EPA-450/3-82-005a

Revised Standards for Basic Oxygen Process Furnaces - Background Information for Proposed Standards

Emission Standards and Engineering Division

U.S ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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ENVIRONMENTAL PROTECTION AGENCY

Background Information and Draft Environmental Impact Statement for Revised Standards of Performance for Basic Oxygen Process Furnaces

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1. The proposed standards of performance would limit secondary emissions of particulate matter from new, modified, and reconstructed basic oxygen process steelmaking facilities. The proposed standards implement Section 111 of the Clean Air Act (42 U.S.C. 7411) and are based on the Administrator's determination that the previously promulgated standards for BOPF's no longer reflect application of the best demonstrated technology (BDT) for these facilities.

2. Copies of this document have been sent to the following Federal Departments: Labor, Health and Human Services, Defense, Transportation, Agriculture, Commerce, Interior, and Energy; the National Science Foundation; the Council on Environmental Quality; members of the State and Territorial Air Pollution Program Administrators; the Association of Local Air Pollution Control Officials; EPA Regional Administrators; and other interested parties.

3. The comment period for review of this document is 75 days. Mr. Gene W. Smith may be contacted regarding the date of the comment period.

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TABLE OF CONTENTS

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

UNITS OF MEASUREMENTS

acms	actual cubic meters per second
acfm	actual cubic feet per minute
°C	degrees Celsius
dscm	dry standard cubic meter
dscms	dry standard cubic meters per second
g	gram
mg	milligram (0.001)
kg	kilogram (1,000)
Mg	megagram (1,000,000)
Tg	teragram (1,000,000,000,000)
J	joule
kJ	kilojoule (1,000)
m	meter
cm	centimeter (0.01)
mm	millimeter (0.001)
m^3	cubic meter
m^3/s	cubic meters per second
Pa	pascal
kPa	kilopascal
scfs	standard cubic feet per second
scfm	standard cubic feet per minute
scmm	standard cubic meters per minute
scms	standard cubic meters per second

1. SUMMARY

1.1 REGULATORY ALTERNATIVES

The Clean Air Act Amendments of 1977 require that the Administrator review and, if appropriate, revise established standards of performance for new stationary sources at least every 4 years. Review of the standards of performance for particulate emissions from basic oxygen process furnaces (BOPF's) at iron and steel plants (40 CFR 60.140, Subpart N) was completed in 1979 and a notice of review was published on March 21, 1979 (44 FR 17460). Review of the primary standard resulted in recommendations for revisions to the standard in three areas: (1) the inclusion of controls for secondary emissions; (2) the clarification of the definition of a BOPF; and (3) the clarification of the sampling period used to determine compliance. Based on the first recommendation, a new Subpart Na has been proposed for the control of secondary emissions from BOPF's, hot metal transfer stations, and skimming stations in BOPF shops at iron and steel plants. Further information regarding the review of the primary standard may be found in the EPA document, "A Review of Standards of Performance of New Stationary Sources--Iron and Steel Plants/Basic Oxygen Process Furnaces" (EPA-450/3-78-116).

Four regulatory alternatives were considered as the basis for the proposed standards. Regulatory Alternative I corresponds to no additional Federal standards for emissions from BOPF steelmaking facilities. The level of emission control of this alternative is represented by the current new source performance standard (NSPS) that limits the mass and opacity of primary particulate emissions from an affected BOPF. These emission limits can be met with either an open or closed hood capture system in combination with an electrostatic precipitator (ESP) or scrubber for particulate collection. However, due to the advantages of closed hood control when only primary emission control is required, new BOPF shops would probably incorporate closed hood systems under this alternative.

Under Regulatory Alternative II, additional NSPS would be proposed to limit secondary emissions from the BOPF, hot metal transfer station, and skimming station. Standards for secondary emissions associated with this alternative would be achievable using auxiliary hooding ducted to a baghouse for the control of emissions from hot metal transfer and skimming and either of two methods for the control of top blown furnace emissions. If open hooding were used for the control of primary emissions from top blown furnaces, the primary control system could also be used to capture and collect secondary emissions. If closed hooding were the primary emission control method, a furnace enclosure with hooding evacuated to a baghouse could be used to meet the standards.

Because primary emissions are controlled to a greater degree with a closed hood system, total emissions (primary and secondary) to the atmosphere from a new BOPF shop would be less if closed hooding were used. Under Regulatory Alternative III, the existing NSPS for primary emissions would be revised to a limit that could only be achieved with the use of a closed hood system. Standards for secondary emissions would be based on the use of a furnace enclosure with hooding evacuated to a baghouse for the control of emissions from top or bottom blown furnaces plus auxiliary hooding ducted to a baghouse for the control of emissions from hot metal transfer and skimming.

Under Regulatory Alternative IV, standards would be set for secondary emissions from the affected facilities based on the use of a total building evacuation system. The limits of the primary NSPS would not be changed, therefore allowing the use of either closed or open hooding for primary emission control.

1.2 IMPACTS OF REGULATORY ALTERNATIVES

It is assumed that closed hooding would be used as the primary emission control method to meet the existing NSPS under Regulatory Alternative I. Particulate emissions to the atmosphere from a typical plant (i.e., a new BOPF shop with two 270-Mg (300-ton) top blown furnaces) with closed hood primary control on the furnaces and uncontrolled secondary emissions would be approximately 1,374 Mg/yr (1,515 tons/yr). The solid waste generated by the collection of primary particulate emissions would be approximately 41,325 Mg/yr (45,552 tons/yr). The electrical energy required for emission control under Regulatory Alternative I would be about 16 million kWh/yr for a typical plant. The total plant capital cost and the pollution control annualized cost for a typical new shop are estimated at $187.5 million (1980 dollars) and $5.4 million/yr, respectively. The estimated impacts of the other alternatives on a typical plant as measured against the baseline impacts of Regulatory Alternative I are shown in Table 1-1.

The longer term effects of the regulatory alternatives were evaluated by estimating the sum effect of each alternative on all BOPF steelmaking facilities for which construction was commenced during the period from 1981 to 1986. The computation of these industry wide impacts was based on an estimated increase in BOPF steelmaking capacity of 6.8 million Mg/yr (7.5 million tons/yr) by 1986. This projected new capacity is equivalent to the construction of approximately three new BOPF shops. Industry wide particulate emissions (controlled primary emissions plus uncontrolled secondary emissions) would be approximately 3,221 Mg/yr (3,551 tons/yr) for facilities commencing construction from 1981 to 1986. The solid waste to be handled due to the collection of emissions would be 96,855 Mg/yr (106,763 tons/yr). Industry wide electrical energy requirements under Regulatory Alternative I would be about 37.5 million kWh/yr. Industry wide capital and annualized costs for emission control would be about $42 million and $12.6 million/yr, respectively. The estimated industry wide impacts of the other alternatives, as measured against the baseline impacts of Regulatory Alternative I, are shown in Table 1-2.

A matrix summarizing the environmental and economic impacts is presented in Table 1-3.

TABLE 1-1. IMPACTS OF REGULATORY ALTERNATIVES ON A TYPICAL NEW BOPF SHOP AS COMPARED TO ALTERNATIVE I

	Alternative II	Alternative III	Alternative IV
Environmental impacts			
· Emission reduction	978 Mg/yr (1,078 tons/yr)	1,052 Mg/yr (1,160 tons/yr)	172 Mg/yr (190 tons/yr)
· Percent emission reduction	71	77	13
· Percent increase in solid waste	2	3	1
· Water pollution	No impact	No impact	No impact
Energy impacts			
· Electrical energy increase for emission control	9.7 million kWh/yr	20 million kWh/yr	118 million kWh/yr
· Percent increase	61	125	738
Economic impacts			
· Increase in capital costs (1980$)	7.8 million	12.6 million	42.4 million
· Increase in annual costs (1980$)	2.4 million	3.8 million	11.9 million
· Cost of pollutant removal	$2,475/Mg ($2,245/ton)	$3,649/Mg ($3,310/ton)	$69,300/Mg ($62,800/ton)
· Percent increase in cost of producing raw steel	0.3	0.5	n.p.

n.p. = Analysis not performed for this alternative.

TABLE 1-2. INDUSTRY WIDE IMPACTS OF REGULATORY ALTERNATIVES AS COMPARED TO ALTERNATIVE I

	Alternative II	Alternative III	Alternative IV
Environmental impacts			
· Emission reduction	2,292 Mg/yr (2,527 tons/yr)	2,466 Mg/yr (2,718 tons/yr)	404 Mg/yr (445 tons/yr)
· Percent emission reduction	71	77	13
· Percent increase in solid waste	2	3	1
· Water pollution	No impact	No impact	No impact
Energy impacts			
· Electrical energy increase for emission control	22.8 million kWh/yr	46.9 million kWh/yr	276 million kWh/yr
· Percent increase	61	125	738
Economic impacts			
· Increase in capital costs (1980$)	18.2 million	29.4 million	99.4 million
· Increase in annual costs (1980$)	5.6 million	3.0 million	28.0 million
· Cost of pollutant removal	$2,245/Mg ($2,245/ton)	$3,649/Mg ($3,310/ton)	$69,300/Mg ($62,800/ton)
· Percent increase in market price of raw steel	0.2	0.4	n.p.

n.p. = Analysis not performed for this alternative.

TABLE 1-3. ASSESSMENT OF ENVIRONMENTAL AND ECONOMIC IMPACTS FOR EACH REGULATORY ALTERNATIVE CONSIDERED

Regulatory Alternative	Air impact	Water impact	Solid waste impact	Energy impact	Noise impact	Economic impact	Inflationary impact
I	0	0	0	0	0	0	0
II	+4**	0	-1**	-3**	0	-2*	-1**
III	+4**	0	-1**	-3**	0	-2*	-1**
IV	+3**	0	-1**	-4**	0	-4*	-2**

Key:

+ Beneficial impact
- Adverse impact
0 No impact
1 Negligible impact
2 Small impact
3 Moderate impact
4 Large impact
* Short-term impact
** Long-term impact
*** Irreversible impact

2. INTRODUCTION

2.1 BACKGROUND AND AUTHORITY FOR STANDARDS

Before standards of performance are proposed as a Federal regulation, air pollution control methods available to the affected industry and the associated costs of installing and maintaining the control equipment are examined in detail. Various levels of control, based on different technologies and degrees of efficiency, are expressed as regulatory alternatives. Each of these alternatives is studied by the U.S. Environmental Protection Agency (EPA) as a prospective basis for a standard. The alternatives are investigated in terms of their impacts on the economics and well-being of the industry, the impacts on the national economy, and impacts on the environment. This document summarizes the information obtained through these studies so interested persons will be able to see the information considered by EPA in the development of the proposed standards.

Standards of performance for new stationary sources are established under Section 111 of the Clean Air Act (42 USC 7411) as amended, herein referred to as the Act. Section 111 directs the Administrator to establish standards of performance for any category of new stationary source of air pollution that ". . . causes, or contributes significantly to air pollution which may reasonably be anticipated to endanger public health or welfare."

The Act requires that standards of performance for stationary sources reflect ". . . the degree of emission reduction achievable which (taking into consideration the cost of achieving such emission reduction, and any nonair quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated for that category of sources." The standards apply only to stationary sources, the construction or modification of which commences after regulations are proposed by publication in the Federal Register.

The 1977 amendments to the Act altered or added numerous provisions that apply to the process of establishing standards of performance.

- EPA is required to list the categories of major stationary sources that have not already been listed and regulated under standards of performance. Regulations must be promulgated for these new categories on the following schedule:

  a. 25 percent of the listed categories by August 7, 1980,

  b. 75 percent of the listed categories by August 7, 1981, and

  c. 100 percent of the listed categories by August 7, 1982.

A governor of a State may apply to the Administrator to add a category not on the list or may apply to the Administrator to have a standard of performance revised.

- EPA is required to review the standards of performance every 4 years and, if appropriate, to revise them.

- EPA is authorized to promulgate a standard based on design, equipment, work practice, or operational procedures when a standard based on emission levels is not feasible.

- The term "standards of performance" is redefined, and a new term, "technological system of continuous emission reduction," is defined. The new definitions clarify that the control system must be continuous and may include a low- or nonpolluting process or operation.

- The time between the proposal and promulgation of a standard under Section 111 of the Act may be extended to 6 months.

Standards of performance, by themselves, do not guarantee protection of health or welfare because they are not designed to achieve any specific air quality levels. Rather, they are designed to reflect the degree of emission limitation achievable through application of the best adequately demonstrated technological system of continuous emission reduction, considering the cost of achieving such emission reduction, any nonair quality health and environmental impacts, and energy requirements.

Congress had several reasons for including these requirements. First, standards with a degree of uniformity are needed to prevent situations where some States may attract industries by relaxing standards relative to other States. Second, stringent standards enhance the potential for long-term growth. Third, stringent standards may help achieve long-term cost savings by eliminating the need for more expensive retrofitting when pollution ceilings may be reduced in the future. Fourth, certain types of standards for coalburning sources can adversely affect the coal market by driving up the price of low-sulfur coal or effectively excluding certain coals from the reserve base because their untreated pollution potentials are high. Congress does not intend for New Source Performance Standards to contribute to these problems. Fifth, the standard-setting process should create incentives for improved technology.

Promulgation of standards of performance does not prevent State or local agencies from adopting more stringent emission limitations for the same sources. States are free under Section 116 of the Act to establish even more stringent emission limits than those established under Section 111 or those necessary to attain or maintain the National Ambient Air Quality Standards (NAAQS) under Section 110. Thus, new sources may in some cases be subject to limitations more stringent than standards of performance under Section 111, and prospective owners and operators of new sources should be aware of this possibility in planning for such facilities.

A similar situation may arise when a major emitting facility is to be constructed in a geographic area that falls under the prevention of significant deterioration of air quality provisions of Part C of the Act. These provisions require, among other things, that major emitting facilities to be constructed in such areas are to be subject to best available control technology. The term best available control technology (BACT), as defined in the Act, means:

> . . . an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under this Act emitted from, or which results from, any major emitting facility, which the permitting authority, on a case-by-case

sources for which new source performance standards were promulgated or under development during 1977, or earlier, were selected on these criteria.

> basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility through application of production processes and available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques for control of each such pollutant. In no event shall application of "best available control technology" result in emissions of any pollutants which will

The Act amendments of August 1977 establish specific criteria to be used in determining priorities for all major source categories not yet listed by EPA. These are:

- The quantity of air pollutant emissions that each such category will emit, or will be designed to emit;
- The extent to which each such pollutant may reasonably be anticipated to endanger public health or welfare; and
- The mobility and competitive nature of each such category of sources and the consequent need for nationally applicable new source standards of performance.

The Administrator is to promulgate standards for these categories according to the schedule referred to earlier.

In some cases it may not be feasible to develop a standard for a source category with a high priority immediately. This problem might arise when a program of research is needed to develop control techniques or because techniques for sampling and measuring emissions may require refinement. In the development of standards, differences in the time required to complete the necessary investigation for different source categories must also be considered. For example, substantially more time may be necessary if numerous pollutants must be investigated from a single source category. Further, even late in the development process the schedule for completion of a standard may change. For example, inability to obtain emission data from well-controlled sources in time to pursue the development process in a systematic fashion may force a change in scheduling. Nevertheless, priority ranking is, and will continue to be, used to establish the order in which projects are initiated and resources assigned.

After the source category has been chosen, the types of facilities within the source category to which the standard will apply must be determined. A source category may have several facilities that cause air pollution, and emissions from some of these facilities may vary from insignificant to very expensive to control. Economic studies of the source category and of applicable control technology may show that air pollution control is better served by applying standards to the more severe pollution sources. For this reason, and because there is no adequately demonstrated system for controlling emissions from certain facilities, standards often do not apply to all facilities at a source. For the same reasons, the standards may not apply to all air pollutants emitted. Thus, although a source category may be selected to be covered by a standard of performance, not all pollutants or facilities within that source category may be covered by the standards.

2.3 PROCEDURE FOR DEVELOPMENT OF STANDARDS OF PERFORMANCE

Standards of performance must:

- Realistically reflect best demonstrated control practice;
- Adequately consider the cost, the nonair-quality health and environmental impacts, and the energy requirements of such control;
- Be applicable to existing sources that are modified or reconstructed as well as new installations; and
- Meet these conditions for all variations of operating conditions considered anywhere in the country.

The objective of a program for developing standards is to identify the best technological system of continuous emission reduction that has been adequately demonstrated. The standard-setting process involves three principal phases of activity: information gathering, analysis of the information, and development of the standard of performance.

During the information-gathering phase, industries are queried through a telephone survey, letters of inquiry, and plant visits by EPA representatives. Information is also gathered from many other sources, and a literature search is conducted. From the knowledge acquired about the industry, EPA selects certain plants at which emission tests are conducted to provide reliable data that characterize the pollutant emissions from well-controlled existing facilities.

In the second phase of a project, the information about the industry and the pollutants emitted is used in analytical studies. Hypothetical "model plants" are defined to provide a common basis for analysis. The model plant definitions, national pollutant emission data, and existing State regulations governing emissions from the source category are then used in establishing "regulatory alternatives." These regulatory alternatives are essentially different levels of emission control.

EPA conducts studies to determine the impact of each regulatory alternative on the economics of the industry and on the national economy, on the environment, and on energy consumption. From several possibly applicable alternatives, EPA selects the single most plausible regulatory alternative as the basis for a standard of performance for the source category under study.

In the third phase of a project, the selected regulatory alternative is translated into a standard of performance, which, in turn, is written in the form of a Federal regulation. The Federal regulation, when applied to newly constructed plants, will limit emissions to the levels indicated in the selected regulatory alternative.

As early as is practical in each standard-setting project, EPA representatives discuss with members of the National Air Pollution Control Techniques Advisory Committee (NAPCTAC) the possibilities of a standard and the form it might take. Industry representatives and other interested parties also participate in these meetings.

The information acquired in the project is summarized in the Background Information Document (BID). The BID, the standard, and a preamble explaining the standard are widely circulated to the industry being considered for control, environmental groups, other government agencies, and offices within EPA. Through this extensive review process, the points of view of expert reviewers are considered as changes are made to the documentation.

A "proposal package" is assembled and sent through the offices of EPA Assistant Administrators for concurrence before the proposed standards are officially endorsed by the EPA Administrator. After they are approved by the Administrator, the preamble and the proposed regulation are published in the Federal Register.

As a part of the Federal Register announcement of the proposed standards, the public is invited to participate in the standard-setting process. EPA invites written comments on the proposal and also holds a public hearing to discuss the proposed standards with interested parties. All public comments are summarized and incorporated into a second volume of the BID. All information reviewed and generated in studies in support of the standard of performance is available to the public in a "docket" on file in Washington, DC.

Comments from the public are evaluated, and the standard of performance may be altered in response to the comments.

The significant comments and EPA's position on the issues raised are included in the "preamble" of a "promulgation package," which also contains the draft of the final regulation. The regulation is then subjected to another round of review and refinement until it is approved by the EPA Administrator. After the Administrator signs the regulation, it is published as a "final rule" in the Federal Register.

2.4 CONSIDERATION OF COSTS

Section 317 of the Act requires an economic impact assessment with respect to any standard of performance established under Section 111 of the Act. The assessment is required to contain an analysis of:

- Costs of compliance with the regulation, including the extent to which the cost of compliance varies, depending on the effective date of the regulation and the development of less expensive or more efficient methods of compliance;
- Potential inflationary or recessionary effects of the regulation;
- Effects the regulation might have on small business with respect to competition;
- Effects of the regulation on consumer costs; and
- Effects of the regulation on energy use.

Section 317 also requires that the economic impact assessment be as extensive as practicable.

The economic impact of a proposed standard upon an industry is usually addressed both in absolute terms and in terms of the control costs that would be incurred as a result of compliance with typical, existing State control regulations. An incremental approach is necessary because both new and existing plants would be required to comply with State regulations in the absence of a Federal standard of performance. This approach requires a detailed analysis of the economic impact from the cost differential that would exist between a proposed standard of performance and the typical State standard.

Air pollutant emissions may cause water pollution problems, and captured potential air pollutants may pose a solid waste disposal problem. The total environmental impact of an emission source must, therefore, be analyzed and the costs determined whenever possible.

A thorough study of the profitability and price-setting mechanisms of the industry is essential to the analysis so an accurate estimate of potential adverse economic impacts can be made for proposed standards. It is also essential to know the capital requirements for pollution control systems already placed on plants so additional capital requirements necessitated by these Federal standards can be placed in proper perspective. Finally, it is necessary to assess the availability of capital to provide the additional control equipment needed to meet the standards of performance.

2.5 CONSIDERATION OF ENVIRONMENTAL IMPACTS

Section 102(2)(C) of the National Environmental Policy Act (NEPA) of 1969 requires Federal agencies to prepare detailed environmental impact statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The objective of NEPA is to build into the decisionmaking process of Federal agencies a careful consideration of all environmental aspects of proposed actions.

In a number of legal challenges to standards of performance for various industries, the United States Court of Appeals for the District of Columbia Circuit has held that environmental impact statements need not be prepared by the Agency for proposed actions under Section 111 of the Clean Air Act. Essentially, the Court of Appeals has determined that the best system of emission reduction requires the Administrator to take into account counter-productive environmental effects of a proposed standard, as well as economic costs to the industry. On this basis, therefore, the Court established a narrow exemption from NEPA for EPA determination under Section 111.

In addition to these judicial determinations, the Energy Supply and Environmental Coordination Act (ESECA) of 1974 (PL-93-319) specifically exempted proposed actions under the Clean Air Act from NEPA requirements. According to Section 7(c)(1), "No action taken under the Clean Air Act shall be deemed a major Federal action significantly affecting the quality of the human environment within the meaning of the National Environmental Policy Act of 1969." (15 USC 793c[1])

Nevertheless, the Agency has concluded that the preparation of environmental impact statements could have beneficial effects on certain regulatory actions. Consequently, although not legally required to do so by section 102 (2)(C) of NEPA, EPA has adopted a policy requiring that environmental impact statements be prepared for various regulatory actions, including standards of performance developed under Section 111 of the Act. This voluntary preparation of environmental impact statements, however, in no way legally subjects the Agency to NEPA requirements.

To implement this policy, a separate section in this document is devoted solely to an analysis of the potential environmental impacts associated with the proposed standards. Both adverse and beneficial impacts in such areas as air and water pollution, increased solid waste disposal, and increased energy consumption are discussed.

2.6 IMPACT ON EXISTING SOURCES

Section 111 of the Act defines a new source as ". . . any stationary source, the construction or modification of which is commenced . . ." after the proposed standards are published. An existing source is redefined as a new source if "modified" or "reconstructed" as defined in amendments to the general provisions of Subpart A of 40 CFR Part 60, which were promulgated in the Federal Register on December 16, 1975 (40 FR 58416).

Promulgation of a standard of performance requires States to establish standards of performance for existing sources in the same industry under Section 111 (d) of the Act if the standard for new sources limits emissions of a designated pollutant (i.e., a pollutant for which air quality criteria have not been issued under Section 108 or which has not been listed as a hazardous pollutant under Section 112). If a State does not act, EPA must establish such standards. General provisions outlining procedures for control of existing sources under Section 111(d) were promulgated November 17, 1975, as Subpart B of 40 CFR Part 60 (40 FR 53340).

2.7 REVISION OF STANDARDS OF PERFORMANCE

Congress was aware that the level of air pollution control achievable by any industry may improve with technological advances. Accordingly, Section 111 of the Act provides that the Administrator ". . . shall, at least every 4 years, review and, if appropriate, revise . . ." the standards. Revisions are made to ensure that the standards continue to reflect the best systems that become available in the future. Such revisions will not be retroactive, but will apply to stationary sources constructed or modified after proposal of the revised standards.

3. BASIC OXYGEN PROCESS STEELMAKING INDUSTRY

3.1 GENERAL

The procedure for making steel by blowing air through molten iron was developed about a century ago and was practiced until the 1960's in the form of the Bessemer process. The advantage of this process was that it was relatively fast and yielded a high material-to-labor ratio. The open hearth process could not be replaced by the blowing process, however, because the steel produced by blowing air through iron contains nitrogen, which makes it more brittle and less ductile than open hearth process steel.

As tonnage quantities of pure oxygen (95 to 99 percent) at low prices became available, the pure oxygen blown steelmaking process became feasible and grew quickly from 1960 on, with a proportionate decline in the open hearth process. The new process is effected in furnaces called Basic Oxygen Process Furnaces (BOPF's). The BOPF technology is now well established for making high quality steel using a minimum amount of labor.

In 1978, the domestic steel industry was composed of 93 companies operating 158 individual plants.[1] The plants may be divided into three groups based on the type of primary operations, products, and marketing approach of the individual companies. These groups are: integrated companies that have primary raw material and ironmaking facilities (blast furnaces), steelmaking units, and finishing mills; alloy and specialty steel companies that produce alloys and special steels but do not engage in ironmaking activities; and nonintegrated companies that operate melting and casting units and fabrication mills for the production of a limited number of products for a regional market.[1] BOPF shops are typically part of integrated steel mills. A schematic flow chart for integrated and nonintegrated steel mills is presented in Figure 3-1.

A list of the integrated steel mills that have BOPF facilities is presented in Table 3-1. The distribution of these plants within the United States is shown in Figure 3-2.[2]

3.2 PROCESS FACILITIES AND THEIR EMISSIONS

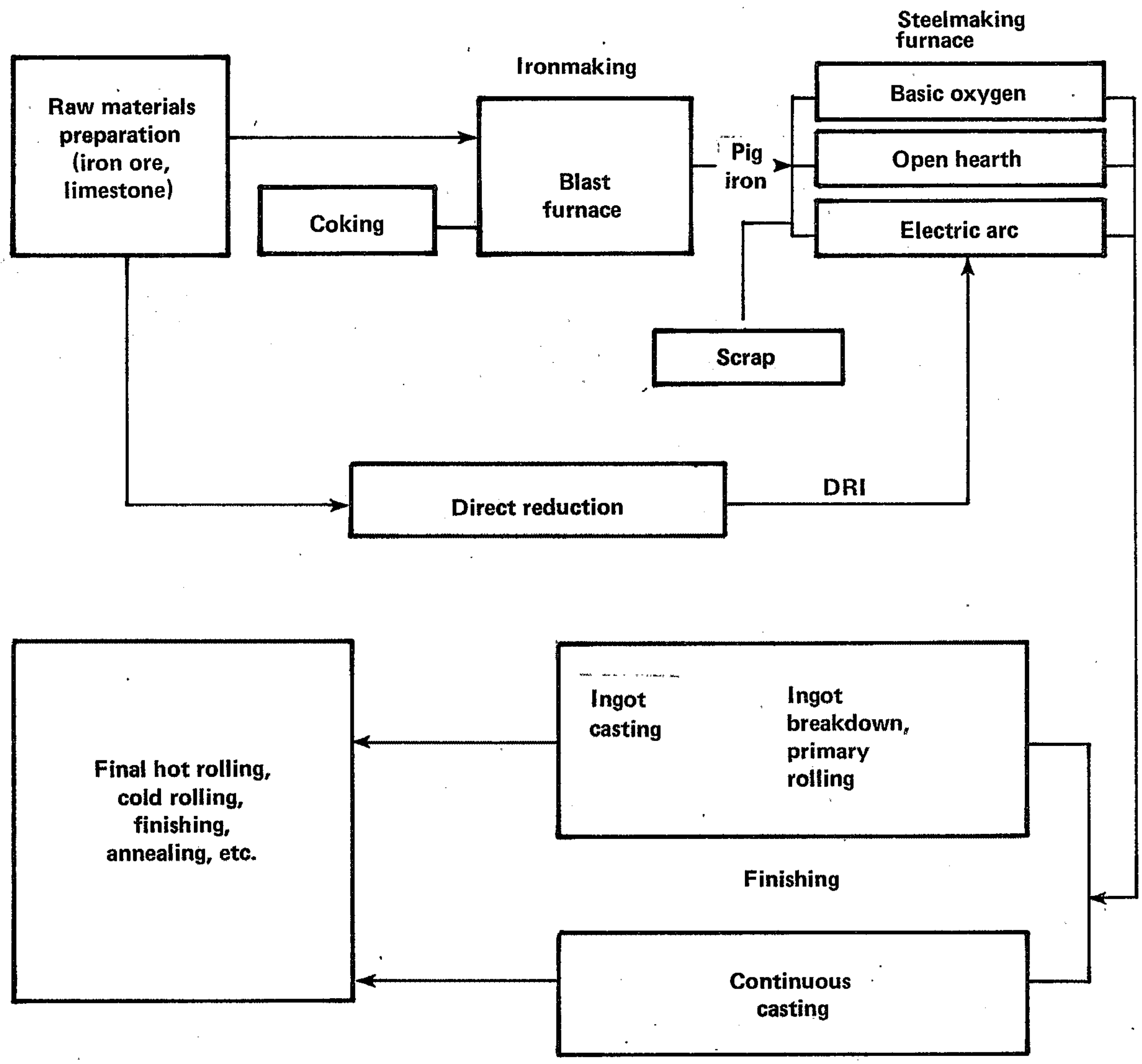
3.2.1 Basic Oxygen Process Furnaces and Their Operation

A basic oxygen process furnace is a large, open-mouthed vessel lined with a basic refractory material (the term "basic" refers to the chemical characteristic of the lining). The furnace is mounted on trunnions that allow it to be rotated through 360° in either direction. A typical vessel can have an opening 3.7 to 4.3 m (12 to 14 ft) in diameter and be 6.1 to 9.1 m (20 to 30 ft) high.

The furnace receives a charge composed of scrap and molten iron which it converts to molten steel. This is accomplished through the introduction of high-purity oxygen that oxidizes the carbon and the silicon in the molten iron, removes these products, and provides heat for melting the scrap. After the oxygen blow is started, lime may be added to the vessel to provide a slag of the desired basicity. Fluorspar may also be added in order to achieve the desired slag fluidity.

Two distinct types of furnaces are in general use (see Figure 3-3). The most common type is the "top blown" furnace, in which oxygen is blown into the vessel through a water-cooled lance that can be lowered into the mouth of the upright furnace. The other type of furnace, commonly called a Q-BOP, is "bottom blown." In this furnace, oxygen is introduced into the vessel through tuyeres (nozzles) in the furnace bottom.

The major reason for installing a Q-BOP furnace is that it does not require a great deal of vertical clearance above the furnace enclosure and can therefore fit into existing open hearth buildings. Existing ancillary facilities can be adapted easily for serving Q-BOP's. Other advantages of bottom blown furnaces are slightly increased yields and higher ratios of scrap to hot metal.



Possible major routes:

Integrated:	coking-blast furnace-basic oxygen-ingot casting-finishing.
Nonintegrated:	scrap-electric furnace-continuous casting-finishing.
Semi-integrated:	direct reduction + scrap-electric furnace-continuous casting-finishing.

Figure 3-1. Schematic flow chart for integrated and nonintegrated steelmaking.[1]

TABLE 3-1. BOPF LOCATIONS AND DESIGN CAPACITIES[2] [a]

EPA Region	Company	Location	Year installed	BOPF furnaces Number	BOPF furnaces Size-Mg (tons)	Capacity million Mg/yr, (million tons/yr)
2	Bethlehem Steel Co.	Lackawanna, N.Y.	1964/66	3	282(310)	4.5(5.0)
	Republic Steel Co.	Buffalo, N.Y.	1970	2	120(130)	0.9(1.0)
3	Alleghany Ludlum Steel Co.	Natrona, Pa.	1966	2	75(80)	0.4(0.5)
	Bethlehem Steel Corp.	Sparrows Pt., Md.	1966	2	200(220)	2.7(3.0)
	Bethlehem Steel Corp.	Bethlehem, Pa.	1968	2	240(270)	3.1(3.5)
	Jones & Laughlin Steel Corp.	Aliquippa, Pa.	1968	3	188(207)	
	National Steel Corp.	Weirton, W. Va.	1967	2	277(360)	5.2(5.8)
	Sharon Steel Corp.	Farrell, Pa.	1974	3[b]	135(150)	1.4(1.6)
	U.S. Steel Corp.	Duquesne, Pa.	1963	2	200(220)	2.2(2.5)
	U.S. Steel Corp.	Braddock, Pa.	1972	2	200(220)	2.2(2.5)
	Wheeling-Pittsburgh Steel Corp.	Monessen, Pa.	1964	2	180(200)	1.4(1.6)
4	Armco Steel Corp.	Ashland, Ky.	1963	2	165(180)	1.8(2.0)
	Republic Steel Corp.	Gadsden, Ala.	1965	2	136(150)	1.3(1.5)
	U.S. Steel Corp.	Fairfield, Ala.	1974/78	3[c]	180(200)	3.2(3.5)
5	Armco Steel Corp.	Middletown, Oh.	1969	2	182(200)	2.0(2.3)
	Bethlehem Steel Co.	Burns Harbor, Ind.	1969	2	270(300)	4.0(4.5)
	Bethlehem Steel Co.	Burns Harbor, Ind.	1978	1	270(300)	0.9(1.0)
	Ford Motor Co.	Dearborn, Mich.	1964	2	218(240)	3.4(3.8)
	Inland Steel Co.	East Chicago, Ind.	1966	2	230(255)	{6.0(6.7)}
	Inland Steel Co.	East Chicago, Ind.	1974	2	190(210)	
	Interlake, Inc.	Chicago, Ill.	1959	2	71(78)	0.9(1.1)
	Jones & Laughlin Steel Corp.	Cleveland, Oh.	1961	2	200(220)	2.7(3.0)
	McLouth Steel Corp.	Trenton, Mich.	1958/59	5	109(120)	2.5(2.8)
	National Steel Corp.	Ecorse, Mich.	1962	2	270(300)	5.2(5.8)
	National Steel Corp.	Ecorse, Mich.	1970	2	209(230)	
	National Steel Corp.	Granite City, Ill.	1967	2	215(235)	2.2(2.5)
	Republic Steel Corp.	Warren, Oh.	1965	2	136(150)	1.9(2.2)
	Republic Steel Corp.	Cleveland, Oh.	1966/77	2	200(220)	3.3(3.7)
	Republic Steel Corp.	So. Chicago, Ill.	1976	2[c]	204(225)	2.0(2.3)
	U.S. Steel Corp.	Gary, Ind.	1965	3	195(215)	{7.2(8.0)
	U.S. Steel Corp.	Gary, Ind.	1973	3[c]	180(200)	
	U.S. Steel Corp.	So. Chicago, Ill.	1969	3	180(200)	2.7(3.0)
	U.S. Steel Corp.	Lorain, Oh.	1971	2	205(225)	2.7(3.0)
	Wheeling-Pittsburgh Steel Corp.	Steubenville, Oh.	1965	2	250(275)	2.6(2.9)
	Jones & Laughlin Steel Corp.	East Chicago, In.	1970	2	264(290)	2.7(3.0)
8	CF&I Steel Corp.	Pueblo, Colo.	1961	2	107(118)	1.2(1.4)
9	Kaiser Steel Corp.	Fontana, Calif.	1978	2	208(229)	2.1(2.4)

[a]Revised by RTI.

[b]This facility consists of one standard top-blown BOPF and two Kaldo Process BOPF's, the latter vessels being inclined and rotating during the oxygen blow. The Kaldo units have been virtually supplanted by the standard fixed unit.

[c]Q-BOP installation.

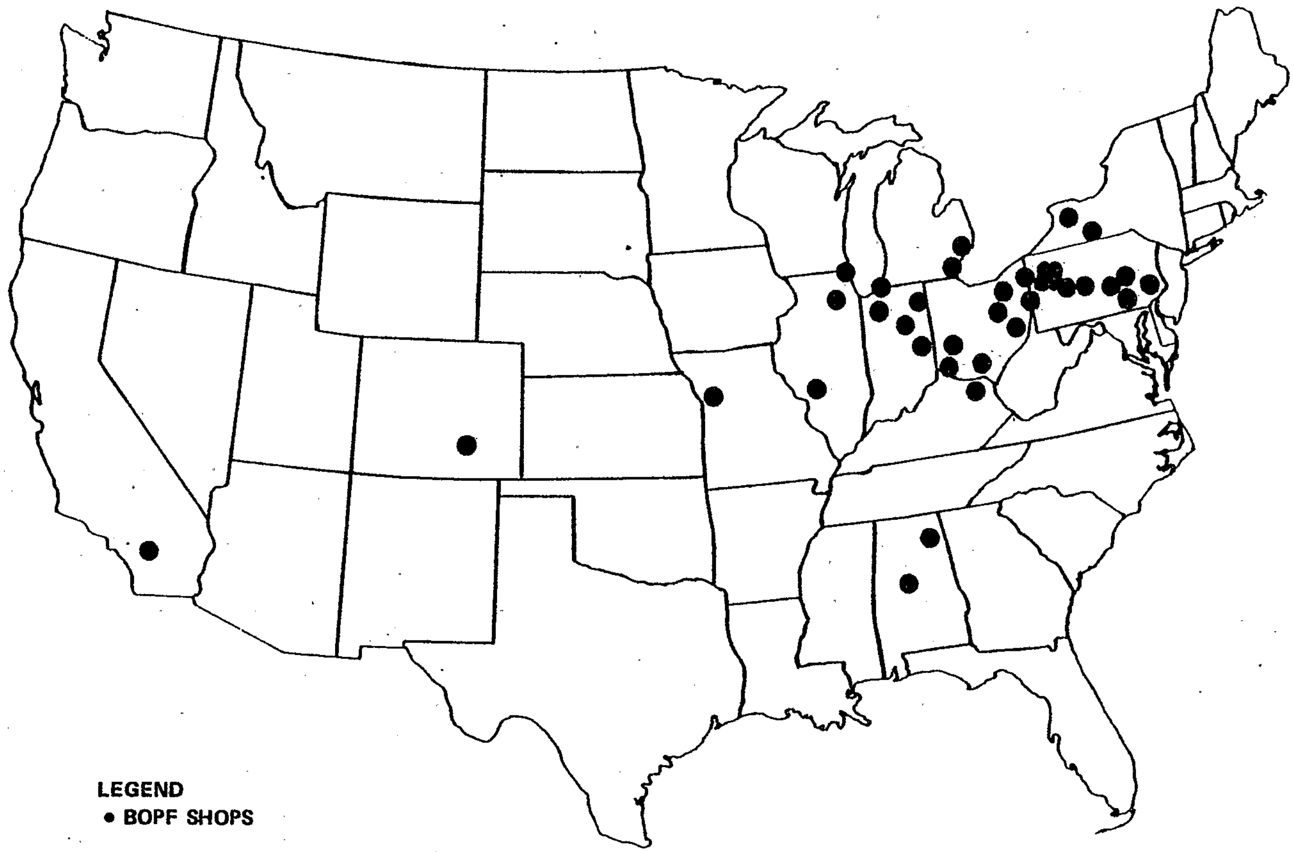


Figure 3-2. Geographic distribution of the U.S. BOPF steelmaking facilities.

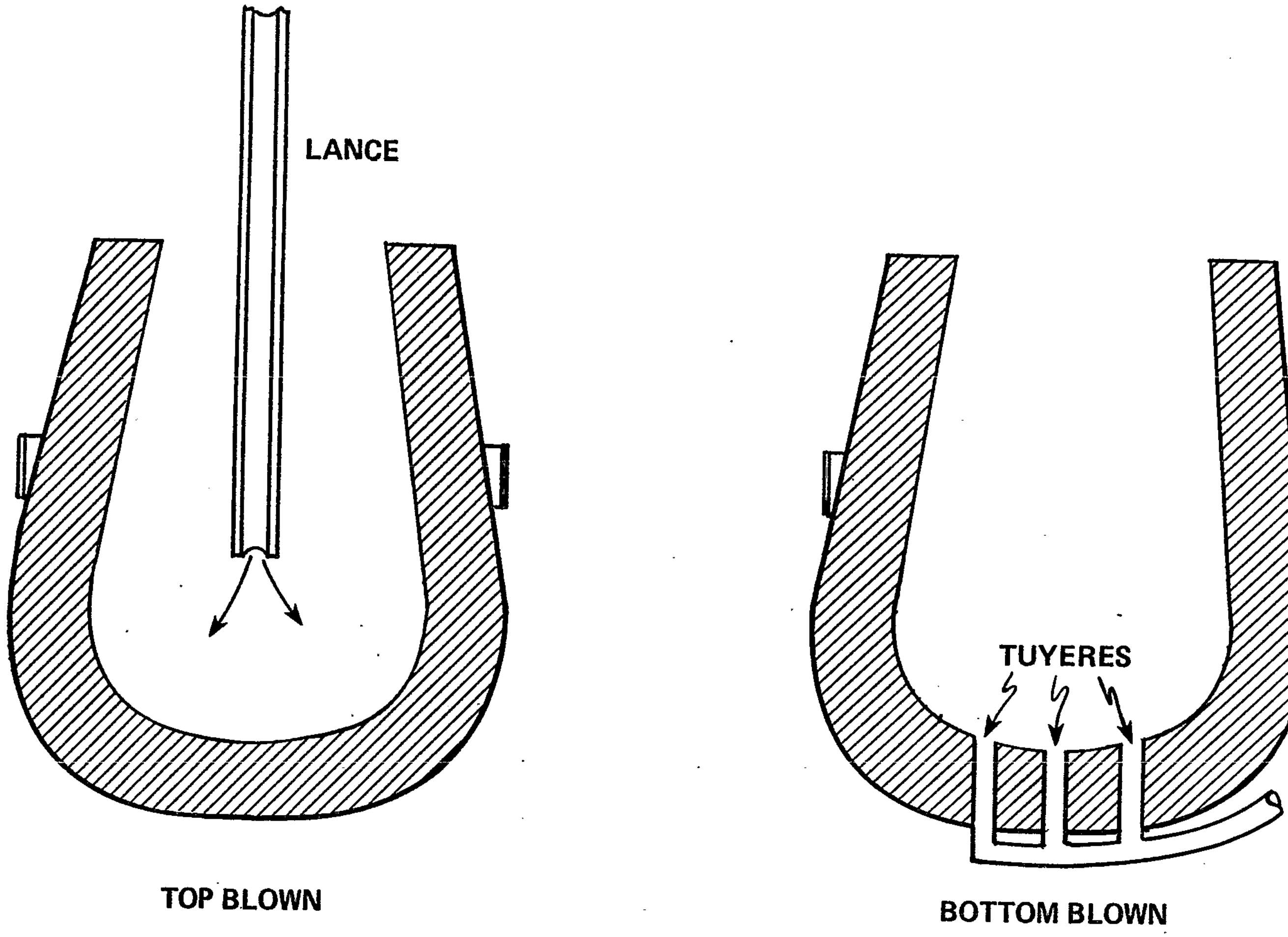


Figure 3-3. Top blown and bottom blown BOPF vessels.

A third type of furnace is currently being used on an experimental basis at the National Steel plant in Granite City, Illinois. This typical top blown furnace has been modified to allow 90 percent of the oxygen to be introduced through the conventional oxygen lance and the other 10 percent to be injected through bottom and side tuyeres within the vessel.[3] This particular installation is called the Klöchner Maxhütte Scrap (KMS) conversion system.[4] [5] Presently, there is not much information available about the success of the KMS system or about the liklehood of its being adopted in other BOPF shops.

Steel is produced via the basic oxygen process in distinct operations that occur in the following order:

1. Charging--The addition of scrap metal or hot metal to the BOPF.

2. Oxygen blow--The refining stage of the process, in which pure oxygen is blown into the BOPF.

3. Turndown--After the blow, the vessel is tilted toward the charging aisle to facilitate taking hot metal samples and making temperature measurements.

4. Reblow--If the samples taken during the turndown indicate the need, oxygen can again be blown into the vessel, usually for only a very brief period.

5. Tapping--Pouring the molten steel out of the BOPF into the teeming ladle.

6. Deslagging--Pouring residual slag out of the BOPF into a slag pot.

7. Teeming--The pouring of molten steel into ingot molds.

These operations are illustrated in Figures 3-4 and 3-5.

Generally, a BOPF shop is arranged in three parallel aisles. The charging aisle has one or more cranes for conveying charge material (molten iron and scrap) to the furnace, as well as for carrying ladles of molten slag away from the furnace. The furnace aisle contains the furnaces, collection hoods for fumes, lances for injecting the oxygen into the bath, and the overhead bins for storing and metering out the various flux materials and alloy additions. The pouring, teeming, or tapping aisle handles the finished heats of steel. It has one or more

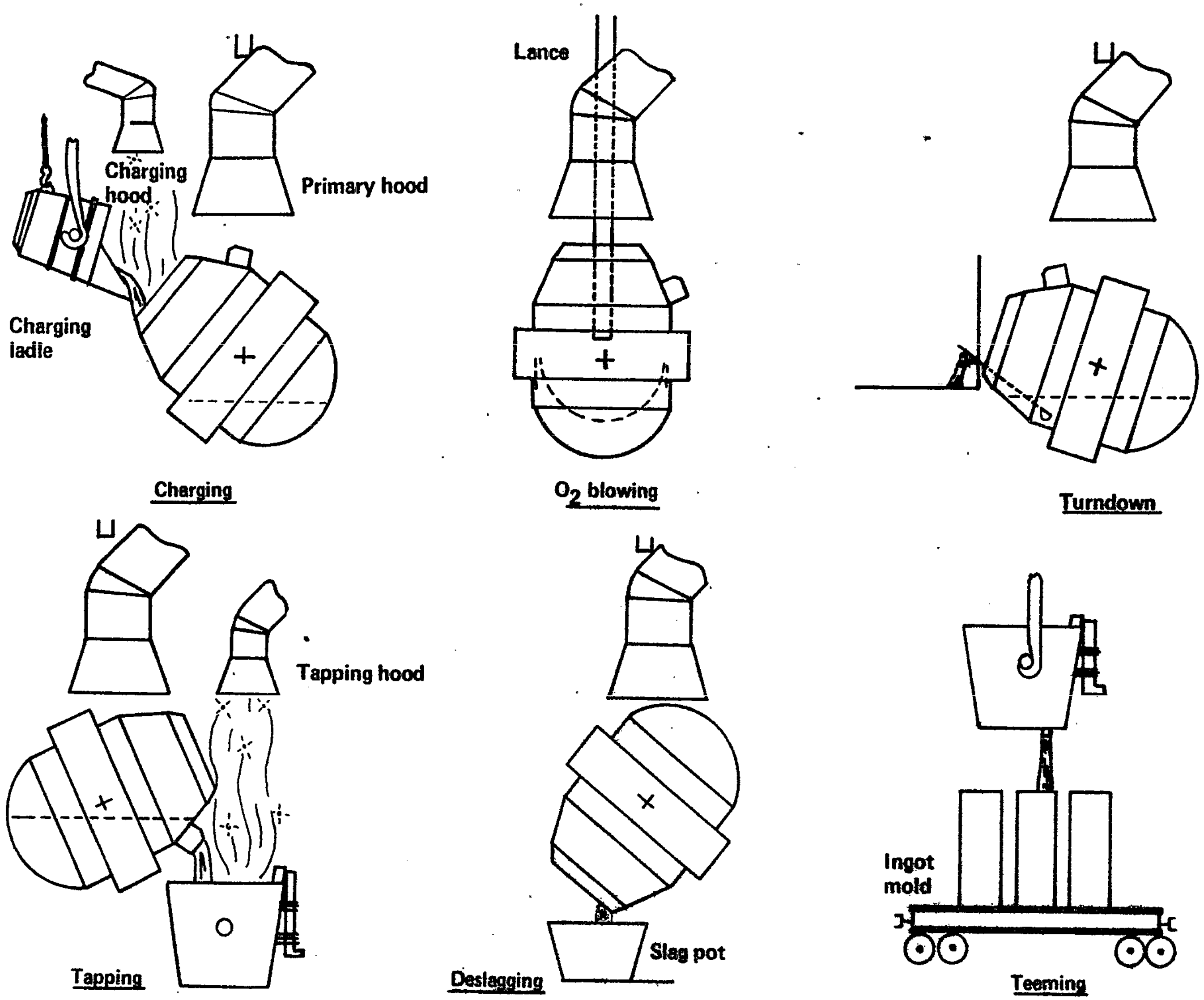


Figure 3-4. Steps for making steel by the basic oxygen process.

