	3.4E+06
7	Bethlehem Steel, Lackawanna, NY	7	1.0	13.4	5.1E+05	1.7E+06	7.1E+05	2.6E+05	1.7E+06	4.5E+05
		8	1.0	13.8	5.3E+05	1.7E+06	7.2E+05	2.6E+05	1.7E+06	4.5E+05
8	Citizens Gas, Indianapolis, IN	E	0.5	3.0	1.5E+05	4.3E+05	2.0E+05	2.2E+05	4.3E+05	2.7E+05
		H	0.5	3.1	1.5E+05	4.3E+05	2.0E+05	2.1E+05	4.3E+05	2.6E+05
		1	1.0	4.4	2.6E+05	0.0E+00	2.6E+05	2.6E+05	0.0E+00	2.6E+05
9	Empire Coke, Holt, AL	1	0.5	6.3	1.5E+05	7.8E+05	2.4E+05	1.5E+05	7.8E+05	2.4E+05
		2	0.5	5.9	1.5E+05	7.8E+05	2.4E+05	1.5E+05	7.8E+05	2.4E+05
10	Erie Coke, Erie, PA	A	0.5	7.6	1.1E+05	0.0E+00	1.1E+05	1.1E+05	0.0E+00	1.1E+05
		B	0.5	7.6	1.2E+05	0.0E+00	1.2E+05	1.2E+05	0.0E+00	1.2E+05
11	Geneva Steel, Provo, UT	1	0.5	3.6	9.1E+04	0.0E+00	9.1E+04	9.1E+04	0.0E+00	9.1E+04
		2	0.5	2.4	9.1E+04	0.0E+00	9.1E+04	9.1E+04	0.0E+00	9.1E+04
		3	0.5	2.8	9.1E+04	0.0E+00	9.1E+04	9.1E+04	0.0E+00	9.1E+04
		4	0.5	3.6	9.1E+04	0.0E+00	9.1E+04	9.1E+04	0.0E+00	9.1E+04
12	Gulf States Steel, Gadsden, AL	2	1.0	13.3	1.7E+05	2.8E+06	4.9E+05	1.7E+05	2.8E+06	4.9E+05
		3	1.0	7.3	1.7E+05	2.8E+06	4.9E+05	1.7E+05	2.8E+06	4.9E+05
13	Inland Steel, East Chicago, IN	6	1.0	5.6		PLAN TO SHUT DOWN				
		7	1.0	8.9						
		9	1.0	9.1						
		10	1.0	12.1						
		11	1.0	8.7						
14	Koppers, Woodward, AL	1	1.0	1.4	2.7E+05	9.0E+04	2.8E+05	2.7E+05	9.0E+04	2.8E+05
		2A	0.5	0.0	2.1E+05	9.0E+04	2.2E+05	2.1E+05	9.0E+04	2.2E+05
		2B	0.5	1.7	2.7E+05	3.9E+05	3.1E+05	2.7E+05	3.9E+05	3.1E+05
		4	0.5	1.4	2.7E+05	3.9E+05	3.1E+05	2.7E+05	3.9E+05	3.1E+05
		5	0.5	0.6	2.7E+05	3.9E+05	3.1E+05	2.7E+05	3.9E+05	3.1E+05
15	LTV Steel, Cleveland, OH	6	1.0	6.5	2.8E+05	0.0E+00	2.8E+05	3.1E+05	0.0E+00	3.1E+05
		7	1.0	11.2	4.1E+05	0.0E+00	4.1E+05	3.1E+05	0.0E+00	3.1E+05

TABLE B-1. SUMMARY OF MACT COSTS (1991 DOLLARS)