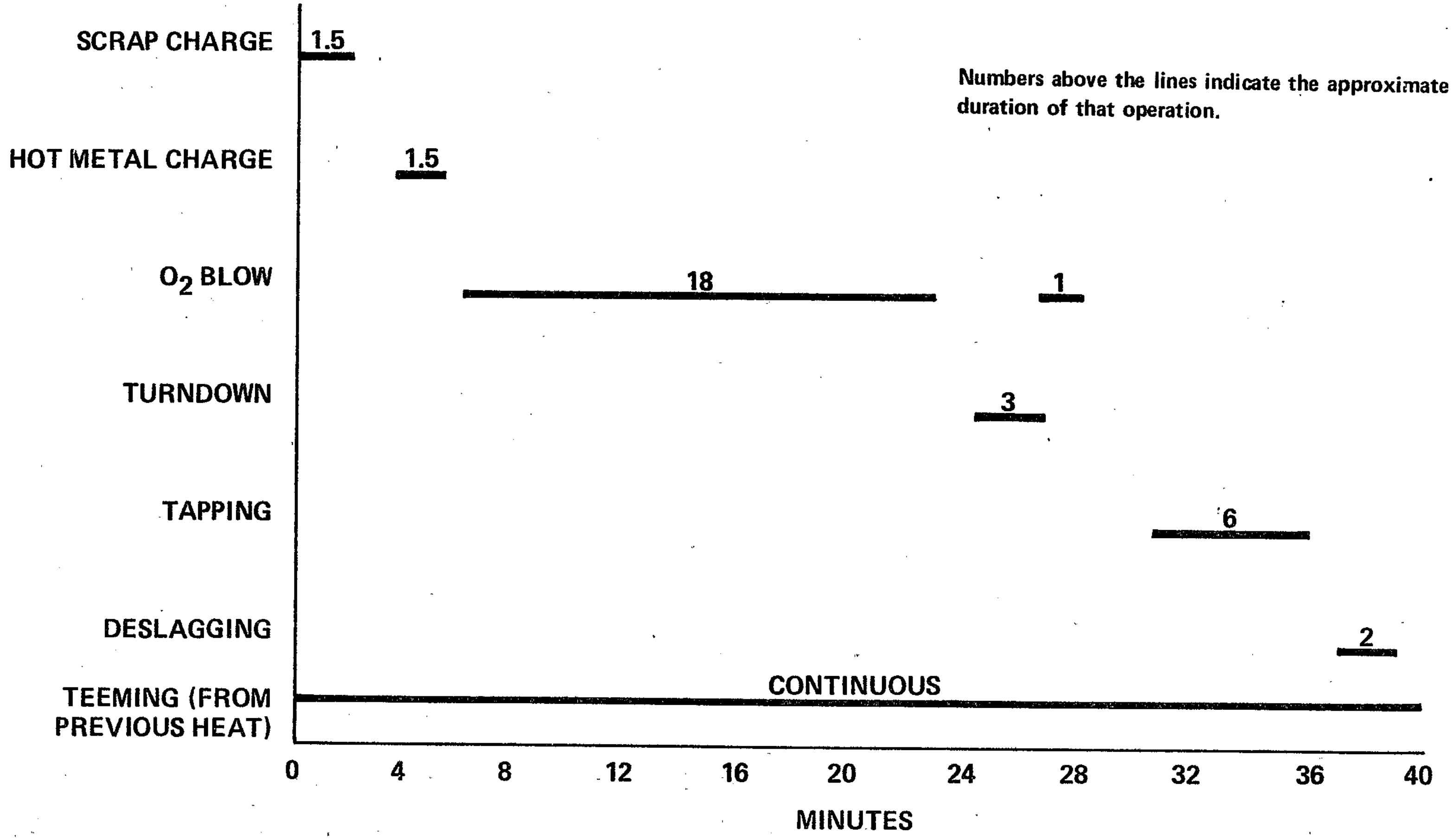


Figure 3-5. Time sequence of top blown BOPF operations.

overhead cranes and facilities for pouring the molten steel either into ingot molds or into continuous casting machines.

Adjacent to the charging aisle is a scrap yard with overhead cranes where scrap is transferred from railroad cars into the charging boxes. The charging boxes are moved by special railed cars from the scrap yard into the charging aisle. Other railed cars under the furnace hold the steel and slag ladles (teeming ladle and slag pots). These cars transfer the slag ladles from under the furnace to the charging aisle and move the steel ladles into the teeming aisle.

The emissions generated during the oxygen blow are captured by a large, water-cooled hood located directly above the furnace. This hood is called the primary hood since it captures the primary (blowing) emissions.

During the oxygen blow of a top blown furnace, the oxygen lance is lowered through an opening (the lance hole) in the top of the primary hood. It is stopped a short distance above the molten iron and the flow of oxygen (blow) is initiated. The vessel is upright during the blow, allowing the fumes to pass directly from the mouth of the furnace into the mouth of the primary hood. At other times during the process, the vessel may be tilted so that the mouth of the vessel does not align with the opening in the hood, and capture of the fumes by the primary hood is less likely (Figure 3-4). The vessel is tilted toward the charging aisle for at least four of the operations; namely, charging the scrap, charging with molten iron, sampling the heat for analysis, and dumping the slag. With very few exceptions, the furnace is tilted toward the tapping aisle only when pouring the finished heat of steel from the furnace into the teeming ladle. Alloy additions may be made to the furnace while it is upright under the hood. However, additions are more commonly made to the teeming ladle while it is being filled with steel from the furnace.

There are several ancillary operations associated with the basic oxygen process of making steel. The first is the scrap handling operation described above. The next is hot metal transfer, or the transfer of molten iron from the torpedo car to the charging ladle and from the charging ladle to the furnace itself. (In several BOPF shops, hot metal is poured from the torpedo car into a mixer from which it is eventually poured into the charging ladle. The mixer is a refractory-lined vessel with sufficient capacity to hold the contents of several torpedo cars.) The handling of molten iron may include the operation of mechanically skimming slag from the top of the hot metal. A third operation is the teeming of the finished steel into ingot molds or into continuous casting machines. Finally, there is the handling and disposing of molten slag, generally accomplished by carrying the slag pot to some location where the slag can be safely poured on the ground and allowed to cool. The solidified slag is then loaded into trucks or railroad cars for transport to a disposal site.

Figure 3-6 is a schematic elevation of a typical two-furnace shop and indicates all of the facilities described above. Figure 3-7 shows a schematic cross section that illustrates the various operating units.[6]

3.2.1.1 Material Flow. A flow sheet for steelmaking in the BOPF is shown in Figure 3-8. The principal components of the charge are scrap and molten iron. Scrap usually arrives at the shop in railroad gondola cars and is transferred to the charging box (scrap bucket) by a magnet on an overhead crane. Molten iron is brought to the shop by railroad torpedo cars and is transferred to the charging ladle at the hot metal transfer station. This station is usually equipped with a hood for capturing the emissions that evolve during the transfer operation. When the furnace vessel is ready for charging, it is tilted toward the charging aisle and the charging box is lifted and emptied into the vessel. Next, the ladle of molten iron is poured into the vessel over the scrap. The vessel is turned upright, the oxygen lance is lowered (for top blown furnaces), and the blow commences. During the blow, the desired quantities of lime and fluorspar may be fed through the chute into the vessel from the weigh hopper. In Q-BOP's, these materials are injected through the tuyeres.

Two forms of primary (blowing) emission collection equipment are in common use. One form is an open hood directed to an electrostatic precipitator (ESP) and is similar to that shown in Figures 3-6 and 3-7. The emissions that evolve during the oxygen blow are captured by

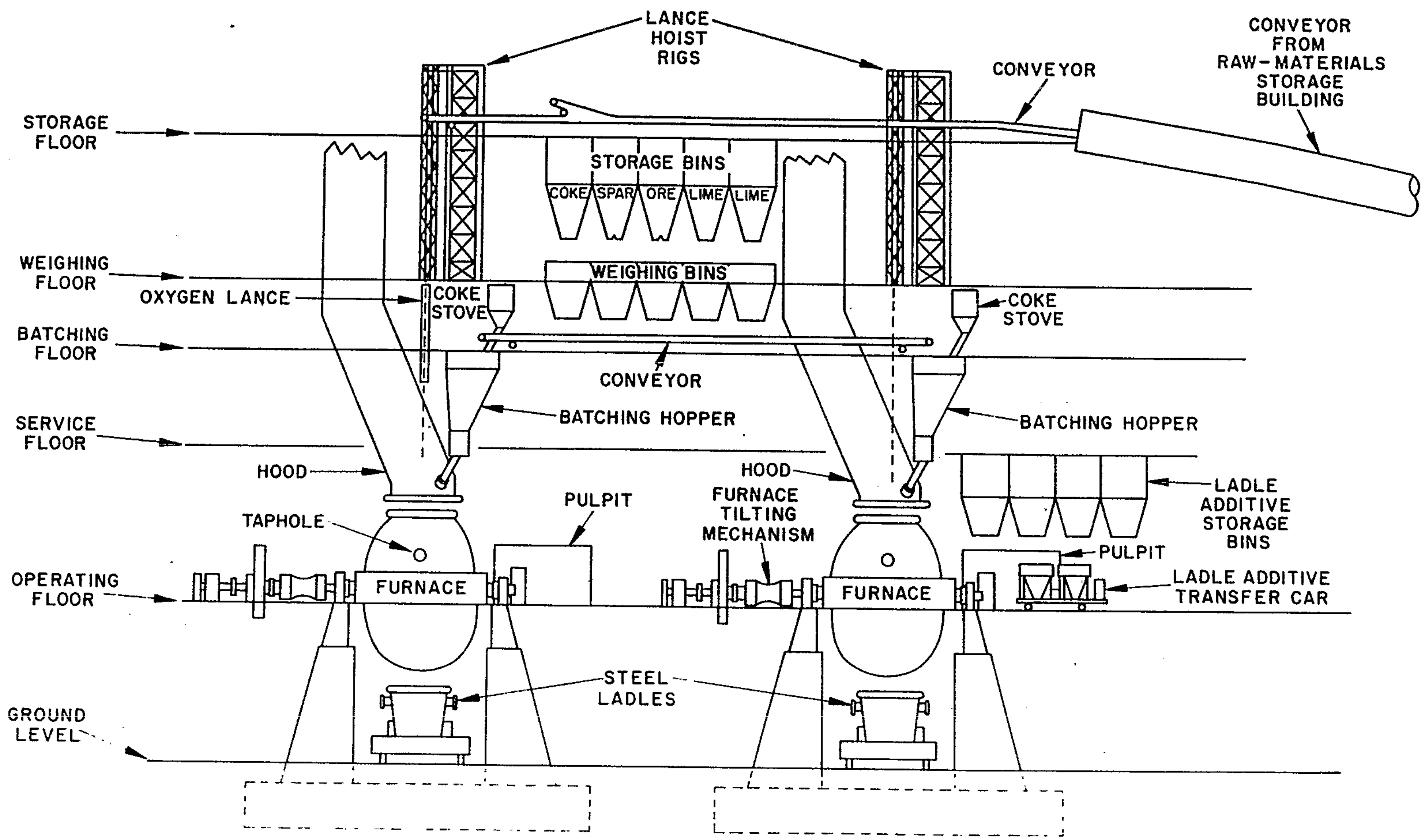


Figure 3-6. Schematic elevation of a typical two-furnace shop.

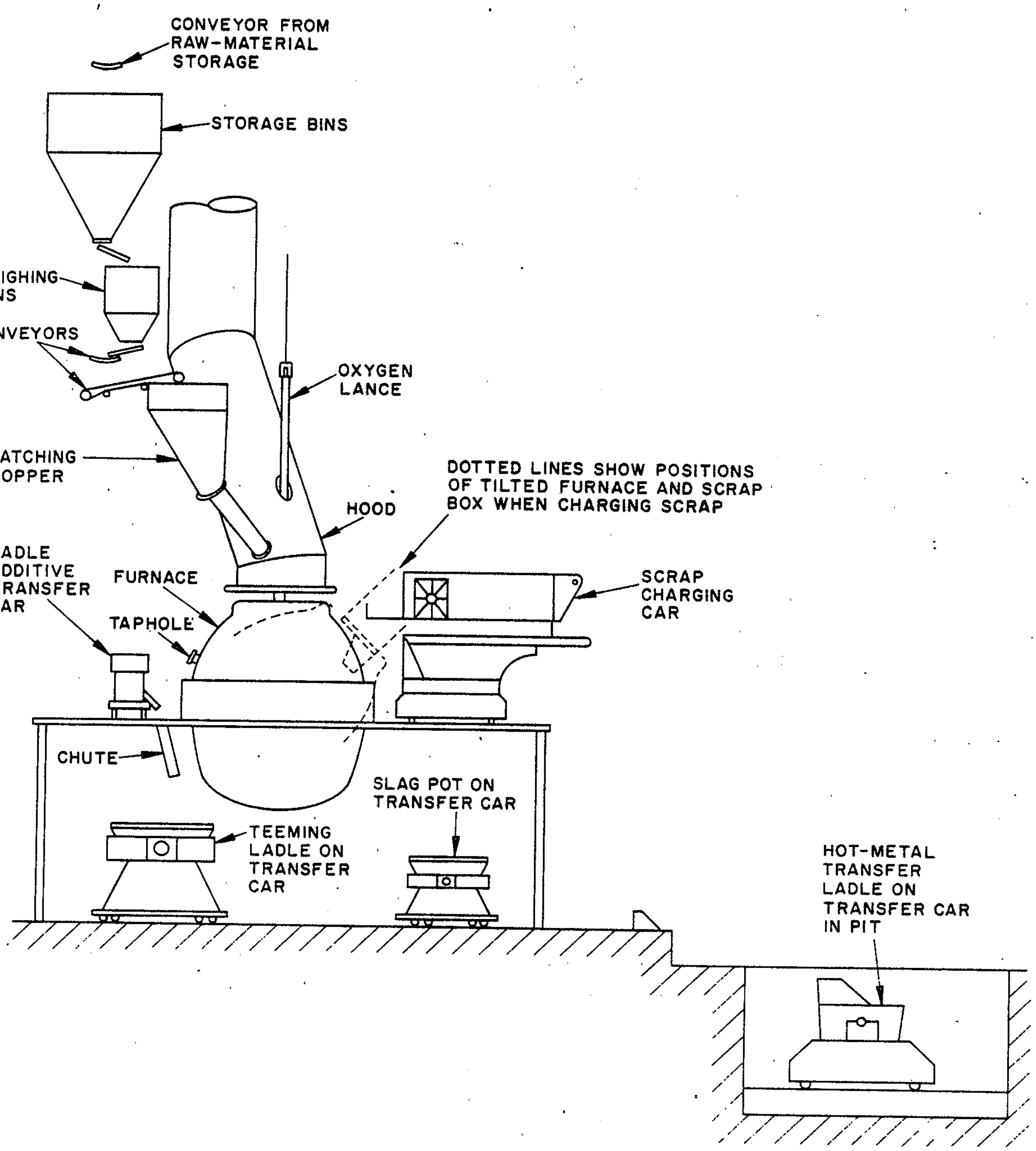
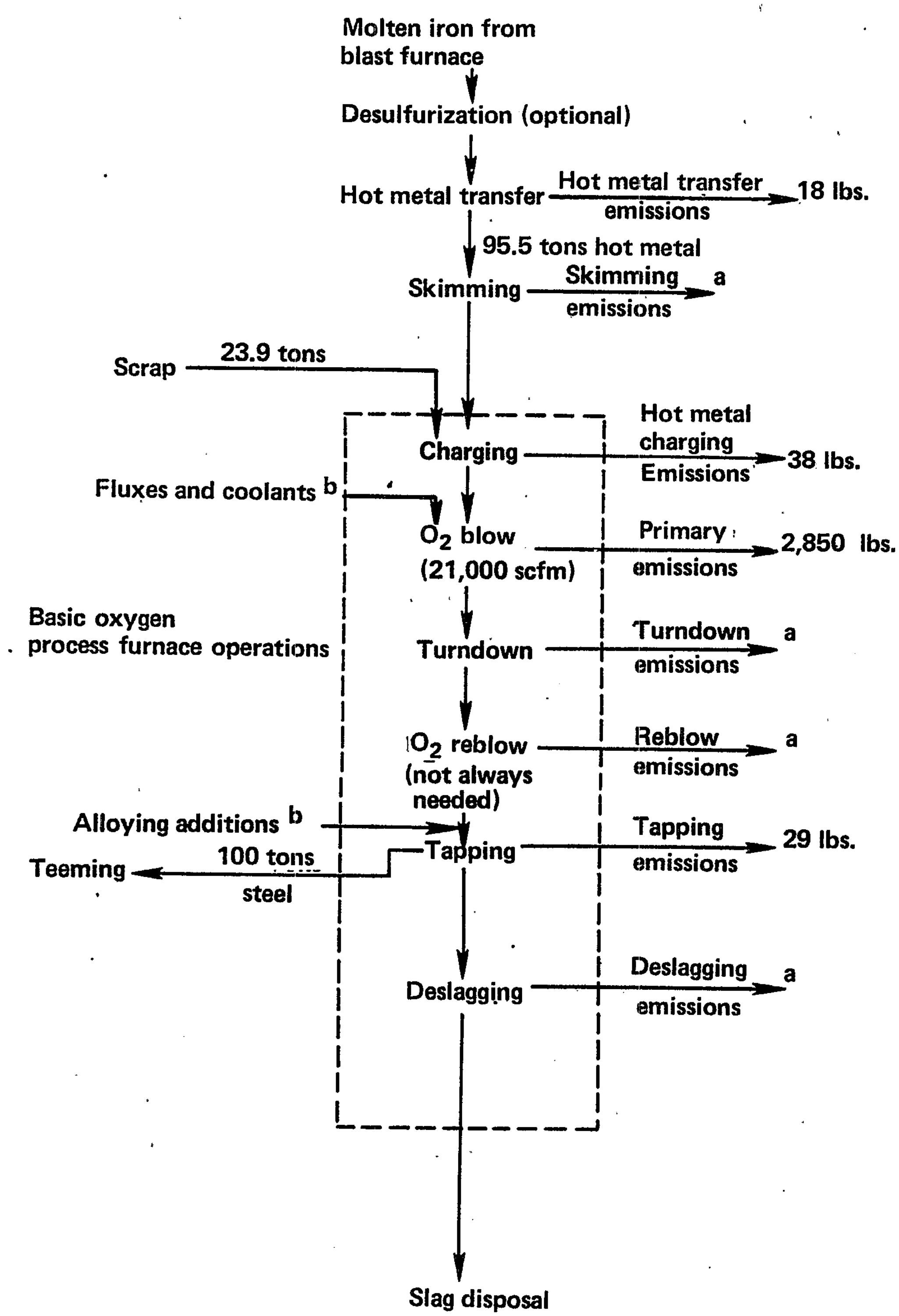


Figure 3-7. Schematic cross section of a furnace shop.



[a] quantities unknown

[b] quantities vary from one heat to the next

Figure 3-8. Flow diagram for basic oxygen process furnace operations.

the hood, enter a hood cooling section where some heat is extracted, and pass through a conditioning chamber where the gas is cooled and humidified to the required levels for proper electrostatic precipitator operation. The gas cleaning system commonly consists of precipitators, fans, dust handling equipment, and a stack for carrying away the cleaned gases. Electrostatic precipitators can be used with open hoods because the combustible CO generated during the oxygen blow burns at the mouth of the vessel, reducing the risk of explosions which could be set off by sparks in the precipitator. Alternatives to ESP's are scrubbers or, as has been tried at one plant, baghouses. Additional information regarding control techniques for basic oxygen process steelmaking operations is presented in Chapter 4.

The other primary emission system is the closed hood, in which the diameter of the hood face is roughly the same as the diameter of the mouth of the vessel. The lower portion of the hood is a skirt that can be lowered onto the mouth of the vessel. This seals off the space between the hood and the vessel, thus limiting the amount of air that can enter the system. The gas (mainly CO) is collected in an uncombusted state. The volume of gas collected in a closed hood system is reduced by as much as 80 to 85 percent as compared to that of an open hood system. Gas cleaning is performed by a scrubber to minimize the risk of explosion. The cleaned gas is usually flared at the stack.[6]

Because there is less danger of explosion in the open hood system (most of the carbon monoxide has been converted to carbon dioxide), all of the vessels in the shop may be connected to a common gas cleaning system. Conversely, the closed hood system must have a separate scrubber system for each vessel because of the potential explosion hazard from leakage of air into the system from an idle furnace.

Generally, the flux bins are filled by a belt conveyor system from a hopper at ground level. This hopper is usually equipped to be loaded from a railroad car, a truck, or both. Transfer points of the conveyor system are generally fitted with hooding and small, individual baghouses.

When the heat is complete, the vessel is tilted and the steel is poured into the teeming ladle. The transfer car moves the ladle into the pouring aisle and a crane picks up the ladle and carries it over to the train of ingot molds parked at the teeming station. A stopper or slide gate in the bottom of the ladle is opened and each ingot is filled in turn. Alternatively, the ladle may be carried to the top of a continuous casting machine for the production of continuously cast products. After the steel is out of the vessel, the slag is poured into a slag pot. When the pot is filled, it is run into the charging aisle by means of a transfer car. The charging crane then picks up the pot and carries it away for disposal.

The slag is sometimes disposed of by pouring it on the ground at one end of the shop, where it is allowed to cool. Alternatively, the pot of molten slag may be carried away from the shop and the slag processed at a remote site. In either case, the metallics are generally removed from the slag by a magnet and returned to the blast furnace or sinter plant and charged as a portion of the burden. The remaining slag is generally disposed of in a dump area.[6]

3.2.1.2 Material Balance. As indicated on the flow sheet (Figure 3-8), in order to produce a metric ton of steel in the BOPF the following raw materials are required:

1. Ferrous charge materials consisting of approximately 70 percent molten iron and approximately 30 percent scrap (higher percentages of hot metal may be used if desired).* The typical yield in a BOPF with an open hood is 85 percent. Therefore, to produce 1,000 kg (2,205 lb) of steel, 825 kg (1,819 lb) of molten iron and 350 kg (772 lb) of scrap are required. In the closed hood, the yield increases to approximately 87 percent and the use of molten iron and scrap drops correspondingly. Some shops have the capability of preheating the scrap prior to the addition of the molten iron. This practice would add about 15 min to the tap-to-tap time; however, less molten iron and more scrap could be used. In general, the proportion of hot metal might drop from 70 to 60 percent with scrap preheating.

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*Calculations presented elsewhere in this document are based upon the assumption that 80 percent of the charge is hot metal and 20 percent is scrap.

2. Flux materials consisting of lime and fluorspar. Lime is the principal ingredient. Its quantity is generally about 90 kg (198 lb) per megagram of steel and varies corresponding to the sulfur content of the iron and the specification of the finished steel with regard to freedom from sulfur. The quantity of fluorspar is determined by the need to maintain a fluid slag and is generally 3 percent by weight of the amount of lime. During 1979, the domestic steel industry used 6.6 Tg (7.3 million tons) of lime and 305 Gg (337,000 tons) of fluorspar in basic oxygen process steelmaking.[7]

3. Oxygen in the amount of 3.1 scmm (110 scfm) per metric ton of steel is injected into the bath. The amount of oxygen used depends on two factors. One is the composition of the molten iron, especially with respect to its content of such materials as carbon, silicon, and manganese. The other is the final carbon level required in the finished steel.

4. Ladle additions consist of alloying elements, such as manganese, nickel, and chromium, that are required in varying amounts, depending upon the required final composition of steel.

The basic oxygen process, in addition to producing steel, yields slag, gases, and gas-borne particulates. The amount of slag is essentially equal to the amounts of lime and spar added to the heat, plus additions for refining of the bath and minus the emissions of slag to the hood along with the furnace gases.

The amount of gases from the furnace varies according to the type of fume collection system employed. These primary emission control systems are discussed below:[6]

1. Open hood operation with ESP involves the greatest volume of gas, approximately 0.78 dscms/Mg (1,500 dscfm/ton) of heat size. This high value results from the absolute necessity to combust completely all of the carbon monoxide that is emitted from the furnace, thereby avoiding any possibility of explosion in the precipitator. A supplementary benefit of the high volume is that it facilitates the capture of emissions from the mouth of the vessel when it is tilted partially out of the hood to receive scrap and molten iron.

2. Open hood operation with wet scrubber generally involves less flow of gases than does the open hood-precipitator system, the amount being approximately 0.52 dscms/Mg (1,000 dscfm/ton) of heat size for top blown furnaces. The reduced volume results from the need to conserve energy in the scrubber systems, which usually operate with a pressure

drop in the range of 127 to 178 cm (50 to 70 in) of water. Also, the presence of combustibles in the scrubber system would not entail a significant risk of explosion.

3. Closed hood operation with scrubber involves the least flow of the three systems, appoximately 0.15 dscms/Mg (290 dscfm/ton) of heat size for top blown furnaces and 0.17 dscms/Mg (325 dscfm/ton) for bottom blown furnaces. This reduced value results because secondary air to complete the combustion of carbon monoxide is not permitted to enter the hood. Energy requirements for cleaning the gases in the closed system, because of the sharply reduced volumes, are lower than those for the open system.

The amount of particulates carried out of the furnace into the primary emissions gas cleaning system is approximately 14.25 kg/Mg (28.5 lb/ton) of steel produced. Each of the gas cleaning systems described above is capable of reducing the concentration of particulates in the clean gas to, or below, the level of the existing New Source Performance Standard, i.e., 50 mg/dscm (0.022 gr/dscf).[8] Therefore, the mass rate of particulates in the clean gas depends essentially upon the volume of gas leaving the stack and, in turn, is related to the type of cleaning system employed.

3.2.1.3 Methods of Operation.

3.2.1.3.1 Top blown furnaces--In the basic oxygen steelmaking process, molten iron is converted to steel using a jet of oxygen to remove most of the carbon and silicon. The heat generated by oxidation melts the scrap. Removal of impurities is accomplished by means of the slag, the chief goal being to remove as much of the sulfur from the steel as is possible. Meeting the desired specifications of the end product is usually accomplished by the addition of suitable alloying materials to the teeming ladle while the steel is being tapped.

In comparison to other steelmaking processes, a typical BOPF furnace produces a heat of steel in a very short time. Tap-to-tap times in a high performance shop may be as brief as 30 minutes. To accomplish this, the process is highly mechanized and is under some form of computer control. Computer control may be applied directly from the computer through electrical circuits to the furnace or, as is most often the case, the computer provides information to the operator, who then controls the process. High performance depends on equipment that is sophisticated and reliable. These factors tend not only to produce steel at a rapid rate but also to avoid abnormal operating conditions.

The lining of the BOPF furnace is made of high quality basic refractory material. During a campaign that may last 1,000 to 2,000 heats or more, the linings become worn, especially near the slag line. These points of wear may be patched between heats by various gunning techniques (spraying of patching materials onto the wear points). Eventually, linings wear so much that the furnace must be taken out of service, the refractory removed, and a new lining installed. Approximately 1 week is required to remove the old lining and replace it with a new one.

A less frequent cause of vessel downtime is the intense heating and cooling of the steel shell of the vessel which ultimately affects the quality of the steel shell itself. As a result of these changes, the entire vessel must be replaced every 7 to 15 years.

Since a vessel is entirely out of service for approximately 1 week while being relined, it is imperative that both vessels in a two-vessel shop are not scheduled for reline at the same time. To avoid this situation, the number of heats in each vessel is carefully monitored. Visual and instrumented inspections of the linings are performed frequently so that relines can be scheduled well in advance. One operating mode option for a two-vessel shop is to operate one vessel while the other is on standby. Alternatively, both vessels may be operated either sequentially or simultaneously. In some shops, sequential operation is mandatory due to limited oxygen supplies. In open primary hood shops equipped with only one ESP, simultaneous operation may be precluded by the limited capacity of the ESP system. Where the oxygen supply is adequate, simultaneous operation may be practiced with some overlap in the blow periods. Synchronous operation of furnaces would be precluded by the limited availability of the charging aisle cranes. In three-vessel shops, operations are scheduled so that only one vessel at a time is relined. Thus, two vessels are always available for use.

When an upset occurs that may damage the equipment, the environment, or the process itself, the process can be shut down instantly by stopping the flow of oxygen and raising the lance. The heat may remain in the vessel for a relatively long period of time, possibly 6 or more hours, until necessary repairs have been made. However, dumping the heat is preferred if a very long delay is anticipated.

The hood that conveys the gases away from the furnace is water cooled. Water may be recirculated through a heat exchanger and returned again for use in the hood. Alternatively, the water may be converted to steam and delivered to other steelmaking operations. On some steam generating hoods, fuel is fired into the hood between blow periods in order to maintain a constant rate of steam output. Another way of maintaining the output at a constant rate is to use a steam accumulator; however, the generation of steam per ton of steel is less with this method because no supplementary fuel is used.

As indicated above, it is possible to decrease the amount of molten iron required by preheating the scrap. This is accomplished with a second lance inserted in place of the oxygen lance after charging of the scrap but prior to the hot metal charging operation. The second lance injects oxygen and natural gas or oil and preheats the scrap to a glowing red color. After preheating the scrap, the lance is withdrawn and the vessel is tilted to receive the hot metal charge. Pouring of molten iron over the heated scrap results in a violent reaction and the production of copious emissions. The pouring rate must be controlled carefully in order to ensure that the hooding captures substantially all of the emissions.[6] At the present time, scrap preheating is not widely practiced in the United States.

3.2.1.3.2 Bottom blown furnaces (Q-BOP's)--The Q-BOP process offers an alternative to the use of an oxygen lance. This is the latest version of the basic oxygen process and is similar to a process developed by Oxygen Blasen Maximillian-Huette, Bavaria, Germany (OBM process). The Q-BOP process is now being licensed in the United States by the U.S. Steel Corporation.

The Q-BOP process is carried out in a basic lined vessel that is fitted with bottom tuyeres, each of which is made up of two concentric tubes. The oxygen is injected through the center tube of the tuyere and is shrouded by a shield of hydrocarbon gas (usually natural gas), which is injected through the larger of the two concentric tubes. On entry into the vessel, the hydrocarbon is cracked endothermically, thus absorbing the heat that would otherwise be liberated when the oxygen first contacts the molten metal. This absorption of heat protects the tuyeres from the rapid erosion that would otherwise take place during the oxygen blow.

When a Q-BOP vessel is tilted to receive scrap and molten iron or to sample for steel analysis, it is necessary to maintain a flow through the tuyeres so that they do not become blocked. In normal practice, the oxygen and natural gas are turned off when the vessel is tilted and these gases are replaced by a flow of nitrogen. In any event, there is a copious flow of emissions from the mouth of the vessel due to the gas flow from the tuyeres. Two large, horizontally sliding doors assist in directing the gases back into the collection system and protect the workers who are on the charging floor. These doors are opened only to permit the addition of scrap and molten iron and are closed at all other times.[6]

The principal advantage claimed for the Q-BOP is that it requires less headroom in the furnace aisle than does a top blown BOPF. This feature has allowed the installation of Q-BOP's in existing open hearth buildings, thereby decreasing costs in construction of the facility and allowing a continuity of steelmaking operations during the conversion.[6] The overhead clearance requirements of top blown furnaces make it impossible to fit them into existing open hearth buildings.

Of the 14 BOPF's that have come on stream in the last 8 years, 8 are Q-BOP's. Five of these furnaces are in converted open hearth steelmaking shops and the other three are part of a greenfield facility.

3.2.2 Emissions

The U.S. Environmental Protection Agency (EPA) has estimated that, in 1979, the nationwide total of particulate emissions was 9.5 Tg (10.5 million tons) from industrial processes, which includes iron and steel and the other primary metals industries, contributing

47 percent of this total (Table 3-2). As shown in Table 3-3, the primary metals industries produced 609.8 Gg (672,000 tons) of particulate emissions in 1979 with iron and steel producing 78 percent of that total. Of the 474.7 Gg (523.3 thousand tons) of particulates produced by the iron and steel industry, 64.9 Gg (71.5 thousand tons) were emitted by BOPF operations (Table 3-4). This constitutes 14 percent of the total particulate emissions from all iron and steel sources.

On a total nationwide basis, the trend in particulate emissions has been downward (see Table 3-5). The 1970 total of 21 Tg (23 million tons) had been reduced by 55 percent to 9.5 Tg (10.5 million tons) in 1979. The iron and steel industry has performed slightly better during the same time period, having reduced its emissions from 1.2 Tg (1.4 million tons) in 1970 to 470 Gg (518,000 tons) in 1979 for an overall reduction of 62 percent.

The operations in the BOPF shop are directly responsible for two general categories of pollution: air pollution and solid waste pollution. Water pollution, where it occurs, is a by-product of gas cleaning operations.

There are two principal sources of air pollution associated with BOPF's. One of these sources is the steelmaking process itself, which generates dense emissions of fumes. These fumes, which are generally captured by the primary hood, are called the primary emissions. These emissions are mainly iron oxides which result from the reaction between oxygen and molten iron, and particles of slag. The reaction between the carbon dissolved in the iron and oxygen produces CO at a rate of about 70 kg/Mg (140 lb/ton) of steel produced.[9] For a more complete list of the particulate components of BOPF primary emissions, see Table 3-6.

The gases that leave the mouth of the furnace, in addition to being dusty, are extremely hot. In the closed hood system, temperatures can reach approximately 1,650° C (3,000° F). In the open system, CO combustion takes place at the entrance of the hood, raising the temperature perhaps another 540° C (1,000° F). Before the gases may

TABLE 3-2. NATIONWIDE PARTICULATE EMISSION ESTIMATES FOR 1979[8]

Source category	Particulate emissions/year Teragrams	(Million tons)
Transportation		
Highway vehicles	1.1	(1.2)
Aircraft	0.1	(0.1)
Railroads	0.1	(0.1)
Vessels	0.0	(0.0)
Other off-highway vehicles	0.1	(0.1)
Transportation Total	1.4	(1.5)
Stationary Source Fuel Combustion		
Electric utilities	1.5	(1.7)
Industrial	0.6	(0.7)
Commercial-Institutional	0.2	(0.2)
Residential	0.2	(0.2)
Fuel combustion total	2.5	(2.8)
Industrial processes[a]	4.3	(4.7)
Solid waste disposal		
Incineration	0.2	(0.2)
Open burning	0.2	(0.2)
Solid waste total	0.4	(0.4)
Miscellaneous		
Forest fires	0.8	(0.9)
Other burning	0.1	(0.1)
Miscellaneous organic solvent	0.0	(0.0)
Miscellaneous total	0.9	(1.0)
Total	9.5	(10.5)

[a]Includes iron and steel industry.

TABLE 3-3. PARTICULATE EMISSIONS FROM PRIMARY METALS INDUSTRIES FOR 1979[10]

Source	Particulate emissions/year	
	Gigagrams	(Thousand tons)
Iron and steel	474.7	(523.3)
Aluminum	56.8	(62.6)
Copper	26.1	(28.8)
Zinc	3.4	(3.8)
Lead	6.1	(6.7)
Other	42.7	(47.0)
Total	609.8	(672.0)

TABLE 3-4. PARTICULATE EMISSION FROM THE IRON AND STEEL INDUSTRY FOR 1979[11]

Source	Particulate emissions/year	
	Gigagrams	(Thousand tons)
Coke manufacturing	131.5	(145.0)
Blast furnace	23.6	(26.0)
Sintering	42.9	(47.3)
Open hearth furnace	26.5	(29.2)
Basic oxygen process furnace	64.9	(71.5)
Electric arc furnace	95.7	(105.5)
Other	89.6	(98.8)
Total	474.7	(523.3)

TABLE 3-5. NATIONWIDE TOTAL PARTICULATE EMISSION AND IRON AND STEEL INDUSTRY PARTICULATE EMISSION TRENDS, 1970-1979[10]

	1970	1975	1979
Nationwide total	21 Teragrams (23 million tons)	11.6 Teragrams (12.8 million tons)	9.5 Teragrams (10.5 million tons)
Iron and steel industry	1,250 Gigagrams (1,278 thousand tons)	630 Gigagrams (694 thousand tons)	470 Gigagrams (578 thousand tons)

TABLE 3-6. COMPARISON OF PARTICULATE COMPOSITION FROM OPEN AND CLOSED HOOD COLLECTION SYSTEMS[a] [2]

Component	Open hood collection process (weight, percent)	Closed hood collection process (weight, percent)
Fe total	59	75
Fe metal	--	10
Fe as FeO	1.6	63
Fe as Fe_3O_4, Fe_2O_3[b]	57.4	2
CaO	2	2
SiO_2	1	1

[a]Partial analysis is given in each case.

[b]Calculated by difference.

be cleaned of their particulate matter, they must be cooled.[6] The methods of cooling and cleaning the gases are briefly described in Section 3.2.1.2.

3.2.2.1 Fugitive Emission Sources. There are a variety of ancillary operations in a BOPF shop which generate emissions that may not be captured by the primary hood. These emissions are known as fugitive or secondary emissions. The available emission factors for these sources are listed in Table 3-7. Descriptions of the sources are given below:

1. Reladling or "hot metal transfer" of molten iron from the torpedo car to the charging ladle is accompanied by the emissions of kish, a mixture of fine iron oxide particulates together with larger graphite particles. The usual method of control is to provide a close-fitting hood and a baghouse. A spark box between the hood and the baghouse protects the bags from destruction by large, hot particulates. Normally, the spark box is built integrally with the baghouse.

2. Desulfurizing of molten iron may be accomplished by various reagents such as soda ash, lime, magnesium, or calcium carbide. Injection of the reagents into the molten iron is accomplished pneumatically, either with dry air or nitrogen. Desulfurizing may take place at various locations within the iron and steelmaking facility; however, if the location is the BOPF shop, then desulfurizing is often accomplished at the reladling station to take advantage of the fume collection system at that location.

3. Skimming of slag from the ladle of molten iron keeps this source of high sulfur out of the steelmaking process. Skimming is often done under a hood because it results in the emissions of fine particulates called "kish." The hood is usually connected to a baghouse.

4. Charging of scrap and molten iron into the BOPF vessel results in a dense cloud of emissions. Emissions from the charging of hot metal are particularly severe if the scrap is dirty, oily, otherwise contaminated, or contains such potential sources of explosion as water or ice.[15] In some open hood shops, if the main hood is large enough and the volume of air flow is sufficient, it is possible to capture most of the charging fumes in the primary collection system of the vessel. In this case, as much of the vessel mouth as possible is kept under the hood and the iron is poured at a slow controlled rate. In other facilities (closed hood primary systems), it is necessary to provide auxiliary hoods in front of the main collection hood. On occasion, a facility

TABLE 3-7. UNCONTROLLED EMISSION FACTORS FOR BOPF PROCESS[12 13 14]

Process	Emission factor	
Primay emissions		
Oxygen blowing	14.25 kg/Mg steel	28.5 lb/ton steel
Secondary emissions		
Hot metal transfer	89.5 g/Mg steel[a] (96 g/Mg hot metal poured)	0.179 lb/ton steel[a] (0.19 lb/ton hot metal poured)
Skimming	b	b
Scrap charge	b	b
Hot metal charge		
Top blown	189 g/Mg steel[a] (200 g/Mg hot metal poured)	0.377 lb/ton steel[a] (0.4 lb/ton hot metal poured)
Bottom blown	310 g/Mg steel[a] (330 g/Mg hot metal poured)	0.62 lb/ton steel[a] (0.6 lb/ton hot metal poured)
Turndown		b
Tapping		
Top blown	146 g/Mg steel	0.291 lb/ton steel
Bottom blown	460 g/Mg steel	0.92 lb/ton steel
Deslagging		b
Teeming	35 g/Mg steel	0.07 lb/ton steel
Slag handling		b
Ladle maintenance		b
Flux handling		b

[a]Based on 85 percent furnace yield and 80 percent of charge being hot metal.

[b]No emission factors are available for these processes.

may also have a hood at the building monitor to capture any fumes that escape the hoods at the vessel. More charging emissions are produced in bottom blown than in top blown furnaces due to the constant flow of gas through the tuyeres.

5. Tapping of the molten steel from the BOPF vessel into the ladle results in iron oxide fumes. The quantity of fumes is substantially increased by additions into the ladle of alloying materials such as silicon and manganese.[16] Some BOPF facilities enclose the space at the rear of the furnace in such a manner that the fumes are ducted into the main collection system. In other facilities the fumes are permitted to exit through the roof monitors.

6. Turndown of the vessel for the purpose of taking samples or for pouring out the slag results in emissions. These emissions are particularly copious in the case of the Q-BOP due to the flow of nitrogen which must be maintained through the tuyeres in the bottom of the vessel in order to keep out the molten metal and slag. Some facilities have a pair of sliding doors on the charging floor in front of the vessel. These doors are kept closed as much as possible to direct the fumes into the primary collection system.

7. Slag handling may consist of transporting the ladle of molten slag from the shop to a remote dump area or dumping the molten slag on the ground at the end of the shop and allowing it to cool there. The dumping of slag and its subsequent removal by bulldozer is a dusty operation that is generally uncontrolled.

8. Teeming of steel from the ladle to the ingot mold or continuous caster results in emissions that are normally uncontrolled. In some shops where leaded steels are poured, the resultant fumes are extremely hazardous to the health of the workers. In these cases, local hooding is provided.

9. Flux handling is effected with a sophisticated system comprised of receiving hoppers for accepting deliveries from trucks or railroad cars, a belt conveyor, large overhead storage bins, weigh hoppers, feeders, and controls. Hooding is provided at the various transfer points to capture the particulates that escape when the bulk material falls. Exhaust ducts lead from the hoods to one or more baghouses.

10. Skull burning and ladle dumping (ladle maintenance). The molten steel that remains in the ladle after teeming may cool and solidify between successive uses. In the vessel, skulls may build up around the lip, and after accumulating for some time, may interfere with proper operation. To prevent this, skulls are burned out with oxygen lances. This lancing procedure results in the emission of iron oxide

fumes. Ladles must also be relined at intervals to protect the steel shell. The ladles are turned upside down to dump loose material onto the shop floor. This generates fugitive dust.[6]

11. Fugitive blowing emissions (puffing emissions) are process emissions that escape capture by both primary and secondary emission control devices. Occasionally, during a blow, chemical reactions within the heat or splashing of the slag will generate large quantities of excess emissions that cannot be handled by the hoods in the furnace enclosure. The frequency or severity of these episodes cannot be predicted or anticipated during the blow.

12. Torpedo car deskulling and dekishing. Skulls that build up around the pouring spout of torpedo cars are broken up with a jackhammer and dumped on the ground. This operation produces fugitive dust. Excess molten slag that remains in the car after hot metal transfer can be dumped into a pit. This operation, which is called dekishing, produces fugitive kish.

3.2.2.2 Nonprocess Sources of Fugitive Emssions. Two other sources of pollution are those associated with the disposal of solid waste from the process. The first results from the transportation and disposal of the BOPF dust. Unless closed containers or trucks are used, the act of transporting the dust can cause some of it to be reentrained into the air. If the dust is recycled to the ironmaking process, its disposal does not cause further environmental problems. However, in most BOPF facilities, the contaminants in the dust, principally oxides of zinc and tin, may cause serious problems in the blast furnace. Rather than recycle the dust, the operators find it necessary to either "store" it on the ground in the open or dump it in a landfill. In either case, special precautions must be taken to prevent wind from picking up the dust and reentraining it into the air or to prevent rain from leaching out toxic compounds from the dust and delivering them to the underground aquifer or the nearby water course.[6]

The second source is the BOPF slag recycling operation. In a separate facility, metallics are recovered from the slag by magnets and returned to the steelmaking operations. Some of the slag, because its content is relatively low in sulfur and high in lime, may be charged into the blast furnace. The remaining slag is disposed of in the landfill. As with the dust, special care is required to avoid the adverse aspects of leaching.[4]

There are no direct sources of water pollution associated with the basic oxygen process. Those water pollution sources that may exist result from the particular type of fume collection system employed. However, since all of the waste water streams discussed are amenable to recycling after treatment within the plant (zero effluent), water pollution from BOPF operations can be controlled.[17] If a scrubber is used, there could be discharge of scrubber water. Normally, most of this is recycled through a clarifier. Facilities would be required to deal with any blowdown to the water system. Even a dry precipitator system could discharge contaminated water. This would result from the final step in gas cooling, which is the quenching and conditioning of the gases by means of water spray. If the quantity of water used in conditioning or its method of application is not carefully controlled, there could be an effluent of water from the conditioning process that is contaminated with BOPF dust.[6]

3.2.3 Process Emissions Characterization

3.2.3.1 Emissions Generated During the Oxygen Blow. Particulate matter emissions from BOPF's are produced primarily by refractory erosion and by condensation of vaporized metal oxides and coagulation of these particles to form agglomerates. Thus, BOPF particulate matter emissions consist mainly of spherical particles or agglomerates of spherical particles with similar properties.[2]

There are no recent data on the particle size distribution of uncontrolled particulates from the oxygen blow. Data gathered prior to 1970 indicate a relatively coarse size distribution.[2] However, in view of the fact that high pressure drop scrubbers are required for particulate control, it is believed that more than 50 percent of the particulate is less than 10 micrometers in diameter.