No.	PLANT	BATTERY	NUMBER OF BATTER UNITS	AVERAGE PERCENT LEAKING DOORS	MACT COSTS - EPA			MACT COSTS - INDUSTRY		
					OPRTNG	CAPITA	TOTAL ANNUAL	OPRTNG	CAPITA	TOTAL ANNUAL
16	LTV Steel, Pittsburgh, PA	P1	0.5	5.7	9.1E+04	0.0E+00	9.1E+04	1.4E+05	0.0E+00	1.4E+05
		P2	0.5	7.1	1.3E+05	0.0E+00	1.3E+05	1.4E+05	0.0E+00	1.4E+05
		P3N	0.5	7.0	1.2E+05	0.0E+00	1.2E+05	1.4E+05	0.0E+00	1.4E+05
		P3S	0.5	7.8	1.5E+05	0.0E+00	1.5E+05	1.4E+05	0.0E+00	1.4E+05
		P4	1.0	6.9	1.9E+05	0.0E+00	1.9E+05	2.1E+05	0.0E+00	2.1E+05
17	LTV Steel, Chicago, IL	2	1.0	3.4	1.5E+05	0.0E+00	1.5E+05	1.5E+05	0.0E+00	1.5E+05
18	LTV Steel, Warren, OH	4	1.0	4.9	1.5E+05	0.0E+00	1.5E+05	2.1E+05	0.0E+00	2.1E+05
19	National Steel, Ecorse, MI	5	1.0		3.7E+04	0.0E+00	3.7E+04	3.7E+04	0.0E+00	3.7E+04
20	National Steel, Granite City, IL	A	0.5	2.8	1.5E+05	0.0E+00	1.5E+05	1.5E+05	0.0E+00	1.5E+05
		B	0.5	4.9	3.7E+04	0.0E+00	3.7E+04	3.7E+04	0.0E+00	3.7E+04
21	New Boston, Portsmouth, OH	1	1.0	5.4	2.6E+05	5.4E+06	8.9E+05	3.1E+05	5.4E+06	9.5E+05
22	Sharon Steel, Monessen, PA	1B	0.5	3.0	9.1E+04	0.0E+00	9.1E+04	1.2E+05	0.0E+00	1.2E+05
		2	0.5	3.1	9.1E+04	0.0E+00	9.1E+04	1.1E+05	0.0E+00	1.1E+05
23	Shenango, Pittsburgh, PA	1	1.0	3.4	3.7E+04	0.0E+00	3.7E+04	3.7E+04	0.0E+00	3.7E+04
		4	1.0	7.1	2.8E+05	0.0E+00	2.8E+05	2.8E+05	0.0E+00	2.8E+05
24	Sloss Industries, Birmingham, AL	3	0.5	5.5	1.5E+05	3.0E+05	1.8E+05	2.0E+05	3.0E+05	2.4E+05
		4	0.5	4.5	1.5E+05	3.0E+05	1.8E+05	2.0E+05	3.0E+05	2.4E+05
		5	1.0	1.9	2.6E+05	6.0E+05	3.3E+05	3.7E+05	6.0E+05	4.4E+05