In the closed hood collection process, the dust is composed mainly of iron oxide (FeO), magnetite, and small amounts of metallic iron. Because FeO and magnetite agglomerate more easily than hematite, the dust particles are larger than those obtained from the open hood collection process. In the open hood collection process, the particles consist of an outer surface of hematite surrounding a core of magnetite.[2]

The particulate generation rate in the basic oxygen process depends on several factors, including oxygen blow rate, blowing method, carbon content of iron, percentage of scrap charged, quality of scrap charged, rate of additions, and condition of the refractory lining of the vessel. During the production cycle, the gas evolution rate and gas temperature vary considerably. Due to the resultant variations in the concentration of particulate matter and gas temperature and volume in the inlet gas stream, emissions are greater in the beginning of the blowing period than during the remainder of the oxygen blow and the rest of the cycle. Particulate emissions from oxygen blowing are estimated to be about 14.25 kg/Mg (28.5 lb/ton) of raw steel.[13]

3.2.3.2 Emissions from Secondary Sources. The secondary sources of emissions within a BOPF shop are hot metal transfer, desulfurization, skimming, charging, turndown, tapping, deslagging, teeming, ladle maintenance, flux handling, and slag handling and disposal. The fugitive nature of these emissions make them very difficult to study and quantify. For this reason, very little work has been done to characterize the emissions from these secondary sources.

Emission factors have been developed for hot metal transfer, charging, tapping, and teeming.[6] These are listed in Table 3-7. The emission factor for hot metal transfer is 89.5 g/Mg (0.179 lb/ton) of steel produced. This factor is an average derived from tests during which the pouring rates ranged from 26.4 Mg (29.1 tons) to 82 Mg (90.4 tons) of hot metal per minute.[12] Charging and tapping emission factors are different for top and bottom blown furnaces, with the greater factors for the bottom blown furnaces being attributable to the constant purging of the tuyeres.

Little is known about the particle-size distribution of BOPF fugitive emissions. The size distribution for Q-BOP charging emissions is presented in Table 3-8. Approximately 50 percent of the particles are 10.5 μm or less. The composition of BOPF fugitive emissions is

TABLE 3-8. PARTICLE SIZE DISTRIBUTION FOR Q-BOP CHARGING EMISSIONS[18]

Particle size range (μm)	Percent of particles within size range
<1.55	3.1
1.55-3.6	30.2
3.6-10.5	16.2
>10.5	50.2

TABLE 3-9. COMPOSITION OF FUGITIVE EMISSIONS FROM BOPF's[2]

Facility	Source of fugitive emissions	Percent of sample											Benzene soluble organics
		Fe	FeO	Fe_2O_3	CaO	MgO	SiO_2	PbO	ZnO	MnO	C	Cd	
National Steel Wierton, W.Va.	Hot metal charging emissions:												
	a. Clean scrap in initial charge	13.1	12.7	8.3	3.5	1.0	5.2	0.3	3.4	0.5	34.3		
	b. Galvanized scrap in initial charge	3.3	8.3	12.7	2.0	0.5	2.6	0.2	5.3	0.3	60.3		
	c. Oily scrap in initial charge	11.3	16.7	10.6	2.9	0.7	3.0	0.8	8.1	0.6	37.8		(a)
	d. No. 2 bundles in initial charge (large % or galvanized sheet scrap)	3.8	17.6	10.5	1.7	0.5	2.8	1.8	12.0	0.6	41.5		
Colorado Fuel & Iron Corp. Pueblo, Col.	Total fugitive emissions as collected at building roof monitor			53.6	12.7	8.6	6.7	<4.1	6.8	1.1	3.2	<1.0	1.2
Colorado fuel & Iron Corp. Pueblo, Col.	Baghouse particulate collected from auxiliary hood capturing charging and tapping emissions			32.6	6.7	1.0	6.4	2.0	16.2	1.4	8	.2	

[a]Gaseous methane averaged 61 ppm.

TABLE 3-10. ELEMENTAL ANALYSIS OF BOPF CHARGING EMISSION PARTICULATES[19]

Element	Concentration in gas μg/m³	Element	Concentration in gas μg/m³
Molybdenum	75	Vanadium	76
Niobium	10	Titanium	MC[a]
Zirconium	26	Scandium	<0.6
Yttrium	<2.4	Calcium	MC[a]
Strontium	16	Potassium	MC[a]
Rubidium	9	Chlorine	MC[a]
Bromine	346	Sulfur	62
Selenium	49	Phosphorus	MC[a]
Arsenic	46	Silicon	MC[a]
Germanium	0.8	Aluminum	MC[a]
Gallium	33	Magnesium	MC[a]
Zinc	MC[a]	Sodium	MC[a]
Copper	180	Fluorine	MC[a]
Nickel	35	Boron	25
Cobalt	17	Lithium	2
Iron	MC[a]	Cerium	24
Manganese	MC[a]	Lanthanum	9
Chromium	512	Barium	MC[a]
Uranium	9	Cesium	0.6
Thorium	<9	Tellurium	15
Bismuth	3	Antimony	6
Lead	MC[a]	Tin	18
Mercury	0.8	Cadmium	73
		Silver	17

[a]Major Component: concentration in sample greater than 1,000 ppm.

presented in Table 3-9. While iron and iron oxides make up most of the emissions, the relative amounts of the various compounds are influenced by the type of scrap charged. A detailed elemental analysis of the hot metal charging emissions generated at one top blown BOPF plant is presented in Table 3-10.

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4. EMISSION CONTROL TECHNIQUES

4.1 INTRODUCTION

Primary control systems for basic oxygen process furnaces (BOPF's) have been described in Chapter 3 and elsewhere.1 Briefly summarizing, the CO produced may be burned at the mouth of the vessel; then the particulate matter, the products of combustion, and the excess air are drawn into an "open hood," cooled, and cleaned by a wet scrubber or an electrostatic precipitator (ESP).

Alternatively, to reduce the temperature and volume of the gas to be cleaned, the gas may be cleaned before burning. In this case, a carefully fitted "closed hood" is required and cleaning with a wet scrubber is necessary because of the hazard of igniting this potentially flammable gas if cleaned in an ESP. The application of primary emission control techniques to both open and closed hoods are described in this chapter.

Emissions that occur during those steps in the cycle that require the vessel to be tipped out from under the hood--scrap charging, hot metal charging, sampling, tapping, and deslagging--are often poorly controlled by the primary system. The ancillary operations of hot metal transfer and slag skimming are not controlled at all by the primary system. Both types of emissions, ancillary emissions and furnace emissions, may be called "secondary emissions." Other secondary emission sources that may be found in the BOPF shop are desulfurization of hot metal, ladle repair, and ladle deskulling, teeming, flux handling, and slag handling. Dekishing of torpedo cars is a secondary emission source that is usually external to the BOPF shop. Performance data in this chapter include some emission data from these latter sources.

Secondary furnace emissions typically are produced by unconfined sources such as leaks from the primary furnace hood or the open top of a ladle. With the use of control techniques, these emissions are captured by enclosures or hoods and are usually ducted to a particulate control device. Capture techniques are as follows:

- Furnace enclosures
- Local hoods
- Building evacuation
  - Full
  - Partial
- Adaptation of primary furnace hooding (for open hoods only)

Particulate removal techniques are as follows:

- Baghouses
  - Pressurized
  - Suction
- Electrostatic Precipitators
  - Classical
  - Roof-mounted
- Scrubbers

This chapter describes specific control techniques for primary furnace emissions and secondary furnace emissions and for hot metal transfer and hot metal skimming.

4.2 CAPTURE OF SECONDARY EMISSIONS FROM FURNACE OPERATIONS (CHARGING, SAMPLING, TAPPING)

When the vessel is tipped out from under the hood of the primary control system, whether for charging, sampling, or discharging refined steel, the traditional primary control system may be rendered ineffective. Potential remedies range from enclosing the space around the vessel, to specialized hoods, to building evacuation.

4.2.1 Furnace Enclosures

A furnace enclosure is a structure that may partially (on at least two sides) or fully (on four sides plus the top) enclose a furnace vessel. Most of the BOPF's brought on stream in this country since 1973 are enclosed.[2]

A partial enclosure may be designed to shield the BOPF from most drafts (other than that of natural convection), permitting hoods within or adjacent to the enclosure to be more effective at lower air flow rates. In comparison to a full enclosure, a partial enclosure is less expensive, easier to retrofit (possibly without interrupting production), and less likely to impede operations.

However, the trend is toward "total" enclosures.[2] Figures 4-1 and 4-2 show such installations. Since the vessel is designed routinely to tilt about only one horizontal axis, the enclosure can be fairly simple on two sides. The enclosure roof is usually penetrated by the primary exhaust duct, and it must be high enough for a closed system to permit maneuvering the hood. Similarly, the flux chute and the oxygen lance of top blown vessels must penetrate either the roof of the enclosure or the primary hood. Within the enclosure, and sometimes as part of the enclosure, are charging and tapping hoods.

The enclosure can extend partially or completely to the operating floor at the rear, i.e., the side where tapping occurs, facing the teeming aisle. Tapping is carried out at and below the level of the vessel, and there is a tendency for hot, dusty gases to escape in the natural draft induced by the process heat. A hood that is either permanently arranged so that it does not interfere with operations or that is otherwise retractable to collect tapping emissions is desired.

Most of the complications attending full enclosure arise in the front, i.e., the side at which charging is carried out, facing the charging aisle. Here the enclosure includes a door (or doors) that is moved out of the way while charging scrap and hot metal. Since these operations occur at and above the vessel, natural convection will permit a plume of hot dusty gas to escape into the building. Figure 4-1 shows the charging ladle mouth inside the furnace enclosure and

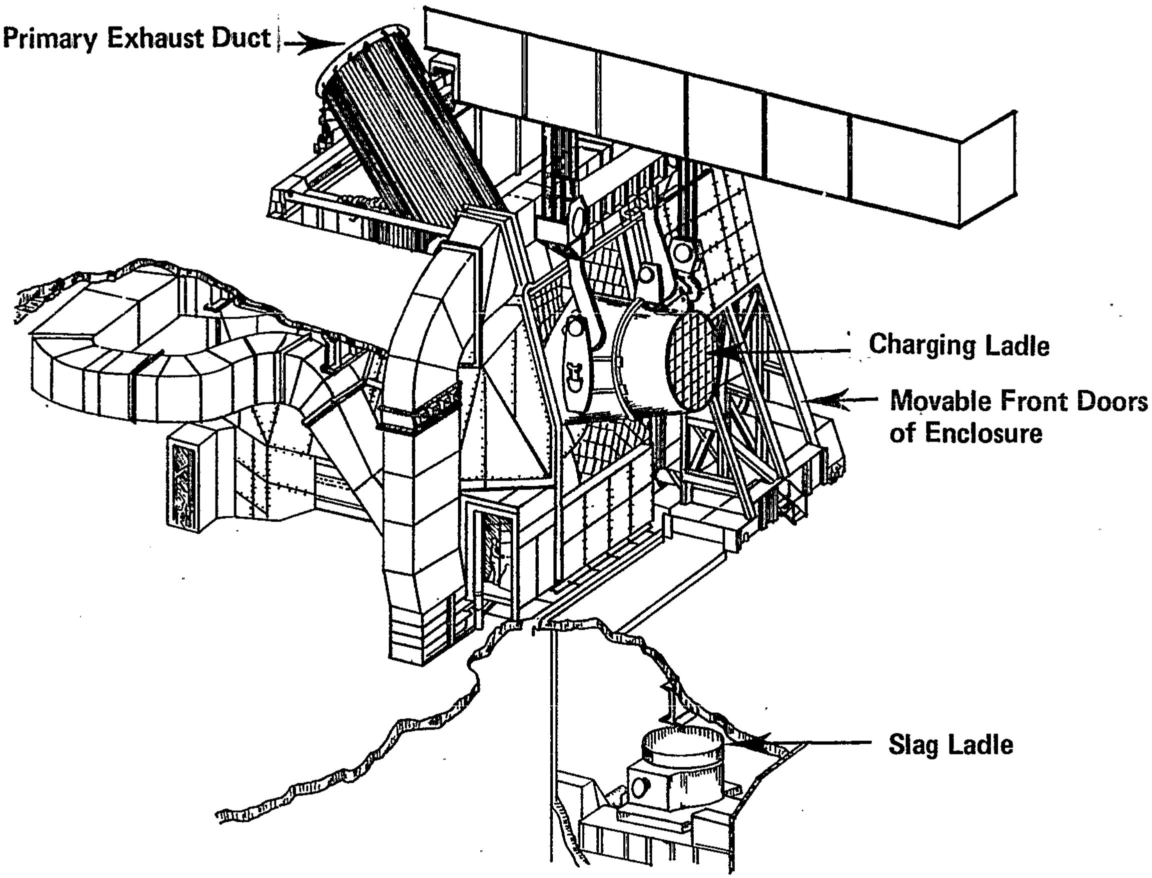
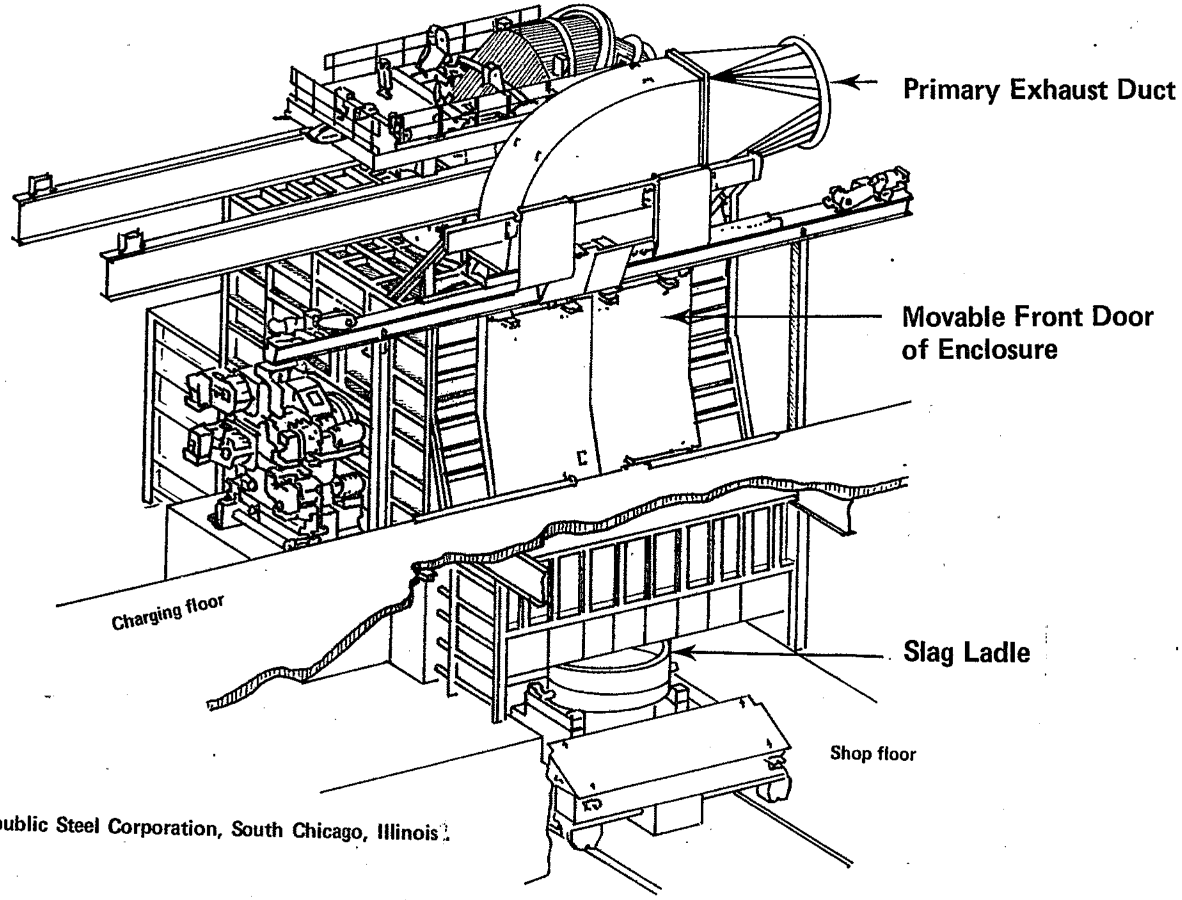


Figure 4-1. BOPF furnace enclosure.



Source: Republic Steel Corporation, South Chicago, Illinois.

Figure 4-2. Furnace enclosure for a Q-BOPF.[3]

under the charging hood. If high fume capture efficiency is to be achieved, it is necessary to design the ladle, scrap box, hood, furnace enclosure, and crane facilities to allow the transfer to occur close to and under the hood. This design also tends to minimize the air evacuation rate required to achieve high fume capture efficiency. Chain curtains can be used to decrease the open area between the charging ladle and hood face, and unlike a rigid metal partition, they are not subject to damage. Achievement of an effective system design is complicated by clearances needed for the movement of cranes and other heavy equipment.

If the enclosure doors are to maintain their original fit, they must not warp, despite the differences between inside and outside temperatures. This requirement suggests that the doors be of substantial construction and generously insulated, water cooled,[4] or both.

Figure 4-1 shows an opening at ground level on the charging side. This opening permits the entry and removal of a transfer car carrying the slag pot into which the furnace slag is poured. The concept of total enclosure requires that a vertical shield designed to close this opening be attached to the transfer car.[4] Because the environment is less severe here, this shield can be portable and need not be as substantially constructed as the enclosure doors.

The total enclosure, then, is not truly total. The housing is penetrated by ductwork and is opened and closed to permit access, and the quality of closure is imperfect at best. However, the goal is not perfect enclosure, but the substantial prevention of emissions to the building. As such, if the capture system draws dusty air from inside the enclosure, and if the enclosure and the exhaust system are compatibly designed and are operated knowledgeably, the goal will be achieved.

The control system (capture plus particulate removal) may be an extension of the primary control system. A hood designed to collect charging emissions and another for tapping emissions could be ducted to the primary system. Gas flows could be adjusted for the differing demands of the several parts of the cycle.

In the closed hood system that intermittently handles a flammable gas, the use of the primary system to control dusty air from secondary sources presents the possibility of an explosion. However, the facilities in at least one shop have been designed to permit safe collection of secondary emissions in the closed hood primary system.[3]

The more typical alternative is to duct the charging and tapping hoods in the furnace enclosure to a secondary control unit, commonly a bag filter. Such systems will be further described in following sections.

Furnace operations dictate the necessity for opening and closing the doors on a furnace enclosure. For a total enclosure, the charging of scrap and hot metal to the furnace vessel requires the door(s) to be open. Immediately following hot metal charging, the door(s) may be closed. Since observation of the vessel top is important to the operator (visual feedback on the occurrence of foaming and slopping over the vessel top), a television picture or small observation port in the upper part of the enclosure could be used to satisfy this need. As the oxygen blow is completed, it is necessary to take a metal sample and measure the metal temperature. In the United States, most furnaces must be turned down to do this. Another opening in the enclosure door may be provided to insert a thermocouple and sampling spoon. Where such an opening has not been provided, it is necessary to open the doors at least partially. This may cause poor control of furnace emissions during the sampling period. If the doors are left open for the remainder of the production cycle, generally poorer capture of secondary furnace emissions can be expected. In their Oita and Yawata Works, Nippon Steel uses a sublance assembly to measure temperature and obtain a metal sample.[5] [6] In a manner similar to that for the oxygen lance, the sublance is lowered into the furnace through a hole in the furnace enclosure. This sublance assembly avoids turndown for sampling, thus eliminating potential secondary emissions.

Doors on the tapping side of the enclosure generally need not be opened except for maintenance. Observation ports with closure flaps can be provided at required locations.

Examples of plants with furnace enclosures that are considered for best secondary controls systems are discussed in the following sections.

4.2.1.1 Kaiser Steel (Closed Hood, Top Blown). The Kaiser Steel secondary emission control facility at Fontana, California, controls furnace emissions (charging, tapping, puffing of the primary, turndown) from two 205-Mg (225-ton) furnaces plus hot metal transfer and hot metal skimming.[7] A schematic diagram of the secondary emission control system is presented in Figure 4-3. The furnace enclosure is similar to that in Figure 4-1.

The secondary emission control system has two fans, each rated at 149 acms (315,000 acfm) at 50 cm (20 in) of water column and 230° C (450° F).[8] Both fans operate to provide the baghouse design flow of 283 acms (600,000 acfm). Dampers are used to reduce gas flow and energy consumption when full system flow is not required. Air flow is divided among the various secondary hoods according to the needs for each operation. The operations permitted to occur simultaneously depend on whether one or both furnace vessels are being used. Based on design information, hot metal charging requires the largest air flow, or about three-quarters of system capacity. The Kaiser system does not permit hot metal transfer, hot metal skimming, or a hot metal charge to the other vessel while one vessel is being charged. The system does permit oxygen blow, turndown, tapping, or deslagging on the second vessel when one vessel is being charged.

Hot metal transfer or hot metal skimming may occur at any time that neither furnace is being charged. On this basis, about one-third system flow capacity is required for hot metal transfer or skimming.

The baghouse is a 12-compartment (two cells each), positive pressure installation with 33,400 m^2 (360,058 ft^2) gross cloth area. The gross air-to-cloth ratio is 0.533:1 m/min (1.75:1 ft/min) with a net air-to-cloth ratio of 0.610:1 $m^3/min/m^2$ (2.0:1 $ft^3/min/ft^2$) when three cells are offline. Bag fabric is fiberglass treated with silicones, graphite, and teflon. Bag cleaning is performed by a reverse air system.

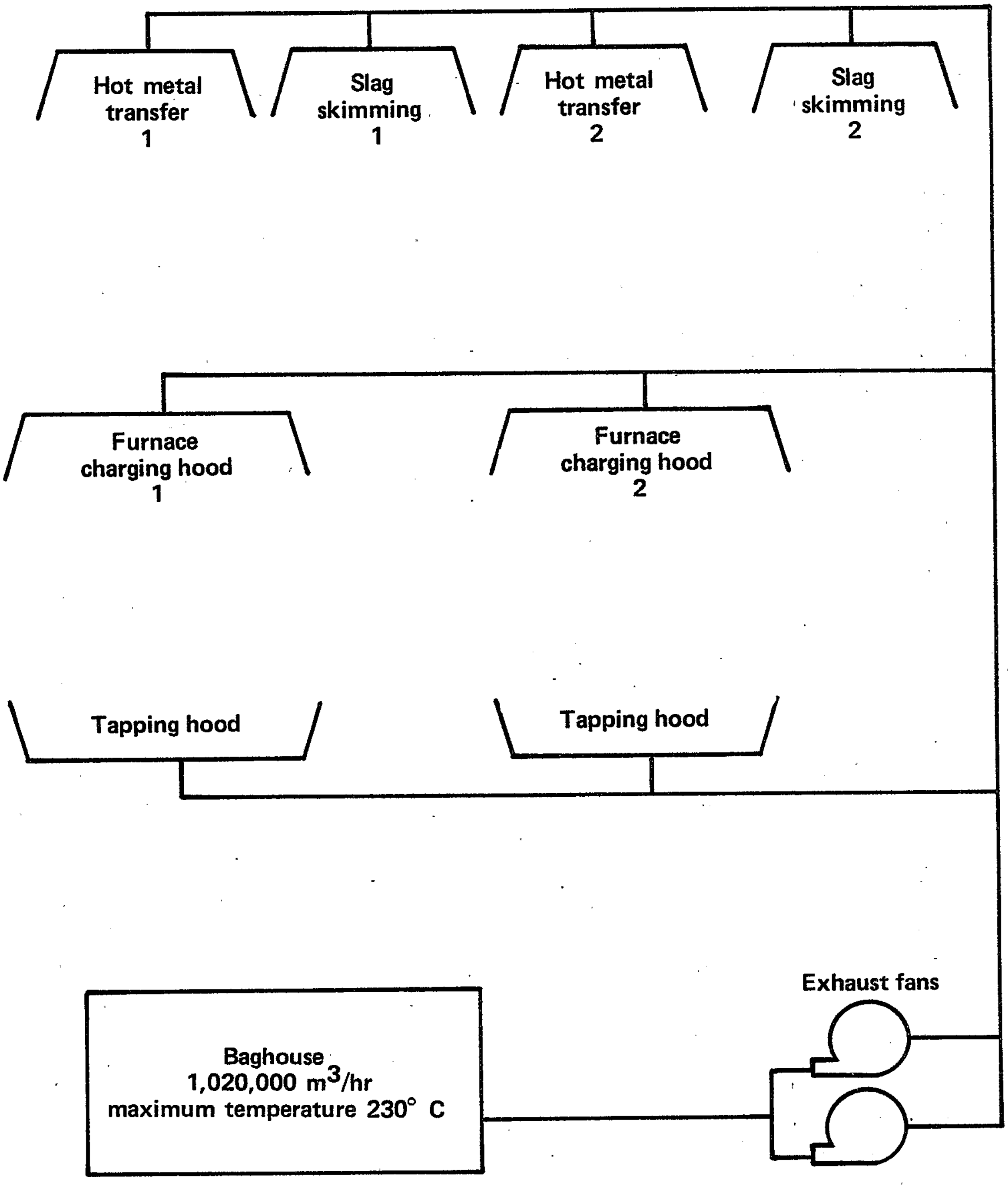


Figure 4-3. Schematic of Kaiser Steel-Fontana basic oxygen secondary emission control system.

Performance of the secondary emission control facility at Kaiser has been measured by visible emission methods. Visible emission measurements of roof monitor discharges were made during April 1980.[9] The measurements were made in accordance with EPA Reference Method 9.

These measurements, however, have been analyzed by computing 3-minute averages instead of the 6-minute averages directed by Reference Method 9. The use of a 3-minute average was selected because of the short duration and rapidly varying intensity of secondary visible emissions characteristic of the BOPF steel production cycle. All of the 3-minute averages were segregated by furnace cycle to analyze performance of the secondary emission control system by furnace cycle. Table 4-1 displays the maximum 3-minute average opacity and the second highest 3-minute average opacity occurring during each observed furnace cycle.

Selection of the maximum 3-minute average opacity was made by computing running (or moving) averages for each cycle. The highest moving average was chosen; then the second highest was chosen in such a way that none of the individual readings used to compute either average were common. Therefore, the maximum and second highest 3-minute averages are mutually exclusive observations. The mean maximum 3-minute average was 5.4 percent and the mean second highest 3-minute average was 1.5 percent. These data were further analyzed statistically to determine 95 percent prediction limits; i.e., there is a 5-percent probability (1 chance in 20) that a further observation at this plant or another plant performing equally well would exceed this limit. For the maximum 3-minute averages, the 95-percent prediction limit is 16 percent opacity. For the second highest 3-minute averages, the prediction limit is 7 percent opacity.

The data taken at Kaiser represent single-furnace operation. They include the effects of hot metal transfer, hot metal skimming, teeming, charging, tapping, and other secondary source emissions. Based on these data, the Kaiser secondary emission control system was more effective than the other top blown, closed hood installations for which data were obtained.

TABLE 4-1. KAISER STEEL, FONTANA, CALIFORNIA
ROOF MONITOR OPACITY OBSERVATIONS
3-MINUTE AVERAGES[9]

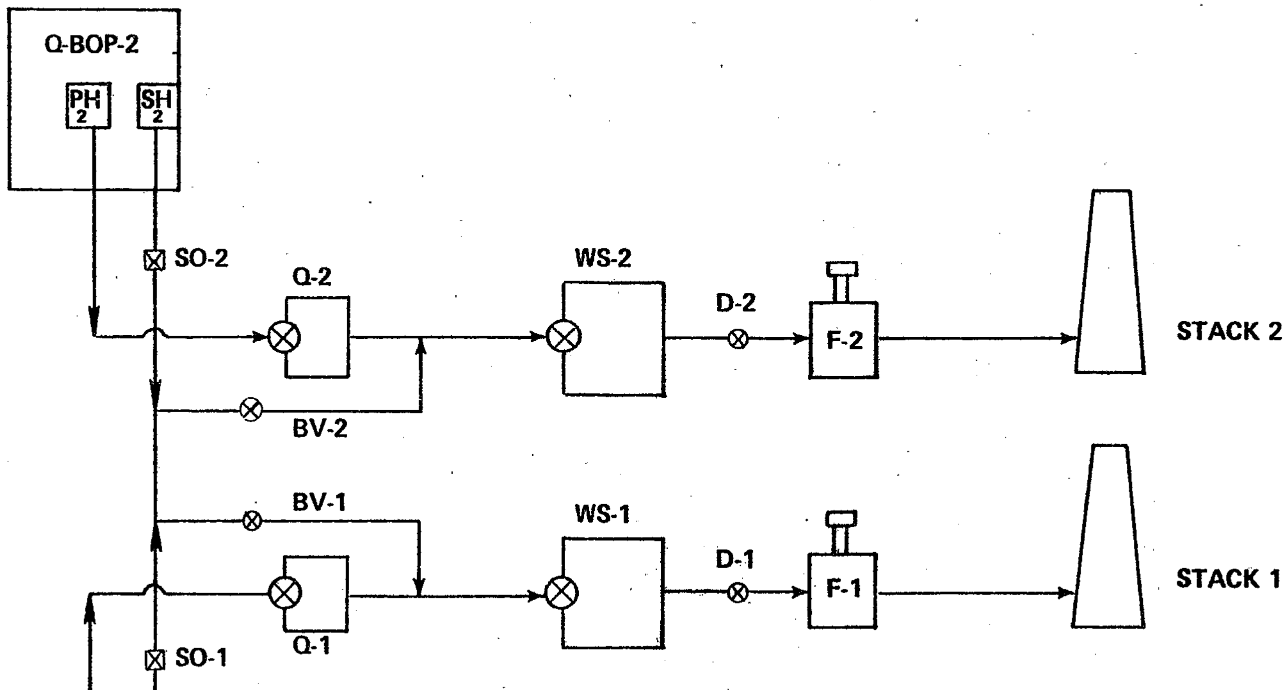
Date	Run	Maximum average		Seond highest average	
		Observer 1	Observer 2	Observer 1	Observer 2
4/7/80	1	10.4	5.4	4.2	4.2
4/8/80	2	2.1	2.5	0.0	0.0
	3	14.2	13.8	10.0	10.4
	4	10.3	10.4	0.0	10.4
	5	5.0	5.4	3.3	3.8
	6	12.5	16.3	2.9	1.7
	7	7.1	5.8	3.3	3.8
4/9/80	8	7.9	5.4	1.3	0.8
	9	3.3	3.3	0.0	0.0
	10	0.0	0.8	0.0	0.0
	11	8.3	6.3	0.0	0.0
	12	0.0	0.0	0.0	0.0
	13	0.0	0.0	0.0	0.0
	14	0.0	0.0	0.0	0.0
4/10/80	15	17.1	13.3	0.4	0.0
	16	0.0	0.0	0.0	0.0
	17	0.0	0.0	0.0	0.0
	18	5.0	5.4	3.3	0.0
	19	7.9	6.7	0.0	0.0
4/11/80	20	15.0	0.0	0.0	0.0
	21	0.0	0.0	0.0	0.0

4.2.1.2 Republic Steel, Chicago (Closed Hood, Bottom Blown). Only three plants in the United States presently have bottom blown furnaces (Q-BOPF's). Republic Steel near Chicago is one of them. The two furnace vessels in the Republic Steel plant have a capacity of 205 Mg (225 tons). The secondary emission control system at this plant includes full-furnace enclosures with charging hoods at the front of each enclosure (Figure 4-2). There are no tapping hoods, and neither hot metal transfer emissions nor hot metal skimming emissions are ducted to this system. The Chicago shop is the best controlled bottom blown BOPF shop in the United States.

The operations of the Q-BOPF during charging and turndown require gas (either nitrogen or oxygen) to be blown through the tuyeres to prevent liquid metal, slag, or solids from entering and clogging the tuyeres. This factor makes the capture of secondary emissions more difficult than for top blown furnaces.

Draft for the charging hood at the Republic plant is obtained from the primary fume control system, as shown in Figure 4-4. Each furnace has its own primary gas cleaning system; however, a crossover duct between the two furnaces permits the system for the nonoperating furnace to be used for secondary emission control. With both gas cleaning system fans drafting the charging hood, the flow rate is about 176 acms (373,000 acfm) at 93° C (200° F) during hot metal charging.[10] During the oxygen blow, the charging hood is drafted continuously through the scrubbing system of the nonoperating vessel. During turndown and tapping, the charging hood is drafted by the scrubbing system of the nonoperating vessel. Fume capture during these latter operations is assisted by drafting the primary hood as well. Fumes captured in the secondary (charging) hood bypass the quencher and pass directly to the venturi in the scrubbing system. The design pressure drop of the venturi during furnace charging is 218 cm (86 in) of water column.

The performance of the secondary emission control system at Republic Steel, as indicated by roof monitor opacity observations, was poorer than the best performing top blown secondary emission control



ABBREVIATIONS

Q-BOP = QUELLE–BASIC OXYGEN PROCESS FURNACE AND PECOR ENCLOSURE
PH = PRIMARY HOOD
SH = SECONDARY HOOD
SO = SHUTOFF VALVE
Q = QUENCHER
BV = BELL VALVE
WS = WET SCRUBBER (VENTURI)
D = DAMPER
F = INDUCED DRAFT FAN

Figure 4-4. Republic Steel Corporation's South Chicago, Illinois, Q-BOP emission control system.

system. Data are available for two test series, June 1979 and June 1980.[10 11] These measurements were made in accordance with EPA Reference Method 9. The data was analyzed is the same manner as that for Kaiser Steel. Tables 4-2 and 4-3 display the maximum 3-minute average opacity and the second and third highest 3-minute averages occurring during each furnace cycle for the two test series. The overall mean of the maximum 3-minute averages was 17.5 percent as compared to 5.4 percent for Kaiser. The overall mean of the second highest 3-minute averages was 10.0 percent as compared to 1.5 percent for Kaiser. The overall mean of the third highest 3-minute averages was 6.6 percent. Also in comparison to Kaiser, it is apparent that many of the maximum 3-minute averages exceeded 20 percent opacity, whereas none did for Kaiser. Statistical analysis of these data for 95 percent prediction limits, as discussed in Section 4.2.1.1 for Kaiser, yields 55 percent for the maximum 3-minute averages and 26 percent for the third highest 3-minute averages.

During the 1979 tests, it was noted that leakage occurring on the tapping side of the furnace enclosure contributed to tapping fugitive emissions.[10] The addition of a separate tapping side hood to the enclosure might improve overall system performance.

4.2.2 Primary Control Systems Used for Secondary Emission Control

A number of consent decrees negotiated between EPA and steel companies have included provisions for reducing roof monitor discharges from existing BOPF shops. In several cases, roof monitor emissions have been decreased to levels complying with consent decree terms by using primary emission control systems to capture charging and tapping emissions. This use of the primary system to achieve compliance has been aided by the adoption of operating practices conducive to lesser fume generation and by the modification of, and addition to, process equipment and pollution control equipment.

In general, those shops with relatively large flow capacity in their primary control system are better suited to achieving low roof monitor emissions from furnace operations. Higher flow capacity means that higher indraft velocities can be achieved to capture fugitive emissions at a given distance from the hood.

TABLE 4-2. REPUBLIC STEEL, SOUTH CHICAGO, ILLINOIS
Q-BOPF ROOF MONITOR OPACITY OBSERVATIONS[a]
3-MINUTE AVERAGES[10]

		Maxium average		Second highest average		Third highest average	
		Observers		Observers		Observers	
Date	Run	1	2	1	2	1	2
6/18/79	1	12.4	44.6	12.5	13.3	12.5	12.9
6/18/79	1	---	46.3	---	42.5	---	27.5
	2	---	33.8	---	32.1	---	29.2
	3	---	38.8	---	24.2	---	22.9
	4	---	44.6	---	20.4	---	8.8
	5	---	23.8	---	22.5	---	18.8
6/19/79	6	12.5	11.7	12.5	11.3	11.3	10.4
	7	16.7	5.0	6.3	3.3	5.0	2.9
	8	10.8	9.6	5.4	0.0	2.1	0.0
	9	2.3	2.9	0.4	0.8	0.4	0.0
	10	2.5	0.0	0.0	0.0	0.0	0.0
	11	3.8	8.8	1.3	5.8	1.3	5.4
6/20/79	12	10.8	0.8	2.9	0.0	2.1	0.0
	13	15.8	2.5	5.8	2.1	3.8	1.3
	14	0.8	2.9	0.8	2.1	0.4	0.4
	15	4.6	2.1	3.8	0.8	1.7	0.4
	16	3.8	3.8	1.7	0.0	0.4	0.0
	17	11.3	4.2	8.8	0.4	5.4	0.4
	18	8.8	1.3	5.8	1.3	1.7	0.0
6/21/79	19	60.4	---	34.2	---	11.3	---
	20	27.5	5.0	26.3	1.7	2.1	0.8
	21	22.5	12.5	6.7	6.3	6.3	5.4
	22	10.0	4.2	2.5	3.3	2.1	1.7
	23	5.0	0.8	1.3	0.4	0.0	0.0
	24	6.7	1.7	1.3	0.8	0.8	0.4
	25	5.0	3.3	4.6	2.9	4.2	0.4
6/22/79	26	30.8	18.3	21.7	9.2	12.9	3.8
	27	45.4	13.8	20.8	13.3	12.5	12.9

[a]Tested by GCA Corporation.

TABLE 4-3. REPUBLIC STEEL, SOUTH CHICAGO, ILLINOIS Q-BOP MONITOR OPACITY OBSERVATIONS[a] 3-MINUTE AVERAGE[11]

Date	Run	Maximum average		Second highest average		Third highest average	
		Observers		Observers		Observers	
		1	2	1	2	1	2
6/2/80	1	29.6	----	5.0	----	3.3	----
	2	5.8	4.6	2.5	3.3	0.8	0.8
6/3/80	3	40.0	37.9	14.2	14.6	14.2	12.9
	4	35.0	28.8	23.3	25.8	21.3	17.1
	5	17.1	46.3	8.3	14.6	4.6	11.7
	6	29.2	32.1	24.6	21.7	21.7	17.5
6/4/80	7	9.6	7.9	3.8	1.7	3.3	1.7
	8	12.1	10.8	8.3	7.1	7.9	2.5
	9	9.2	5.8	5.8	4.6	5.0	4.6
6/5/80	10	1.3	2.1	0.8	1.7	0.0	0.8
	11	23.3	23.3	7.5	8.8	0.0	0.8
	12	59.2	41.7	37.5	19.2	16.7	14.6
	13	42.1	32.1	8.3	5.0	7.1	4.6
	14	40.8	43.8	39.6	36.3	30.0	15.8
	15	27.5	28.8	22.1	14.6	14.6	8.3

[a]Tested by Clayton Environmental Consultants.

Another factor contributing to the success of this approach is the reduction of fume generation. The use of clean scrap (non-oil-bearing, nongalvanized), the slow pouring of hot metal into the furnace, the careful positioning of the hot metal ladle with respect to the hood face and furnace mouth, and the proper furnace tilt angle are all means of reducing charging emissions.

Extension (flanges) from the primary hood into the charging and tapping aisles helps to provide more draft closer to the points of emission. Likewise, an extension of the pouring spout on the hot metal charging ladle will move the emission generation point closer to or under the hood.

4.2.2.1 Bethlehem Steel, Bethlehem, Pennsylvania. This BOPF shop has two 272-Mg (300-ton) furnaces with an open-hood-type primary gas cleaning system. Each furnace is partially enclosed by side walls, with no enclosure on the charging or tapping sides. An awning has been constructed on the tapping side between the side enclosures that extends toward the teeming aisle, as shown in Figure 4-5. This awning acts as a flanged extension of the primary hood and helps direct tapping fumes into the primary hood. There is also an extension from the primary hood on the charging side of the furnace.

During hot metal charging operations, the gas evacuation rate for the primary hood is 236 acms (500,000 acfm) at about 82° C (180° F).[12 13] The initial portion of the hot metal charge is performed with the furnace mouth tipped only partially out from under the hood. As the charge nears completion, the furnace is turned further, bringing out the entire mouth. Fume escape is worst at the end of the charge. During the oxygen blow, the primary hood evacuation rate is about 353 acms (750,000 acfm) at a temperature of 210° C (420° F).[12 13] When the vessel is turned down for tapping or other reasons, the evacuation rate is 236 acms (500,000 acfm) at about 82° C (180° F).[12 13]

The primary and secondary gas cleaning device for this BOPF shop is an ESP. A dropout chamber precedes six horizontal dry precipitators operating in parallel.

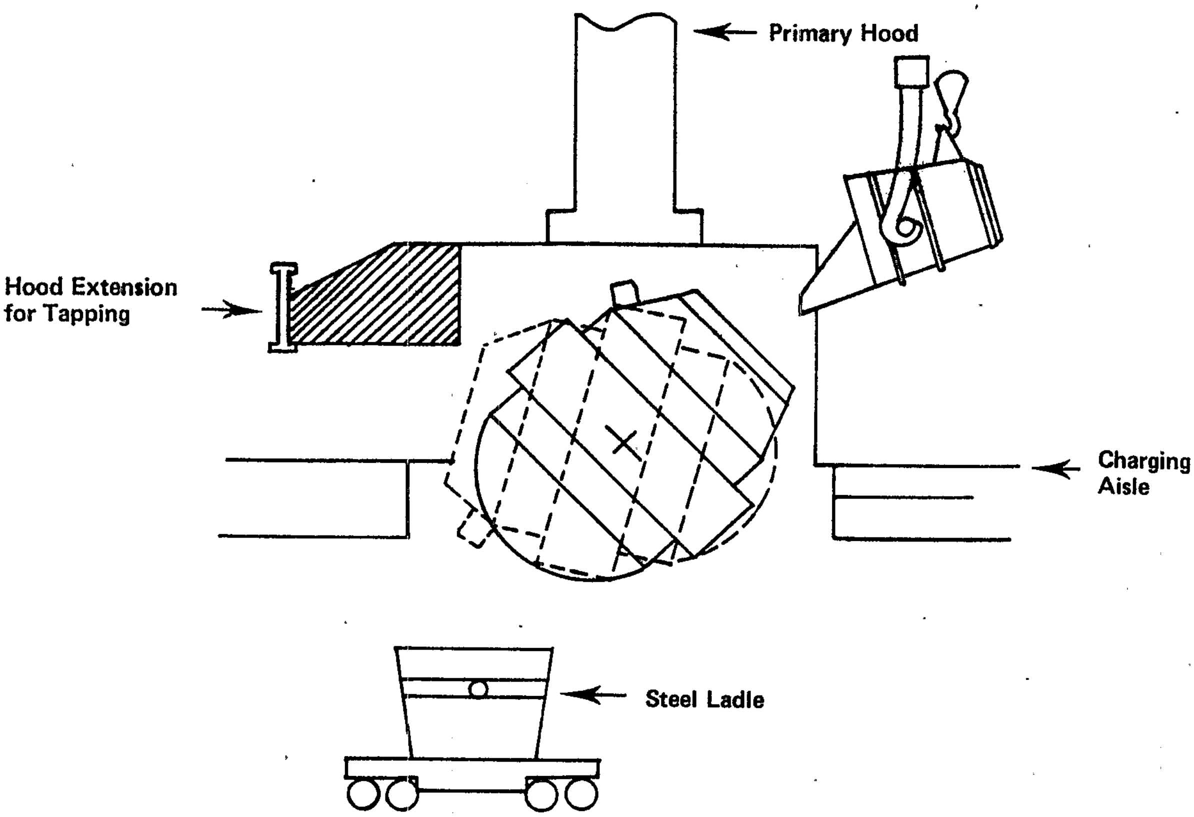


Figure 4-5. Bethlehem Steel, Bethlehem, Pennsylvania—BOPF partial furnace enclosure for open primary hood.

Roof monitor visible emissions observations were performed at this plant in June 1980.[14] The observations were made in accordance with EPA Reference Method 9. As previously discussed, the measurements were analyzed by computing 3-minute averages instead of the 6-minute averages directed by Method 9. From the 3-minute averages segregated by furnace cycle, a maximum 3-minute average and second highest 3-minute average were chosen for each cycle, as discussed in Section 4.2.1.1. These data are presented in Table 4-4. The mean maximum 3-minute average is 1.4 percent and the mean second highest average is 0.3 percent, as compared to 5.4 percent and 1.5 percent, respectively, at Kaiser Steel. Also as discussed in Section 4.2.1.1, 95 percent prediction limits were calculated for the Bethlehem data. The limit based on maximum 3-minute averages is 6 percent and the limit based on second highest 3-minute averages is 2 percent.

All these data for Bethlehem Steel represent single-furnace operation. In addition to furnace operations, slag pot dumping, ladle deskulling, hot metal transfer, and teeming occurred during these tests.

A significant portion of the performance achieved at the Bethlehem plant must be attributed to good operating practice and skillful crane and furnace maneuvering. The plant is missing the benefits of a full-furnace enclosure and the advantage of local hoods closer to and immediately above the fume sources found in new plants. The effectiveness of secondary emission control at the Bethlehem shop by using the primary hood is superior to the effectiveness of the Kaiser system. However, the techniques employed at Bethlehem are not applicable to all BOPF shops. The Bethlehem shop vessels are equipped with open hoods while most modern BOPF vessels are of closed hood design.

A further consideration in examining the effectiveness of primary systems used for secondary emission control is how well total emissions are controlled. Test data for Bethlehem's primary system presented in Section 4.4.2.1 show the open hood system to be much less effective for the control of primary emissions than the most effective closed hood primary systems. However, a new shop might choose to employ the

TABLE 4-4. BETHLEHEM STEEL, BETHLEHEM, PENNSYLVANIA
ROOF MONITOR OPACITY OBSERVATIONS
3-MINUTE AVERAGES[14]

Date	Run	Maximum average		Second highest average	
		Observer 1	Observer 2	Observer 1	Observer 2
6/23/80	1	0.83	1.25	0.83	0.42
	2	3.75	2.50	0.0	0.0
	3	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0
	5	0.0	0.42	0.0	0.0
6/25/80	6	0.0	0.42	0.0	0.0
	7	6.67	5.83	0.0	0.0
	8	0.0	0.0	0.0	0.0
	9	0.0	0.0	0.0	0.0
6/26/80	10	1.25	0.42	0.0	0.0
	11	5.0	3.33	3.75	1.67
	12	0.83	1.25	0.0	0.42

open hood design with a more efficient particulate control device that could match the closed hood effectiveness for primary emissions and also effectively collect secondary furnace emissions.

4.2.2.2 Jones and Laughlin (J&L) Steel, Aliquippa, Pennsylvania.[15] This is a three-vessel shop with a nominal capacity of 188 Mg (205 tons) per furnace per cycle.[15] The primary gas cleaning systems for these furnaces are open hood type with two ESP's. Normal operation in this shop is two vessels in service that can be blown simultaneously, if desired.

To achieve the control of secondary emissions from furnace operations, each furnace is enclosed on three sides--tapping side plus the sides with trunnion rings. The front or charging side may be partially enclosed while the oxygen blow is in progress by means of a curtain mounted on a trolley rail. Curtains have been hung underneath the furnace operating floor to restrict air movement into the partial furnace enclosure from the teeming ladle car side.

The gas capture and cleaning system for the shop consists of open combustion hoods above each furnace, an evaporation chamber for each furnace, downcomers to a common manifold and damper arrangement, two ESP's, an outlet manifold leading to a draft arrangement with seven fans, and two discharge stacks. The design of the evaporation chamber includes the provision for steam injection or water injection to achieve the correct moisture level in the waste gas for effective ESP performance.

The damper arrangement provides for isolating the hood at the furnace on which maintenance needs to be done. This prevents wasting available draft on nonoperating furnaces. Gas flow from the combustion hoods is controlled by louvered dampers between the downcomers and precipitator inlets.

Two precipitators remove particulate from the waste gas streams. Each ESP has its own stack. One precipitator consists of six chambers with five fields each. The total collection surface available in this precipitator is 26,648 m^2 (286,848 ft^2). The second precipitator consists of eight chambers with five fields in the direction of gas flow. The total collection surface area in this precipitator is 44,146 m^2 (475,200 ft^2). With two furnaces in operation, normal practice is to use six of the eight chambers in the one precipitator for one furnace, and the remaining two chambers plus the other ESP for the other furnace. Based on actual gas flow during recent tests of 328 acms (695,000 acfm), the respective specific collection areas are 115 and 101 m^2 per acms (584 and 512 ft^2 per 1,000 acfm).[15] The design of the precipitators' damper systems is such that a single precipitator chamber can be taken out of service for maintenance while the other precipitator chambers remain in use.

The seven induced draft fans are normally divided up four and three between the two precipitators. However, the damper arrangement permits the center fan to be used with either of the two precipitators, depending upon the draft needs and whether one of the other fans may be out of service for maintenance. There is sufficient draft with only six fans that the furnaces can continue to operate at full production.

J&L personnel operate the draft system wide open during hot metal charging, tapping, and oxygen blowing. The waste gas flow under these conditions is reported to be about 221 scms (468,100 scfm).[15]

There is a time delay on the damper controls in the system to prevent puffs that may occur at the end of the oxygen blowing periods by premature closing of the dampers. The primary hood is not drafted at all during vessel turndown.

To improve precipitator performance, water conditioning sprays are used to add moisture to the gas stream during the oxygen blowing cycle. Because the flue gas temperature is too low at the beginning of the blowing cycle to evaporate a sufficient amount of water, steam is injected. Steam injection is used during the hot metal charging operation and also during tapping operations due to low gas temperature at those times. Steam injection during hot metal charging of the furnace is controlled by a timer and lasts approximately 2 min. The crane operator is not supposed to begin pouring hot metal until he hears the steam turned on. Steam injection at the beginning of the oxygen blow is also controlled by a timer. The steam is turned on as the oxygen lance is lowered into the furnace and continues to flow for about 1½ min into the blowing period. Steam injection is practiced for approximately 15 min per furnace cycle. The steam injection rate is approximately 36,300 kg/hr (80,000 lb/hr) for the duration of the injection period.

A water ring and water sprays are used to reduce fugitive emissions from the hood during furnace puffing. A water ring is placed on the oxygen lance and water sprays are placed around the lance hole in the hood. The function of the water ring and sprays is to partially cool the gases leaving the furnace, especially during periods of puffing, to reduce gas volume and avoid exceeding the capacity of the system to withdraw these gases. In the case of the water sprays around the lance hole, the purpose is to reduce fume leakage from the lance hole opening. The lance water ring technology is proprietary and available from Republic Steel Corporation.

To avoid fugitive discharges from the flux chute, a flapper valve has been installed in the chute. It allows flux materials to fall through, but closes to prevent fumes from rising up through the chute at other times.

Hot metal charging practices have been changed since adoption of the program to control secondary emissions. The normal hot metal charging rate prior to this program was 45 s; it is now a minimum of 75 s. During hot metal charging, the furnace is tilted to an angle of 38° from the vertical. To improve fume capture by the primary hood, a longer pouring spout has been installed on all the charging ladles. After hot metal is charged to the furnace, the emission control practice requires the movement of the curtain on the charging side of the furnace to a position in front of the furnace to reduce the open area.

Doors on the tapping side of the furnace enclosure are kept closed while the vessel is in operation. Holes in the tapping side doors and windows in the furnace enclosure provide the needed visibility for the operators.

In October 1980, 6 days of roof monitor visible emission tests were performed at the plant under the direction of EPA Region III.[16]

The observations were made in accordance with EPA Reference Method 9. These data were analyzed by computing 3-minute average opacities instead of 6-minute averages. The maximum and second highest 3-minute averages were selected for each cycle on each furnace. Because the furnace operations are overlapping, some of the values reported are common to both furnaces. Tables 4-5 and 4-6 display the test results. The data are representative of simultaneous two-furnace operation, hot metal transfer, and teeming, which occurred during these tests. The overall mean maximum 3-minute average was 3.9 percent and the mean second highest 3-minute average was 2.1 percent as compared to Kaiser Steel's 5.4 percent and 1.5 percent, respectively. As discussed in Section 4.2.1.1, 95 percent prediction limits were calculated for these data. The limit for the maximum 3-minute averages was 11 percent and the limit for the second highest 3-minutes averages was 6 percent.

Both purchased and in-house scrap are used in the furnaces. Normally they do not use much No. 2 bundle, but it was used during these performance tests to see how well the emission controls would perform.[15] The J&L personnel reported that steel heats to which molybdenum is added are particularly smoky, so molybdenum heats were also made during the performance tests, again to see how well the emission controls would perform.[15]

4.2.3 Canopy or Roof Hoods, Partial Building Evacuation

Hooding is a common method for capturing particulate emissions from scattered sources in a plant. The design of hoods for BOPF secondary emissions is complicated by cross drafts that develop within the building, interfering with fume capture. A hood that is located close to the source and intended to reduce cross drafts may get in the way of crane operations. Every design is a compromise between hood and vessel clearance and the clearance necessary for crane operations.

The design of a hood, a duct, a fabric filter, and an exhaust fan to handle a specified volume of air is routine. The temporal variation in average temperature and dust loading can cause mild fluctuations in volume, which can be accommodated by modest overdesign. It is more difficult to predict the source of the air that flows into the hood,

TABLE 4-5. J&L STEEL, ALIQUIPPA, PENNSYLVANIA
ROOF MONITOR OPACITY OBSERVATIONS
3-MINUTE AVERAGES[16]

	No. 2 furnace		
Date	Run	Maximum average	Second highest average
10/6/80	1	3.8	3.3
10/7/80	2	3.3	2.1
	3	5.0	1.7
	4	2.1	0.4
	5	0.0	0.0
	6	0.0	0.0
	7	0.0	0.0
10/8/80	8	5.0	1.7
	9	1.3	0.0
	10	5.8	4.2
	11	9.6	5.0
	12	3.3	2.1
10/9/80	13	6.7	5.8
	14	5.8	0.0
	15	11.7	3.3
	16	11.3	2.5
	17	1.3	0.0
	18	10.4	8.3
10/10/80	19	2.1	1.3
	20	0.8	0.4
	21	2.1	0.4
	22	2.1	0.0
10/13/80	23	1.7	1.7
	24	2.1	0.0
	25	11.7	5.4
10/14/80	26	2.1	0.0
	27	5.0	1.7
	28	4.2	3.8
	29	2.9	2.5
	30	4.2	2.5
	31	4.6	4.2

TABLE 4-6. J&L STEEL, ALIQUIPPA, PENNSYLVANIA
ROOF MONITOR OPACITY OBSERVATIONS
3-MINUTE AVERAGES[16]

	No. 3 furnace		
Date	Run	Maximum average	Second highest average
10/6/80	1	2.1	0.8
10/7/80	2	0.0	0.0
	3	1.7	0.8
	4	2.1	0.4
	5	0.0	0.0
	6	0.0	0.0
	7	0.0	0.0
10/8/80	8	5.0	1.7
	9	5.8	4.2
	10	5.0	4.6
	11	9.6	4.6
	12	3.3	3.3
10/9/80	13	2.1	1.3
	14	0.4	0.4
	15	5.8	2.1
	16	11.7	3.3
	17	2.5	2.5
	18	7.1	0.8
10/10/80	19	1.3	0.0
	20	2.1	0.8
	21	2.1	0.0
10/13/80	22	1.7	1.7
	23	2.1	0.0
	24	11.7	0.0
	25	5.4	2.1
10/14/80	26	0.8	0.0
	27	2.1	0.0
	28	1.7	1.3
	29	4.2	3.8
	30	4.2	2.9
	31	4.6	3.8
	32	5.4	4.6

unless the hood fits closely around the source. However, close fitting can interfere with the batch operations of the process. If the hood is positioned so as not to interfere and the system is undersized, part of the rising plume may escape on one side while clean air is drawn in on the other. Cross drafts are unpredictable; sheet metal barriers may be erected to diminish their effect. If the hood is to capture the plume consistently, a remedy is overdesign or a "factor of safety." The degree of excess capacity in a system cannot be known until it is operated under a variety of climatic and production conditions.

Apart from the emissions that are collected regularly at fixed locations, certain necessary maintenance operations generate dust that is less susceptible to collection by local hoods. For example, when it is necessary to reline a ladle, it will be allowed to cool; after dislodging the refractory lining, the ladle will be turned upside down and dumped into a truck or onto the shop floor.

Local hoods exhausting to a secondary system are only a part of the secondary emission control system. Of those observed, the best systems exhaust the several local hoods to a single baghouse, using interlocks and status lights to ensure that the full air-moving power of the system is devoted to only a few tasks at any one time.[7 17]

Buildings to cover hot operations like glass melting, synthetic graphite production, and BOPFs exploit natural convection for operator comfort. The heated air rises and exits through roof openings (roof monitors) with covers that prevent rain from falling on the furnaces. Fine particles can be entrained in this rising air and exit through the monitors.

The canopy hood is one answer for some emissions that either have not been provided for or that inevitably escape the local hoods described above. To the degree that the source is concentrated in one area of the building, but not so concentrated as to permit local hooding of the desired capture efficiency, there will be a relatively concentrated plume of hot dusty gas rising from that area. A canopy hood will not interfere with operations; can collect the fine, entrained particulate at relatively low velocities; and can be ducted continuously to a collecting device.

There are disadvantages to canopy hoods. Cross drafts in the shop can displace rising fume so that it evades the hood, or the rising plume may expand and diffuse to dimensions larger than the hood face. The canopy hood system adds a significantly larger gas volume to be cleaned. When added to an existing system, canopy hoods may reduce draft in the rest of the system to the point that air velocity in the other hoods is too low to capture fume effectively.

One means of reducing the impact of cross drafts and avoiding the problem of the plume's becoming larger than the hood face dimensions is to use partial building evacuation. The building structure, in essence, becomes the hood for a particular part of the operation. Partition walls may be installed between building columns to prevent lateral movement of the plume into adjacent portions of the building. These partition walls may extend as low as crane operations will permit and may extend as high as the roof. Sheeting or partitions may also be used to seal the roof area to prevent the escape of emissions by natural thermal draft. One or more duct connections may be made into the sealed portion of the building to extract contaminated air for gas cleaning.

A further variation of this approach is available by altering the choice of gas cleaning device. Instead of ducting contaminated air away to a remote collector, the collector may be erected immediately above the enclosed roof area. At least three companies presently offer roof-mounted ESP's that take advantage of the natural thermal drafts above the hot processes. However, none are installed in U.S. BOPF shops. Since precipitators are characteristically low-pressure-drop devices, the thermal draft assist means little or no fan power is required to move contaminated air through the collector. Additional information concerning roof-mounted collectors will be presented later in this chapter.

4.2.3.1 <u>Inland Steel, East Chicago, Indiana (Closed Hood, Top Blown)</u>. There are two principal secondary emission control systems in this plant. One system treats furnace emissions captured in local hoods located in the partial furnace enclosure. The second system cleans emissions captured by partial building evacuation and emissions from local hoods at the hot metal transfer and hot metal skimming stations.

Local hoods within the partial furnace enclosure include a charging hood, a tapping hood, and a wrap-around hood (at the side of the furnace) to capture puffing emissions during the oxygen blow. During charging, only the charging hood is drafted; during tapping, the tapping hood and wraparound hoods are drafted. While oxygen blowing is occurring, all three hoods are drafted. Air flow for the furnace enclosure secondary emission control system is induced through a venturi scrubber by a fan rated for 62 acms (131,000 acfm) at 21° C (70° F).[18] The overall system pressure drop is 130 cm (51 in) of water column. Since this evacuation rate is not sufficient to capture all charging and furnace deslagging emissions, the partial building evacuation system provides additional capture of these emissions.

The partial building evacuation system is applied only to the furnace charging aisle. There is a curtain wall between the charging aisle and furnace aisle to prevent substantial movement of charging emissions into the uncontrolled furnace aisle. There are two duct takeoffs in the charging aisle roof, one centered above each furnace. A damper is provided in each takeoff to open or close it as necessary. During hot metal charging and furnace deslagging, the damper is opened to maximize the evacuation rate above the affected furnace.

The total air flow capacity for this partial building evacuation-hot metal handling secondary emission control system is 189 acms (400,000 acfm) at 135° C (275° F). Flow is divided between partial building evacuation and hot metal handling, with 130 acms (275,000 acfm) allotted to the roof ventilation system and 59 acms (125,000 acfm) to the hot metal station. The available system pressure drop is 38 cm (15 in) of water column, and gas cleaning is provided by a baghouse.

The relatively low charging hood draft (as compared to Kaiser's) leads to a strong dependence on the partial building evacuation system to capture fugitive emissions escaping the partial furnace enclosure. Although curtain walls and partitions are used to reduce the effects of cross drafts at Inland, the partial building evacuation rate appears to be insufficient to prevent leakage from the enclosed portion of the building. The partial building evacuation rate of 189 acms (400,000 acfm) is less than that available through Kaiser's local charging hood. Considering that as the charging plume rises, additional building air becomes entrained in the plume, the partial building evacuation rate should be considerably greater than that for a local hood. For this reason, the Inland No. 2 BOPF facility is not considered a candidate for best secondary emission control.

4.2.4 Building Evacuation

Extension of the canopy hood concept leads to total building evacuation. In effect, the entire building becomes a hood. Theoretically, a well-designed building evacuation system should be able to capture nearly 100 percent of all secondary emissions. There are disadvantages, however. Exhausting the air at a sufficient rate for building evacuation requires a system gas flow larger than that described for local hoods. Consequently, costs are greater. Since fan work is proportional to the product of pressure drop (Δp) and flow rate, and given the same type of collector (fabric filter) for both local hooding and building evacuation, the energy expenditures will be higher for the building evacuation system.

Particulate emissions from BOPF shops equipped for building evacuation could also be greater than particulate emissions from shops equipped with furnace enclosures or hoods. Baghouses tend to produce relatively constant outlet concentrations over a wide range of inlet particulate concentrations. In comparing the particulate emissions from baghouses applied to building evacuation versus furnace enclosures and hoods, the principal parameter then is flow. The capture of emissions near the source tends to require less flow than ventilating a large building. At equal concentrations, the mass emission rate from a building evacuation baghouse would be greater because of the much larger exhaust volume. Although outlet concentrations from a baghouse installed to control particulates from building evacuation should theoretically be lower than concentrations from a furnace enclosure baghouse, there are not enough data to demonstrate a lower concentration limit for building evacuation baghouses than for furnace enclosures or local hood baghouses.

There are no total building evacuation systems applied to BOPF shops in the United States. There are several such systems in use for other types of steelmaking, particularly electric arc steelmaking and argon/oxygen decarburizer (AOD) steelmaking. Three of the plants that use these systems produce alloy and stainless steel.

Babcock and Wilcox in Beaver Falls, Pennsylvania, operates two plants--Wallace Run and Koppel. The Wallace Run plant has one shop with two 22.7-Mg (25-ton) electric arc furnaces (EAF's) and another shop with a 45.5-Mg (50-ton) and a 68.2-Mg (75-ton) EAF. The Koppel plant has a 45.5-Mg (50-ton), a 68.2-Mg (75-ton), and three 90.9-Mg (100-ton) EAF's. The design building evacuation rates at Wallace Run are 109 and 217 acms (230,000 and 460,000 acfm), respectively, for the small and large shops. Total design evacuation rate for the Koppel plant is 850 acms (1.8 million acfm).[19] The Koppel plant system is designed to provide one air change every 2.5 minutes. Design gas temperature for all these systems is about 100° C (212° F).

To achieve satisfactory air movement through the buildings, ventilation openings (to supply and distribute incoming air) were added and changed. At some locations, partition walls (curtains) were installed on building columns to reduce the travel of fume into adjacent areas. Roof monitors were sealed and duct takeoffs were installed in the roof above the furnaces.[19]

In both of the plants, the fume capture systems are connected to baghouses. Details of the collector design are discussed in a later section of this chapter.

Crucible Steel at Midland, Pennsylvania, operates an EAF and AOD facility to produce alloy and stainless steel. There are four EAF's each with an 81.8-Mg (90-ton) capacity and one AOD vessel with a 90.9-Mg (100-ton) capacity. Duct takeoffs for the evacuation system are in the roof of the building. The evacuation rate for the whole building is 850 acms (1.8 million acfm) at a design temperature of

121° C (250° F).[20] The fume collection system for this plant is a baghouse. Recovered dust contains chrome and nickel because of the stainless alloying process; the dust is recycled. Additional data on baghouse design are presented in a later section of this chapter.

4.2.5. <u>Factors Affecting Fume Capture</u>

Several process factors affect the ability of hoods in secondary emission control systems to capture fumes. One important factor already mentioned is the type of furnace. The differences between top and bottom blown furnace operations have been discussed in Chapter 3. The need to maintain a flow of gas through the bottom blown furnace tuyeres tends to generate a larger volume of gas and fume to be captured during hot metal charging. Other important process factors include furnace additives, scrap types, and furnace operating practices.

The amount of fume generated is affected by additives to the steel. Additions are made to the furnace or the steel ladle, or both. Common furnace additions include materials used as fluxing agents such as dolomite, burnt lime, and fluorspar. Deoxidizing agents such as ferrosilicon and silicomanganese are also added to the furnace.[21] Ladle additions during or after tapping are numerous and include ferromanganese, chromium, aluminum, phosphorus, sulfur, and molybdenum. Among the additives of importance from an emissions standpoint are chromium, molybdenum, and sulfur.[21]

As was previously described in Section 4.2.2.2, the test series performed at J&L, Aliquippa, explored the effects of some additives on roof monitor visible emissions.[17] Comparisons of the observed maximum 3-minute opacities were made among groups of furnace cycles (grouped by additive) for the J&L test series.[22] While differences in the amount of fume generation were expected between cycles with various types of additives, there were no statistically significant differences detected in the average maximum 3-minute opacities that were observed at the roof monitor for the five additives compared to the cycles without those additives.[22]

Variation of scrap charge composition can also affect fume capture. There are a large number of scrap types classified according to size, density, and source of scrap, as shown in Table 4-7.[23] Generally, the use of in-house scrap (which tends to be cleaner) is the preferred mode of operation.

Scrap contaminated with oil produces large volumes of gas and fumes during hot metal charging as the molten iron and combustible material come into contact. Wet scrap can similarly produce increased emissions when the water flashes to steam on contact with molten metal. Both oily scrap and wet scrap produce serious in-plant safety problems, so there is additional incentive to avoid those types of scrap.

As was discussed in Section 4.2.2.2, the J&L test series included some test runs with purchased scrap. Therefore, the effects of some purchased scrap types on roof monitor visible emissions were present in the data that are analyzed and presented in Table 4-6.

The use of certain operating practices can improve the degree of fume capture. These have been described for specific plants previously in Sections 4.2.2.1 and 4.2.2.2. Slow pouring the hot metal from the ladle to the furnace and minimizing the angle of furnace tilt (perhaps putting longer pouring spouts on the hot metal ladle) to keep the fume generation point close to the hood are the most important of these.

4.2.6 Other Control Systems

A literature survey conducted for EPA in 1977 found descriptions of eight control systems for charging emissions at BOPF's in this country.[24] Seven consisted of auxiliary hoods connected to open hood primary systems, as outlined in Section 4.2.2. The eighth control system was the patented Gaw damper.[23] This damper is placed at the inlet (face) of the open hood primary system and is used to reduce the open area of the hood face during charging and tapping. The opening is constricted to increase hood face velocity and direct hood suction to the side of the hood nearest the charging or tapping operation. The relationship among gas properties, fan performance, system resistance, and total volumetric flow rate is complex. To design such a system for specified performance during charging and to adjust it after installation is difficult since emissions from one charge to the next

TABLE 4-7. SCRAP TYPES AND CONTAMINANTS

ISIS Code No.[a]	Grade	Thickness	Bundle or piece size	Density Kg/m³ (lb/ft³)	Contaminants: Zinc	Lead	Tin	Other coatings	Sources
200	No. 1 heavy melting	6+ mm (1/4+ in)	P 150 cm × 60 cm (P 60 in × 24 in)	-	-		THESE		
201	No. 1 heavy melting	6+ mm (1/4+ in)	P 90 cm × 45 cm (P 36 in × 18 in)	-	-		CONTAMINANTS		
202	No. 1 heavy melting	6+ mm (1/4+ in)	P 150 cm × 45 cm (P 60 in × 18 in)	-	-		NOT		
203	No. 2 heavy melting	3+ mm (1/8+ in)	Charge box	-	Galvanized		PERMITTED		
204	No. 2 heavy melting	-	P 45 cm × 90 cm (P 18 in × 36 in)	-	Galvanized		UNDER THESE		Prepared auto scrap
205	No. 2 heavy melting	-	P 90 cm × 45 cm (P 36 in × 18 in)	-	Galvanized		SPECIFICATIONS		Prepared auto scrap (free of sheet iron or thin gauge material)
206	No. 2 heavy melting	-	P 150 cm × 45 cm (P 60 in × 18 in)	-	Galvanized				Prepared auto scrap (free of sheet iron or thin gauge material)
207	No. 1 busheling	-	30 cm² (12 in²)	=	No	No	No	No	New factory bushels. No auto or fender stock
208	No. 1 bundles	Sheets	Charge box	1,200 (75)	No	No	Chem. detinned	No	No auto or fender stock
209	No. 2 bundles	Sheets	Charge box	1,200 (75)	Galvanized	No	No	No	-
210	Shredded scrap	-	-	800 (50)	-	From auto bodies			Autos; Unprepared Nos. 1 and 2 steel
211	Shredded scrap	-	-	1,100 (70)	-	From auto bodies			Autos; Unprepared
212	Shredded clippings	Sheets	-	950 (60)	-	-	-	-	-
213	Shredded tin cans	-	-	-	-	Solder	Tin or Al Tops TFS	No Cans	-
214	No. 3 bundles	Sheets	Charge box	1,200 (75)		No restrictions whatsoever			

(continued)

TABLE 4-7. (continued)

ISIS Code No.[a]	Grade	Thickness	Bundle or piece size	Density Kg/m³ (lb/ft³)	Contaminants: Zinc	Contaminants: Lead	Contaminants: Tin	Contaminants: Other coatings	Sources
215	Incinerator bundles	-	Charge box	1,200 (75)	-	Solder	Tin	Al?	Incinerated tin cans
216	Terne plate bundles	Sheets	Charge box	1,200 (75)	-	Lead	-	-	-
217	Bundled No. 1	3+ mm (1/8+ in)	Charge box	1,200 (75)	No	No	No	No	No. 1 Steel
218	Bundled No. 2	3+ mm (1/8+ in)	Charge box	1,200 (75)		From auto body, chassis, driveshafts, and bumpers			60% Auto and Fender stock
219	Machine shop turnings	-	-	-	-	-	-	-	Machine shop (no iron borings)
220	Machine shop turnings and iron borings	-	-	-	-	-	-	-	Machine shop
221	Shoveling turnings	-	-	-	-	-	-	Free of excess oil	Machine shop (no iron borings)
222	Shoveling turnings and iron borings	-	-	-	-	-	-	Free of excess	Machine shop
223	Iron borings	-	-	-	-	-	-	Free of excess oil	Machine shop
224	Auto slabs	-	P 90 cm × 45 cm (P 36 in × 18 in)	-		From auto bodies			Automobiles
225	Auto slabs	-	P 60 cm × 45 cm (P 24 in × 18 in)	-		From auto bodies			Automobiles
226	Briquetted iron borings				Analysis and density to consumer's specifications				
227	Briquetted steel turnings				Analysis and density to consumer's specifications				
228	Mill scale	-	-	-	-	-	-	Magnetic	-

[a]Institute of Scrap Iron and Steel

are quite variable. Perhaps for these reasons the industry has not widely adopted the Gaw damper. Engineers from National Steel, who studied the device as it applied to a 1-ton pilot furnace, gave it a favorable report, but anticipated that there might be maintenance problems at full scale.[23] In pilot study, Republic Steel at Gadsden, Alabama, has retrofitted two furnace hoods with Gaw dampers.[25]

The same pilot study described charging through a "launder," i.e., a refractory-lined chute built through the hood.[23] Since the vessel did not have to be tipped for charging, emissions were collected by the primary system. This scheme worked well but apparently has not been commercialized.

4.2.6.1 Foreign Installations. Other BOPF secondary emission control systems in use outside the United States have performed in a manner comparable to the system at Kaiser Steel.[17] No official visible emissions observations have been performed on these systems, however. Specifically, the Oita and Yawata Works of Nippon Steel are examples of well controlled BOPF facilities in Japan.[5 6] The Taranto Works of Italsider in Taranto, Italy, is also in this category.[26] All of these plants depend on furnace enclosures and local hooding to capture furnace emissions. Local hooding is also applied to other secondary emission sources in these plants, i.e., hot metal transfer, hot metal skimming, ladle deskulling, external desulfurization of hot metal, and steel transfer for continuous casting.

At least one foreign installation with partial building evacuation has been observed to control visible emissions from secondary emissions relatively well. The Chiba Works of Kawasaki Steel has a relatively new Q-BOP shop. The No. 3 shop has two 230-Mg (250-ton) bottom blown furnaces. This plant was constructed with furnace enclosures, including charging hoods inside the enclosures and roof-mounted ESP's to collect furnace emissions that escape during hot metal charging as shown in Figure 4-6.[17] One precipitator is located above each furnace. The design gas flow rate for each is 225 acms (477,000 acfm).[27] The total gas flow in the secondary system for the local hoods is 300 acms (635,400 acfm). This latter capacity is shared with other secondary

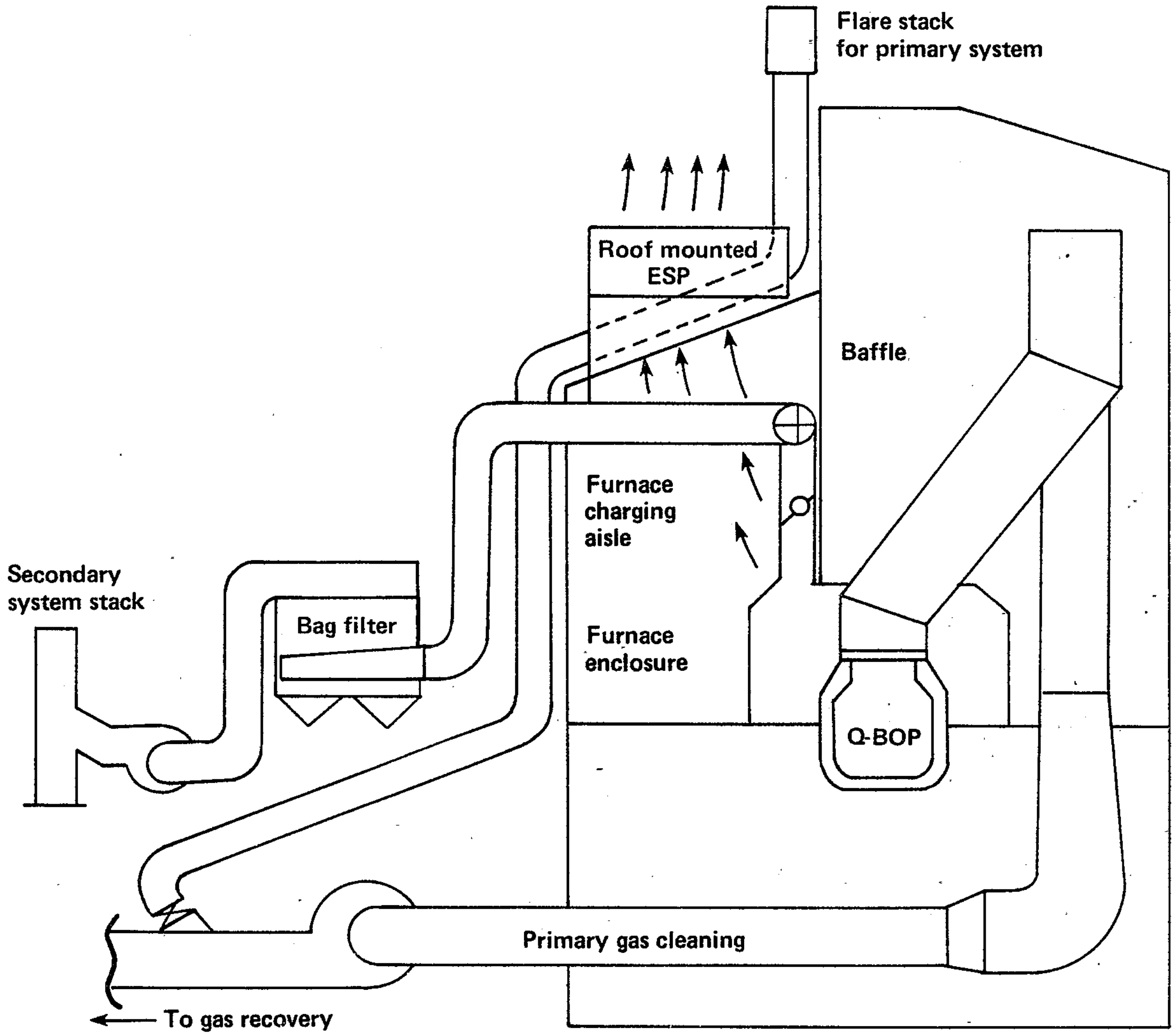


Figure 4-6. Kawasaki-Chiba Works plant arrangement with partial building evacuation.

sources, including raw materials handling, torpedo car desulfurization, hot metal transfer, and hot metal skimming.

Based on limited observations of roof-mounted ESP performance, their application to bottom blown furnace shops in combination with local hooding looks promising for matching the performance of furnace enclosures alone for top blown furnaces. Application to top blown furnaces may be considered as well to supplement furnace secondary emission control systems with relatively low flow rates.

4.3 CONTROL OF SECONDARY EMISSIONS FROM ANCILLARY OPERATIONS (HOT METAL TRANSFER AND SKIMMING)

Given the trend to enclosed BOPF's, the emissions from charging, sampling, and tapping are closely associated with the vessel, and their control is integrated with the design of the enclosure. Charging, sampling, and tapping do not occur during blowing, so the integration of these operations with a primary furnace control system is theoretically feasible. However, the ancillary operations of hot metal transfer and hot metal skimming take place at various times and distances from the furnace. The integration of their control with that of the other operations would be both structurally and operationally awkward. Therefore, the trend has been to install a separate secondary control system.

Local hoods are the principal choice for capture of emissions from hot metal transfer and hot metal skimming. Hoods placed above the source are more effective than those attempting to capture the hot emissions with side draft unless side draft exhaust ventilation is employed in conjunction with a cover over the mixer or ladle.

4.3.1 Kaiser Steel, Fontana, California.[7]

Kaiser Steel performs hot metal transfer and ladle deslagging (skimming) at one side of the BOPF shop where there are two stations. A shed or lean-to is built onto the side of the main building as shown in Figure 4-7. Torpedo cars are moved into the shed on tracks passing through the shed. Chain curtains hanging from the top of each entrance help to restrict the opening size and reduce required draft. The torpedo car pours hot metal through a slot into a shop ladle sitting

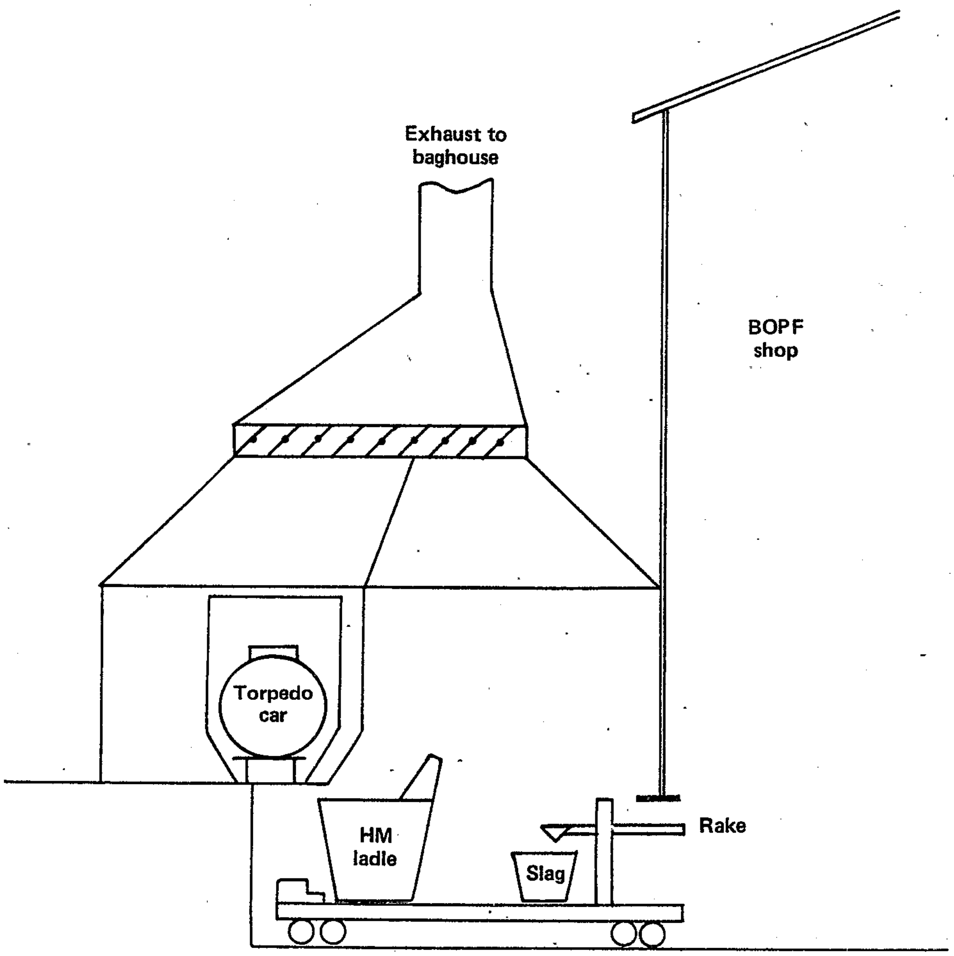


Figure 4-7. Kaiser Steel hot metal transfer and skimming station.

on a transfer car below ground level. Upon completion of the hot metal transfer, a ladle transfer car moves under an adjacent hood in the same station where slag is raked off the metal surface while the ladle is tilted. Both hoods in the station are evacuated through the same duct. Draft is apportioned between the two hoods by means of dampers located at the duct entrance above the station.

Operation of the system in conjunction with the furnace enclosure hoods is discussed in Section 4.2.1.1. The estimated gas evacuation rate during hot metal transfer and skimming is about one-third system capacity or 94 acms (200,000 acfm).[8] Tests at Kaiser, Fontana, showed that the hood system captures virtually all of the particulates from hot metal transfer and skimming.[9] Consequently, there are no visible emissions from the roof monitor for these Kaiser secondary sources.

4.3.2 U.S. Steel, Fairfield, Alabama[28]

Hot metal handling operations are performed at two locations in this plant, at a north and a south hot metal mixer. Molten iron is brought into the building in torpedo cars and poured into the hot metal mixers for storage. Hot metal ladles are filled by pouring the molten iron out of the opposite side of the mixers. Therefore, there are two transfer points associated with each mixer, a torpedo car transfer point and a ladle transfer point. Both ladle transfer stations are partially enclosed in that the ladle is set in a pit and a partial cover is rolled into place above the ladle as the metal transfer takes place. Side draft hoods are used at all of the transfer points. The south mixer is evacuated through a dust control system shared with the canopy hood over Furnace C (one of three furnace vessels). The gas flow capacity of the system is about 230 acms at 93° C (490,000 acfm at 200° F). However, only a portion of this draft is available to the transfer hoods.

The control device is a six-compartment, pressure-type baghouse with a gross air-to-cloth ratio of 0.79:1 m/min (2.6:1 ft/min) and a net air-to-cloth ratio of 0.94:1 m/min (3.1:1 ft/min) with one compartment offline. The bag fabric is nomex and bag cleaning is performed by a shaker mechanism.

The north mixer transfer points are controlled by a separate system with a maximum evacuation rate of 80 acms at 120° C (170,000 acfm at 250° F). It is a suction-type baghouse with eight compartments. The gross air-to-cloth ratio is 0.94:1 m/min (3.1:1 ft/min). Bag cleaning is accomplished by a shaker mechanism and the fabric type is dacron. No visible emissions evaluation was attempted on the transfer points at the hot metal mixers. However, the fume capture was noted to be very effective. Visible emissions observations were performed on the baghouse discharge points. The data are presented and discussed in Section 4.5.1.2.

4.4 CONTROL OF PRIMARY EMISSIONS[1]

Primary emissions refer to those emissions leaving the mouth of the furnace vessel during the oxygen blow that are captured by the primary hood. The types of control equipment used in the United States to capture and collect particulate emissions from the vessel mouth are open hood systems with scrubbers or ESP's and closed hood systems used in conjunction with scrubbers. Selection of a control device for the vessel waste gases is interrelated with the selection of hood design for capturing the gases.

Carbon monoxide is emitted from the vessel mouth during the oxygen blowing phase of the cycle. The gas temperature is sufficiently hot to promote combustion of CO if air is permitted to mix with the waste gas. A design decision must be made to determine how much air, if any, is allowed to mix with the gas, so that hood cooling capacity can be matched to the system needs. Obviously, some air must be admitted to obtain the capture velocity that is required to contain fume emissions within the hood.

Many of the early BOPF furnace installations used precipitators for controlling particulate emissions. Because of the potential for igniting CO/air mixtures by precipitator sparking, it was necessary to use an open hood to admit large quantities of excess combustion air at the hood and to facilitate the complete combustion of CO. This design decision led to larger gas volumes to be treated for control of particulate emissions than is necessary for closed hood furnaces.

More recent plant designs have incorporated limited or partial combustion of CO (closed hood design), thereby reducing the heat generated in the hood and the gas volume to be treated. Careful control of the amount of air admitted to the hood allows 10 to 50 percent combustion of CO according to the designer's preference. Gas cleaning over recent years has involved exclusively scrubbers to reduce explosion hazards. The advantages of partial combustion are reduced energy consumption for gas cleaning, as compared to a scrubber on a full combustion hood, and the potential for recovering CO as a low-grade fuel source--7.5 million J/scm (200 BTU/scf). Though many plants in the United States are now operating with partial combustion hoods, none of the plants are recovering the CO and the gas is flared before discharging it to the atmosphere.

Under the present new source performance standard (NSPS) for BOPF primary emissions, particulate discharges are limited to 50 mg/dscm (0.022 gr/dscf). Because of the large differences in waste gas flows that are produced by the various open and closed hood designs, the total particulate discharges vary significantly. For instance, with a typical open hood, ESP gas flow rate of 47 dscm/min/Mg (1,500 dscfm/ton) of steel, 2.35 g/min (0.0047 lb/min) of particulate may be discharged per megagram (ton) of steel.[29] For a typical closed hood scrubber flow rate of 9.1 dscm/min/Mg (290 dscfm/ton) of steel for a top blown furnace, only 0.47 g/min (0.00094 lb/min) of particulate may be discharged per megagram (ton) of steel.[29] Therefore, from the standpoint of total air pollutant emissions, the closed hood scrubber control technology is more effective. Data presented later in this section support this point.

4.4.1 Closed Hood Scrubber Control Technology

Figure 4-8 shows a typical configuration for a scrubber installed on a BOPF with a closed hood. In the closed system, the hood usually fits close to the furnace mouth to restrict the inflow of combustion air. Since a completely closed hood would restrict vessel tilting, the hood skirt must be movable. Otherwise, the flow of combustion air must be restricted by some other means than a close fitting hood.

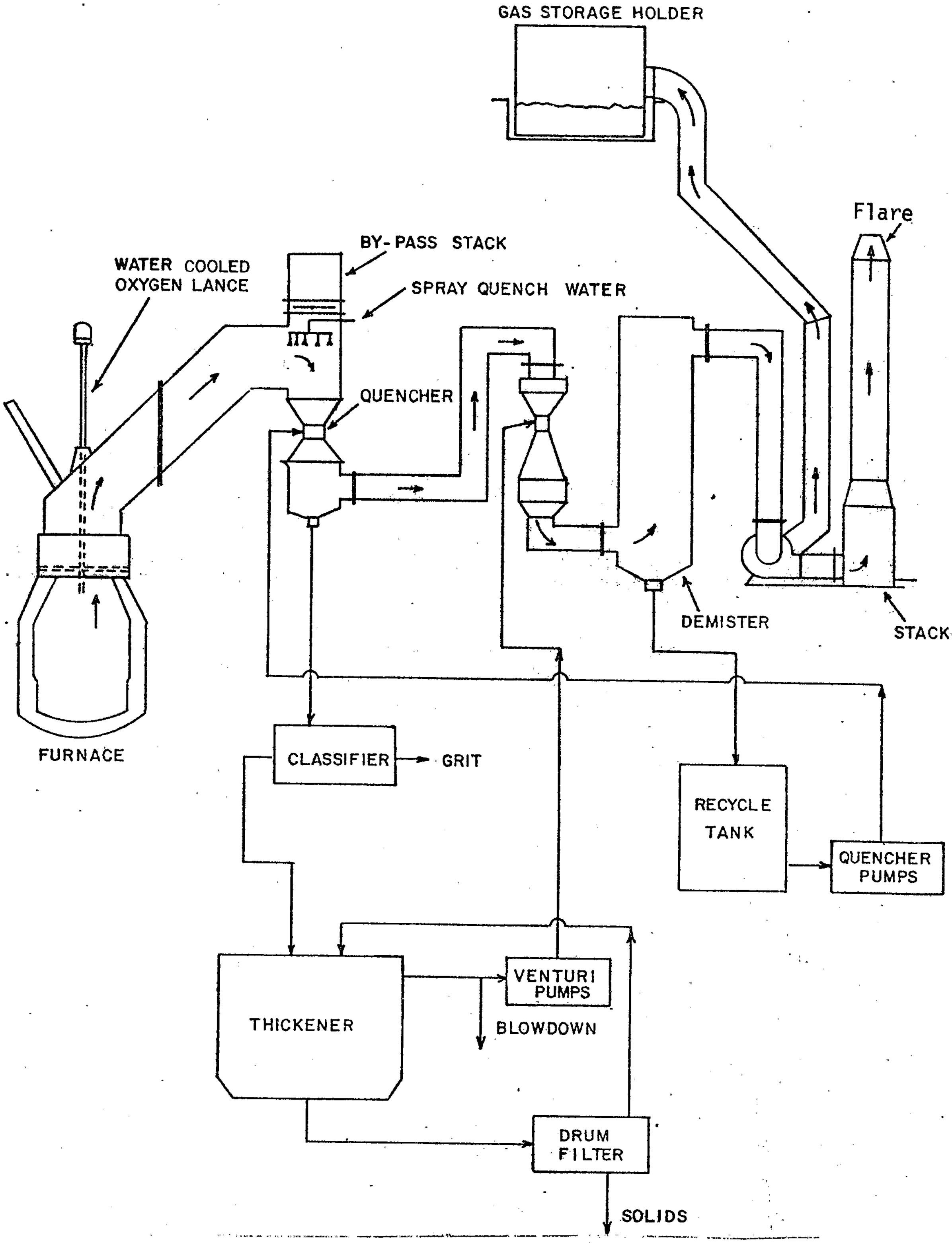


Figure 4-8. Typical scrubber configuration for closed hood BOPF.[1]

There is also a need to limit the amount of air infiltration downstream of the hood. Normal points of leakage in an open hood system such as the lance port and flux chutes must be sealed and purged of nitrogen before use.

Initial cooling of the gas leaving the furnace is carried out via a water-cooled hood. Cooling is continued by the use of a spark box or quencher, in which grit and coarse particles resulting from refractory and chunks of slag or metal are separated from the gas stream. Quenchers reduce the gas temperature to less than 93° C (200° F) and saturate the gas with water vapors.

From the quencher, the waste flows to a high-energy scrubbing device where the removal of fine particles occurs. The most common scrubber type is a venturi with an adjustable throat. The venturi is opened or closed to increase or decrease gas velocity, i.e., pressure drop through the throat.

An integral part of the scrubbing unit is a moisture-separating device to knock out drops of water carried out of the throat. The device may be a series of baffles or a centrifugal chamber in which the gas rotates, causing the drops to impinge on the chamber walls. Also, an after-cooling chamber is sometimes used in which the used cooling water is sprayed to further reduce the gas temperature. At cooler temperatures, moisture condenses from the gas, thus reducing the volume of gas to be handled by the fan. The system may have multiple venturi throats, but draft is provided only by a single fan. The gas cleaning facilities are not shared between adjacent furnace vessels; each furnace has an independent gas cleaning system. At present all closed hood systems in the United States flare the carbon-monoxide-rich waste gas stream generated during oxygen blowing. Alternatively, the gas may be recovered in a gas holding device and used as fuel gas for other plant operations.

Draft control for the closed hood systems is critical to the proper control of the combustion reaction. The systems typically include hood pressure sensors to alter draft via the adjustable venturi throat. Because the hood draft is so carefully limited to near atmospheric pressure, there is a tendency for these primary systems to emit hood puffs.

A recycle water system is the typical way in which scrubber wastewater is handled. This system incorporates a preclassifier, a thickener(s), and a thickener underflow dewatering device. Schematically, the "clean" water overflow from the thickener is pumped to the venturi throat. The use of high pressure spray nozzles dictates the need for a relatively clean water supply at this point. The water and solids are separated from the gas stream in the moisture separator.

The water out of the separator flows to a recycle or surge tank. From the tank, part of this water is pumped to the quencher and part to the thickener(s). The used quench water, containing coarse particles, flows through the preclassifier before returning to the thickener. There are variations on this flow arrangement as to location of the preclassifier and the recycle tank, but the water supply to the venturi must be the cleanest water available in the system.

Underflow from the thickener(s) is pumped to a rotary drum vacuum filter or centrifuge for dewatering. The cake produced is usually trucked to a landfill in an open or tank truck. If the dewatering operation is not sufficiently effective, the tank truck would be the preferred method of transport.

Improved settling and sludge dewatering may be achieved by the addition of polyelectrolytes. Blowdown from the recycle system may require pH adjustment and further removal of suspended solids to meet effluent guideline limitations. Chemical additions are also made to the recycled water to control scaling and corrosion.