25	Toledo Coke, Toledo, OH	C	1.0	9.7	3.6E+05	6.0E+05	4.3E+05	3.0E+05	6.0E+05	3.7E+05
26	Tonawanda, Buffalo, NY	1	1.0	2.2	2.6E+05	6.0E+05	3.3E+05	2.6E+05	6.0E+05	3.3E+05
27	USX, Clairton, PA	1	0.7	5.8	1.1E+05	0.0E+00	1.1E+05	1.6E+05	0.0E+00	1.6E+05
		2	0.7	6.3	1.3E+05	0.0E+00	1.3E+05	1.6E+05	0.0E+00	1.6E+05
		3	0.7	7.0	1.5E+05	0.0E+00	1.5E+05	1.6E+05	0.0E+00	1.6E+05
		7	0.7	4.8	1.1E+05	0.0E+00	1.1E+05	1.6E+05	0.0E+00	1.6E+05
		8	0.7	6.8	1.4E+05	0.0E+00	1.4E+05	1.6E+05	0.0E+00	1.6E+05
		9	0.7	7.3	1.5E+05	0.0E+00	1.5E+05	1.6E+05	0.0E+00	1.6E+05
		13	0.7	3.1	3.7E+04	0.0E+00	3.7E+04	3.7E+04	0.0E+00	3.7E+04
		14	0.7	3.2	3.7E+04	0.0E+00	3.7E+04	3.7E+04	0.0E+00	3.7E+04
		15	0.7	3.5	3.7E+04	0.0E+00	3.7E+04	3.7E+04	0.0E+00	3.7E+04
		19	1.0	5.9	1.5E+05	0.0E+00	1.5E+05	2.1E+05	0.0E+00	2.1E+05
		20	1.0	3.9	3.7E+04	0.0E+00	3.7E+04	3.7E+04	0.0E+00	3.7E+04
		B	1.0	3.0	3.7E+04	0.0E+00	3.7E+04	3.7E+04	0.0E+00	3.7E+04
28	USX, Gary, IN	2	1.0	9.0	3.4E+05	0.0E+00	3.4E+05	3.4E+05	0.0E+00	3.4E+05
		3	1.0	9.4	3.5E+05	0.0E+00	3.5E+05	3.4E+05	0.0E+00	3.4E+05
		5	0.5	6.0	1.6E+05	0.0E+00	1.6E+05	2.6E+05	0.0E+00	2.6E+05
		7	0.5	5.1	1.5E+05	0.0E+00	1.5E+05	2.6E+05	0.0E+00	2.6E+05
29	Wheeling-Pitt, East Steubenville, WV	1	0.7	4.5	1.8E+05	1.6E+06	3.8E+05	2.2E+05	1.6E+06	4.1E+05
		2	0.7	5.7	1.8E+05	1.6E+06	3.8E+05	2.2E+05	1.6E+06	4.1E+05
		3	0.7	4.6	1.8E+05	1.6E+06	3.8E+05	2.2E+05	1.6E+06	4.2E+05
		8	1.0	6.4	2.8E+05	0.0E+00	2.8E+05	3.2E+05	1.1E+07	2.2E+06
	TOTALS	82	61.0		1.5E+07	6.6E+07	2.5E+07	1.5E+07	1.0E+08	3.3E+07