4.4.1.1 Control System Performance--Closed Hood, Top Blown. The data base for this subcategory is composed of tests performed in developing the current NSPS as far back as 1971 and more recent compliance tests in 1978. The particulate measurements were made in accordance with EPA Reference Method 5. All of these data were obtained by sampling over the period beginning with the oxygen blow (or scrap preheat) and ending just prior to tapping. These data are presented in Tables 4-8 and 4-9. For the purposes of the analysis of data in Table 4-8, all the particulate emissions measured were assumed to have been produced during the oxygen blow only.

Since the length of oxygen blow can have a significant effect on the total particulate emissions, the data have been normalized to unit time of oxygen blow. The mean emission rate for top blown furnaces listed in the table is 0.443 g/Mg (0.886×10^{-3} lb/ton) of steel produced per minute of oxygen blow/cycle.

Table 4-9 presents the test results based on outlet concentration as opposed to a process weight basis. The concentration data for the top blown furnaces were obtained by sampling during both blowing and nonblowing periods of the furnace cycle. These concentrations were adjusted by calculations based on the assumption that all particulate mass measured was emitted during oxygen blowing only. This assumption tends to overestimate the concentration that would be measured during oxygen blowing only. The 3-test averages for both Kaiser Steel furnaces were below the present NSPS of 0.05 g/dscm (0.022 gr/dscf) even with the adjustment. The three-test average for Armco Steel on an adjusted basis is 0.055 g/dscm (0.024 gr/dscf), which is above the present NSPS. As discussed in Section 4.2.1.1, 95-percent prediction limits were calculated for these data. The 95-percent prediction level for primary emissions from the closed hood collection devices was 0.066 g/dscm (0.029 gr/dscf).

Other closed hood, top blown furnace performance data tending to support the principal data base are shown in Tables 4-10 and 4-11. The test reports in which these data were found were subjected to an internal review by EPA. The review criteria included a data reduction check, availability of all field and analytical data, documentation of process and control device operating parameters, and the presence of an on-site regulatory observer or authorized representative. The data in Tables 4-10 and 4-11 were not put into the principal data base because they failed to meet one or more of the above criteria.

4.4.1.2 <u>Control System Performance--Closed Hood, Bottom Blown</u>. The data base for this subcategory consists of tests performed to determine compliance in 1978. These measurements were also made in

TABLE 4-8. PRINCIPAL PRIMARY EMISSION DATA--CLOSED HOOD[30 31 32 33]

Plant	Date	Blow time (min)	Number of cycles	Emissions: Process weight basis, g/Mg steel produced (lb/ton)	Emissions: Normalized process weight, g/Mg steel produced/min oxygen blow/cycle (lb/ton/min/cycle × 10^3)	Scrubber pressure drop, cm H_2O (in H_2O)
Kaiser Steel[a]						
BOPF 5	12/16/78	31.31	2	9.30 (0.0186)	0.594 (1.190)	175 (69)
	12/18/78	29.64	2	9.09 (0.0182)	0.613 (1.229)	178 (70)
	12/18/78	32.25	2	8.85 (0.0177)	0.549 (1.100)	185 (73)
BOPF 6	12/14/78	31.92	2	7.26 (0.0145)	0.455 (0.911)	226 (89)
	12/14/78	30.28	2	5.22 (0.0105)	0.345 (0.691)	224 (88)
	12/16/78	30.97	2	6.97 (0.0140)	0.450 (0.902)	221 (87)
ARMCO Steel[a]						
	10/20/71	123.75	6	5.77 (0.0116)	0.280 (0.561)	~152 (~60)
	10/21/71	117.80	6	7.01 (0.0141)	0.357 (0.716)	~152 (~60)
	10/23/71	124.14	6	7.11 (0.0143)	0.344 (0.689)	~152 (~60)
U.S. Steel[b]						
Furnace C	10/17/78	78.50	6	7.37 (0.0148)	0.563 (1.129)	165 (65)
	10/18/78	71.10	5	8.32 (0.0167)	0.585 (1.173)	168 (66)
	10/19/78	64.30	5	8.18 (0.0164)	0.636 (1.275)	170 (67)
Furnace X	12/13/78	69.88	5	7.24 (0.0145)	0.518 (1.038)	173 (68)
	12/14/78	80.15	5	10.23 (0.0205)	0.638 (1.279)	168 (66)
	12/15/78	71.95	5	7.48 (0.0150)	0.520 (1.042)	173 (68)

[a]Top blown furnace.

[b]Bottom blown furnace.

TABLE 4-9. PRINCIPAL PRIMARY EMISSION DATA--CLOSED HOOD[30 31 32 33]

Plant	Date	Blow time (min)	Number of cycles	Emissions: Process weight basis, g/Mg steel produced (lb/ton)	Emissions: Outlet concentration, g/dscm (gr/dscf)	Scrubber pressure drop, cm H_2O (in H_2O)
Kaiser Steel[a]						
BOPF 5	12/16/78	31.31	2	9.30 (0.0186)	0.048 (0.021)[b]	175 (69)
	12/18/78	29.64	2	9.09 (0.0182)	0.046 (0.020)[b]	178 (70)
	12/18/78	32.25	2	8.85 (0.0177)	0.041 (0.018)[b]	185 (73)
BOPF 6	12/14/78	31.92	2	7.26 (0.0145)	0.034 (0.015)[b]	226 (89)
	12/14/78	30.28	2	5.22 (0.0105)	0.030 (0.013)[b]	224 (88)
	12/16/78	30.97	2	6.97 (0.0140)	0.039 (0.017)[b]	221 (87)
ARMCO Steel[a]						
	10/20/71	123.75	6	5.77 (0.0116)	0.048 (0.021)[b]	~152 (~60)
	10/21/71	117.80	6	7.01 (0.0141)	0.071 (0.031)[b]	~152 (~60)
	10/23/71	124.14	6	7.11 (0.0143)	0.046 (0.020)[b]	~152 (~60)
U.S. Steel[c]						
Furnace C	10/17/78	78.50	6	7.37 (0.0148)	0.048 (0.021)	165 (65)
	10/18/78	71.10	5	8.32 (0.0167)	0.048 (0.021)	168 (66)
	10/19/78	64.30	5	8.18 (0.0164)	0.053 (0.023)	170 (67)
Furnace X	12/13/78	69.88	5	7.24 (0.0145)	0.043 (0.019)	173 (68)
	12/14/78	80.15	5	10.23 (0.0205)	0.055 (0.024)	168 (66)
	12/15/78	71.95	5	7.48 (0.0150)	0.048 (0.021)	173 (68)

[a]Top blown furnace.

[b]Adjusted to oxygen blow time only.

[c]Bottom blown furnace.

TABLE 4-10. SUPPLEMENTARY PRIMARY EMISSION DATA--CLOSED HOOD[34 35 36 37 38 39]

Plant	Date	Blow time (min)	Number of cycles	Emissions: Process weight basis, g/Mg steel produced (lb/ton)	Emissions: Normalized process weight, g/Mg steel produced/min oxygen blow/cycle (lb/ton/min/cycle × 10^3)	Scrubber pressure drop, cm H_2O (in H_2O)
U.S. Steel[a] Lorain						
	11/16/71	97.20	6	0.97 (0.0020)	0.060 (0.120)	>178 (>70)
	11/17/71	102.20	6	3.93 (0.0079)	0.231 (0.463)	>178 (>70)
	11/18/71	109.10	6	1.73 (0.0035)	0.095 (0.191)	>178 (>70)
	11/26/72	102.80[b]	6	1.04 (0.0021)	0.061 (0.122)	--
	11/27/72	102.80[b]	6	0.71 (0.0014)	0.042 (0.084)	--
	11/27/72	102.80[b]	6	2.40 (0.0048)	0.140 (0.280)	--
U.S. Steel[c] Gary						
East	4/17/75	78.00	4	13.77[d] (0.0276)	0.706 (1.415)	160 (63)
	4/21/75	77.00	4	14.52[d] (0.0291)	0.753 (1.510)	158 (62)
	4/24/75	73.00	4	10.49[d] (0.0210)	0.575 (1.152)	173 (68)
West	4/22/75	67.00	4	5.42[d] (0.0109)	0.324 (0.684)	160 (63)
	4/23/75	68.00	4	2.21[d] (0.0044)	0.130 (0.261)	158 (62)
	4/23/75	72.00	4	5.96[d] (0.0119)	0.331 (0.663)	163 (64)
Republic Steel[c]						
	8/4/77	48.00	4	6.67[d] (0.0134)	0.556 (1.113)	203 (80)[e]
	8/6/77	48.00	4	6.91[d] (0.139)	0.576 (1.154)	203 (80)[e]
U.S. Steel[c]						
Furnace U	11/6/74	75.00	5	4.76[d] (0.0095)	0.317 (0.635)	180 (71)
	11/7/74	64.00	4	5.57[d] (0.0112)	0.348 (0.698)	175 (69)
	11/7/74	59.00	4	5.42[d] (0.0109)	0.367 (0.736)	173 (68)
Furnace C	9/8/78	67.25	5	7.79 (0.0156)	0.580 (1.161)	170 (67)
	9/9/78	55.20	4	10.68 (0.0214)	0.774 (1.551)	160 (63)
	9/9/78	70.67	5	7.91 (0.0159)	0.560 (1.121)	178 (70)

[a]Top blown furnace.

[b]Average oxygen blow based on earlier tests.

[c]Bottom blown furnace.

[d]Based on 200 tons/heat, nominal production.

[e]Design value, Reference 10.

TABLE 4-11. SUPPLEMENTARY PRIMARY EMISSION DATA--CLOSED HOOD[34 35 36 37 38 39]

Plant	Date	Blow time (min)	Number of cycles	Emissions: Process weight basis, g/Mg steel produced (lb/ton)	Emissions: Outlet concentration (g/dscm [gr/dscf])	Scrubber pressure drop, cm H_2O (in H_2O)
U.S. Steel[a] Lorain						
	11/16/71	97.20	6	0.97 (0.0020)	0.007 (0.003)[c]	>178 (>70)
	11/17/71	102.20	6	3.93 (0.0079)	0.030 (0.013)[c]	>178 (>70)
	11/18/71	109.10	6	1.73 (0.0035)	0.011 (0.005)[c]	>178 (>70)
	11/26/72	102.80[b]	6	1.04 (0.0021)	0.007 (0.003)[c]	---
	11/27/72	102.80[b]	6	0.71 (0.0014)	0.005 (0.002)[c]	---
	11/27/72	102.80[b]	6	2.40 (0.0048)	0.018 (0.008)[c]	---
U.S. Steel[d] Gary						
East	4/17/75	78.00	4	13.77[e] (0.0276)	0.021 (0.009)[c]	160 (63)
	4/21/75	77.00	4	14.52[e] (0.0291)	0.023 (0.010)[c]	158 (62)
	4/24/75	73.00	4	10.49[e] (0.0210)	0.018 (0.008)[c]	173 (68)
West	4/22/75	67.00	4	5.42[e] (0.0109)	0.011 (0.005)[c]	160 (63)
	4/23/75	68.00	4	2.21[e] (0.0044)	0.005 (0.002)[c]	158 (62)
	4/23/75	72.00	4	5.96[e] (0.0119)	0.011 (0.005)[c]	163 (64)
Republic Steel[d]						
	8/4/77	48.00	4	6.67[e] (0.0134)	0.053 (0.023)	203 (80)[f]
	8/6/77	48.00	4	6.91[e] (0.0139)	0.050 (0.022)	203 (80)[f]
U.S. Steel[d]						
Furnace U	11/6/74	75.00	5	4.76[e] (0.0095)	0.030 (0.013)	180 (71)
	11/7/74	64.00	4	5.57[e] (0.0112)	0.032 (0.014)	175 (69)
	11/7/74	59.00	4	5.42[e] (0.0109)	0.034 (0.015)	173 (68)
Furnace C	9/8/78	67.25	5	7.79 (0.0156)	0.055 (0.024)	170 (67)
	9/9/78	55.20	4	10.68 (0.0214)	0.059 (0.026)	160 (63)
	9/9/78	70.67	5	7.91 (0.0159)	0.050 (0.022)	178 (70)

[a]Top blown furnace.

[b]Average oxygen blow based on earlier tests.

[c]Adjusted to oxygen blow time only.

[d]Bottom blown furnace.

[e]Based on 200 tons/heat, nominal production.

[f]Design value, Reference 10.

accordance with EPA Reference Method 5. All of these data were obtained by sampling during the primary oxygen blow only. The data are presented in Tables 4-8 and 4-9. The data in Table 4-8 have also been normalized to unit time of oxygen blow. The mean emission rate for the bottom blown furnaces listed in the table is 0.577 g/Mg (1.153×10^{-3} lb/ton) of steel produced per minute of oxygen blow/cycle. Both the process weight column and normalized process weight column data have been adjusted to reflect total emissions during the entire oxygen blowing period. The adjustment was made by multiplying emissions measured during the primary oxygen blow by the factor (total blow time/primary blow time).

Table 4-9 shows the measured emission concentration for bottom blown furnaces. These concentrations were not adjusted because the measurements were made during oxygen blow only. The three-test averages for both furnaces are less than or equal to the present NSPS.

Other closed hood, bottom blown furnace performance data tending to support the principal data base are shown in Tables 4-10 and 4-11. These data were not included in the principal data base after EPA review due to test and test report deficiencies as discussed in Section 4.4.1.1.

4.4.2 Open Hood Scrubber and ESP Control Technology

An open hood scrubber control system is basically the same as the closed hood system. The hood skirt is in a fixed position instead of movable and no precautions for leakage into the system are necessary. Control systems may be shared between furnaces and multiple fans operating in a parallel flow arrangement can be used if desired.

When a precipitator is used (Figure 4-9), gas cooling downstream from the hood skirt is continued by the use of water sprays located in the upper part of the hood. These sprays are generally controlled by time and temperature to turn on and off at various points in the operating cycle. The intent is to limit the gas temperature reaching the precipitator and to moisture condition the gases for better precipitation. The maximum temperature of gases entering the precipitator is usually kept under 343° C (650° F). Flaring of carbon-

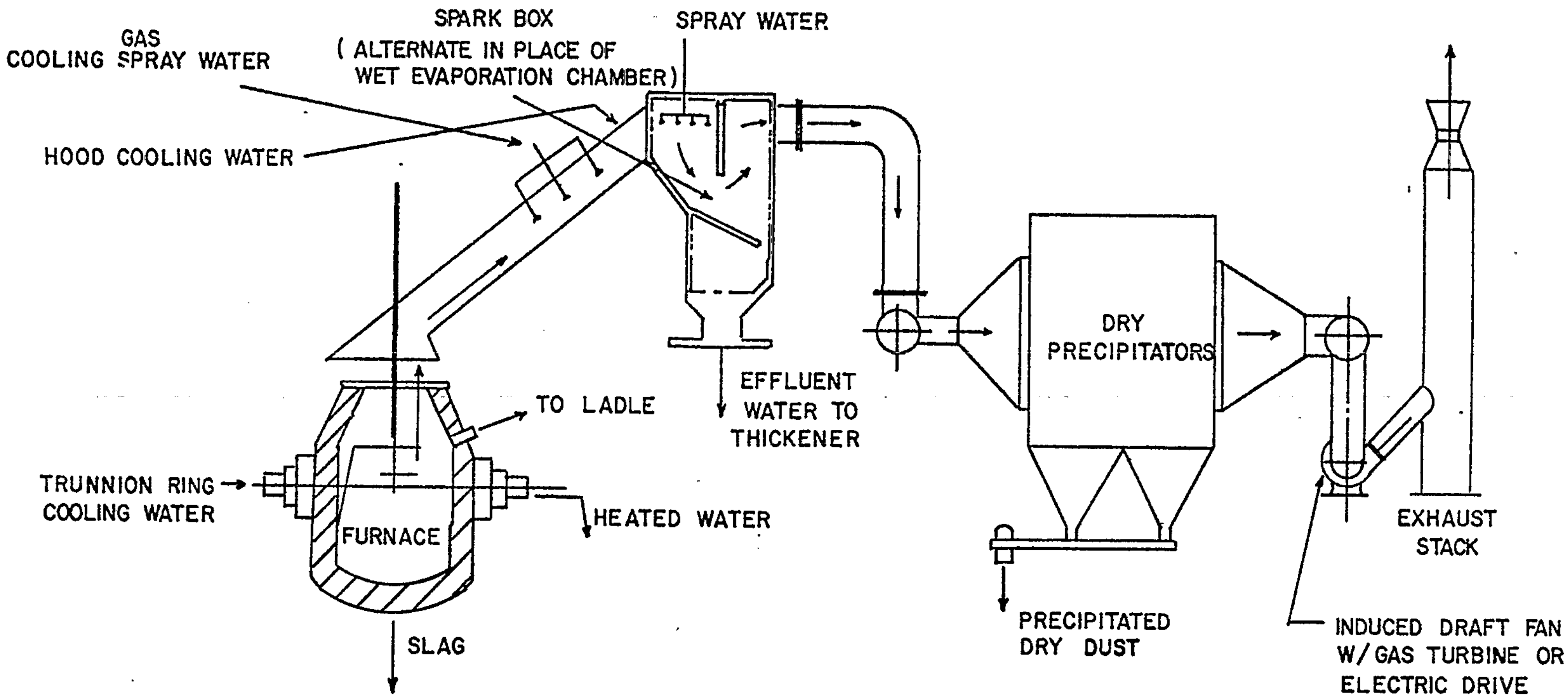


Figure 4-9. Typical configuration for BOPF with open hood ESP.[1]

monoxide-rich gas practiced in closed hood systems is not necessary in open hood systems since the CO is burned in the open hood.

Because the gas temperature is relatively low during hot metal charging and the early minutes of a blow, some plants use steam injection either at the hood sprays or spark box location to achieve the desired conditioning of gases. Water sprays do not evaporate sufficiently under the low temperature conditions, and puffs of iron oxide fume are typically observed coming from the stack during this period. Steam injection, both at the beginning and end of the blow, can reduce these puffing emissions.

Downstream of the spark box, the gases are carried to an inlet plenum that distributes the gas to multichambered precipitators. On the outlet side of the precipitator there is usually a manifold arrangement that distributes the gases among multiple fans. The precipitators may or may not have spare capacity in terms of an extra chamber or extra collection field in the direction of gas flow. It is common that at least one spare fan is available.

In a two-vessel shop, ducts from each vessel join into a common flue upstream of the precipitator inlet plenum. Isolation of each vessel from the precipitator is usually managed by installing guillotine dampers upstream of the junction point. When a vessel is being relined, the fans are then drafting only the operating vessel; otherwise, much draft is wasted on the nonoperating vessel.

Draft and temperature monitoring are normally done at several locations in the system. Sprays are used to control precipitator temperatures; so the spray must be temperature controlled to a certain extent.

At several locations in the system, suction pressure is sensed and used to control the opening and closing of flow control (louver) dampers. For certain phases of the operating cycle, there are specific draft set points that control the evacuation rate of the system. Full system draft is typically used during hot metal charging and the oxygen blow. There may be little or no draft during the remainder of the operating cycle. Draft is limited when hot gases are not available to avoid too much precipitator cooling. The continual expansion and contraction of hood, ducting, and precipitator is structurally detrimental, resulting in leaks. Corrosion may also be a problem for a precipitator if cold air is alternated with hot, moist gas.

Dust removal from the precipitator hopper is most often done by screw conveyors to some common discharge point. Dust removal from the precipitator site is usually by truck to a landfill site.

Overflow water from the spray chamber or spark box flows or is pumped to a settling tank of some sort and the settled solids dragged out by conveyor. If not recycled, plants generally combine the overflow or the blowdown with process water from other plant areas for clarification prior to discharge.

4.4.2.1 Performance Data--Open Hood Control Systems. Performance data from open hood control systems are available from the period between 1975 and 1979. The data were obtained primarily during compliance tests and the data show compliance with the present NSPS. The data are presented in Table 4-12. All the data were taken during oxygen blowing only. None of the three-run averages exceeded 0.050 g/dscm (0.022 gr/dscf). As discussed in Section 4.2.1.1, 95-percent prediction limits were calculated for these data. The 95-percent prediction level for primary emissions from the open hood furnaces was 0.039 g/dscm (0.017 gr/dscf).

It is apparent that some of these open hood control systems complying with the present NSPS have not achieved emission levels as low as those achieved by closed hood control systems. Use of additional precipitator collection surface area or higher scrubber pressure drops in combination with reduced gas flow rates might allow open hood control systems to achieve similar low emission rates on a more consistent basis.

4.5 PARTICULATE MATTER CONTROL DEVICES

The dominant feature of the particles arising in the several steps of the basic oxygen process is their size. The size distributions for Q-BOP charging emissions was presented in Table 3-8. The finest particles are believed to be formed by condensation, the quenching of vaporized iron when it contacts combustion air at the mouth of the

TABLE 4-12. OPEN HOOD SYSTEM PERFORMANCE DATA[40, 41, 42, 43, 44]

Plant	Date	Emissions: Outlet concentration g/dscm (gr/dscf)	Emissions: Process weight basis, g/Mg steel produced (lb/ton × 10^3)
U. S. Steel South Works[a]	6/27/77	0.0089 (0.0039)	1.95 (3.91)[b]
		0.0086 (0.0038)	2.92 (5.85)[b]
		0.0103 (0.0045)	3.45 (7.10)[b]
		0.0087 (0.0038)	2.94 (5.89)[b]
	6/29/77	0.0141 (0.0062)	5.64 (11.31)[b]
		0.0127 (0.0056)	5.14 (10.30)[b]
		0.0112 (0.0049)	3.39 (6.80)[b]
		0.0101 (0.0044)	3.86 (7.74)[b]
	7/1/77	0.0167 (0.0073)	5.74 (11.51)[b]
		0.0165 (0.0072)	6.04 (12.11)[b]
		0.0118 (0.0052)	4.41 (8.84)[b]
		0.0119 (0.0052)	4.10 (8.22)[b]
CF&I Steel[c]	4/10/78	0.0503 (0.0220)	33.38 (66.91)[b]
	4/11/78	0.0224 (0.0098)	13.30 (26.66)[b]
		0.0263 (0.0115)	18.71 (37.51)[b]
	4/12/78	0.0222 (0.0097)	13.77 (27.60)[b]
		0.0214 (0.0094)	12.55 (25.16)[b]
Republic Steel[c]	10/20/75	0.0275 (0.0120)	---
	10/21/75	0.0297 (0.0130)	---
	10/22/75	0.0275 (0.0120)	---
Youngstown Sheet and Tube[c] (Now J&L Steel)	6/12/78	0.030 (0.013)	18.64 (37.37)[d]
	6/13/78	0.018 (0.008)	10.98 (22.00)[d]
	6/14/78	0.027 (0.012)	13.62 (33.03)[d]

[a]Scrubber.

[b]Based on 200 tons nominal capacity.

[c]ESP.

[d]Based on 280 tons nominal capacity.

vessel. Mixed with these fine particles of condensed iron oxide in the secondary emissions are graphite or kish that are formed from carbon present in molten iron. If not collected, these emissions, particularly the iron fume, are carried by natural convection up to and out of the roof monitor. If these rising velocities are in the range 0.3 to 3.0 m/s[45] (1 to 10 ft/s), and the particles have specific gravities near five, then sizes up to 200 μm could be lifted.[46] When the plume mixes with cooler air and slows somewhat before accelerating through the constriction imposed by the roof monitor, there may be an opportunity for particles larger than perhaps 40 μm to "rain out," but the smaller fume is entrained.

Devices suitable for the collection of such fine solids with a 98-percent or higher efficiency are the fabric filter, the high performance wet scrubber, and the ESP. Precipitators and wet scrubbers are in widest use for primary emissions. Fabric filters are in widest use of the three types in BOPF secondary emission control.[19] In fact, these three devices can be designed with such efficiencies that the limitation in overall performance on secondary emissions traces to the hood rather than the control device.

4.5.1 The Fabric Filter

This control device has been amply described in previous EPA documents[47,48] and vendors' literature. Only a brief summary is appropriate here. The fume, after capture at the hood and transport through a duct, comes to the fabric filter. The interstices between the fibers in a woven or felted bag are partially blocked by particles not removed during the last cleaning operation, and ordinarily a coating or cake of particles is deposited on the fabric. The gas can penetrate the cake and the underlying fabric, but few particles can pass through an undamaged fabric with a cake deposited on it. The collection efficiency can be very high (> 99 percent) if damaged fabric is promptly replaced.

The common geometry is multiple cylindrical fabric bags disposed in several independent compartments to permit cleaning and maintenance. As the dusty air is filtered, the cake builds up and the pressure drop increases. On a predetermined schedule, or when the pressure drop across a compartment has risen to a predetermined level, the bags in that compartment are cleaned mechanically or pneumatically, although never to their original condition. The solids thus collected drop into a hopper. If the solids are abrasive or if cleaning is too frequent or vigorous, bag life is shortened; frequent bag failure is expensive and reduces the average collection efficiency. For similar reasons, the dust should not approach a freshly cleaned bag too fast; this maximum face velocity or air-to-cloth ratio for iron oxide is said to be about 0.61 $m^3/min/m^2$ (2 $ft^3/min/ft^2$).[47] Current bag materials and cleaning methods may have modified this figure somewhat. Taken together with the desired exhaust volume and the specified excess capacity, this rule of thumb dictates the total fabric area and the cost of the control unit.

Depending on the gas temperatures involved, polyester, aramide, or fiberglass fabrics may be used for the secondary emissions. If certain operations should happen to be near the filter unit, it is conceivable that hot particles may be cast onto the fabric. Since the smaller particles cool more rapidly, it is necessary to provide a spark box to deflect the larger ones.

Dust-handling facilities must be provided. Ideally, the collected solids are recycled to the process via the sinter plant. However, if the charge is in part galvanized or terne scrap, the charging emissions may contribute unacceptable levels of zinc or lead to the filter catch. Since these ingredients are detrimental to blast furnace refractory linings, such solids (in this country) are commonly landfilled.[49]

Fabric filters are in use for several steel process gas cleaning applications. The facility at Kaiser Steel for secondary emission control treats waste gases from charging, tapping, puffing (during oxygen blow), furnace deslagging, hot metal transfer, and hot metal skimming. Fabric filters are used to collect hot metal transfer emissions at numerous plants in the United States. Fabric filters are also applied to many U.S. EAF's. In addition to the U.S. installations, there are many secondary emission control systems with fabric filter collectors in use in BOPF shops outside the United States, particularly in Japan but also in several European plants. Fabric filters are not normally used for the control of primary emissions from BOPF shops.

4.5.1.1 Performance Data--Mass Emissions. Performance test data are available from fabric filter controlled systems applied to both BOPF secondary sources and EAF's. Because the particulate characteristics are similar, data on the performance of EAF enclosures are applicable to BOPF secondary emission control baghouses. Figure 4-10 presents the performance data graphically. Each point represents an individual test run. As is evident, all of the outlet concentrations are below 22.8 mg/dscm (0.010 gr/dscf).

4.5.1.2 Performance Data--Visible Emissions. Visible emissions data for discharged gases leaving BOPF secondary emission baghouses have been obtained for three sources. Visible emissions were read during the performance testing of the Wheeling-Pittsburgh Steel hot metal transfer baghouse in Mingo Junction, Ohio.[52] Similar data were obtained from two baghouses at U.S. Steel Q-BOPF in Fairfield, Alabama.[56] One baghouse serves the canopy hood above Furnace C for collecting fugitive hot metal charging emissions and the south hot metal mixer and transfer station. The other baghouse serves the north hot metal mixer and transfer station.

The test method used was EPA Reference Method 9. The data were analyzed, however, by computing 3-minute averages instead of 6-minute averages. These data are summarized in Tables 4-13, 4-14, and 4-15. As is evident, none of the 3-minutes averages equalled or exceeded 5 percent opacity.

4.5.2 Wet Scrubbers

This class of particulate control devices has been amply described.[46 58] Scrubbers are most frequently used for primary emission control. Few scrubbers are currently used for secondary emission control.[3 17 18]

Briefly, the operating principle of the venturi scrubber is as follows: The dusty gas is forced into a constriction, where it attains a velocity in the range 45 to 150 m/s (150 to 500 ft/s). At about

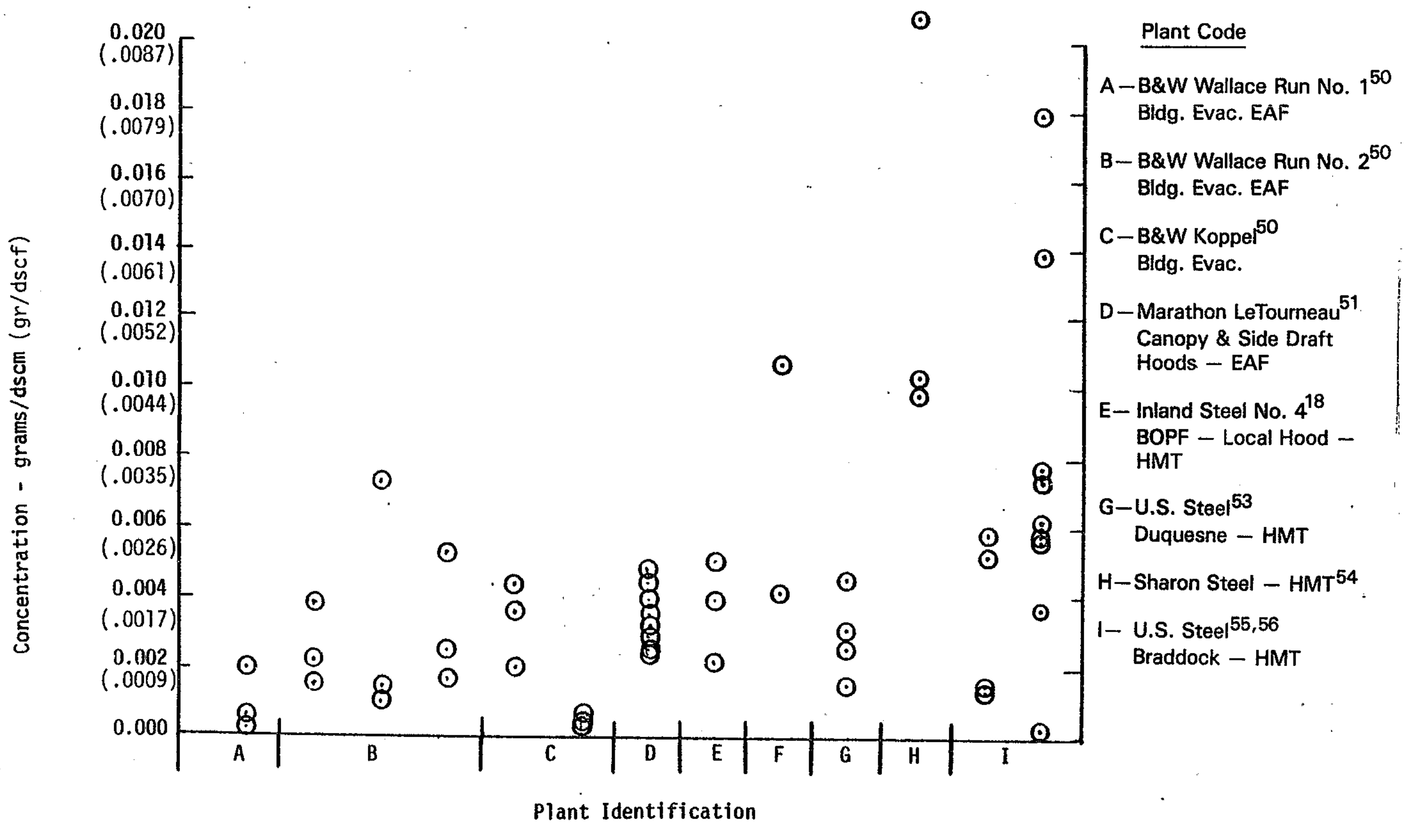


Figure 4-10. Fabric filter outlet concentration for BOPF and EAF sources.

TABLE 4-13. WHEELING-PITTSBURGH STEEL, MINGO JUNCTION, OHIO, HMT BAGHOUSE VISIBLE EMISSION DATA[52]

Date	Time Start	Time Stop	Number of 3-minute averages	Opacity (percent)
7/29/80	1400	1505	18	0.0
			1	0.4
			2	0.8
			1	4.2
	1511	1530	6	0.0
	1600	1614	5	0.0
7/30/80	1100	1120	6	0.0
			1	0.4
	1140	1204	8	0.0
	1220	1249	10	0.0
	1315	1335	7	0.0
	1400	1426	9	0.0
7/31/80	1100	1123	6	0.0
			2	0.4
	1138	1204	8	0.0
			1	0.4
	1215	1244	10	0.0
	1250	1310	7	0.0
	1340	1356	5	0.0
	1425	1438	4	0.0

TABLE 4-14. UNITED STATES STEEL, FAIRFIELD, ALABAMA, CANOPY HOOD AND SOUTH MIXER BAGHOUSE[57]

Date	Time Start	Time Stop	Number of 3-minute averages	Opacity (percent)
Observer: Howison				
5/11/81	1434	1533	20	0.0
	1542	1635	18	0.0
5/12/81	0937	1000	8	0.0
5/13/81	1200	1259	10	0.0
			3	0.4
			2	1.3
			2	1.7
			2	2.1
			1	2.5
	1310	1409	9	0.0
			6	0.4
			3	1.3
			1	2.1
			1	4.2
	1420	1519	19	0.0
			1	2.5
5/14/81	0930	1029	20	0.0
	1200	1259	16	0.0
			2	0.4
			2	1.3
	1310	1409	16	0.0
			2	0.4
			2	0.8
	1420	1519	19	0.0
			1	0.4
	1530	1629	20	0.0
5/15/81	1345	1444	19	0.0
			1	0.8
	1455	1554	20	0.0
	1605	1634	10	0.0
Observer: Clark				
5/11/81	1433	1532	20	0.0
	1542	1632	18	0.0
5/12/81	0937	1000	7	0.0
5/13/81	1200	1259	14	0.0
			5	0.8
			1	1.3
	1310	1409	14	0.0
			2	0.4
			2	0.8
			1	3.3
			1	5.0

(continued)

TABLE 4-14 (continued)

Date	Time Start	Time Stop	Number of 3-minute averages	Opacity (percent)
5/13/81	1421	1520	19	0.0
			1	2.5
	1530	1617	16	0.0
5/14/81	0930	1029	20	0.0
	1200	1259	18	0.0
			1	1.3
			1	1.7
	1310	1409	17	0.0
			3	0.4
	1420	1519	30	0.0
	1530	1629	20	0.0
5/15/81	1345	1444	20	0.0
	1455	1554	20	0.0
	1605	1634	10	0.0

TABLE 4-15. UNITED STATES STEEL, FAIRFIELD, ALABAMA, NORTH MIXER BAGHOUSE[57]

Date	Time Start	Time Stop	Number of 3-minute averages	Opacity (percent)
Observer: Howison				
5/12/81	1115	1156	11	0.0
			1	0.8
			2	0.4
5/13/81	0930	1029	20	0.0
	1040	1139	20	0.0
5/14/81	1045	1144	20	0.0
5/15/81	0930	1029	20	0.0
Observer: Clark				
5/12/81	1115	1156	10	0.0
			1	1.7
			1	2.5
			1	4.2
			1	0.4
5/13/81	0930	1029	20	0.0
	1039	1138	20	0.0
5/14/81	1045	1144	20	0.0
5/15/81	0930	1029	20	0.0
	1040	1139	20	0.0

this point, the dusty gas encounters a sheet or spray of liquid (ordinarily recirculated water) having a relatively low velocity. The interaction creates many small droplets that rapidly attain the velocity of the gas. While the droplets are accelerating, the air must pass around each droplet and the heavier particles tend to impact on the droplets in the process . More water and a higher (initial) relative velocity permit the collection of finer particles.

The pressure drop across the device for secondary emssions is 80 to 120 cm (30 to 50 in) of water and 153 cm (60 in) or more of water for primary systems, and the fan work is accordingly high. In fact, the energy consumption of the venturi scrubber is the highest of the three high performance control units described in this section.

Downstream of the venturi proper, a cyclone separates the dirty water droplets from the gas. The resulting slurry of particles in water is conveyed to a settling pond or a thickener, from which a relatively clean overflow is recirculated. Makeup water is required because the dusty gas is hot and must be cooled by evaporation of a direct spray of water. The underflow from a thickener may be filtered and the wet cake recycled under certain circumstances, as described in Section 4.4.1.

Performance of scrubbers applied to primary emission control is discussed in Sections 4.4.1 and 4.4.2. Performance data are displayed in Tables 4-8 through 4-12.

4.5.3 <u>The Electrostatic Precipitator</u>

This control device has also been amply described.[47 59] When a static potential of several thousand volts is maintained between a metal plate and a wire parallel to it, gas moving through the space between the plate and the wire will be ionized (corona discharge). The resulting ions and electrons become attached to dust particles in the gas, usually imparting a net charge. The particles thus charged experience a coulombic attraction toward the plate or grounded electrode. The larger particles will reach the plate and be removed from the gas before it leaves the apparatus. A higher potential (voltage) (within limits) or more residence time will cause the collection of finer particles.

The dust cake that builds up on the plates may fall off by its own weight, or it may be dislodged by mechanical impact on the plate or by washing. Dry dust can be handled as in the fabric filter case, and the slurry from a wet ESP is comparable to that from a wet scrubber.

Precipitators for large-scale, continuous applications are normally compartmentalized. This requires independent power supplies but permits some maintenance without shutdown.

A limiting voltage has been referred to above. When the voltage is raised to a certain level that depends on the gas--its temperature and humidity--and on the geometry, character, and thickness of the cake, an unstable arc replaces the stable corona discharge. The arc is of no use to the process and may damage the power supplies if continued. Therefore, progressively better performance is achieved as the potential is raised, until an arc is struck. In modern ESP's the power supply automatically reduces voltage when arcing occurs; the voltage is brought back up until another arc occurs, and so on. A fortunate consequence of this equipment feature is the ability of the system to track the continually changing composition and temperature of the primary or secondary BOPF emissions.

Because the ionizing behavior of the gas and the character of the cake depend on gas temperature and composition, it is sometimes desirable to condition the gas. This may be as simple as adding moisture, but in other industries it has been found feasible to inject substances such as ammonia, ozone, or sulfur trioxide. For primary BOPF applications, moisture (as water or steam) is essential to good performance. Steam conditioning is important for good performance for secondary emission control, as described in Section 4.2.2.2.

The distinctive feature of the ESP in the steel industry is its low power consumption--the lowest of the three devices considered here. Secondary emission collection by ESP's in the United States is the result of exhausting the secondary gas stream through a primary system or conversion of ESP's once used for primary emissions to secondary system applications. No new ESP's have been constructed specifically for BOPF secondary emission control. Performance data for ESP's applied to BOPF's are presented in Section 4.4.2, Table 4-11.

Previous mention was made in this chapter of steel plants outside the United States having constructed roof-mounted ESP's specifically for secondary emission control. These BOPF roof installations are primarily supplements to local hoods connected to fabric filters. In the case of the Kawasaki Steel, Chiba Works Q-BOPF, the roof-mounted ESP is an effective addition to control the difficult fugitive emissions generated by bottom blowing when the furnace is turned down.[17] The design inlet concentration for this plant is 0.4 g/scm (0.175 gr/scf) and the corresponding outlet is 0.03 g/scm (0.013 gr/scf).[60] Actual measurements have shown an inlet maximum of 1.09 g/scm (0.48 gr/scf) and a maximum outlet of 0.038 g/scm (0.017 gr/scf). In two other installations, outlet concentrations as low as 0.02 g/scm (0.0087 gr/scf) have been measured. Additional collector surface area could provide lower outlet concentrations, but increased collector size and weight would result.

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5. MODIFICATION, RECONSTRUCTION, AND ADDITIONS

In accordance with Section 111 of the Clean Air Act, as amended in 1977, standards of performance shall be established for new sources within a stationary source category that "may contribute significantly to air pollution . . . ." Affected facilities are those for which standards of performance have been promulgated and whose construction or modification began after the proposal of the standards.

Under the provisions of 40 CFR 60.14 and 60.15, an "existing facility" may become subject to standards of performance if deemed modified or reconstructed. An "existing facility" as defined in 40 CFR 60.2(aa) is a facility for which a standard of performance has been promulgated but for which construction or modification began before the date of proposal of that standard. The following discussion examines the applicability of these provisions to basic oxygen process furnace facilities and describes conditions under which existing facilities could become subject to standards of performance.

An important note is that a plant may contain both affected and existing facilities and that reclassifying a facility from existing to affected status by new construction, modification, or reconstruction does not necessarily subject any other facility within that source to standards of performance.

5.1 SUMMARY OF 40 CFR 60 PROVISIONS FOR MODIFICATIONS AND RECONSTRUCTIONS

5.1.1 Modification

Section 40 CFR 60.14 defines modification as follows:

> "Except as provided under paragraph (e) and (f) of this section, any physical or operational changes to an existing facility which result in an increase in emission rate to the atmosphere of any pollutant to which a standard applies shall be a modification. Upon modification, an existing facility shall become an affected

facility for each pollutant to which a standard applies and for which there is an increase in the emission rate."

Paragraph (e) specifies certain physical or operational changes that are not considered as modifications, irrespective of any changes in the emission rate. These changes include:

1. Routine maintenance, repair, and replacement;
2. An increase in production rate accomplished without a capital expenditure [as defined in Section 60.2(bb)];
3. An increase in hours of operation;
4. Use of alternate fuels or raw materials if the existing facility were designed to accommodate the alternate fuel or raw material prior to the standard (conversion to coal required for energy considerations, as specified in Section 111 (a)(8) of the Clean Air Act is also exempted.);
5. Addition or use of any system or device whose primary function is the reduction of air pollutants, except when an emission control system is removed or replaced by a system considered to be less efficient; and
6. Relocation or change in ownership.

Paragraph (f) provides for superseding any conflicting provisions.

Paragraph (b) of CFR 60.14 clarifies what constitutes an increase in emissions and the methods for determining the increase. The emphasis is on the use of emission factors. However, other methods such as material balances, continuous monitoring systems, and manual emission tests may be used where utilization of emission factors is not conclusive. Paragraph (c) of CFR 60.14 affirms that the addition of an affected facility to a stationary source does not make any other facility within the source subject to standards of performance.

5.1.2 Reconstruction

Section 40 CFR 60.15 defines reconstruction as follows:

> "An existing facility, upon reconstruction, becomes an affected facility, irrespective of any change in emission rate. 'Reconstruction' means the replacement of components of an existing facility to such an extent that: (1) the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost that would be required to construct a comparable entirely new facility, and

(2) it is technologically and economically feasible to meet the applicable standards set forth in this part."

The purpose of this provision is to ensure that an existing facility is not perpetuated by replacing all but minor components, such as support structures, frames, and housing, rather than totally replacing the facility in order to avoid becoming subject to applicable standards of performance.

When it is determined that reconstruction has occurred, the regulations require that the affected facility be equipped to meet all applicable new source performance standards.

5.2 APPLICABILITY OF MODIFICATION REGULATIONS TO BOPF SHOP FACILITIES

5.2.1 General

When a change to an existing facility at a BOPF shop increases particulate emissions, it may or may not be deemed to be "modified," depending upon the following factors:

1. The definition of the affected facility.
2. The applicability of the exception provisions of 40 CFR 60.14.
3. The applicability of any other exception provisions that are specially promulgated for the affected facility.

Examples of facility changes at a BOPF shop which may or may not qualify as modifications are as follows:

1. Addition of another BOPF.
2. Addition or expansion of hot metal transfer facilities.
3. Addition or expansion of skimming facilities.
4. Converting a BOPF from top blown to bottom blown or to top and bottom blown.
5. Converting an open hood BOPF to a closed hood BOPF.
6. Converting a closed hood BOPF to an open hood BOPF.
7. Increasing the production capacity of a BOPF.
8. Modifying facilities to permit scrap preheat.

9. Addition or expansion of other BOPF shop facilities.

10. Modifying air pollution control facilities.

These cases are discussed in the following sections.

5.2.2 Addition of Another BOPF

Because the affected facility is defined as only the BOPF, then this kind of change would not be a modification, but would be new source construction and, therefore, the new facility would be subject to NSPS.

5.2.3 Addition or Expansion of Hot Metal Transfer or Skimming Facilities

Hot metal transfer and skimming are each defined as a separate affected facility. Therefore, the addition of either would be new source construction.

The expansion of an existing hot metal transfer or skimming station could be deemed a modification if particulate emissions to the atmosphere increased on a mass rate (kg/hr) basis as a result of the expansion. If emissions increased and the change were not exempted under §60.14(e), then the modified facility would be subject to NSPS. An expansion of the facility could be considered an increase in production rate and under §60.14(e)(2), if it were accomplished without a capital expenditure, it would not be a modification.

5.2.4 Converting a Top Blown BOPF to a Bottom or Top and Bottom Blown BOPF

This type of change would increase secondary particulate emissions. It is not certain what effect this kind of change would have on primary particulate emissions. Under §60.14(a), modification determinations are made on the basis of whether or not the emission rate of a pollutant increases. No distinction is made as to the specific nature of the pollutant (e.g., primary or secondary). Therefore, if there is a net increase in the total primary and secondary particulate emission rates to the atmosphere as the result of converting a top blown BOPF to a bottom blown or top and bottom blown BOPF, then the BOPF would be subject to NSPS for both primary and secondary particulate emissions. Conversely, if it could be demonstrated that the increase in secondary emissions was offset with a similar decrease in primary emissions (i.e., total emissions did not increase), then the change would not be a modification.

5.2.5 Converting an Open Hood BOPF to a Closed Hood BOPF or Vice Versa

In at least one instance, open hood BOPF's have been converted to closed hood BOPF's. In general, primary emissions from well-controlled open hood BOPF's are greater than those from well-controlled closed hood systems. For cases where secondary emissions from an open hood BOPF are controlled using the primary hood, secondary emissions from the open hood system are less than secondary emissions from a closed hood BOPF where the primary hood is the only means used for secondary emission control. Estimates based on emission factors for secondary emissions (Chapter 3) and data on the comparative primary emissions (Chapter 4) indicate that the net difference in secondary emissions is greater than the net difference between primary emissions for the foregoing cases. Consequently, for these cases total particulate emissions would be increased by changing from open hood to closed hood BOPF systems, unless the closed hood BOPF is equipped for effective secondary emission control. For this latter case, total particulate emissions from the closed hood BOPF would be less than total particulate emissions from an open hood BOPF.

5.2.6 Increasing the Production Rate of a BOPF

Increasing the production rate of a BOPF could increase particulate emissions. If an increase in production rate could be accomplished without a capital expenditure on the facility, then it would not be a modification as discussed in Section 5.1.1. A capital expenditure is an expenditure that exceeds the product of the applicable "annual asset guideline repair allowance percentage (AAGRAP)" specified in the latest edition of Internal Revenue Service Publication 534 and the facility's installed cost. The AAGRAP listed in IRS Publication 534, as revised in November 1980, is 18 percent. Increases in production capacity that are effected by improving operating techniques would thus probably not be modifications. Equipment changes to increase production would have to be evaluated on a case-by-case basis.