TABLE B-2. SUMMARY OF LAER COSTS (1991 DOLLARS)

			LAER COSTS EPA		LAER COSTS INDUSTRY				
No.	PLANT	BATTERY	CAPITAL	TOTAL ANNUAL	CAPITA	TOTAL ANNUAL	PADUP REBUILD TRIGGERED EARLY	BYPRODUC PLANT REPAIRS	TOTAL CAPITAL COST ESTIMATE
1	ABC Coke, Tarrant, AL	A	1.5E+07	2.3E+06	2.1E+07	3.1E+06			2.1E+07
		5	0.0E+00	2.6E+05	0.0E+00	2.6E+05			0.0E+00
		6	0.0E+00	2.6E+05	0.0E+00	2.6E+05			0.0E+00
2	Acme Steel, Chicago, IL	1	3.0E+05	1.7E+05	3.0E+05	4.0E+05			3.0E+05
		2	3.0E+05	1.7E+05	3.0E+05	4.0E+05			3.0E+05
3	Armco Inc., Middletown, OH	1	0.0E+00	2.8E+05	0.0E+00	2.8E+05	6.4E+07	3.3E+06	6.8E+07
		2	0.0E+00	2.8E+05	0.0E+00	2.8E+05	6.4E+07	3.3E+06	6.8E+07
		3	NOT APPLICABLE					3.3E+06	3.3E+06
4	Armco Inc., Ashland, KY	3	NOT APPLICABLE						
		4	1.7E+07	2.4E+06	4.9E+07	5.0E+06			4.9E+07
5	Bethlehem Steel, Bethlehem, PA	A	3.0E+06	7.7E+05	3.0E+06	8.9E+05		3.3E+06	6.3E+06
		2	0.0E+00	2.3E+05	0.0E+00	2.3E+05	8.4E+07	3.3E+06	8.7E+07
		3	0.0E+00	2.3E+05	0.0E+00	2.3E+05	8.4E+07	3.3E+06	8.7E+07
6	Bethlehem Steel, Burns Harbor, IN	1	0.0E+00	5.3E+05	0.0E+00	5.3E+05	9.5E+07	5.0E+06	1.0E+08
		2	0.0E+00	5.3E+05	0.0E+00	5.3E+05	9.5E+07	5.0E+06	1.0E+08
7	Bethlehem Steel, Lackawanna, NY	7	4.3E+06	1.2E+06	4.3E+06	1.2E+06			4.3E+06
		8	4.3E+06	1.2E+06	4.3E+06	1.2E+06			4.3E+06
8	Citizens Gas, Indianapolis, IN	E	0.0E+00	3.1E+05	0.0E+00	3.1E+05			0.0E+00
		H	0.0E+00	3.1E+05	0.0E+00	3.1E+05			0.0E+00
		1	0.0E+00	5.3E+05	0.0E+00	5.3E+05			0.0E+00
9	Empire Coke, Holt, AL	1	0.0E+00	3.5E+05	0.0E+00	3.5E+05			0.0E+00
		2	0.0E+00	3.5E+05	0.0E+00	3.5E+05			0.0E+00
10	Erie Coke, Erie, PA	A	1.0E+05	2.2E+05	1.0E+05	2.2E+05			1.0E+05
		B	1.0E+05	2.2E+05	1.0E+05	2.2E+05			1.0E+05
11	Geneva Steel, Provo, UT	1	0.0E+00	2.3E+05	0.0E+00	2.3E+05			0.0E+00
		2	0.0E+00	2.3E+05	0.0E+00	2.3E+05			0.0E+00
		3	0.0E+00	2.3E+05	0.0E+00	2.3E+05			0.0E+00
		4	0.0E+00	2.3E+05	0.0E+00	2.3E+05			0.0E+00
12	Gulf States Steel, Gadsden, AL	2	0.0E+00	7.6E+05	0.0E+00	7.6E+05	5.8E+07	5.0E+06	6.3E+07
		3	0.0E+00	7.6E+05	0.0E+00	7.6E+05	5.8E+07	5.0E+06	6.3E+07
13	Inland Steel, East Chicago, IN	6		PLAN TO					
		7		SHUT					
		9		DOWN					
		10		IN 1994					
		11		PLAN TO SHUT DOWN IN 1992.					
14	Koppers, Woodward, AL	1	0.0E+00	5.0E+05	0.0E+00	5.0E+05			0.0E+00
		2A	0.0E+00	3.3E+05	0.0E+00	3.3E+05			0.0E+00
		2B	0.0E+00	4.2E+05	0.0E+00	4.2E+05			0.0E+00
		4	0.0E+00	4.2E+05	0.0E+00	4.2E+05			0.0E+00
		5	0.0E+00	4.2E+05	0.0E+00	4.2E+05			0.0E+00
15	LTV Steel, Cleveland, OH	6	7.8E+06	1.4E+06	1.4E+07	2.0E+06		5.0E+06	1.9E+07
		7	0.0E+00	5.3E+05	0.0E+00	5.3E+05	5.6E+07	5.0E+06	6.1E+07

TABLE B-2. SUMMARY OF LAER COSTS (1991 DOLLARS)