Relining the furnace with thinner refractory material would tend to increase production capacity. However, since relining the furnace is considered to be routine maintenance, this would not cause the BOPF to become modified and therefore subject to NSPS (see Section 5.1.1).

5.2.7 Changes in a BOPF to Permit Scrap Preheat

A BOPF might be altered to inject fuel for scrap preheat. There would theoretically be increased particulate emissions from the fuel combustion. However, there are no data to confirm this theory. If natural gas or fuel oil is used for scrap preheat, it would be difficult to measure any particulate emission increase since the emission increase would be small in comparison with total emissions from other parts of the production cycle.

Theoretically, this type of change could be a modification. However, in the absence of any data showing that an emission increase has occurred it would be difficult to make this determination.

5.2.8 Addition or Expansion of Other BOPF Shop Facilities

Additions or expansions of other BOPF facilities could involve hot metal desulfurization, dekishing, teeming, ladle cleaning, and slag handling. Since these facilities are not affected facilities, any changes to them would not be "modifications."

5.3 APPLICABILITY OF RECONSTRUCTION REGULATIONS TO BOPF SHOP FACILITIES

5.3.1 General

As discussed in Section 5.2.2, a reconstructed source must be equipped to meet the applicable NSPS. Determining if reconstruction has occurred involves (1) comparing reconstruction costs with the cost of a comparable new facility and (2) determining the technical and economic feasibility of installing controls to meet NSPS.

One purpose of the reconstruction regulations is "to recognize that replacement of many of the components of a facility can be substantially equivalent to totally replacing it at the end of its useful life with a newly constructed affected facility" (42 FR 58417, December 16, 1975).

5.3.2 Basic Oxygen Process Furnace

The affected facility for determining reconstruction costs for a BOPF is as follows:

1. The BOPF vessel, including lining, supports, and foundations.
2. The BOPF drive, controls, control room, and instrumentation, including electrical and hydraulic systems and supports and foundations.

3. The oxygen lance, controls, and instrumentation, including electrical and hydraulic systems and supports.

4. The steel ladle and/or slag pot positioning systems, including controls, instrumentation, supports, and foundations.

The affected facility does not include any of the air pollution control system such as the furnace enclosure, primary hood, ductwork, exhaust ventilation system, air pollution control device, or stack. All facilities used to transport or handle raw materials to the furnace and to transport or handle products from the furnace are not part of the affected facility. These latter systems include facilities such as additive handling systems, ladles, scrap buckets, slag pots, cranes, etc.

Vessel replacement, lining replacement, and oxygen lance replacement by themselves are not considered reconstruction. Because of extreme temperature conditions, vessel replacement is an inherent consequence of making steel by the basic oxygen process. About every 7 to 15 years the vessel shell must be replaced because of changes in the characteristics of the metal of the shell. Replacement cost is about $1 million, or about 20 percent of the $5-million cost of vessel shell, trunnion ring and drive, lance system, and controls.[1] Vessel linings are routinely renewed about every 1,000 to 2,000 production cycles. In addition, parts of the oxygen lance must be renewed on a continuing basis. Consequently, these are not replacements within the intent of the reconstruction regulations as described in Section 5.3.1.

5.3.3 Hot Metal Transfer Station

The affected facility for determining reconstruction costs for a BOPF hot metal transfer station is as follows:

1. The pit and other foundations and supports.

2. Ladles and/or vessels that are an integral part of the station.

3. Systems used to moved the hot metal BOPF ladles within the station.

4. Instrumentation, controls, control room, hydraulic and electrical systems used for hot metal transfer.

The affected facility does not include the air pollution control system such as the hood, ductwork, exhaust ventilation system, air pollution control device, and stack. All facilities used to transport hot metal to and from the station are not part of the affected facility.

In determining costs for reconstruction purposes, routine maintenance and consumable item replacement costs should not be included such as spare parts and mixer vessel replacements that are normally needed to conduct operations. In each case the intent of the regulations as described in Section 5.3.1 should be considered in determining if the cost should be included to decide if reconstruction has occurred.

5.3.4 Hot Metal Skimming Station

The affected facility for determining reconstruction costs for a hot metal skimming station includes all parts of the station that are needed for skimming the hot metal, including foundations and supports, and hydraulic, electrical, and instrumentation systems, control rooms, and controls.

The affected facility does not include the air pollution control system such as the hood, ductwork, exhaust ventilation system, air pollution control device, and stack. All facilities used to transport hot metal to and from the skimming station are not part of the affected facility.

5.4 REFERENCES

1. Telecon. Turner, J. H., Research Triangle Institute with Schempp, E. G., Pennsylvania Engineering Corporation. July 29, 1981. BOPF vessel costs.

6. MODEL PLANTS AND REGULATORY ALTERNATIVES

The impact of various emission control regulations on BOPF's is determined through an analysis of model plants. Model plants are parametric descriptions of both the types of plants that are presently in operation and those which, in EPA's judgment, may be constructed, modified, or reconstructed in the future.

Regulatory alternatives are the courses of action that EPA considers for regulating emissions. Each alternative represents a different level of emission control for the affected facilities and is associated with a particular regulatory action. The bases of the alternatives are the control techniques discussed in Chapter 4. Numerous other courses of action were investigated and then rejected for consideration in conjunction with selection of the alternatives discussed in this chapter.

6.1 MODEL PLANTS

6.1.1 Model Plant Selection

Fifteen model plants have been developed to represent the basic oxygen process furnace (BOPF) source category. Descriptions of the models, including a separate hot metal transfer and slag skimming facility (Model I), are presented in Table 6-1. Schematic drawings of selected models are presented in Figure 6-1.

Two sizes of furnace vessels are represented in the models, with design capacities of 136 Mg (150 tons) and 272 Mg (300 tons). Actual heat sizes may vary slightly depending on production requirements and hot metal availability. The 136-Mg (150-ton) models are representative of some older shops and shops that are involved in the production of

TABLE 6-1. BOPF MODEL PLANTS

Model plant	Description[a]	Production capacity Mg/yr (tons/yr)	Operating mode[b]
A	Two new 272-Mg (300-ton) vessels, closed hoods with scrubbers, top blown equipped with furnace enclosures and baghouse.	2,900,000 (3,200,000)	Sequential
B	One new 272-Mg (300-ton) vesseladded to two existing 272-Mg (300-ton) vessels, closed hood with scrubber, top blown, equipped with furnace enclosure and baghouse.	5,350,000 (5,900,000)	Overlapping
C	Two new 272-Mg (300-ton) vessels, closed hoods with scrubbers,bottom blown, equipped with furnace enclosures and baghouse.	2,900,000 (3,200,000)	Sequential
D	One new 272-Mg (300-ton) vessel added to two existing 272-Mg (300-ton) vessels, open hood with ESP, top blown, equipped with local hoods and baghouse.	5,350,000 (5,900,000)	Overlapping
E	Two existing 272-Mg (300-ton), top blown vessels converted to top-bottom blown (KMS) process, closed hoods with scrubbers equipped with furnace enclosures and baghouse.	2,900,000 (3,200,000)	Sequential
F	Two new 136-Mg (150-ton) vessels, closed hoods with scrubbers, top blown, equipped with furnace enclosures and baghouse.	1,450,000 (1,600,000)	Sequential

See footnotes at end of table. (continued)

TABLE 6-1. (continued)

Model plant	Description[a]	Production capacity Mg/yr (tons/yr)	Operating mode[b]
G	One new 136-Mg (150-ton) vessel added to two existing 136-Mg (150-ton) vessels, closed hood with scrubber, top blown, equipped with furnace enclosure and baghouse.	2,630,000 (2,900,000)	Overlapping
H	Two new 272-Mg (300-ton) vessels,closed hoods with scrubbers, bottom blown equipped with furnace enclosures and baghouse. Conversion of an open hearth shop to basic oxygen process.	2,900,000 (3,200,000)	Sequential
I	Hot metal transfer and skimming station with baghouse.	Meets shop production needs	Not applicable
J	Two new 272-Mg (300-ton) vessels,open hoods, with ESP, top blown. Secondary emissions controlled with primary system.	2,900,000 (3,200,000)	Sequential
K	One new 272-Mg (300-ton) vessel added to two existing 272-Mg (300-ton) vessels, open hood with ESP, top blown, primary system used to control secondary emissions.	5,350,000 (5,900,000)	Overlapping
L	Two new 272-Mg (300-ton) vessels,closed hoods with scrubbers, top blown, equipped with furnace enclosures and baghouse.	4,540,000 (5,000,000)	Overlapping
N	Two new 272-Mg (300-ton) vessels, open hoods with ESP, bottom blown, primary system used to control secondary emissions.	2,900,000 (3,200,000)	Sequential

See footnotes at end of table. (continued)

TABLE 6-1. (continued)

Model plant	Description[a]	Production capacity Mg/yr (tons/yr)	Operating mode[b]
O	Two new 272-Mg (300-ton) vessels, open hoods with scrubbers, top blown, primary system used to control secondary emissions.	2,900,000 (3,200,000)	Sequential
P	One new 272-Mg (300-ton) closed hood vessel added to two existing 272-Mg (300-ton) open hood vessels, top blown. New vessel has primary scrubber, furnace enclosure and baghouse. Existing vessels have ESP for primary control	5,350,000 (5,900,000)	Overlapping

[a]All models of new plants include a hot metal transfer and skimming station. Models of additions to existing plants do not include a hot metal transfer and skimming station.

[b]In sequential operation only one vessel operates at any time with no overlap in the production cycles. In overlapping operation two vessels operate simultaneously with varying degrees of overlap in their production cycles.

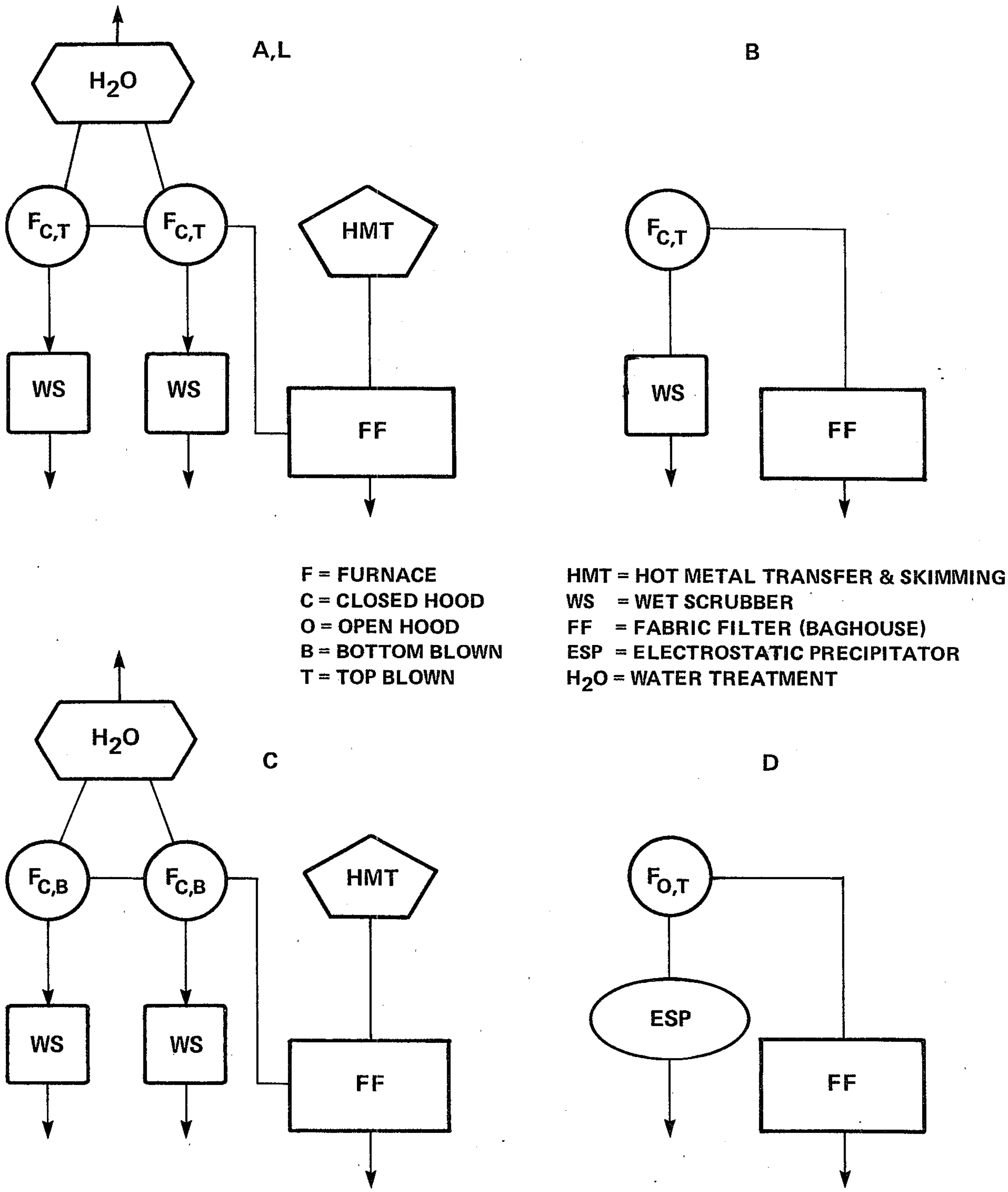
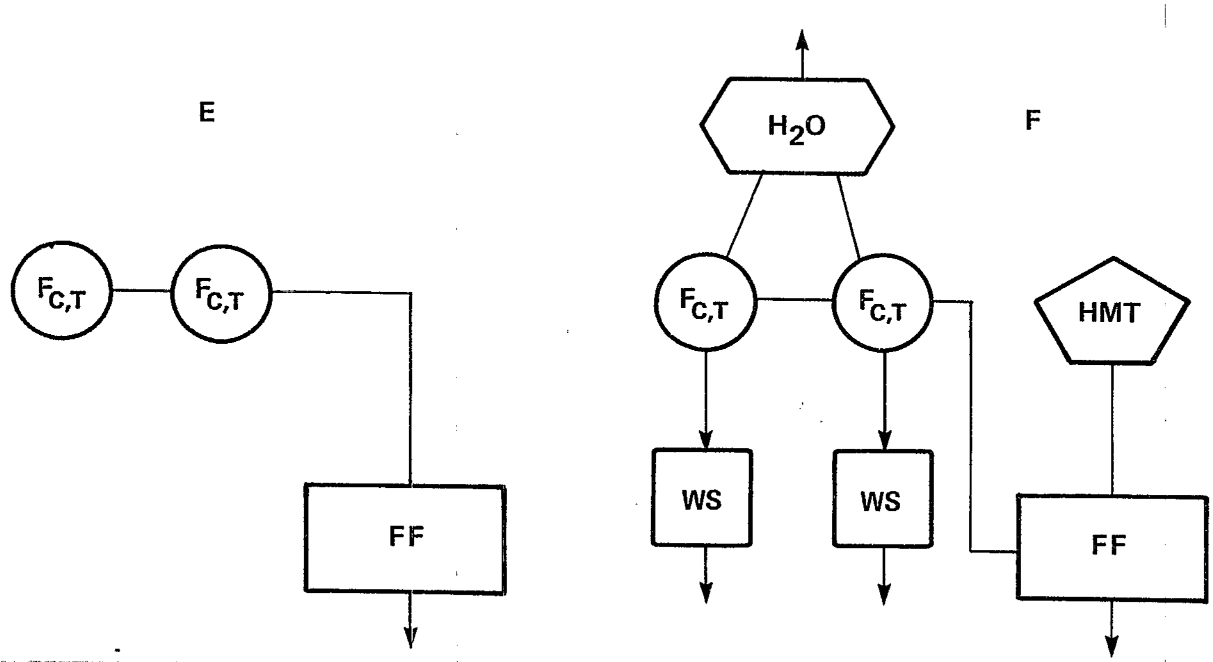


Figure 6-1. BOPF model plants.



F = FURNACE
C = CLOSED HOOD
B = BOTTOM BLOWN
T = TOP BLOWN

HMT = HOT METAL TRANSFER & SKIMMING
WS = WET SCRUBBER
FF = FABRIC FILTER (BAGHOUSE)
H_2O = WATER TREATMENT

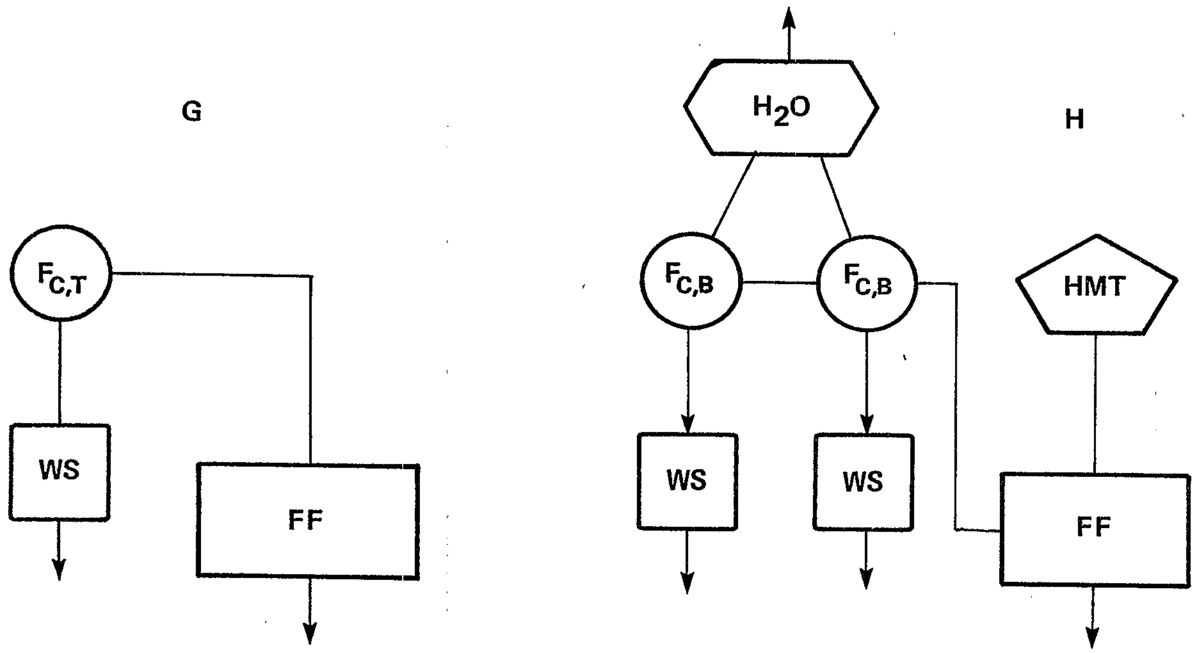


Figure 6-1. BOPF model plants. (con.)

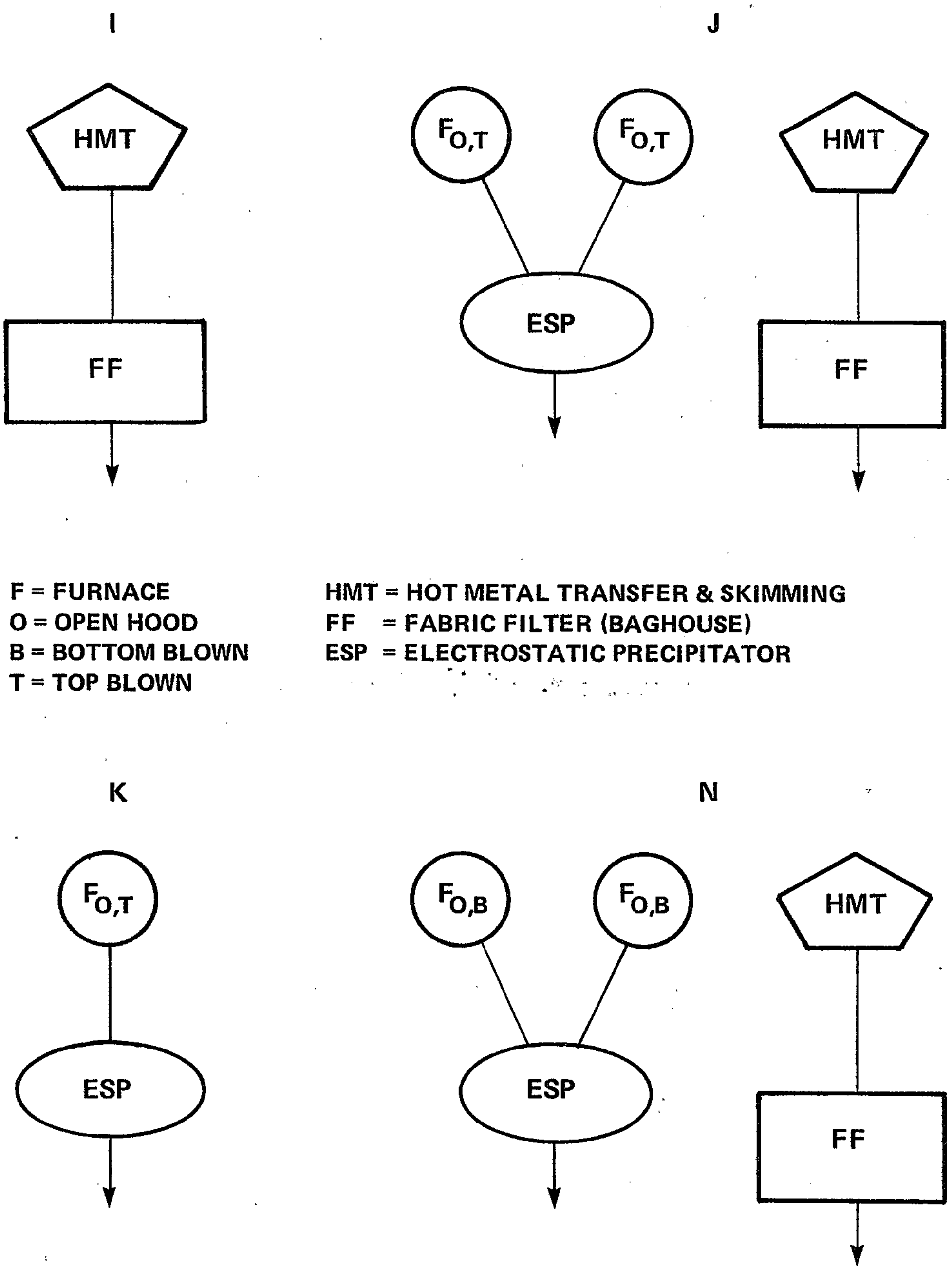
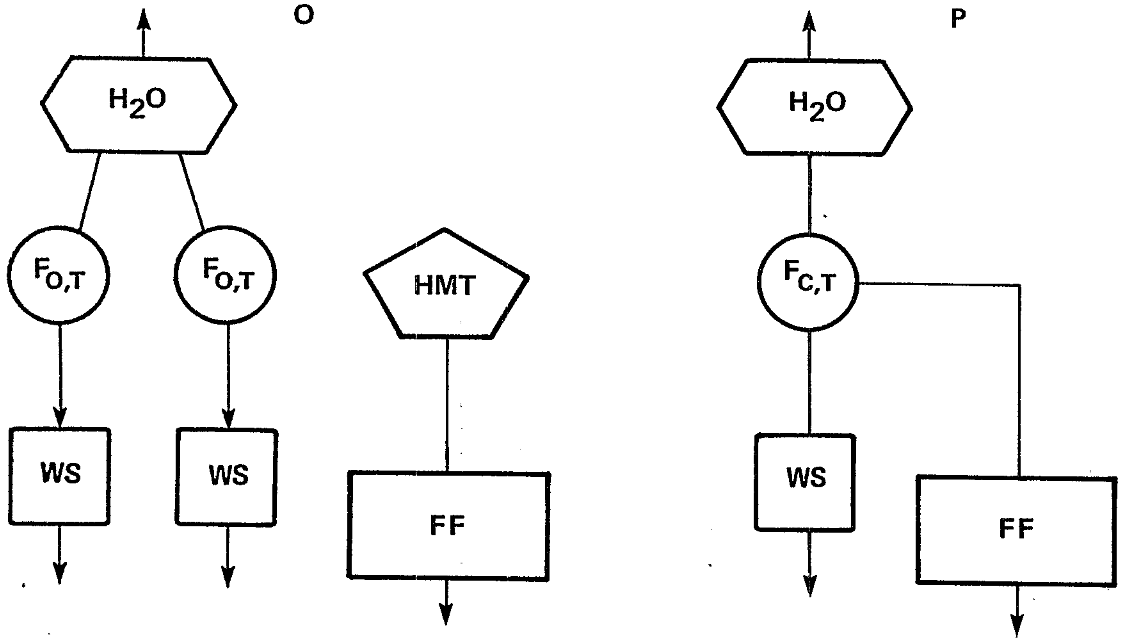


Figure 6-1. BOPF model plants. (con.)



F = FURNACE
C = CLOSED HOOD
O = OPEN HOOD
T = TOP BLOWN

HMT = HOT METAL TRANSFER & SKIMMING
WS = WET SCRUBBER
FF = FABRIC FILTER (BAGHOUSE)
H_2O = WATER TREATMENT

Figure 6-1. BOPF model plants. (con.)

specialty steels. The 272-Mg (300-ton) vessel models are characteristic of the major, high volume, steel production facilities that exist today in the United States.

Several different operational schedules are possible in multiple vessel shops. In a two-vessel shop, one vessel may be used while the second one remains idle, or alternatively, both vessels may be in service at the same time with some overlap possible in their cycles. (For example, one vessel may be charged or tapped while the other vessel is in the blowing phase). In a three vessel shop, one or two vessels may be in operation while the third is idle. In shops that have sufficient oxygen capacity, portions of the blowing phase of the cycles may overlap.

The model plants also differ in the type of primary emission collection hood present (open or closed hoods). This distinction is made because some shops with open primary hoods can use these systems to enhance secondary emission control, particularly during charging and tapping. Most of the older plants have open primary hoods in which complete combustion of the process off-gas takes place (complete combustion system). The trend in new shops is towards the installation of closed primary hoods that limit combustion of the off-gas to about 10 percent of the total volume of combustible gas generated (suppressed combustion system). The high concentration of combustible gas remaining in the exhaust makes it essential to use a scrubber for gas cleaning. After cleaning, the combustible gases are flared at the stack. The exhaust rate in a closed hood system is considerably less than that in an open hood system because excess air for combustion is excluded. The design parameters for the model plant pollution control systems are given in Tables 6-2, 6-3, and 6-4.

Model A (Table 6-1) is representative of a new shop with two 272-Mg (300-ton) top blown vessels. The secondary emission control system consists of full furnace enclosures, equipped with charging and tapping hoods, ducted to a common baghouse. Model C is a similar installation with bottom blown furnaces (Q-BOP's). Model H is also a Q-BOP shop but, unlike Model C, which is a greenfield facility, this

TABLE 6-2. DESIGN PARAMETERS OF THE MODEL PLANTS POLLUTION CONTROL SYSTEMS GAS CLEANING DEVICES

Device	Parameter
ESP (primary systems)	SCA = 72.8 m^2/acms (370 ft^2/1,000 acfm)
Scrubber venturi (primary systems)	ΔP = 16.2 kPa (65 inH_2O)
Baghouse (secondary systems)	Air-to-cloth ratio = 0.61 m/min (2.0 ft/min)

TABLE 6-3. MODEL PLANT PRIMARY POLLUTION CONTROL SYSTEM GAS FLOW RATES

Furnace	Primary hood type	Gas cleaning device	Gas flow rate
272-Mg (300-ton) top blown	Open	Scrubber	281 acms at 82° C (596,000 acfm at 180° F)
272-Mg (300-ton) top blown	Open	ESP	461 acms at 204° C (977,000 acfm at 400° F)
272-Mg (300-ton) top blown	Closed	Scrubber	81.6 acms at 82° C (173,000 acfm at 180° F)
272-Mg (300-ton) bottom blown	Closed	Scrubber	91.6 acms at 82° C (194,000 acfm at 180° F)
272-Mg (300-ton) bottom blown	Open	ESP	517 acms at 204° C (1,096,000 acfm at 400° F)
136-Mg (150-ton) top blown	Closed	Scrubber	40.6 acms at 82° C (86,000 acfm at 180° F)

standard. This would be done when only one vessel was operating, because the data supporting potential standards were obtained in shops operating single vessels.

In shops that contain unregulated sources, a roof-monitor standard would have to allow for emissions seen at the monitor that may not be easily attributable to a given source within the shop. The approach for these cases would be to allow unregulated sources to be shut down during compliance testing.

The affected sources in greenfield BOPF shops are hot metal transfer, skimming, and furnace operations. Sources that would remain unregulated under all alternatives are teeming, slag handling, ladle and furnace maintenance, and flux handling.

6.2.2 Regulatory Alternative I (Baseline)

Regulatory Alternative I (identified as the "baseline" alternative to which other, more stringent alternatives are compared) would involve no change in the current NSPS for primary emissions. If this alternative is selected, it is anticipated that closed hood BOPF facilities would be the most economical for achieving the NSPS as discussed in Chapter 8. Under Alternative I, there would be no NSPS for secondary emissions. In the absence of additional NSPS, states may still choose to require secondary emission control at new facilities. However, for the purpose of computing the relative impacts of more stringent alternatives, it is assumed that under Alternative I, secondary emissions from all new facilities would be uncontrolled.

6.2.3 Regulatory Alternative II

Under Regulatory Alternative II, additional NSPS would be proposed to limit the opacity of roof monitor emissions from the BOPF, hot metal transfer, and skimming and to limit emissions from any air pollution control device other than the primary emission control system that is used to control secondary emissions. Regulatory Alternative II would involve no change in the current NSPS for primary emissions and, thus, would allow the use of either closed hood or open hood control of BOPF primary emissions. The roof monitor opacity limits would be achievable using either a furnace enclosure with hooding for the capture of secondary emissions from the furnace (as would be done at shops using closed hood primary control), or the primary hood for the capture of furnace secondary emissions (as would be done at shops using open hood primary control). However, if this alternative is selected, it is anticipated that open hood control of the BOPF would be the most economical alternative if the primary emission control system is also used to capture secondary emissions (see Chapter 8). Charging emissions can be captured by the primary system if the furnace is kept as close to vertical as can be achieved during the introduction of the hot metal. The capture of the emissions is made possible by the large gas volume exhausted through the open hood system (Table 6-3). Effective capture of charging emissions from a 272-Mg (300-ton) furnace can be achieved with a primary system evacuation rate of 461 acms (977,000 acfm) at 204° C (400° F). The capture of tapping emissions can be facilitated by enclosing the tapping side of the furnace enclosure with refractory-lined doors or, as has been done at one plant, by installing an awning-like extension on the tapping side of the enclosure (see Chapter 4). Doors and awnings serve to contain the tapping emissions and direct them towards the primary hood. Cleaning of the secondary emissions would be accomplished with the primary system gas cleaning device.

Emissions generated during hot metal transfer and skimming can be controlled with local hooding ducted to a secondary emission collection system gas cleaning device. Effective hot metal transfer facilities at which tests were conducted were exhausted at a rate of approximately 94.4 acms (200,000 acfm) at 66° C (150° F) (see Chapter 4). Gas cleaning was accomplished with a baghouse.

6.2.4 Regulatory Alternative III

This alternative would change the current NSPS for primary emissions from a standard achievable by either open or closed hood primary control to one based on closed hood primary control. This would involve changing the current NSPS for primary emissions from a mass-per-unit-gas-volume basis to a mass-per-unit-production basis. Since the gas volume per unit of production for open hood systems is much greater than for closed hood systems, Alternative III might preclude the use of open hood BOPF facilities. The available data are not sufficient to show that open hood BOPF facilities could comply with Regulatory Alternative III. It would add NSPS for secondary emissions from BOPF shops that would limit the opacity of roof monitor emissions and that would limit emissions from any air pollution control device other than the primary emission control device that is used to control secondary emissions. Charging and tapping emissions from closed hood furnaces can be controlled effectively with full furnace enclosures equipped with charging and tapping hoods. Alternative III can be achieved with evacuation rates for 272-Mg (300-ton) vessels of 283 acms (600,000 acfm) at 66° C (150° F) for top blown furnaces and 354 acms (750,000 acfm) at 66° C (150° F) for bottom blown furnaces. Effective gas cleaning can be achieved with a baghouse although scrubbers or ESP's can also be used. Full-furnace enclosures probably would not be suitable for open hood systems in which a limitation on the amount of air available for primary fume combustion might create an explosion hazard. For these systems, partial enclosures with charging and tapping hoods would provide adequate control.

Emissions from top blown, closed hood 136-Mg (150-ton) furnaces can be controlled as described above for 272-Mg (300-ton) furnaces with a secondary system evacuation rate of 189 acms (400,000 acfm) at 66° C (150° F). Canopy hood systems or partial building evacuation systems may be effective alternatives to furnace enclosures. At the present time, however, the test data are insufficient to support the efficacy of either of these systems.

6.2.5 Regulatory Alternative IV

Regulatory Alternative IV would involve no change in the current NSPS for primary emissions. This alternative would add NSPS for secondary emissions from BOPF shops that would prohibit any visible secondary emissions and that would limit emissions from any air pollution control device, other than a primary emission control device, that is used to control secondary emissions. Alternative IV is based on the use of building evacuation to meet the no-visible-secondary-emission requirement.

The most economical system for achieving the primary emission requirements of Alternative IV would be closed hood BOPF facilities as

TABLE 6-6. PRELIMINARY EMISSION LIMITATIONS FOR COMPARING REGULATORY ALTERNATIVES

Emission source and parameter	Alternative number	Emission limitation used for computing imports
Primary control device--mass emissions	I, IV	50 mg/dscm (0.022 gr/dscf)
	III	15 mg/kg (0.03 lb/ton) of steel produced
Primary control device--opacity	I, II, III, IV	10 percent with an exceedance of less than 20 percent allowed once each production cycle
Roof monitor--opacity	I	None
	II, III	10 percent with an exceedance of not greater than 20 percent allowed once each production cycle
	IV	No visible emissions
Secondary control device--mass emissions	I	None
	II, III, IV	23 mg/dscm (0.01 gr/dscf)
Secondary control device--opacity	I	None
	II, III, IV	5 percent

described in conjunction with Alternative III (see Chapter 8). The requirement for no visible secondary emissions can be achieved by sealing the BOPF shop building and installing an exhaust ventilation system capable of changing the air once every 2.5 min. A baghouse would most probably be installed to comply with air pollution control device effectiveness requirements. However, either ESP systems or scrubbers could be used.

As discussed in Section 6.1.2, emissions from sources equipped to meet the limits of Alternative IV are greater than the emissions from sources equipped to meet the limits of Alternatives II and III. As shown in Tables 8-2 and 8-3, the annual cost for meeting the limits of Alternative IV is greater than the annual cost for meeting the limits of Alternatives II and III. Consequently, Alternative IV is not a viable regulatory option. This alternative is included primarily to show that it was considered and to document why it is not practical.

6.2.6 Emission Limitations

Table 6-6 shows the emission limitations corresponding to the various regulatory alternatives. The limitations were used for comparing the impact of the various alternatives discussed in Chapters 7, 8, and 9. These emissions limits represent the performance capabilities of the control techniques (as discussed in Chapter 4) that are the basis for the alternatives.

6.3 REFERENCES

1. Anonymous, National Blueprints Big BOP Shop Conversion. 33 Metal Producing. November 1979. p. 63.

2. Telecon. Goldman, L., Research Triangle Institute, with Hoffman, Dan, Granite City Works, National Steel Corporation. May 28, 1981. Discussion of KMS system for BOPF's.

3. Cuscino, T. Particulate Emission Factors Applicable to the Iron and Steel Industry. Midwest Research Institute, Kansas City, Missouri. EPA-450/4-79-028. September 1979. pp. 27-31.

7. ENVIRONMENTAL IMPACT

Chapter 7 identifies the productive and adverse environmental changes caused by the addition of BOPF secondary emission controls. The following impacts are discussed:

- The impact of reducing particulate matter and other air emissions.
- The impact of emission control on water pollution.
- The impact of emission control on solid wastes.
- The energy impact of emission control.
- Other environmental impacts such as noise.
- Other environmental concerns such as resource commitments and trade-offs.

7.1 GENERAL

This chapter provides background information for use in making decisions on the various regulatory alternatives. As discussed in Chapter 6, the various alternatives selected for consideration are:

I. Baseline alternative (the basis to which other alternatives are compared). No change in the current new source performance standard (NSPS) for primary emissions from basic oxygen process furnaces (BOPF's).

II. Promulgation of an additional NSPS for secondary emissions from BOPF facilities with no change in the current NSPS for primary emissions.

III. Promulgation of an additional NSPS for secondary emissions from BOPF facilities and a new NSPS for primary emissions that might preclude the installation of open hood BOPF facilities.

IV. Promulgation of an additional NSPS for secondary emissions from BOPF facilities that might preclude the use of any control technique other than building evacuation and with no change in the current NSPS for primary emissions.

Although all alternatives would allow either open or closed hood furnaces and either top or bottom blown furnaces, the type of new BOPF shop selected will depend largely upon: (1) the cost of control for each alternative, and (2) the technical feasibility of achieving the emission limitation. For Alternative I (baseline), the most likely system that would be applied is a closed hood BOPF, since the cost of primary emission control is less costly for a closed hood BOPF than for an open hood BOPF (compare Models A and J, Table 8-2). For Alternative II the lowest cost system for both primary and secondary emission control is an open hood system where the primary emission control system is used to control secondary emissions (compare Models A and J, Table 8-2). Alternative III might preclude the use of an open hood system. Consequently, it would be necessary to use a closed hood system (see Model A, Table 8-2). As discussed in conjunction with Alternative I, a closed hood type shop would probably be the most economical for meeting the requirements of Alternative IV. Table 7-1 shows the control basis for each alternative.

This chapter also provides information that can be used if other regulatory alternatives are considered. Within each regulatory alternative there are several different model plant situations that might occur. These various model plant situations are described in Chapter 6. The alternatives evaluated in this chapter involve top blown shops equipped with two 272-Mg (300-ton) vessels operated in such a manner that one is on-line at all times while the other vessel is available for service. As discussed in Chapter 6, there are numerous different sizes and types of vessels and modes of operation.

The estimates of changes in mass emissions, solid waste generation, and energy consumption are based on new source construction adding 6.81 Tg (7.5 million tons) of steelmaking capacity during the period 1981 through 1986 (see Table 7-2). The increases would be less than those estimated because of 4.15 Tg (4.6 million tons) of retirements during the period between 1981 and 1986. The offset for retirements is not estimated because it is not certain whether the retired facilities

TABLE 7-1. TYPICAL REGULATORY ALTERNATIVE PLANTS

Plant	Description
I	Baseline plant. Two 272-Mg (300-ton) vessels, closed hood, top blown, no secondary control. Primary control by scrubber emits 50 mg/dscm (0.022 gr/dscf). Production 2,900,000 Mg/yr (3.2 million tons/year). Represented by Model Plant A without secondary control.
II	Open hood plant. Two 272-Mg (300-ton) vessels, open hood, top blown, combined primary and secondary control with ESP system. Control device emits 50 mg/dscm (0.022 gr/dscf). Production 2.9 million Mg/y (3.2 million tons/year) Represented by Model Plant J.
III	Furnace enclosure plant. Two 272-Mg (300-ton) vessels, closed hood, top blown. Primary control by scrubber emits 15 mg/kg (0.03 lb/ton). Secondary control by furnace enclosure and baghouse emits 23 mg/dscm (0.01 gr/dscf). Production 2.9 million Mg/yr (3.2 million tons/year). Represented by Model Plant A.
IV	Building evacuation plant. Two 272-Mg (300-ton) vessels, closed hood, top blown. Primary control by scrubber emits 50 mg/dscm (0.022 gr/dscf). Secondary control by building evacuation and baghouse emits 23 mg/dscm (0.01 gr/dscf). Production 2.9 million Mg/yr (3.2 million tons/year). Represented by Model Plant A with building evacuation instead of furnace enclosure.

TABLE 7-2. U.S. BOPF STEELMAKING CAPACITY[4]

Year	Total capacity		Additions		Retirements	
	Tg/yr	10^6 tons/yr	Tg/yr	10^6 tons/yr	Tg/yr	10^6 tons/yr
1979	81.88	90.26	1.32	1.45	-	-
1980	-	-	-	-	-	-
1981	80.54	88.78	0.49	0.54	1.83	2.017
1982	81.30	89.62	0.76	0.835	-	-
1983	85.78	94.55	4.47	4.931	-	-
1984	86.16	94.97	0.38	0.416	-	-
1985	84.23	92.85	0.40	0.443	2.32	2.554
1986	84.54	93.19	0.31	0.339	-	-

would be open hearth or BOPF furnaces. Since the offset would be the same for all four alternatives valid impact comparisons can be made without taking the offsets into account.

The ambient air concentration estimates are based on the operation of 272-Mg (300-ton) vessel plants, as previously discussed. Although it is possible that larger facilities might be constructed, it is unlikely that any facilities would be more than 25 percent larger. Currently, there are only six U.S. BOPF shops equipped with vessels larger than 245 Mg (270 tons). Vessel sizes in these shops range from 254 Mg (280 tons) to 320 Mg (350 tons).

7.2 AIR POLLUTION IMPACT

As shown in Figure 3-8, uncontrolled primary emissions of particulate matter from either top or bottom blown BOPF vessels are 14,250 g/Mg (28.5 lb/ton) of steel produced. Using production capacity estimates for 1981 given in Table 7-2, nationwide emissions would be 1.15 Tg (1.27 million tons) if primary emissions were not controlled.

As shown in Table 3-5, the uncontrolled secondary emission of particulate matter from BOPF hot metal transfer, charging, tapping, and teeming ranges from 460 g/Mg of steel produced for top blown vessels to 895 g/Mg for bottom blown vessels (0.92 to 1.79 lb/ton). Under current new source performance standards (NSPS) primary emissions from a new BOPF shop are limited to 50 mg/dscm (0.022 gr/dscf). For closed hood furnaces, this limit is estimated to be equivalent to 15 mg/kg (0.03 lb/ton) of steel produced. For open hood furnaces, because of their greater volume of gas flow, the limit is estimated to be equivalent to 75 mg/kg (0.15 lb/ton) of steel produced. Primary emissions from furnaces not subject to the current NSPS range from 103 mg/dscm (0.045 gr/dscf) to 206 mg/dscm (0.090 gr/dscf).

As shown in Table 3-4, 1979 nationwide particulate emissions from BOPF operations are estimated to be 64.9 Gg (71,500 tons). This includes 51.8 Gg (57,100 tons) of secondary emissions and 13.1 Gg (14,400 tons) of primary emissions. The estimates assume that 98.8 percent of the primary particulates are controlled and that 23 percent of the secondary particulates are controlled.[2] Steel production during the years 1976 through 1979 ranged from 70.2 to 75.7 Tg (77.4 million to 83.4 million tons).[3] Since there was very little difference among production rates during these 4 years, it is estimated that 1981 production will be about the same and that 1981 emissions will be the same as 1979 emissions.

The four regulatory alternatives described in Chapter 6 may be represented by typical regulatory alternative plants (TRAP's). Four TRAP's defined in Table 7-1 are used to make comparisons among the regulatory alternatives. These plants are selected to be similar in size to plants of the type most likely to be built under each regulatory alternative.

Emissions from the TRAP's are given in Table 7-3. Reductions from baseline are 66 percent for open hood, 77 percent for furnace enclosure, and 20 percent for building evacuation. When divided into primary and secondary emissions, all TRAP's have the same primary emissions except open hood, which has increased emissions of 631 percent over the baseline. Reductions from the baseline for secondary emissions are 88 percent for open hood, 79 percent for furnace enclosure, and 21 percent for building evacuation.

The projected increase in nationwide emissions through 1986 under each alternative is shown in Table 7-4. This table is based on a projected new capacity addition of 6.81 Tg/yr (7.5 million tons/yr) and the assumption that BOPF shops built under an alternative would be of the same type as the TRAP for that alternative. Percentage reductions from baseline are the same as above, although the total amounts are different.

7.3 AMBIENT AIR IMPACTS

Dispersion calculations have been made for three of the regulatory alternatives as described below.

Regulatory Alternative I--Baseline

> Two 272-Mg (300-ton) closed hood, top blown vessels; one vessel in operation, one on standby. Heat cycle is 50 minutes.

TABLE 7-3. EMISSIONS FROM TYPICAL REGULATORY ALTERNATIVE PLANTS: TWO 272-Mg VESSELS, 2.90 Tg/yr CAPACITY

Plant	Emissions[a]						Reduction from baseline	
	Primary		Secondary		Total		Total	
	kg/d	(tons/d)	kg/d	(tons/d)	kg/d	(tons/d)	kg/d	(tons/d)
I (Baseline)	118	(0.13)	3,647	(4.02)	3,765	(4.15)	-	-
II (Open hood)	646	(0.71)	440	(0.48)	1,086	(1.19)	2,679	2.96
III (Furnace enclosure)	118	(0.13)	763	(0.84)	881	(0.97)	2,884	3.18
IV (Building evacuation)	118	(0.13)	3,174	(3.50)	3,292	(3.63)	473	0.52

[a]Based on Table 6-5.

TABLE 7-4. FUTURE NATIONWIDE EMISSIONS FROM TYPICAL REGULATORY ALTERNATIVE PLANTS: 6.81 Tg/yr TOTAL CAPACITY[a]

Plant	Future Emissions					
	Primary		Secondary		Total	
	Mg/yr	(tons/yr)	Mg/yr	(tons/yr)	Mg/yr	(tons/yr)
I (Baseline)	102	(113)	3,119	(3,438)	3,221	(3,551)
II (Open hood)	553	(609)	376	(415)	929	(1,024)
III (Furnace enclosure)	102	(113)	653	(720)	755	(833)
IV (Building evacuation)	102	(113)	2,715	(2,993)	2,817	(3,106)

[a]Based on Table 6-5.

Hot metal transfer emissions are uncontrolled and are at a rate of 89.5 mg/kg (0.179 lb/ton) of BOPF steel 272 Mg (300 tons) per heat. These emissions are emitted from the roof monitor directly above the operation. This is at a different location than the charging and tapping emissions and the teeming emissions.

Charging and tapping emissions are uncontrolled at rates of 189 and 146 mg/kg (0.377 and 0.291 lb/ton), respectively. These emissions are emitted from the roof monitor directly above the operation. This is at a different location than the hot metal transfer and teeming emissions.

Teeming emissions are uncontrolled and are at a rate of 35.0 mg/kg (0.07 lb/ton). These emissions are emitted from the roof monitor directly above the operation. Since the teeming aisle is long, the plume length at the roof monitor is much greater than for hot metal transfer, charging, and tapping. Consequently, at times teeming emissions could mingle with the other emissions.

Since all of the foregoing operations are cyclic, the actual rate of emissions varies with time. The cycle is repeated about once every 50 min. For modeling purposes an average emission rate for a 50-min cycle was used.

Primary emissions are controlled to a level of 50 mg/dscm (0.022 gr/dscf) and are discharged from a 67.7-m (220-ft) stack. Flow rate is 41.1 scms (87,000 scfm) at 82° C (180° F).

Regulatory Alternative II

Two 272-Mg (300-ton) open hood, top blown vessels; one vessel in operation, one on standby. Heat cycle is 50 minutes.

Charging and tapping emissions are controlled with the primary systems to a level of 50 mg/dscm (0.022 gr/dscf) and are discharged from a 67.7-m (220-ft) stack. Flow rate is 461 acms (977,000 acfm) at 204° C (400° F).

Hot metal transfer operations are controlled by a separate baghouse to a level of 23 mg/dscm (0.01 gr/dscf) and are discharged from a stack as in Case 2. Flow rate is 94.4 acms (200,000 acfm) at 66° C (150° F).

Teeming emissions are discharged uncontrolled from the roof monitor.

Regulatory Alternative III

Two 272-Mg (300-ton) closed hood top blown vessels; one vessel in operation, one on standby. Heat cycle is 50 minutes.

Hot metal transfer, charging, and tapping emissions are ventilated at a rate of 283 acms (600,000 acfm) at 66° C (150° F) to a baghouse that reduces emissions to 23 mg/dscm (0.01 gr/dscf). Teeming emissions are discharged uncontrolled from the roof monitor.

Primary emissions are 15 mg/kg (0.03 lb/ton). Flow rate is 81.6 acms (173,000 acfm) at 82° C (180° F). Secondary controlled emissions are discharged from a separate 6.1-m (20-ft) stack located on top of a 24.4-m (80-ft) baghouse.

Regulatory Alternative IV

The air quality impact of Regulatory Alternative IV was not analyzed because analysis showed that emissions with Alternative IV are greater than emissions with Alternatives II or III and that costs with Alternative IV are greater than costs with Alternatives II or III. Consequently, Alternative IV is a more costly, less effective alternative and is impractical (see Tables 6-5, 7-10, 8-2, and 8-4).

Tables 7-5 and 7-6 show the results of the dispersion calculations. These tables give estimates of ground-level concentrations of particulate matter at various distances downwind from the BOPF shops. Meteorological data from Chicago and Pittsburgh were chosen so that periods of calm winds were minimized, and plant orientations were chosen to give maximum annual concentrations. Calculations were performed using the EPA Industrial Source Complex Dispersion Model. The tables show that BOPF model shops slightly exceed ambient air quality standards when secondary emissions are not controlled. Maximum concentrations occur at distances of 0.2 km (656 ft) from the shop.

When the model shops are assumed to have secondary emission control, both configurations produce downwind maximum concentrations appreciably below the Federal National Ambient Air Quality Standards for particulate matter:[5]

Primary--75 μg/m^3--annual geometric mean.

Secondary--260 μg/m^3--maximum 24-hr concentration not to be exceeded more than once per year.

Reduction of emissions from BOPF operations are offset by increased emissions from electric power produced to operate the BOPF emission

TABLE 7-5. ESTIMATED MAXIMUM ANNUAL ARITHMETIC AVERAGE GROUND-LEVEL PARTICULATE CONCENTRATIONS AT SELECTED DISTANCES (MICROGRAMS PER CUBIC METER)

Regulatory Alter-native	0.2 km	0.3 km	0.5 km	0.7 km	1.0 km	1.5 km	3.0 km	5.0 km	10.0 km	Maximum	Distance to maximum (km)
					Chicago, IL						
I	77.3	56.1	35.6	25.2	16.9	10.4	4.3	2.2	0.8	77.3	0.2
II	9.1	5.9	3.8	2.8	1.9	1.2	0.6	0.4	0.2	9.1	0.2
III	7.7	5.6	3.8	2.7	1.9	1.3	0.6	0.4	0.2	7.7	0.2
					Pittsburgh, PA						
I	76.7	54.1	34.3	24.1	16.0	9.8	4.0	2.0	0.7	76.7	0.2
II	8.9	5.5	3.5	2.6	1.7	1.1	0.5	0.3	0.1	8.9	0.2
III	7.3	5.5	3.5	2.5	1.8	1.2	0.6	0.3	0.2	7.3	0.2

TABLE 7-6. ESTIMATED MAXIMUM 24-HOUR ARITHMETIC AVERAGE GROUND-LEVEL PARTICULATE CONCENTRATIONS AT SELECTED DISTANCES (MICROGRAMS PER CUBIC METER)

Regulatory Alternative	0.2 km	0.3 km	0.5 km	0.7 km	1.0 km	1.5 km	3.0 km	5.0 km	10.0 km	Maximum	Distance to maximum (km)
						Chicago, IL					
I	573.5	446.2	288.3	203.6	137.3	85.4	35.8	19.8	8.8	573.9	0.2
II	61.6	41.1	26.5	23.2	16.8	11.8	6.3	3.8	1.9	61.6	0.2
III	52.1	39.6	27.1	22.3	16.7	11.6	5.9	3.4	1.8	52.1	0.2
						Pittsburgh, PA					
I	557.3	446.1	314.3	236.3	169.2	112.9	54.0	30.2	13.5	557.3	0.2
II	56.7	40.1	29.2	22.4	17.0	12.1	6.4	3.9	2.0	56.7	0.2
III	51.1	43.6	31.9	24.9	18.3	12.6	6.4	3.9	2.1	51.1	0.2

control system. Table 7-7 shows power plant emissions for each regulatory alternative. As shown, these emissions are small in comparison with the emissions shown in Table 7-4. They represent 0.53 to 5.6 percent of the TRAP emissions.

Reduction of secondary particulate emissions from BOPF's would also reduce organic and inorganic emissions. For the hot metal addition phase associated with a 233-Mg (257-ton) Q-BOP charge, uncontrolled organic emissions have been measured as 64.1 mg/dscm (0.028 gr/dscf) or about 6.9 mg/kg (0.014 lb/ton) of total charge.[6] About 50 percent of the emissions were associated with particle sizes of less than 3 μm. Fused aromatics, amines, and carboxylic acid were present. Uncontrolled inorganic emissions during the hot metal addition include nickel, iron, chromium, calcium, arsenic, lead, sulfur, and phosphorus, as shown in Table 7-8.

7.4 WATER POLLUTION IMPACT

Scrubbers and wet gas cooling systems are installed at BOPF shops in conjunction with air pollution control. Scrubbers are almost the universal choice for control of primary particulate emissions from closed hood BOPF shops. At some open hood BOPF shops, scrubbers are installed for primary particulate emission control. At other open hood shops electrostatic precipitators (ESP's) are used. Where ESP's are used the gases are cooled prior to the electrical system. The gas cooling system can be designed as either a dry or a wet system. For dry cooling systems, all of the water is evaporated into the gas stream. For wet cooling systems, there is an excess of water and, consequently, there is a wastewater stream out of the gas cooler. Scrubbers are not commonly applied for control of BOPF secondary particulate emissions, except where the primary emission control system is used for secondary emission control.

For the various alternatives discussed in Section 7.1, Alternative III would have the greatest potential for increasing water pollution. Alternative III might preclude the use of open hood BOPF facilities, thereby requiring the use of closed hood systems that need to be equipped with scrubbers to avoid potential explosion hazards.

TABLE 7-7. ADDITIONAL POWER PLANT AND TOTAL PARTICULATE EMISSIONS ATTRIBUTABLE TO TYPICAL REGULATORY ALTERNATIVE PLANTS: 6.81 Tg/yr Total Capacity[7]

	Emissions[a]					
	BOPF shop		Power plant		Total	
Regulatory Alternative	Mg/yr	(tons/yr)	Mg/yr	(tons/yr)	Mg/yr	(tons/yr)
I (Baseline)	3,221	(3,551)	17.0	(18.8)	3,238	(3,570)
II (Open hood)	929	(1,024)	27.4	(30.2)	956	(1,054)
III (Furnace enclosure)	755	(833)	38.2	(42.2)	793	(875)
IV (Building evacuation)	2,817	(3,106)	142	(157)	2,959	(3,263)

TABLE 7-8. UNCONTROLLED INORGANIC EMISSIONS FROM HOT METAL ADDITION TO A Q-BOP[a]

Element	Concentration in off-gas from Q-BOP mg/m^3 [b]	 gr/scf[b]
Nickel	0.18	0.000079
Iron	85.30	0.0373
Chromium	0.26	0.00011
Calcium	64.00	0.0280
Arsenic	0.021	0.000009
Lead	0.15	0.000066
Sulfur	7.90	0.00345
Phosphorus	0.53	0.000232
	158.34	0.0692

[a]Reference 6, pp. 22, 30-32.

[b]During hot metal addition only; about 1 min of each production cycle. Total particle concentration = 1,298 mg/m^3.

However, since both scrubber and gas cooler wastewater effluents are amenable to total recycle (zero effluent), any water pollution impact caused by BOPF particulate emission control would be negligible.[8] The potential water pollution impact of solid waste disposal is discussed in Section 7.5.

7.5 SOLID WASTE IMPACT

Solid waste produced from BOPF operations consists of particulate matter collected from primary and secondary control devices. For shops equipped with scrubbers the particulate matter is separated from the scrubber water before being disposed of. For shops equipped with ESP's or baghouses, the dry dust is disposed of directly. Collected dusts and sludge cake are most often disposed of by trucking to landfill or similar disposal sites. Solid waste generation requires the use of land for disposal. Disposal potentially involves pollution of ground waters by leachates.

Table 7-9 shows the amounts of solid waste expected to be generated from TRAP's when future new BOPF capacity of 6.81 Tg/yr (7.5 million tons/yr) is in place, as well as for the individual plants.

Total percentage increases in solid waste above baseline for the various regulatory alternatives are 2.17 percent for open hood, 2.55 percent for furnace enclosure, and 0.68 percent for building evacuation. The increases are due almost entirely to collected secondary emissions. With these small increases, the increase in waste disposal land requirements and any leaching problems would be negligible.

7.6 ENERGY IMPACT

Total energy input to the steelmaking process up through the BOPF is equivalent to 11,561 kWh/Mg (10,488 kWh/ton).[9] Air pollution control energy requirements for the TRAP's range from 5.5 to 46.2 kWh/Mg (5.0 to 41.9 kWh/ton). These amounts represent 0.05 and 0.40 percent of the steelmaking energy requirements.

Primary and secondary emission control systems require energy to overcome system pressure drop, to pump water in systems that use scrubbers, and to transport waste materials within and outside the

TABLE 7-9. FUTURE SOLID WASTE GENERATION FROM TYPICAL REGULATORY ALTERNATIVE PLANTS: TOTAL NATIONWIDE AND SINGLE PLANT CAPACITY

Regulatory Alternative	Solid waste generated					
	Primary		Secondary		Total	
	Mg/yr	(tons/yr)	Mg/yr	(tons/yr)	Mg/yr	(tons/yr)
Total nationwide capacity (6.81 Tg/yr)[a]						
I (Baseline)	96,855	(106,763)	0	0	96,855	(106,763)
II (Open hood)	96,417	(106,280)	2,730	(3,009)	99,147	(109,289)
III (Furnace enclosure)	96,855	(106,763)	2,466	(2,719)	99,321	(109,482)
IV (Building evacuation)	96,855	(106,763)	403	(445)	97,259	(107,208)
Single plant capacity (2.90 Tg/yr)[a]						
I (Baseline)	41,325	(45,552)	0	0	41,325	(45,552)
II (Open hood)	41,138	(45,346)	1,165	(1,284)	42,303	(46,630)
III (Furnace enclosure)	41,325	(45,552)	1,052	(1,160)	42,377	(46,712)
IV (Building evacuation)	41,325	(45,552)	172	(190)	41,497	(45,742)

[a]Based on Table 8-9.

plant site. Table 7-10 gives energy requirements for the various TRAP's when future new BOPF domestic steelmaking capacity of 6.81 Tg (7.5 million tons) is in place and for the individual plants. Comparison of the total TRAP energy requirements above baseline shows that the open hood alternative requires 60.8 percent more, the furnace enclosure alternative requires 125 percent more, and the building evacuation alternative requires 738 percent more energy.

The 125-percent increase for the furnace enclosure alternative is entirely attributable to secondary control, as is the 735-percent increase for building evacuation. For the open hood alternative, approximately 20 percent of the increase is due to primary control by ESP and the rest is due to secondary control.

One method of reducing energy consumption would be to recover heat values from hot gases produced during charging and tapping. This recovery would be minimal, however, since the major heat evolution is from blowing.

During the primary emission phase, heat recovery from water cooled open hoods would yield about 167,000 kJ/Mg (71.8 Btu/lb) of steel, while CO recovered from suppressed combustion systems would produce about 420,000 kJ/Mg (181 Btu/lb) of steel.[10] European practice in some installations has been to recover CO for its fuel value, but U.S. practice has been to flare the CO. Recovery of 420,000 kJ/Mg (181 Btu/lb) of steel for 6.18 Tg (6.8 million tons) of steel would amount to 2,600 TJ (2.46 billion Btu) more heat recoverable in 1986 than in 1981 from primary control.

7.7 OTHER ENVIRONMENTAL IMPACTS

Control of secondary emissions will not require new types of equipment. Volume of noise generated will increase in proportion to new BOPF furnaces built, but noise intensity will not increase, and may decrease, as new equipment designs such as less noisy air compressors come on the market.

TABLE 7-10. CONTROL SYSTEM ENERGY REQUIREMENTS FOR TYPICAL REGULATORY ALTERNATIVE PLANTS: TOTAL NATIONWIDE AND SINGLE PLANT CAPACITY

Regulatory Alternative	Control system energy requirements (millions of kWh/yr)		
	Primary	Secondary	Total
Total nationwide capacity (6.81 Tg/yr)[a]			
I (Baseline)	37.5	0	37.5
II (Open hood)	44.6	15.7	60.3
III (Furnace enclosure)	37.5	46.9	84.4
IV (Building evacuation)	37.5	276	314
Single plant capacity (2.90 Tg/yr)[a]			
I (Baseline)	16.0	0	16.0
II (Open hood)	19.0	6.70	25.7
III (Furnace enclosure)	16.0	20.0	36.0
IV (Building evacuation)	16.0	118	134

[a]Based on reference 7.

7.8 OTHER ENVIRONMENTAL CONCERNS

One effect of promulgating an NSPS for secondary BOPF emissions may be to lengthen operating lifetimes of existing shops. As long as existing equipment is continued in service it will produce secondary (and primary) emissions at a rate determined by the difference between Federal NSPS and state and local standards for existing sources. The increased lifetimes of existing shops would come about from diversion of capital from purchasing steel production facilities to purchasing particulate control equipment. This long-term loss is expected to be minor.

7.9 REFERENCES

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8. COSTS

8.1 COST ANALYSIS OF REGULATORY ALTERNATIVES

Tables 8-1 through 8-5 give cost information for the model plants described in Chapter 6.

8.1.1 Basis for Capital Cost Estimates

Capital costs represent the initial investment necessary to install and commission the system. All costs are based on July 1980 dollars. Capital costs consist of direct and indirect costs incurred prior to the startup of the system for continuous operation. Direct costs include the costs of various items of equipment and the labor and material (construction costs including field overhead) required for installing these items and interconnecting the systems. Indirect costs include the costs of such items as freight, procurement, and allocated costs associated with the purchase and installation of the control equipment.

8.1.1.1 Direct Costs. The purchased cost of the equipment and the cost of installing it are considered direct costs. The cost of an equipment item is the purchase price paid to the equipment supplier on a free-on-board (f.o.b.) basis; this does not include any freight charges. Installation costs cover the interconnection of the system, including piping costs, electrical costs, and the other work needed to commission it, such as the cost of securing permits and the cost of insurance for the equipment and personnel onsite. The costs of foundations, supporting structures, enclosures, ducting, control panels, instrumentation, insulation, painting, and similar items are attributed to installation. Costs including site development, relocation, or alteration of existing facilities, administrative facilities,

TABLE 8-1. CAPITAL COSTS OF CONTROL[a]--BOPF EMISSIONS--JULY 1980[1 2]
(millions of dollars)

Case	Model	Plant investment[b]	Primary pollution control investment[c]	Water pollution control investment[d,e]	Secondary pollution control investment[c]	Hot metal transfer and skimming pollution control investment[f]	Total pollution control investment
A	Two new 272-Mg (300-ton) vessels, closed hoods with scrubbers, top blown equipped with furnace enclosures and baghouse. Production 2,900,000 Mg (3,200,000 tons) per year.	169.6	13.2	4.7	12.2	0.36[g]	30.5
B	One new 272-Mg (300-ton) vessel added to two existing 272-Mg (300-ton) vessels, closed hood with scrubber, top blown, equipped with furnace enclosure and baghouse. Production 5,350,000 Mg (5,900,000 tons) per year.	105.3	7.0	0	10.4	0	17.4
C	Two new 272-Mg (300-ton) vessels, closed hoods with scrubbers, bottom blown, equipped with furnace enclosures and baghouse. Production 2,900,000 Mg (3,200,000 tons) per year.	169.6	14.0	4.7	14.0	0.36[g]	33.1
D	One new 272-Mg (300-ton) vessel added to two existing 272-Mg (300-ton) vessels, open hood with ESP, top blown, equipped with local hoods and baghouse. Production 5,350,000 Mg (5,900,000 tons) per year.	105.3	16.8	0	10.4	0	27.2
E	Two existing 272-Mg (300-ton) vessels converted to KMS process, closed hoods with scrubbers, top and bottom blown, equipped with furnace enclosures and baghouse. Production 2,900,000 Mg (3,200,000 tons) per year.	16	0[h]	0	15.0	0	15.0
F	Two new 136-Mg (150-ton) vessels, closed hoods with scrubbers, top blown, equipped with furnace enclosures and baghouse. Production 1,450,000 Mg (1,600,000 tons) per year.	84.8	9.3	3.1	9.26	0.24[g]	21.9

See footnotes at end of table.

(continued)

TABLE 8-1. (continued)

Case	Model	Plant investment[b]	Primary pollution control investment[c]	Water pollution control investment[d,e]	Secondary pollution control investment[c]	Hot metal transfer and skimming pollution control investment[f]	Total pollution control investment
G	One new 136-Mg (150-ton) vessel added to two existing 136-Mg (150-ton) vessels, closed hood with scrubber, top blown, equipped with furnace enclosure and baghouse. Production 2,630,000 Mg (2,900,000 tons) per year.	50.7	5.0	0	7.6	0	12.6
H	Two new 272-Mg (300-ton) vessels, closed hoods with scrubbers, bottom blown equipped with furnace enclosures and baghouse. Conversion of an open hearth shop to basic oxygen process. Production 2,900,000 Mg (3,200,000 tons) per year.	99.8	14.7	4.7	14.7	0.43[g]	34.5
J	Two new 272-Mg (300-ton) vessels, open hoods, top blown, equipped with ESP for primary and secondary control. Production 2,900,000 Mg (3,200,000 tons) per year.	169.6	21.3	0	1.0	3.4	25.7
K	One new 272-Mg (300-ton) vessel added to two existing 272-Mg (300-ton) vessels, open hood, top blown, primary system ESP used for secondary control. Production 5,350,000 Mg (5,900,000 tons) per year.	105.3	17.4	0	0.6	0	18.0
L	Two new 272-Mg (300-ton) vessels, closed hoods with scrubbers, top blown, equipped with furnace enclosures and baghouse. Production 4,540,000 Mg (5,000,000 tons) per year.	169.6	13.2	4.7	12.2	0.36[g]	30.5
N	Two new 272-Mg (300-ton) vessels, open hoods, bottom blown, equipped with ESP for primary and secondary control. Production 2,900,000 Mg (3,200,000 tons) per year.	169.6	22.4	0	1.0	3.4	26.8

See footnotes at end of table.

(continued)

TABLE 8-1. (continued)

Case	Model	Plant investment[b]	Primary pollution control investment[c]	Water pollution control investment[d,e]	Secondary pollution control investment[c]	Hot metal transfer and skimming pollution control investment[f]	Total pollution control investment
O	Two new 272-Mg (300-ton) vessels, open hoods, top blown, equipped with scrubbers for primary and secondary control. Production 2,900,000 Mg (3,200,000 tons) per year.	169.6	19.3	6.8	1.0	3.4	30.5
P	One new 272-Mg (300-ton) closed hood vessel added to two existing 272-Mg (300-ton) open hood vessels, top blown. New vessel has primary scrubber, furnace enclosure and baghouse, existing vessels have ESP for primary control. Production 5,350,000 Mg (5,900,000 tons) per year.	105.3	7.0	4.7	10.4	0	22.1

[a]Includes direct and indirect capital costs.

[b]Plant investments were taken from Temple, Barker & Sloane, personal communication to J. O. Copeland, August 4, 1980, from Cullen Shafer.

[c]Assumes separate control device for closed hood, and common control device for open hood. Investments were taken from reference 1 with some minor adjustments for secondary pollution control equipment.

[d]For BAT 2 control (see note e).

[e]Costs were supplied by Effluent Guidelines Division (EGD) of EPA. A 0.6 scale factor was used with EGD data, and costs were adjusted to July 1980 from July 1978 using a C.E. Cost index value of 219.2. Existing plants were assumed not to require additional water treatment facilities for the addition of a third vessel to two existing vessels, except for Model P. Plants with primary control by ESP were assumed not to require water treatment facilities.

[f]Assumes same control device as secondary emission control except for models J, N, and O.

[g]For models with new closed hood vessels (greenfield shops), only hooding, ductwork and dampers were used as the major cost elements.

[h]The KMS conversion was assumed to use existing primary pollution control equipment.

TABLE 8-2. ANNUAL COSTS OF CONTROL[a]--BOPF EMISSIONS--JULY 1980[1] [2]
(millions of dollars)

Case	Model	Primary pollution control			Water pollution control			Secondary pollution control			Hot metal transfer and skimming pollution control		
		\$/yr	\$/Mg[b]	(\$/ton)[b]	\$/yr	\$/Mg[b]	(\$/ton)[b]	\$/yr	\$/Mg[b]	(\$/ton)[b]	\$/yr	\$/Mg[b]	(\$/ton)[b]
A	Two new 272-Mg (300-ton) vessels, closed hoods with scrubbers, top blown equipped with furnace enclosures and baghouse. Production 2,900,000 Mg (3,200,000 tons) per year.	4.82	1.66	(1.51)	0.54	0.19	(0.17)	3.41	1.18	(1.07)	0.43[d]	0.14	(0.13)
B	One new 272-Mg (300-ton) vessel added to two existing 272-Mg (300-ton) vessels, closed hood with scrubber, top blown, equipped with furnace enclosure and baghouse. Production 5,350,000 Mg (5,900,000 tons) per year.	2.62	0.49	(0.44)	0	0		2.99	0.56	(0.51)	0	0	0
C	Two new 272-Mg (300-ton) vessels, closed hoods with scrubbers, bottom blown, equipped with furnace enclosures and baghouse. Production 2,900,000 Mg (3,200,000 tons) per year.	5.07	1.74	(1.58)	0.54	0.19	(0.17)	3.94	1.36	(1.23)	0.51[d]	0.18	(0.16)
D	One new 272-Mg (300-ton) vessel added to two existing 272-Mg (300-ton) vessels, open hood with ESP, top blown, equipped with local hoods and baghouse. Production 5,350,000 Mg (5,900,000 tons) per year.	4.71	0.88	(0.80)	0	0	0	2.99	0.56	(0.51)	0	0	0
E	Two existing 272-Mg (300-ton) vessels converted to KMS process, closed hoods with scrubbers, top and bottom blown, equipped with furnace enclosures and baghouse. Production 2,900,000 Mg (3,200,000 tons) per year.	0[c]	0	0	0	0	0	4.50	1.55	(1.41)	0	0	0

See footnotes at end of table.

(continued)

TABLE 8-2. (continued)

Case	Model	Primary pollution control			Water pollution control			Secondary pollution control			Hot metal transfer and skimming pollution control		
		$/yr	$/Mg[b]	($/ton)[b]	$/yr	$/Mg[b]	($/ton)[b]	$/yr	$/Mg[b]	($/ton)[b]	$/yr	$/Mg[b]	($/ton)[b]
F	Two new 136-Mg (150-ton) vessels, closed hoods with scrubbers, top blown, equipped with furnace enclosures and baghouse. Production 1,450,000 Mg (1,600,000 tons) per year.	3.32	2.29	(2.08)	0.36	0.25	(0.23)	2.68	1.85	(1.68)	0.29[d]	0.20	(0.18)
G	One new 136-Mg (150-ton) vessel added to two existing 136-Mg (150-ton) vessels, closed hood with scrubber, top blown, equipped with furnace enclosure and baghouse. Production 2,630,000 Mg (2,900,000 tons) per year.	1.78	0.67	(0.61)	0	0	0	2.24	0.85	(0.77)	0	0	0
H	Two new 272-Mg (300-ton) vessels, closed hoods with scrubbers, bottom blown equipped with furnace enclosures and baghouse. Conversion of an open hearth shop to basic oxygen process. Production 2,900,000 Mg (3,200,000 tons) per year.	5.17	1.79	(1.62)	0.54	0.19	(0.17)	4.02	1.39	(1.26)	0.53[d]	0.19	(0.17)
J	Two new 272-Mg (300-ton) vessels, open hoods, top blown, equipped with ESP for primary and secondary control. Production 2,900,000 Mg (3,200,000 tons) per year.	6.12	2.11	(1.91)	0	0	0	0.47	0.17	(0.15)	1.19	0.41	(0.37)
K	One new 272-Mg (300-ton) vessel added to two existing 272-Mg (300-ton) vessels, open hood, top blown, primary system ESP used for secondary control. Production 5,350,000 Mg (5,900,000 tons) per year.	5.16	0.96	(0.87)	0	0	0	0.31	0.06	(0.05)	0	0	0

See footnotes at end of table.

(continued)

TABLE 8-2. (continued)

Case	Model	Primary pollution control			Water pollution control			Secondary pollution control			Hot metal transfer and skimming pollution control		
		\$/yr	\$/Mg[b]	(\$/ton)[b]	\$/yr	\$/Mg[b]	(\$/ton)[b]	\$/yr	\$/Mg[b]	(\$/ton)[b]	\$/yr	\$/Mg[b]	(\$/ton)[b]
L	Two new 272-Mg (300-ton) vessels, closed hoods with scrubbers, top blown, equipped with furnace enclosures and baghouse. Production 4,540,000 Mg (5,000,000 tons) per year.	5.51	1.21	(1.10)	0.54	0.12	(0.11)	3.68	0.82	(0.74)	0.17[d]	0.03	(0.03)
N	Two new 272-Mg (300-ton) vessels, open hoods, bottom blown, equipped with ESP for primary and secondary control. Production 2,900,000 Mg (3,200,000 tons) per year.	6.34	2.18	(1.98)	0	0	0	0.50	0.18	(0.16)	1.19	0.41	(0.37)
O	Two new 272-Mg (300-ton) vessels, open hoods, top blown, equipped with scrubbers for primary and secondary control. Production 2,900,000 Mg (3,200,000 tons) per year.	8.66	2.99	(2.71)	1.52	0.53	(0.48)	0.94	0.32	(0.29)	1.19	0.41	(0.37)
P	One new 272-Mg (300-ton) closed hood vessel added to two existing 272-Mg (300-ton) open hood vessels, top blown. New vessel has primary scrubber, furnace enclosure and baghouse, existing vessels have ESP for primary control. Production 5,350,000 Mg (5,900,000 tons) per year.	2.62	0.90	(0.82)	0.54	0.19	(0.17)	2.99	1.03	(0.93)	0	0	0

[a]Includes fixed capital charges.

[b]Per Mg (ton) of total shop production.

[c]The KMS conversion was assumed to use existing primary pollution control equipment.

[d]For models with new closed hood vessels (greenfield shops), only hooding, ductwork, and dampers were used as the major cost elements.

TABLE 8-3. CAPITAL COST OF CONTROL BY BUILDING EVACUATION[a]--BOPF SECONDARY EMISSIONS--JULY 1980[1,2]
(millions of dollars)

Model	Plant investment	Primary pollution control investment[b]	Water pollution control investment[c]	Secondary pollution control investment	Hot metal transfer and skimming pollution control investment[d]	Total pollution control investment
Two new 272-Mg (300-ton) vessels, closed hood, top blown. Production 2,900,000 Mg (3,200,000 tons) per year.	169.6	13.2	4.7	39.0	3.4	60.3
Two new 272-Mg (300-ton) vessels, closed hood, bottom blown. Production 2,900,000 Mg (3,200,000 tons) per year.	169.6	14.0	4.7	29.5	3.4	51.6

[a] Includes direct and indirect capital costs.

[b] Assumes separate control device for closed hood, and common control device for open hood.

[c] For BAT 2 control.

[d] Required only if hot metal transfer station is not served by the building evacuation system.

TABLE 8-4. ANNUAL COSTS OF CONTROL BY BUILDING EVACUATION[a]--BOPF SECONDARY EMISSIONS--JULY 1980[1,2]
(millions of dollars)

Model	Primary pollution control			Water pollution control			Secondary pollution control			Hot metal transfer and skimming pollution control		
	$/yr	$/Mg[b]	($/ton)[b]	$/yr	$/Mg[b]	($/ton)[b]	$/yr	$/Mg[b]	($/ton)[b]	$/yr	$/Mg[b]	($/ton)[b]
Two new 272-Mg (300-ton) vessels, closed hood, top blown equipped with furnace enclosure and baghouse. Production 2,900,000 Mg (3,200,000 tons) per year.	4.82	1.66	(1.51)	0.54	0.19	(0.17)	11.5	3.96	(3.59)	0.43	0.12	(0.13)
Two new 272-Mg (300-ton) vessels, closed hood, bottom blown, equipped with furnace enclosure and baghouse. Production 2,900,000 Mg (3,200,000 tons) per year.	5.07	1.74	(1.58)	0.54	0.19	(0.17)	8.94	3.08	(2.79)	0.51	0.18	(0.16)

[a]Includes fixed capital charges.

[b]Per Mg (ton) of total shop production.

TABLE 8-5. BOPF SHOP ANNUAL OPERATING COSTS[a]--JULY 1980[1,2] (millions of dollars/yr)

	Case[b] A, C, H, J, N, O	Case B, D, K, P		Case E		Case F	Case G		Case L
		Total	Added[c]	Total	Added[c]		Total	Added[c]	
Scrap	130.43	240.48	110.05	130.05	0	65.22	118.20	52.99	203.80
Hot metal[d]	0	0	0	0	0	0	0	0	0
Operating labor	22.43	33.65	11.22	22.43	0	17.95	26.92	8.97	35.05
Labor overhead	39.71	59.57	19.86	39.71	0	31.77	47.65	15.88	62.05
Electric power	3.90	7.20	3.29	3.90	0	1.95	3.54	1.59	6.10
Water	1.25	2.30	1.05	1.25	0	0.62	1.13	0.51	1.95
Fuel	1.86	3.42	1.57	1.86	0	0.93	1.68	0.75	2.90
Other raw material[e]	36.29	66.91	30.62	36.29	0	18.14	32.89	14.74	56.70
Maintenance	19.26	32.75	13.48	19.26	0	9.63	16.37	6.74	30.10
TOTAL	255.13	446.28	191.14	255.13	0	146.21	248.38	102.17	398.65
Scrap credit[f]	8.16	15.05	6.89	8.16	0	4.08	7.40	3.32	12.75
Energy credit[g]	0	0	0	0	0	0	0	0	0
Net cost[h]	246.97	431.23	184.25	246.97	0	142.13	240.98	98.85	385.90
$/Mg	85.07	80.57	75.22	85.07	0	97.92	91.60	83.82	85.07
($/ton)	(77.18)	(73.09)	(68.24)	(77.18)	(0)	(88.83)	(83.10)	(76.04)	(77.18)

[a] Does not include environmental control annual costs.

[b] Cases for plants described for capital cost of control by hooding.

[c] Added annual operating cost for modification.

[d] Assumes costs of hot metal are charged to prior operations such as blast furnace, coke ovens, etc. Hot metal production costs are estimated to be $185/Mg ($168/ton) of hot metal or $174/Mg ($158/ton) of raw BOPF steel.

[e] Other raw materials include fluxes, additives, and oxygen.

[f] Credit for ingot scrap.

[g] Where BOPF hoods produce useful steam there could be a credit for steam.

[h] Credit for collected dust of about $0.20/Mg ($0.18/ton) of raw BOPF steel not included.

construction of access roads and walkways, and establishing rail, barge, or truck facilities have not been included in developing the roundout costs except as noted.

8.1.1.2 Indirect Costs. The indirect costs include freight from point of origin and indirect capital costs. Indirect capital costs consist of several cost items that are calculated as percentages of the total installed cost (TIC), the direct costs as noted above. The indirect capital costs include the following items:

1. Interest--covers costs accrued on borrowed capital during construction.

2. Engineering costs--includes administrative, process, project, and general costs; design and related functions for specifications; bid analysis; special studies; cost analysis; accounting; reports; procurement; travel expenses; living expenses; expediting; inspection; safety; communications; modeling; pilot plant studies; royalty payments during construction; training of plant personnel; field engineering; safety engineering; and consultant services.

3. Taxes--includes sales, franchise, property, and excise taxes.

4. Allowance for shakedown--includes costs associated with system prior to startup for continuous operation.

5. Spare parts--represents costs of items stocked in an effort to achieve 100 percent process availability; such items include pumps, valves, controls, special piping and fittings, instruments, spray nozzles, and similar equipment.

6. Contingency costs--includes costs resulting from malfunctions, equipment design alterations, and similar unforeseen sources.

7. Contractors fee and expenses--includes costs for field labor payroll, supervision field office, administrative personnel, construction offices, temporary roadways, railroad trackage, maintenance and welding shops, parking lot, communications, temporary piping, electrical, sanitary facilities, rental equipment, unloading and storage of materials, travel expenses, permits, licenses, taxes, insurance, overhead, legal liabilities, field testing of equipment, and labor relations. Contractor fees and expenses are about 5 percent of the TIC.

The indirect cost for a given estimate is about 65.5 percent of the TIC. Indirect costs have been added to all capital costs presented in this chapter.

8.1.1.3 Working Capital. Working capital is not included in the estimated capital costs, nor is the cost of land for sludge disposal.

8.1.2 Basis for Annual Cost Estimates

Annualized costs represent the cost of operating and maintaining the system and the charges needed to recover the capital investment, which are referred to as fixed costs. As with capital costs, all costs are in July 1980 dollars. Components of annualized cost for the secondary emission control system are:

1. Operating labor--based on number of hours of equipment operation. The charge is $18.45 per hour for labor and $22.14 per hour for supervision. Payroll overhead is taken as 20 percent.

2. Maintenance--divided into maintenance labor, materials, and supplies. Total costs for maintenance are about 5 percent of capital costs.

3. Solid waste disposal--includes cost of $13.23 per megagram ($12 per ton) for disposal of nonhazardous material.

4. Utilities--includes electrical power at $0.04 per kilowatt hour, process water at $0.13 per thousand gallons, and steam at $3.72 per 1,000 pounds.

5. Overheads--includes payroll overhead at 20 percent of labor costs and plant overhead at 50 percent of labor costs plus materials and supplies costs.

6. Fixed costs--includes the charges made to recover capital costs over the depreciable life of the system. These costs are taken as a percent of total capital cost (including indirect costs) amounting to 2 percent for taxes, 2 percent for insurance, and approximately 6 to 10 percent for capital recovery.

8.1.3 Description of Facilities

Cost components of the various model plants and associated pollution control equipment are given below.

8.1.3.1. Plant Facilities. Greenfield shops include the BOPF building, BOP furnace (including primary hood), cranes, ladles, and stations for materials handling, hot metal transfer, skimming, teeming, and facilities for slag and scrap handling. The oxygen plant is included, and half of the transportation facilities (the other half is charged to the blast furnace shop). Control rooms and instrumentation, office space within the shop, and locker rooms for the shop are included, as well as auxiliary equipment. Since desulfurization may take place away from the BOPF shop, desulfurization stations are excluded. Pollution control equipment is excluded and treated separately below. Roundout shops include only new vessels. KMS conversion includes only modifications to the vessel.

8.1.3.2 Primary Pollution Control Equipment. For open hood model plants, primary air pollution control equipment is designed to meet an emission limit of 50 mg/dscm (0.022 gr/dscf). For closed hood model plants primary air pollution control equipment is designed to meet an emission limit of 68 mg/dscm (0.03 gr/dscf). Designs include all necessary ductwork, instrumentation, fans, flares, stacks, and auxiliary equipment. A separate primary control system is constructed for each closed hood furnace. The primary hood is included in these costs.

For the open hood model, primary control systems differ from the closed hood systems in that they have all furnaces tied to a single, common primary control system, except when a third vessel is added to two existing vessels. For those models, a second primary control system is added. Open hood systems have no flare.

8.1.3.3 Water Pollution Control Systems. Costs for water pollution control systems are based on use of a clarifier and lime treatment, sulfide treatment, filtration, and pH control of scrubber effluents. No additional costs for water pollution control systems are estimated for roundout cases or for KMS conversion.

8.1.3.4 Secondary Pollution Control Systems. Secondary systems using furnace enclosures are based on pressure baghouses operating at a gas-to-cloth ratio of 0.01 m/s (2 ft/min) and water pressure drop of 50.8 cm (20 in). Ductwork, fans, auxiliary equipment, and the furnace enclosure are included.

For building evacuation costs, designs are based on pressure baghouses operating at a gas-to-cloth ratio of 2:1 and a water pressure drop of 50.8 cm (20 in). Ductwork, fans, and auxiliary equipment are included. System size allows evacuation of the BOPF shop every 2.5 min. Building volumes are taken as 240,607 and 176,830 m^3 (8,496,000 and 6,244,000 ft^3) for shops with two 272-Mg (300-ton) top blown and two 272-Mg (300-ton) bottom blown furnaces, respectively.

8.1.3.5 Hot Metal Transfer and Skimming Pollution Control System. The only costs allocated for hot metal transfer and skimming control systems are for hooding, dampers, and ductwork connections to the secondary emission control system for building evacuation and for vessels with furnace enclosures. Other vessels have a complete baghouse system.

8.2 NEW FACILITIES

8.2.1 Model Plant Costs

Costs for secondary emission control systems are based on baghouses with the design criteria shown in Tables 8-6 and 8-7. For these tables, it is assumed that no water pollution control or hot metal transfer and skimming control are required for shops in which a new vessel is added to existing vessels. Only the new vessel must be controlled and, as stated in Section 8.1.3.3, it is unlikely that water pollution control equipment would be needed in addition to that already existing in the plant, since scrubbers are not ordinarily used for secondary emission control. For KMS conversions (Model E), it is also assumed that existing primary emission control equipment is sufficient. Conversion from an open hearth shop to a BOPF shop requires primary and secondary emission control equipment, as well as water pollution control and hot metal transfer and skimming control equipment. The Chemical Engineering Plant Cost Index was used to adjust costs given in the references for Tables 8-1 through 8-5.

Design criteria given in Tables 8-6 and 8-7 were derived as conservative estimates based on typical specifications for existing installations.

Cost relationships for secondary emission control are given in Table 8-8. These relationships are shown as percentages of total cost represented by primary or secondary control systems or by total pollution control equipment. For primary pollution control investment in furnace

TABLE 8-6. DESIGN CRITERIA FOR MODEL PLANT PRIMARY EMISSION CONTROL SYSTEMS[a]

Model	Control basis	Gas volume: Normal flow, acms	Gas volume: Normal flow, acfm	Gas volume: Reduced flow	Operating time vessel h/yr: Normal flow	Operating time vessel h/yr: Reduced flow
A	Furnace enclosure	81.6	(173,000)	~0	3,504	5,256
B, P	Furnace enclosure	81.6	(173,000)	~0	2,154	3,230
C, E, H	Furnace enclosure	91.6	(194,000)	~0	3,504	5,256
D	Furnace enclosure	461	(977,000)	~0	2,154	3,230
F	Furnace enclosure	40.6	(86,000)	~0	3,504	5,256
G	Furnace enclosure	40.6	(86,000)	~0	2,117	3,176
J	Open hood	461	(977,000)	~0	6,132	2,628
K	Open hood	461	(977,000)	~0	3,769	1,615
L	Furnace enclosure	81.6	(173,000)	~0	5,475	8,213
N	Open hood	517	(1,096,000)	~0	6,132	2,628
O	Open hood	281	(596,000)	~0	6,132	2,628

[a]Emission control based on a scrubber with a venturi pressure drop of approximately 16.2 kPa (65 in H_2O) or an ESP with a specific collection area of 72.8 m^2 per m^3/s (370 ft^2 per 1,000 acfm). Gas temperatures are 82° C (180° F) at the scrubber inlet or 204° C (400° F) at the ESP inlet. Gas moisture content is 39 percent for scrubbers and 25 percent for ESP's.

TABLE 8-7. DESIGN CRITERIA FOR MODEL PLANT SECONDARY EMISSION CONTROL SYSTEMS[a]

Model	Control basis	Gas volume acms	Gas volume (acfm)	Operating time for affected unit, hr/yr
A, L	Furnace enclosure	283	(600,000)	8,760
	Building evacuation	1,600	(3,400,000)	8,760
B, D, P	Furnace enclosure	283	(600,000)	5,384
C, H	Furnace enclosure	354	(750,000)	8,760
	Building evacuation	1,180	(2,500,000)	8,760
E	Furnace enclosure	354	(750,000)	8,760
	Building evacuation	1,180	(2,500,000)	8,760
F	Furnace enclosure	189	(400,000)	8,760
	Building evacuation	1,060	(2,240,000)	8,760
G	Furnace enclosure	189	(400,000)	5,293
J, O	Open hood	94.4[b]	(200,000)[b]	8,760
	Building evacuation	1,600	(3,400,000)	8,760
K	Open hood	0	0	0
N	Open hood	94.4[b]	(200,000)[b]	8,760
	Building evacuation	1,180	(2,500,000)	8,760

[a]Emission control based on a fabric filter with an air-to-cloth ratio of 0.61 m/min (2 ft/min). Building evacuation assumes 2.5 minutes per air change. Gas temperatures at the baghouse are 52° C (125° F) for building evacuation and 66° C (150° F) for furnace enclosures.

[b]Hot metal transfer station.

TABLE 8-8. COST RELATIONSHIPS FOR BOPF PRIMARY AND SECONDARY EMISSION CONTROL

Model plant	Control basis	Primary pollution control investment, percent of total plant investment[a]	Secondary pollution control investment, percent of total plant investment[a]	Total pollution control investment, percent of total plant investment[a]	Primary pollution control annual costs, percent of steel costs[b]	Secondary pollution control annual costs, percent of steel cost[b]	Total pollution control annual costs, percent of steel cost[b]
A	Furnace enclosure	8.95	6.28	15.2	2.17	1.55	3.73
	Building evacuation	7.79	18.4	26.2	2.17	4.83	7.00
B	Furnace enclosure	5.70	8.48	14.2	0.61	0.69	1.30
C	Furnace enclosure	9.23	7.08	16.3	2.27	1.80	4.07
	Building evacuation	8.45	14.9	23.3	2.27	3.83	6.10
D	Furnace enclosure	12.7	7.85	20.5	1.09	0.69	1.79
E	Furnace enclosure	--	48.4	48.4	--	1.82	1.82
	Building evacuation	--	72.6	72.6	--	4.83	4.83
F	Furnace enclosure	11.6	8.90	20.5	2.59	2.09	4.68
G	Furnace enclosure	7.90	12.0	19.9	0.74	0.93	1.67
H	Furnace enclosure	14.5	11.3	25.7	2.31	1.84	4.15
	Building evacuation	12.4	21.7	34.1	2.31	3.83	6.14
J	Open hood	10.9	2.25	13.2	2.48	0.67	3.15
	Building evacuation	9.13	18.2	27.3	2.48	4.83	7.31
K	Open hood	14.1	0.49	14.6	1.20	0.07	1.27
L	Open hood	8.95	6.28	15.2	1.57	1.00	2.57
	Building evacuation	7.79	18.4	26.2	1.57	3.09	4.66
N	Open hood	11.4	2.24	13.7	2.57	0.68	3.25
	Building evacuation	9.96	14.6	24.6	2.57	3.83	6.39
O	Open hood	13.0	2.2	15.2	4.12	0.86	4.98
	Building evacuation	11.0	17.8	28.8	4.12	4.83	8.95
P	Furnace enclosure	9.18	8.16	17.4	0.73	0.69	1.43

[a]Total plant investment = plant investment + total pollution control investment from Tables 8-1 and 8-3. Primary control includes water pollution control. Secondary control includes hot metal transfer and skimming.

[b]These costs are a percentage of the net costs shown in Table 8-5.

enclosures, the range is about 6 to 14 percent and for secondary pollution control investment, about 6 to 12 percent. For open hoods, the primary pollution control investment is about 9 to 14 percent, and for secondary pollution control investment, about 0.5 to 6.3 percent. The KMS conversion, however, has a cost of about 50 percent, because plant investment for the conversion is small compared to greenfield plant investment. For building evacuation, the range of investments is about 15 to 22 percent depending on vessel size and location of blowing. Again the KMS conversion appears high (72.6 percent) because of low plant investment.

For total pollution control investment as a percentage of total plant investment, the percentages range from about 20 to 26 percent for furnace enclosures for all but KMS conversion, which is 60.8 percent. Building evacuation control covers a broader range from about 29 to 46 percent. KMS, again, costs more (75.6 percent) because of low plant investment.

When secondary pollution control annual costs are compared with net cost of steel produced, furnace enclosures on greenfield shops are about 2 to 2.6 percent, and on roundout shops are about 1 to 1.3 percent. Building evacuation systems range from about 5 to 8 percent.

Total annual costs of pollution control compared with net cost of steel are about 1.3 to 4.7 percent for shops with furnace enclosures or open hoods. Building evacuation costs are from about 4.7 to 9.0 percent.

Amounts of emissions collected in the various model plants are given in Table 8-9. These quantities are used to calculate costs of pollution control on a basis of dollars per megagram (dollars per ton) of pollutant collected. The costs are given in Table 8-10. These costs range from a low of $104/Mg ($94/ton) to a high of $62,789/Mg ($69,212/ton) depending on the basis used for comparison. As discussed in Chapter 6, the effectiveness of furnace enclosures on bottom blown furnaces has not been measured accurately. Three capture efficiencies (60, 80, and 100 percent) have been used for estimating purposes, and are included in the ranges given above.