			LAER COSTS EPA		LAER COSTS INDUSTRY		PADUP REBUILD TRIGGERED EARLY	BYPRODUC PLANT REPAIRS	TOTAL CAPITAL COST ESTIMATE
No.	PLANT	BATTERY	CAPITAL	TOTAL ANNUAL	CAPITA	TOTAL ANNUAL			
16	LTV Steel, Pittsburgh, PA	P1	7.6E+06	1.1E+06	1.4E+07	1.6E+06			1.4E+07
		P2	7.6E+06	1.1E+06	1.4E+07	1.6E+06			1.4E+07
		P3N	7.6E+06	1.1E+06	1.4E+07	1.6E+06			1.4E+07
		P3S	7.6E+06	1.1E+06	1.4E+07	1.6E+06			1.4E+07
		P4	9.8E+06	1.6E+06	1.6E+07	2.1E+06			1.6E+07
17	LTV Steel, Chicago, IL	2	0.0E+00	1.5E+05	0.0E+00	1.5E+05			0.0E+00
18	LTV Steel, Warren, OH	4	7.0E+05	5.0E+05	7.0E+05	5.0E+05			7.0E+05
19	National Steel, Ecorse, MI	5	0.0E+00	3.1E+05	0.0E+00	3.1E+05			
20	National Steel, Granite City, IL	A	7.0E+05	3.7E+05	7.0E+05	3.7E+05			7.0E+05
		B	0.0E+00	1.7E+05	0.0E+00	1.7E+05			0.0E+00
21	New Boston, Portsmouth, OH	1	2.8E+06	1.5E+06	2.8E+06	1.5E+06			2.8E+06
22	Sharon Steel, Monessen, PA	1B	0.0E+00	2.3E+05	0.0E+00	2.3E+05			0.0E+00
		2	0.0E+00	2.3E+05	0.0E+00	2.3E+05			0.0E+00
23	Shenango, Pittsburgh, PA	1	0.0E+00	3.1E+05	0.0E+00	3.1E+05			0.0E+00
		4	0.0E+00	4.7E+05	0.0E+00	4.7E+05			0.0E+00
24	Sloss Industries, Birmingham, AL	3	3.5E+05	3.6E+05	3.5E+05	3.6E+05			3.5E+05
		4	3.5E+05	3.6E+05	3.5E+05	3.6E+05			3.5E+05
		5	7.0E+05	6.8E+05	7.0E+05	6.8E+05			7.0E+05
25	Toledo Coke, Toledo, OH	C	0.0E+00	6.0E+05	0.0E+00	6.0E+05	5.1E+07	1.0E+07	6.1E+07
26	Tonawanda, Buffalo, NY	1	0.0E+00	6.0E+05	0.0E+00	6.0E+05			0.0E+00
27	USX, Clairton, PA	1	1.2E+06	4.4E+05	1.2E+06	4.4E+05			1.2E+06
		2	1.2E+06	4.4E+05	1.2E+06	4.4E+05			1.2E+06
		3	1.2E+06	4.4E+05	1.2E+06	4.4E+05			1.2E+06
		7	1.2E+06	4.4E+05	1.2E+06	4.4E+05			1.2E+06
		8	1.2E+06	4.4E+05	1.2E+06	4.4E+05			1.2E+06
		9	1.2E+06	4.4E+05	1.2E+06	4.4E+05			1.2E+06
		13	4.7E+05	2.8E+05	4.7E+05	2.8E+05			4.7E+05
		14	4.7E+05	2.8E+05	4.7E+05	2.8E+05			4.7E+05
		15	4.7E+05	2.8E+05	4.7E+05	2.8E+05			4.7E+05
		19	1.7E+06	6.2E+05	1.7E+06	6.2E+05			1.7E+06
		20	7.0E+05	3.9E+05	7.0E+05	3.9E+05			7.0E+05
		B	0.0E+00	3.1E+05	0.0E+00	3.1E+05			0.0E+00
28	USX, Gary, IN	2	1.1E+07	1.8E+06	1.7E+07	2.3E+06			1.7E+07
		3	1.1E+07	1.8E+06	1.7E+07	2.3E+06			1.7E+07
		5	3.5E+05	3.2E+05	3.5E+05	3.2E+05			3.5E+05
		7	3.5E+05	3.2E+05	3.5E+05	3.2E+05			3.5E+05
29	Wheeling-Pitt, East Steubenville, WV	1	INCLUDED	5.6E+05	0.0E+00	5.6E+05			0.0E+00
		2	IN	5.6E+05	0.0E+00	5.6E+05			0.0E+00
		3	MACT	5.6E+05	0.0E+00	5.6E+05			0.0E+00
		8	1.8E+07	2.6E+06	1.8E+07	5.8E+06			1.8E+07
	TOTALS	82	1.49E+08	4.6E+07	2.4E+08	5.7E+07	7.09E+08	6.00E+07	1.01E+09

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16. ABSTRACT

Under the authority of the 1990 Clean Air Act Amendments, a National Emissions Standard for Hazardous Air Pollutants (NESHAP) is proposed to control emissions from By-product Coke Oven Charging, door leaks, and topside leaks. Because the EPA considers the regulation for By-product Coke Oven batteries to be a "major" rule, the attached Regulatory Impact Analysis was prepared to fulfill the requirements of E012291. This document reviews the need for regulation, control techniques, regulatory options, costs of control, economic impacts, benefits of the regulation, and compares benefits and costs associated with the regulation.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Coke Oven Hazardous Air Pollutant Emission Controls Economic Impact Benefit Cost		13B

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