TABLE 8-9. EMISSIONS COLLECTED FROM AFFECTED FACILITIES IN MODEL PLANTS

Model	Emissions collected, Mg/yr (tons/yr)[a]							
	Furnace primary		Furnace secondary		Hot metal transfer		Building evacuation	
A	41,325	(45,552)	830	(915)	222	(245)	172	(190)
B	25,397	(27,995)	487	(537)	0	0	--	--
C (100% capture)	41,325	(45,552)	2,036	(2,244)	237	(261)	1,824	(2,011)
(80% capture)	41,325	(45,552)	1,595	(1,758)	231	(255)		
(60% capture)	41,325	(45,552)	1,155	(1,273)	173	(246)		
D	25,292	(27,879)	487	(537)	0	0	--	--
E (100% capture)	41,325	(45,552)	2,099	(2,314)	0	0	1,824	(2,011)
(80% capture)	41,325	(45,552)	1,653	(1,822)	0	0		
(60% capture)	41,325	(45,552)	1,205	(1,328)	0	0		
F	20,662	(22,776)	402	(432)	95	(116)	--	--
G	12,484	(13,761)	222	(244)	0	0	--	--
H (100% capture)	41,325	(45,552)	2,036	(2,244)	237	(261)	1,824	(2,011)
(80% capture)	41,325	(45,552)	1,595	(1,758)	231	(255)		
(60% capture)	41,325	(45,552)	1,155	(1,273)	173	(246)		
I	--		--		200	(221)		
J	41,138	(45,346)	964	(1,063)	200	(221)	172	(190)
K	30,720	(27,869)	592	(653)	0	0	--	--
L	64,570	(71,175)	1,376	(1,517)	369	(407)	923	(1,017)
N (100% capture)	41,132	(45,353)	2,224	(2,451)	200	(221)	1,824	(2,011)
(80% capture)	41,142	(45,351)	1,779	(1,961)	200	(221)		
(60% capture)	41,140	(45,348)	1,334	(1,470)	200	(221)		
O	41,215	(45,431)	966	(1,065)	200	(221)	172	(190)
P	25,397	(27,995)	487	(537)	0	0	--	--

[a]Hot metal transfer emissions are collected in the same baghouse as the furnace secondary emissions for some cases, but are shown separately, and are calculated based on apparent baghouse efficiency. For example, Model A has uncontrolled secondary emissions of 1,229 Mg/yr (1,355 tons/yr), excluding teeming, and controlled secondary emissions of 177 Mg/yr (195 tons/yr), excluding teeming (Table 6-5) for an apparent baghouse efficiency of 85.61 percent. Uncontrolled hot metal transfer emissions are 259 Mg/yr (286 tons/yr), of which 259 (286) × 0.8561 = 222 Mg/yr (245 tons/yr) are collected. The same methodology is used for calculating secondary emissions for open hood models in which the primary collector is used for both primary and secondary emissions. An underline is used to indicate emissions collected in the same device.

TABLE 8-10. UNIT COST OF PRIMARY AND SECONDARY EMISSION CONTROL

		Emissions to atmosphere[a]			Annual cost of collection[b]									
					$/Mg particulate					$/ton particulate				
Model	Control basis	Mg/yr	(tons/yr)	Millions of $/yr	Total	Primary	Furnace secondary	Hot metal transfer[c]	Combined secondary[d]	Total	Primary	Furnace secondary	Hot metal transfer[c]	Combined secondary[d]
A	No secondary	1,375	(1,515)	5.36	130	130	0	0	0	118	118	0	0	0
	Furnace enclosure	323	(355)	9.20	217	130	4,108	1,935	3,650	197	118	3,727	1,755	3,325
	Building evacuation	1,202	(1,325)	17.3	417	130	69,212	--	69,212	378	118	62,789	--	62,789
B	No secondary	845	(932)	2.62	104	104	0	0	0	94	94	0	0	0
	Furnace enclosure	358	(395)	5.61	217	104	6,138	0	6,138	197	94	5,568	0	5,568
C (100% capture)--	No secondary	2,640	(2,910)	5.61	136	136	0	0	0	123	123	0	0	0
	Furnace enclosure	367	(405)	10.1	231	136	1,936	2,154	1,959	210	123	1,756	1,954	1,776
	Building evacuation	816	(899)	15.1	349	136	4,901	--	4,901	317	123	4,446	--	4,446
C (80% capture)--	No secondary	2,640	(2,910)	5.61	136	136	0	0	0	123	123	0	0	0
	Furnace enclosure	814	(897)	10.1	234	136	2,470	2,205	2,437	212	123	2,241	2,000	2,211
	Building evacuation	816	(899)	15.1	349	136	4,901	--	4,901	317	123	4,446	--	4,446
C (60% capture)--	No secondary	2,640	(2,910)	5.61	136	136	0	0	0	123	123	0	0	0
	Furnace enclosure	1,262	(1,391)	10.1	237	136	3,412	2,285	3,229	215	123	3,095	2,073	2,930
	Building evacuation	816	(899)	15.1	349	136	4,893	--	4,893	317	123	4,439	--	4,439
D	No secondary	951	(1,048)	4.71	186	186	0	0	0	169	169	0	0	0
	Furnace enclosure	463	(511)	7.70	299	186	6,138	0	6,138	271	169	5,568	0	5,568
E (100% capture)--	No secondary	2,640	(2,910)	0	0	0	0	0	0	0	0	0	0	0
	Furnace enclosure	367	(405)	4.50	104	0	2,144	0	2,144	94	0	1,945	0	1,945
	Building evacuation	816	(899)	9.45	219	0	4,893	--	4,893	199	0	4,439	--	4,439
E (80% capture)--	No secondary	2,640	(2,910)	0	0	0	0	0	0	0	0	0	0	0
	Furnace enclosure	814	(897)	4.50	105	0	2,723	0	2,723	95	0	2,470	0	2,470
	Building evacuation	816	(899)	9.45	219	0	4,893	--	4,893	199	0	4,439	--	4,439
E (60% capture)--	No secondary	2,640	(2,910)	0	0	0	0	0	0	0	0	0	0	0
	Furnace enclosure	1,262	(1,391)	4.50	106	0	3,736	0	3,736	96	0	3,389	0	3,389
	Building evacuation	816	(899)	9.45	219	0	4,893	--	4,893	199	0	4,439	--	4,439
F	No secondary	688	(758)	3.68	179	179	0	0	0	162	162	0	0	0
	Furnace enclosure	191	(210)	6.65	314	179	6,839	2,746	5,976	285	162	6,024	2,500	5,420
G	No secondary	417	(459)	1.78	142	142	0	0	0	129	129	0	0	0
	Furnace enclosure	194	(214)	4.02	316	142	10,119	0	10,119	287	129	9,180	0	9,180
H (100% capture)--	No secondary	2,640	(2,910)	5.71	138	138	0	0	0	125	125	0	0	0
	Furnace enclosure	367	(405)	10.3	236	138	1,974	2,031	2,003	214	125	1,791	2,031	1,816
	Building evacuation	816	(899)	15.2	334	138	4,392	--	4,392	303	125	3,984	--	3,984

(continued)

TABLE 8-10. (continued)

Model	Control basis	Emissions to atmosphere[a] Mg/yr	(tons/yr)	Millions of $/yr	Annual cost of collection[b] $/Mg particulate Total	Primary	Furnace secondary	Hot metal transfer[c]	Combined secondary[d]	$/ton particulate Total	Primary	Furnace secondary	Hot metal transfer[c]	Combined secondary[d]
H (80% capture)--	No secondary	2,640	(2,910)	5.71	138	138	0	0	0	125	125	0	0	0
	Furnace enclosure	814	(897)	10.3	239	138	2,521	2,291	2,491	217	125	2,287	2,078	2,260
	Building evacuation	816	(899)	15.2	334	138	4,392	--	4,392	303	125	3,984	--	3,984
H (60% capture)--	No secondary	2,640	(2,910)	5.71	138	138	0	0	0	125	125	0	0	0
	Furnace enclosure	1,262	(1,391)	10.3	241	138	3,481	2,374	3,302	219	125	3,158	2,154	2,995
	Building evacuation	816	(899)	15.2	334	138	4,392	--	4,392	303	125	3,984	--	3,984
J	No secondary	1,567	(1,727)	6.12	146	149	0	0	0	132	135	0	0	0
	Open hood	396	(437)	7.78	184	149	487	5,936	1,426	167	135	442	5,385	1,293
	Building evacuation	1,202	(1,325)	18.1	438	149	66,717	5,936	34,033	397	135	60,526	5,385	30,875
K	No secondary	963	(1,062)	5.16	191	204	0	0	0	185	185	0	0	0
	Open hood	365	(402)	5.47	202	204	524	0	524	192	185	475	0	475
L	No secondary	2,149	(2,369)	6.05	94	94	0	0	0	85	85	0	0	0
	Furnace enclosure	404	(445)	9.90	149	94	2,674	461	2,205	135	85	2,426	418	2,001
	Building evacuation	1,227	(1,352)	18.0	274	94	12,465	--	12,465	249	85	11,308	--	11,308
N (100% capture)--	No secondary	2,832	(3,122)	6.34	146	154	0	0	0	140	140	0	0	0
	Open hood	396	(437)	8.03	184	154	225	5,936	698	167	140	204	5,385	633
	Building evacuation	1,008	(1,110)	15.8	368	154	4,901	--	4,901	334	140	4,446	--	4,446
N (80% capture)--	No secondary	2,832	(3,123)	6.34	146	154	0	0	0	140	140	0	0	0
	Open hood	843	(929)	8.03	186	154	281	5,936	854	169	140	255	5,385	775
	Building evacuation	1,008	(1,110)	15.8	368	154	4,901	--	4,901	334	140	4,446	--	4,446
N (60% capture)--	No secondary	2,832	(3,122)	6.34	146	154	0	0	0	140	140	0	0	0
	Open hood	1,410	(1,423)	8.03	188	154	375	5,936	1,102	171	140	340	5,385	1,000
	Building evacuation	1,008	(1,110)	15.8	368	154	4,901	--	4,901	334	140	4,446	--	4,446
O	No secondary	1,488	(1,640)	10.2	241	248	0	0	0	219	225	0	0	0
	Open hood	318	(350)	12.3	290	248	973	5,936	1,827	263	225	883	5,385	1,656
	Building evacuation	1,202	(1,325)	22.1	534	248	66,717	--	66,717	484	225	60,526	--	60,526
P	No secondary	845	(932)	3.16	125	125	0	0	0	113	113	0	0	0
	Furnace enclosure	358	(395)	6.15	238	125	6,138	0	6,138	216	113	5,568	0	5,568

[a]Emissions are taken from Table 6-5 and include primary, hot metal charge, hot metal transfer, tapping, and teeming emissions from affected facilities.

[b]Primary, secondary, and hot metal transfer costs based on cost of control for the type (and amount) of emissions collected. Costs are based on Tables 8-2, 8-4, and 8-9.

[c]Includes any skimming control costs.

[d]Average unit cost for furnace secondary and hot metal transfer.

Table 7-12 shows an estimated increase in new BOPF steelmaking capacity of 6.81 Tg (7.5 million tons) from 1981 through 1986. This amount is equivalent to 2.3 to 5.8 times model plant production, depending on which model plant is chosen. Using the 2.3 factor for two new 272-Mg (300-ton) furnaces, capital required to finance primary pollution control equipment for the new capacity (in July 1980 dollars) ranges from $41.2 million to $60.0 million for open hoods and furnace enclosures. Secondary equipment investments, including hot metal transfer stations, range from $10.1 million to $34.8 million for open hoods and furnace enclosures and from $75.7 million to $97.5 million for building evacuation. Annualized costs range from $12.3 million to $23.4 million for primary systems, from $3.82 million to $10.2 million for secondary systems, and from $21.7 million to $27.4 million for building evacuation.

8.2.2 Comparison of Costs for Various Regulatory Alternatives

Tables 8-11 and 8-12 compare the air pollution control costs for the four regulatory alternative plants described in Table 7-1. As shown, building evacuation is a more costly, less effective alternative when compared to open hood or closed hood exhaust ventilation control. Comparing the open hood alternative (II) with the closed hood alternative (III) shows that the closed hood alternative is more effective for reducing particulate emissions and is more costly ($19,100/Mg or $17,300/ton of additional particulate removed).

8.2.3 Typical Regulatory Alternative Plant Costs

Comparison of costs based on Typical Regulatory Alternative Plants (TRAP's) as described in Table 7-1, is given in Table 8-13. These costs are for future new BOPF in-place capacity of 6.81 Tg/yr (7.5 million tons/yr).

Percentage increases in total capital investment above baseline for the various regulatory alternatives are 43.3 percent for open hood, 70.0 percent for furnace enclosure, and 236 percent for building evacuation.

Percentage increases in total annual cost above baseline are 44.4 percent for open hood, 71.4 percent for furnace enclosure, and 222 percent for building evacuation.

TABLE 8-11. EMISSIONS AND CONTROL COSTS FOR TYPICAL REGULATORY ALTERNATIVE PLANTS

Alternative	Total emissions Mg/yr (tons/year)	Total particulate emission control costs $/yr
I	1,375 (1,515)	5,360,000
II	396 (437)	7,780,000
III	323 (355)	9,200,000
IV	1,202 (1,325)	17,290,000

TABLE 8-12. COMPARATIVE UNIT COSTS OF VARIOUS REGULATORY ALTERNATIVES

Alternatives	Unit cost per mass of additional particulate removed $/Mg ($/ton)
II vs. I	2,475 (2,245)
III vs. I	3,650 (3,310)
IV vs. I	69,300 (62,800)
III vs. II	19,100 (17,300)
IV vs. III	∞[a]
IV vs. II	∞[a]

[a]Less effective, more costly alternative.

TABLE 8-13. FUTURE NATIONWIDE CAPITAL AND ANNUAL COSTS OF CONTROL FOR TYPICAL REGULATORY ALTERNATIVE PLANTS: 6.81 Tg/yr TOTAL CAPACITY

Regulatory alternative[a]	Future costs, millions of $/yr					
	Capital			Annual		
	Primary	Secondary	Total	Primary	Secondary	Total
I (Baseline)	42.0	0	42.0	12.6	0	12.6
II (Open hood)	49.9	10.3	60.2	14.3	3.89	18.2
III (Furnace enclosure)	42.0	29.4	71.4	12.6	9.0	21.6
IV (Building evacuation)	42.0	99.4	141.0	12.6	28.0	40.6

[a]See Table 7-1 for definition of typical regulatory alternative plant.

TABLE 8-14. COST ESTIMATE FOR OSHA COMPLIANCE--
BOPF SECONDARY EMISSIONS--JULY 1980
(millions of dollars)

Case	Model	Plant investment	Total pollution control investment	OSHA directed investment[a]
A	Two new 272-Mg (300-ton) vessels, closed hoods with scrubbers, top blown equipped with furnace enclosures and baghouse. Production 2,900,000 Mg (3,200,000 tons) per year.	169.6	30.5	4.27
B	One new 272-Mg (300-ton) vessel added to two existing 272-Mg (300-ton) vessels, closed hood with scrubber, top blown, equipped with furnace enclosure and baghouse. Production 5,350,000 Mg (5,900,000 tons) per year.	105.3	17.4	2.44
C	Two new 272-Mg (300-ton) vessels closed hoods with scrubbers, bottom blown, equipped with furnace enclosures and baghouse. Production 2,900,000 Mg (3,200,000 tons) per year.	169.6	33.1	4.63
D	One new 272-Mg (300-ton) vessel added to two existing 272-Mg (300-ton) vessels, open hood with ESP, top blown equipped with local hoods and baghouse. Production 5,350,000 Mg (5,900,000 tons) per year.	105.3	27.2	3.81

See footnote at end of table. (continued)

TABLE 8-14. (continued)

Case	Model	Plant investment	Total pollution control investment	OSHA directed investment[a]
E	Two existing 272-Mg (300-ton) vessels converted to KMS process, closed hoods with scrubbers, top and bottom blown, equipped with furnace enclosures and baghouse. Production 2,900,000 Mg (3,200,000 tons) per year.	16	15.0	2.10
F	Two new 136-Mg (150-ton) vessels, closed hoods with scrubbers, top blown, equipped with furnace enclosures and baghouse. Production 1,450,000 Mg (1,600,000 tons) per year.	84.8	21.9	3.07
G	One new 136-Mg (150-ton) vessel added to two existing 136-Mg (150-ton) vessels, closed hood with scrubber, top blown, equipped with furnace enclosure and baghouse. Production 2,630,000 Mg (2,900,000 tons) per year.	50.7	12.6	1.76
H	Two new 272-Mg (300-ton) vessels, closed hoods with scrubbers, bottom blown equipped with furnace enclosures and baghouse. Conversion of an open hearth shop to basic oxygen process. Production 2,900,000 Mg (3,200,000 tons) per year.	99.8	34.5	4.83

See footnote at end of table.

(continued)

TABLE 8-14. (continued)

Case	Model	Plant investment	Total pollution control investment	OSHA directed investment[a]
J	Two new 272-Mg (300-ton) vessels, open hoods, top blown, equipped with ESP for primary and secondary control. Production 2,900,000 Mg (3,200,000 tons) per year.	169.6	25.7	3.60
K	One new 272-Mg (300-ton) vessel added to two existing 272-Mg (300-ton) vessels, open hood, top blown, primary system ESP used for secondary control. Production 5,350,000 Mg (5,900,000 tons) per year.	105.3	18.0	2.52
L	Two new 272-Mg (300-ton) vessels, closed hoods with scrubbers, top blown, equipped with furnace enclosures and baghouse. Production 4,540,000 Mg (5,000,000 tons) per year.	169.6	30.5	4.27
N	Two new 272-Mg (300-ton) vessels, open hoods, bottom blown, equipped with ESP for primary and secondary control. Production 2,900,000 Mg (3,200,000 tons) per year.	169.6	26.8	3.75
O	Two new 272-Mg (300-ton) vessels, open hoods, top blown, equipped with scrubbers for primary and secondary control. Production 2,900,000 Mg (3,200,000 tons) per year.	169.6	30.5	4.27

See footnote at end of table. (continued)

TABLE 8-14. (continued)

Case	Model	Plant investment	Total pollution control investment	OSHA directed investment[a]
P	One new 272-Mg (300-ton) closed hood vessel added to two existing 272-Mg (300-ton) open hood vessels, top blown. New vessel has primary scrubber, furnace enclosure and baghouse, existing vessels have ESP for primary control. Production 5,350,000 Mg (5,900,000 tons) per year.	105.3	22.1	3.09

[a]Calculated as 14 percent of total pollution control investment.

Percentage increases in cost of secondary control above primary control are less than 30 percent for open hood (capital or annual), approximately 70 percent for furnace enclosure, and approximately 230 percent for building evacuation.

8.3 MODIFIED/RECONSTRUCTION FACILITIES

The KMS process can be used for either new or modified vessels. Conversion to this process and the open hearth process has been included in Section 8.2.

8.4 OTHER COST CONSIDERATIONS

In addition to the cost of control for secondary emissions, there are other regulatory costs mandated under the Occupational Safety and Health Act (OSHA), the Water Pollution Control Act (WPCA), and the Resource Conservation and Recovery Act (RCRA).

The Office of Technology Assessment shows estimates that OSHA investment costs are about 14 percent of EPA costs on an industry wide basis. Applying this percentage to BOPF secondary emission control options gives the results shown in Table 8-14.

Water pollution control costs would apply to effluents from scrubbers. These costs have been shown in Table 8-1 and range from 13.6 to 22.3 percent of total pollution control investment for new facilities.

There are no existing regulations for RCRA applicable to BOPF shops.

Promulgation of a standard for BOPF secondary emission control is not expected to impose major resource requirements on regulatory and enforcement agencies since the agencies are already maintaining surveillance over BOPF shops for primary emission control.

8.5 REFERENCES

1. Estimated Costs Associated with the Proposed Revision of New Source Performance Standards for Basic Oxygen Furnaces. PEDCo Environmental, Inc., Cincinnati, Ohio. EPA Contract No. 68-02-3554, Work Assignment No. 5. July 1981.

2. Memorandum from Goldman, L. J., Research Triangle Institute to Fitzsimmons, J. G., U.S. Environmental Protection Agency. June 26, 1981.

3. Office of Technology Assessment. Technology and Steel Industry Competitiveness. June 1980. p. 349.

9. ECONOMIC IMPACTS

9.0 SUMMARY OF IMPACTS

Three regulatory alternatives are considered in this analysis. Regulatory Alternative I is the baseline case from which impacts are computed. Under Alternative I, primary emissions are controlled but secondary emissions are not. Alternative II would also control secondary emissions using open-hood collection systems. Alternative III, which is more stringent than II, would require the use of closed-hood collection systems to control secondary emissions. Regulatory Alternative IV, which would require building evacuation, is shown in Chapters 7 and 8 to be not cost-effective. Thus, this alternative is not considered further in this analysis.

A range of impacts is computed for each alternative because there are 14 model plants costed under Alternative I, 5 model plants under Alternative II, and 9 model plants under Alternative III. In an effort to provide a more useful analysis, a single impact estimate is presented for each alternative based on the premise that a new basic oxygen furnace (BOF) shop with two 272-Mg top blown vessels is most representative of future BOF construction. These estimated impacts are summarized below. All dollar estimates are in 1980 dollars.

Regulatory Alternative I is the baseline from which the impacts of Alternatives II and III are computed. It is projected that in 1986 baseline domestic steel output would be 94 million Mg and baseline steel industry employment would be 468,120 workers. In 1986, U.S. steel users would import 19.6 million Mg of foreign steel at baseline.

It should be noted that Alternative I, which controls only primary emissions, has associated impacts in that the average total cost of producing steel in a representative shop, as described above, is $2.03

higher per megagram under Alternative I than under a no-control situation. If the $2.03 cost impact is fully realized in higher steel prices, the price impact is 0.53 percent. It can thus be estimated that in the absence of Alternative I, 1986 steel shipments would be 926,652 Mg, or 0.99 percent, higher. Projected 1986 employment is computed to be 4,615 jobs, or 0.99 percent, higher with no control than under Alternative I. It should be understood that this employment impact and those to follow do not occur as layoffs of employed workers but as lost employment opportunities; that is, there will be 4,615 fewer job openings created by 1986 under Alternative I than there would have been without the control. This employment impact estimate, as well as those that follow, may be an overestimate because employment is likely to increase in sectors of the economy that produce substitutes for steel and in industries that produce control equipment. The 19.6-million-Mg projection of 1986 steel imports under Alternative I is 156,859 Mg, or 0.80 percent, higher than it would be in the absence of the alternative.

The impacts of Alternative II are measured as changes from baseline. The steel price increase of $0.65 per megagram represents an 0.17 percent impact. This price impact would cause an estimated 297,228 Mg output reduction in 1986, a loss of 0.32 percent. It is estimated that 0.32 percent fewer jobs, a total of 1,498 fewer jobs, would be created by 1986 under Alternative II than at baseline. Imports in 1986 are computed to be 50,313 Mg, or 0.26 percent, higher than at baseline. The estimated total cost of compliance with Alternative II in 1986 is $15.6 million. This cost is not incurred in any single year, but over the entire several-year period ending in 1986. It may be an overestimate since it does not account for new capacity adjustments that could result from the regulation.

The impacts of Alternative III are also measured from baseline. The estimated price impact is $1.49 per megagram, or 0.39 percent. Domestic steel output in 1986 would be 686,200 Mg lower under Alternative III than under Alternative I. An estimated 0.73 percent fewer jobs would be created in the steel industry by 1986 under Alternative III. This loss of 3,417 job opportunities may be offset by employment gains elsewhere in the economy. The estimated import impact is 0.59 percent over baseline. The estimated total cost of compliance capital through 1986 is $18.4 million for Alternative III.

9.1 INDUSTRY PROFILE

9.1.1 Introduction

This industry profile focuses on the blast furnaces and steel mills industry. The profile has two main purposes. The first is informative in nature; the profile should provide the reader with a broad overview of the industry. In this sense, the industry profile should be meaningful when read alone. The second purpose is to lend support to an economic analysis involving the industry by helping to assess the appropriateness of using a competitive, monopoly or some other model to analyze the industry. Further, the profile can provide some of the necessary data that will be used in the analysis itself.

The industry profile is comprised of five major sections. The remainder of this introduction, which constitutes the first section, provides a brief, descriptive, and largely qualitative look at the industry. The remaining four sections of the profile conform with a particular model of industrial organization analysis. This model maintains that an industry can be characterized by its basic conditions, market structure, market conduct, and market performance.[1]

The basic conditions in the industry, discussed in the second major section of this profile, are believed to be a major determinant of the prevailing market structure. Most important of these basic conditions are supply and demand conditions. Supply conditions are largely technological in nature, while demand conditions are determined by the attributes of the products themselves.

The market structure of the blast furnaces and steel mills industry is examined in the third section of this profile. Issues addressed include economic aspects of production functions, cost structures, market power, integration, and barriers to entry. Market structure is the second link in the overall framework, and has major influence on the third link, the conduct of market participants.

Market conduct, addressed in the fourth section, concerns price and nonprice behavior of sellers. Of particular interest is the degree to which the industry pricing behavior approximates the competitive pricing model, the monopoly pricing model, or some model of imperfect competition.

The fifth and final section of the industry profile addresses market performance. The historical record of the industry's financial performance is examined, with some emphasis on its comparison with other industries. Industry trends are noted, and projections are presented for key variables such as price, output, and investment.

9.1.1.1 Definition of the Blast Furnaces and Steel Mills Industry. The blast furnaces and steel mills industry (hereafter the steel industry) is the name given to those firms classified in Standard Industrial Classification (SIC) 3312. The industry comprises establishments primarily engaged in the production of hot metal, pig iron, and ferroalloys from iron ore and iron and steel scrap. SIC 3312 also includes establishments that produce coke, an important fuel input to iron production. Establishments primarily engaged in converting pig iron, scrap iron, and scrap steel into steel are also classified in SIC 3312. Finally, SIC 3312 includes establishments primarily engaged in hot rolling iron and steel into such basic products as plates, sheets, bars, and tubing.[2]

The majority of all goods produced by plants in the steel industry are intermediate in nature. As such, they are generally shipped to other plants within SIC 3312 or other industries to be used as inputs in the production of final goods or other intermediate goods. The input/output relationships of SIC 3312 will be dealt with in detail in Section 9.1.2. It is worthwhile to note here that the demand for blast furnace and steel mill products is dependent only indirectly on consumer tastes and preferences. It will be shown later that this indirect link is nonetheless significant.

9.1.1.2 The Steel Industry in the Macroeconomy. The value added by all establishments in SIC 3312 in 1977 was $15,331.9 million. This represents approximately 0.8 percent of total gross national product for 1977. Employment in the steel industry in 1977 was 441,900, which was approximately 0.5 percent of total U.S. employment in 1977. Capital expenditures on new plant and equipment in SIC 3312 was $2,143.1 million in 1977, approximately 0.7 percent of the national total.[3 4]

A comparison of these shares to those of other industries provides a greater understanding of the importance of SIC 3312 in the overall economy. The $15,331.9 million of value added by the steel industry in 1977 was approximately 6.3 percent greater than that of SIC 2911, the petroleum refining industry. Value added by the motor vehicle industry, SIC 3711 in 1977 was approximately 22 percent greater than that of the steel industry.[5] SIC 3312 is thus seen to be among the larger manufacturing industries.

The U.S. steel industry is a major contributor to total world steel production. In 1979, the world leader in steel production was the Soviet Union, which produced 19.9 percent of worldwide steel output. The United States was second, with 16.5 percent of total world production. Japan produced 14.9 percent of total steel produced in 1977.[6]

9.1.2 Basic Conditions

9.1.2.1 Supply Conditions.

9.1.2.1.1 Product description. Nearly all output of SIC 3312 consists of intermediate goods. As such, most steel mill products are sold to producers of other goods. These goods in turn might be final goods such as automobiles, or other intermediate goods, such as engine pistons and valves.

Sales of these intermediate goods can be classified into three types. The first type consists of sales of the intermediate goods from plants classified in SIC 3312 to plants classified in other SIC codes. In 1972, approximately 83 percent of all sales from SIC 3312 were of this type.[7] The second type of sale involves shipments from plants classified in SIC 3312 to other plants classified in the same industry. The third type of sale is actually implicit in nature and is represented by the transfer of goods within a plant from one production stage to another. These two types of intraindustry sales together accounted for approximately 17 percent of all SIC 3312 sales in 1972.[7]

A large number of identifiably different products is produced by plants classified in SIC 3312. For definitional purposes, it is useful to categorize SIC 3312 output into four products: coke, pig iron, raw steel, and finished steel products.

Coke is the carbon residue that results from the heating of coal in the absence of oxygen. Coke constitutes the chief fuel used in the blast furnace to produce pig iron from iron ore. Coke is classified as a steel industry product since it is nearly always produced as a secondary product in SIC 3312 plants. While certain other fuels may be used to supplement coke in the blast furnace, none are used to replace coke entirely.

Pig iron is the chief material input in raw steel production. The conversion of iron ore into pig iron takes place in a blast furnace, fueled mainly by coke. Pig iron is drawn from the furnace in a molten state, and is approximately 93 percent iron and 7 percent impurities. Once produced, the molten iron is utilized in one of two ways. In an integrated steel mill, the molten iron can be charged, with or without iron and steel scrap, into a steel furnace. Alternatively, the molten iron is poured into molds called "pigs" where it solidifies when cooled. In solid form, pig iron can be stored in plant for later conversion into steel or shipped to other steel producing facilities.[8]

Raw steel is the primary product of plants classified in SIC 3312. Produced in one of several types of steel furnaces, steel is substantially freer from impurities than pig iron.

The American Iron and Steel Institute identifies three major grades of steel--carbon, alloy, and stainless.[9] Carbon steel contains only small amounts of such alloying elements as vanadium, molybdenum, manganese, silicon, and copper.[10] Carbon steel is suitable for use in applications not requiring additional strength or other special properties. As most applications are of this type, carbon steel accounted for 85.3 percent by weight of U.S. raw steel production in 1979.[9]

Alloy steel consists of steels containing specific percentages of vanadium, molybdenum, or other elements as well as larger amounts of manganese, silicon, and copper than carbon steel. Tool steel is an alloy containing such elements as tungsten and molybdenum. Its added strength and hardness make it well suited for use in tools and power-driven cutting and shaping machinery. Another alloy, high-strength low-alloy steel, contains only small amounts of alloying elements. At the same time, it is harder than carbon steel because of special processing.[10] Alloy steels are gaining relative importance in the steel market, increasing from 9.7 percent of total U.S. raw steel production by weight in 1970 to 13.2 percent in 1979.[9]

Stainless steel accounted for 1.6 percent by weight of U.S. raw steel production in 1979.[9] Most stainless steel is an alloy of steel, chrome, and nickel. Stainless steel is generally strong and highly resistant to rust and corrosion, making it particularly useful in medical, chemical, and aerospace applications.[10]

Raw steel exists as solid ingots and crude shapes such as slabs, billets, and blooms. Slabs, billets, blooms, and other semifinished shapes are suitable for rolling or other processing into finished steel products. These semifinished products can either be continuously cast from molten steel directly from the furnace or can be formed from reheated steel ingots. Approximately 15 percent of U.S. produced raw steel is continuously cast currently; the rest is produced in ingot form.[11] [12]

The fourth major category of SIC 3312 output is finished steel products. Included in this category are only very basic steel shapes such as plates, sheets, strips, rods, bars, and tubing. Establishments that produce these products are classified in SIC 3312 only if they are "hot-rolled" from iron and steel. Establishments that produce very similar products by a cold-finishing technique are classified in other SIC codes by the type of product. For example, the total value of output by all domestic industries of steel nails and spikes in 1977 was $359.0 million. Of this total, 43 percent was produced in SIC 3312 while 52 percent was produced in SIC 3315--steel wire and related products.[13] [14]

9.1.2.1.2 Production technology.

9.1.2.1.2.1 Raw materials and other inputs. Coke, iron, and steel production require a wide variety of material inputs. Some of these inputs--coal and iron ore for example--are nonrenewable resources. Others such as steel scrap are better labeled renewable. An examination of which goods and services are purchased by plants classified in SIC 3312 can reveal some information about how steel products are produced.

The 1972 input-output (I-O) model of the United States economy identifies 492 distinct goods and services that comprise all economic activity. The national I-O model can be used to determine the economic and technical interrelationships between all 492 "industries." One of the 492 sectors identified is SIC 3312--blast furnaces and steel mills.[7]

One feature of the I-O model allows a determination of the "recipe" for producing $1.00 of output of SIC 3312. This recipe is an industry average, and several cautions should be voiced. First, different plants may use somewhat different mixes of inputs to produce the same kind of product. Second, a plant that produces only coke, for example, will use quite a different set of inputs than a plant that produces only steel. Both plants, however, are classified in SIC 3312. Third, this industry-average recipe is based on the U.S. economy in 1972. No more recent model is available. To the extent that input substitution has occurred in the steel industry since 1972, the input mix has changed.

Of the 492 input-output sectors, the 10 representing the largest input cost shares to the blast furnaces and steel mills industry are recorded in Table 9-1. Most interesting is that the input having the largest cost share in blast furnaces and steel mill products production is blast furnaces and steel mills products themselves. Table 9-1 indicates that the steel industry purchased 17.3 cents of its own output for every dollar of output it produced. This observation can be explained as follows. Producers of iron, who are classified in SIC 3312, purchase significant quantities of coke from coke plants,

TABLE 9-1. IMPORTANT INPUTS TO THE BLAST FURNACES AND STEEL MILLS INDUSTRY--SIC 3312--IN 1972[7]

Input	Share of total input cost (percent)
Blast furnace and steel mill products	17.3
Iron ore	5.8
Railroad transportation	3.7
Wholesale trade services	3.7
Coal	2.7
Industrial chemicals	2.0
Electrometallurgical products	2.0
Scrap	2.0
Electricity	1.7
Natural gas	1.4

which are also classified in SIC 3312. Similarly, steel plants purchase pig iron. The relatively large size of this intraindustry input coefficient stresses the importance of vertical integration in the iron and steel industry.

The second most important input by value is iron ore, which represents an input cost share of 5.8 percent. The third and fourth most significant inputs by value are not goods at all, but services. For each dollar of output, producers in SIC 3312 purchased 3.7 cents of railroad transportation and 3.7 cents of wholesale trade services in order to have all other inputs delivered to their plants.

The 2.7-percent input cost share for coal is a reminder that coke producers are classified in SIC 3312 and that some integrated steel mills produce their own coke. Coal, of course, is the primary input in coke production.

Note finally that the purchase of iron and steel scrap represents the eighth largest cost share input. Few other industries purchase such a large share of scrap. This share can be explained by the importance of iron and steel scrap as a substitute for pig iron in raw steel production.

9.1.2.1.2.2 Production processes. It has been stressed earlier that coke, pig iron, raw steel, and finished steel products are all produced by plants classified in SIC 3312. The purpose of this section is to focus only on the production processes employed to produce the primary output of the industry--raw steel. A discussion of technological change and trends follows in Section 9.1.2.1.2.3.

The production of raw steel generally involves the introduction of some combination of pig iron, iron scrap, and steel scrap into a steel furnace. In the furnace, the impurities in the input charge are oxidized at high temperature. Steelmaking technologies differ in the type of furnace used. There are three primary furnace types currently in use worldwide: the open hearth furnace, the basic oxygen furnace (BOF), and the electric arc furnace (EAF). The Bessemer type furnace has virtually disappeared from use.

The open hearth furnace is the oldest furnace type currently in use in the United States, and is the least prevalent. In 1979, only 14.1 percent of all raw steel produced in the United States was produced using an open hearth process.[9] In this process, pig iron, scrap, or both are placed in a long, shallow furnace made of dolomite or silica brick. Gas or oil is burned to produce a flame that heats the input charge from above the open furnace. Preheated combustion air, sometimes enriched with pure oxygen, is forced into the furnace to aid the oxidation of impurities.[15 16]

One advantage of the open hearth furnace is its ability to handle a charge of all pig iron, all scrap, or any combination of both. This allows open hearth operators to utilize inputs in an economically efficient manner as relative prices change. The major disadvantage of the open hearth process is that the heating cycle time is lengthy--up to 8 hours.[16] Because of the open hearth furnace's lengthy heat time, the process requires approximately 2.5 times as much energy (measured in Btu's) per ton of steel than does the electric arc process. The open hearth process is relatively labor-intensive as well, requiring up to twice as many labor hours per unit of steel as the basic oxygen process.[17]

The BOF process accounted for 61.1 percent of all U.S. steel production in 1979.[9] The metal charge for a BOF must be largely molten furnace iron--seldom less than 70 percent. The remaining charge can be cold pig iron or scrap. A largely molten metal charge is necessary because supplemental heat is not added to a BOF as it is to an open hearth furnace. The sole heat source in a BOF is the latent heat in the molten charge itself.[18] Even without the addition of supplemental heat to a BOF, steel refining is achieved in a short period of time due to the introduction of large quantities of pure oxygen. The availability in recent years of large quantities of pure oxygen at low relative prices has made BOF steelmaking economically feasible.[19]

The chief advantage of BOF steelmaking is that pig iron is converted to steel in a period of approximately 45 minutes. Labor and certain other costs per ton of steel are thus substantially lower for the BOF process than with the open hearth process. The major disadvantage of the BOF process is that the charge must consist mainly of molten iron. A BOF shop must have access to a source of molten metal; it is therefore usually part of an integrated steel mill.

The EAF steelmaking process accounted for 24.9 percent of all U.S. steel production in 1979.[9] In the EAF process, solid iron and scrap steel are placed in the furnace. The EAF can accept a charge of up to 100 percent scrap. Electrically charged electrodes resting above the iron and steel create an electric arc between the electrodes and the metal charge. The heat so generated is the sole heat source, and oxidizes the impurities. Because no impurities are added by fossil fuels, EAF's are particularly well suited to the production of alloy steels and stainless steel.[20]

Because the EAF may be charged entirely with scrap, it need not be affiliated with an integrated plant. EAF facilities can be quite small relative to open hearth or basic oxygen furnace operations. Thus, they are relatively inexpensive to build and market entry is not prohibited by high startup costs.

9.1.2.1.2.3 Technical potential for input substitution and production process innovation. This section discusses the technical potential for input substitution and process innovation in raw steel production. The distinction should be made between technical potential and economic potential.

Technical potential is purely an engineering concept regarding the physical ability to employ different inputs or processes to produce a certain output. Technical potential does not ensure economic potential. Innovation is economically feasible only if (1) technical innovation is possible, and (2) market conditions are such that profit-maximizing firms are willing to incorporate the technology. It is clear that if technical innovation is observed in the industry, it must be both economically and technically feasible. On the other hand, if technical innovation is not observed, only economic feasibility can be absolutely ruled out. Technical potential is thus a necessary, but not sufficient condition for adoption of the technology by firms.

Evidence generally indicates that considerable potential exists in a technical sense for process innovation. However, the domestic steel industry is frequently criticized for being slow to adopt new technologies.[21]

The very fact that significant quantities of steel are produced by three distinctly different basic processes supports the notion that process innovation occurs. Table 9-2 presents the percent of total raw steel produced in the United States from 1968 through 1979 by the three steelmaking processes. The increase in the proportion of steel produced by the basic oxygen and electric arc processes at the expense of the open hearth process is striking. BOF production increased from 37.1 percent of the total in 1968 to 61.1 percent in 1979. Over the same period, EAF production increased nearly twofold.

Technological innovation within the steelmaking processes is evident as well. Preheating scrap metal allows more of it to be used in the basic oxygen process. BOF efficiency is also being increased by the practice of blowing oxygen into the metal charge from below as well as from above the surface.[22]

Significant technological advances of other types are also occurring. Perhaps the most significant change currently is the adoption of continuous casting technology. In continuous casting, freshly refined molten steel from the furnace is poured directly into a water-cooled mold. The hardening steel shape is mechanically pulled continuously from the bottom of the mold and cut into desired lengths. Bypassing the steel ingot stage and subsequent reheating saves energy, time, manpower and waste steel. Continuous casters are being most rapidly employed by EAF operators.[11]

The major material input in raw steel production is metal--molten iron, pig iron and scrap steel. The technical potential for substitution between pig iron and scrap steel can be characterized in two ways. First, in the general activity labeled steelmaking, pig iron

TABLE 9-2. RAW STEEL PRODUCTION BY PROCESS TYPE, 1968 TO 1979[9] (PERCENT)

Year	Open hearth	Basic oxygen	Electric arc
1979	14.1	61.1	24.9
1978	15.5	60.9	23.6
1977	16.0	61.8	22.2
1976	18.3	62.4	19.2
1975	19.0	61.6	19.4
1974	24.4	56.0	19.7
1973	26.4	55.2	18.4
1972	26.2	56.7	17.8
1971	29.5	53.1	17.4
1970	36.5	48.2	15.3
1969	43.1	42.6	14.3
1968	50.1	37.1	12.8

and scrap metal are excellent substitutes for each other. Second, within a defined steelmaking process, substitution potential varies greatly with the type of process.

When steelmaking is considered as a broadly defined, homogeneous activity, input substitution is excellent. The ferrous metal input can be anywhere between 100 percent pig iron (open hearth process) and 100 percent scrap (electric arc process). In practice, a mixture of pig iron and scrap is more typical. Table 9-3 indicates that in 1978 the open hearth process consumed a 53.5 percent pig iron/46.5 percent scrap mixture. In basic oxygen steelmaking, the pig iron/scrap mixture was 72.1 percent/27.9 percent and in electric arc steelmaking, it was 2.7 percent/97.3 percent.

Substitution potential between pig iron and scrap within a given steelmaking process varies, depending on the process. In the open hearth process, the ferrous charge can be all pig iron, all scrap, or any mixture.[24] As indicated though in Table 9-3, pig iron has steadily comprised a little over half of the ferrous charge in open hearth process steel production in recent years.

The basic oxygen furnace is far less tolerant of input substitution than the open hearth furnace. The pig iron/scrap mixture rarely varies far from 70 percent/30 percent. Technological advances, though, are beginning to relax this constraint. By simultaneously bottom-blowing additional oxygen into the BOF and preheating the scrap input, scrap can comprise up to 42 percent of the ferrous charge.[22]

Electric arc furnaces have historically depended on scrap as their major input (see Table 9-3). Technically, though, the EAF can operate satisfactorily with a wide range of variation in pig iron/scrap content.[25]

Substitution among fuel inputs is possible as well. Gas and oil work equally well in generating heat for the open hearth process. In a basic oxygen furnace, the molten ferrous charge itself is the heat source, but varying amounts of oxygen are utilized in the process.

TABLE 9-3. PIG IRON AND SCRAP INPUTS TO RAW STEEL PRODUCTION[23]
(Percent)

	Pig iron	Scrap
1978		
Open hearth	53.5	46.5
Basic oxygen	72.1	27.9
Electric arc	2.7	97.3
1976		
Open hearth	55.7	44.3
Basic oxygen	71.6	28.4
Electric arc	1.5	98.5
1974		
Open hearth	54.2	45.8
Basic oxygen	71.5	28.5
Electric arc	3.0	97.0

9.1.2.2 Demand Conditions.

9.1.2.2.1 Historical demand trends. As indicated earlier, steel is an intermediate good; most sales are to other producing industries. Because steel is an intermediate good, demand for it tends to increase in times of increasing business activity and vice versa.

Apparent consumption of steel mill products in the United States is defined as shipments from U.S. plants plus imports minus exports. It is a measure of how much steel, imported and domestic, U.S. buyers purchase. Table 9-4 depicts 11 years of U.S. apparent consumption of steel mill products and real gross national product (GNP). Note that the decline in real GNP from 1973 to 1975 is accompanied by a decline in apparent consumption of steel mill products. The recovery from 1976 to 1978 is marked by an increase in the demand for steel.

While apparent consumption of steel tends to rise and fall with general economic conditions, it has not increased at an annual rate equal to that of real GNP. The continuously compounded annual rate of growth of real GNP from 1969 to 1979 was 2.8 percent. The comparable growth rate for steel consumption was only 1.1 percent. Possible reasons for the slow growth in steel demand relative to that for general economic activity will be discussed in Section 9.1.2.2.3.

9.1.2.2.2 Important users of steel mill products. In Section 9.1.2.1.2.1, the 1972 input-output table of the U.S. economy was used to identify major suppliers of inputs to SIC 3312--the blast furnaces and steel mills industry. The same table indicates the value of output of steel mill products sold to each of the 492 industries. Table 9-5 identifies the 10 industries that received the most shipments from plants classified in SIC 3312 in 1972.

Table 9-5 indicates that the most important buyer of steel mill products was the steel mill industry itself. This fact emphasizes the great degree of vertical integration in the industry. Coke producers sell their output to producers of pig iron who in turn sell pig iron to steel producers; all are classified in SIC 3312.

The next two most significant purchasers of steel mill products by value of goods purchased are the motor vehicle parts and accessories

TABLE 9-4. U.S. REAL GROSS NATIONAL PRODUCT AND APPARENT CONSUMPTION OF STEEL MILL PRODUCTS[26 27 28]

Year	Real GNP (10^9 1972 $)	Apparent consumption of steel mill products (10^3 Mg)
1979	1,431.6	104,270
1978	1,399.2	105,800
1977	1,340.5	98,365
1976	1,273.0	91,678
1975	1,202.3	80,738
1974	1,217.8	108,485
1973	1,235.0	111,133
1972	1,171.1	96,698
1971	1,107.5	92,981
1970	1,075.5	88,070
1969	1,078.8	93,133

TABLE 9-5. IMPORTANT PURCHASERS OF OUTPUT FROM THE BLAST FURNACES AND STEEL MILLS INDUSTRY--SIC 3312--IN 1972[7]

Purchasing industry	Percent of total SIC 3312 output purchased
Blast furnaces and steel mill products	17.3
Motor vehicle parts and accessories	6.8
Automotive stampings	6.3
Metal cans	5.6
Fabricated structural metal	4.5
Fabricated plate work	3.3
Screws, bolts, nuts, rivets, washers	2.3
Iron and steel forgings	2.1
Miscellaneous fabricated wire products	2.1
Sheet metal work	1.9

industry, which purchased 6.8 percent of all steel in 1972, and the automotive stampings industry, which purchased 6.3 percent of the total in that year. In 1979, 18.6 percent of all steel products was sold to a broadly defined "automotive" market.[29]

As shown in Table 9-5, the remaining seven of the ten most significant purchasers of output of the steel industry are all producers of intermediate goods: metal cans (used as an input to produce canned goods), fabricated structural metal (for building), fabricated plate work, etc. Again, the table stresses the intermediate nature of the goods produced in the steel industry.

9.1.2.2.3 Competing products. Section 9.1.2.2.1 indicated that the growth rate in the demand for steel has lagged behind the growth rate in real GNP in recent years. Section 9.1.2.2.2 emphasized that steel mill products are primarily intermediate goods used in the production of other intermediate goods. It is possible that the relatively slow increase in demand is due to a degree of substitution potential that exists between steel and competing materials for use in the production of other goods. This section addresses this issue.

As stated previously, 18.6 percent of all steel was purchased by automotive producers in 1979. According to one examination:

> ... the longer-range probabilities for more shipments [of steel] to this area [automotive] do not look good. Fuel economy regulations legislated by the government have compelled automobile manufacturers to design more efficient cars. This has meant not only smaller autos [which use less steel], but cars that contain proportionately less steel....[30]

The chief materials being substituted for steel in automobile production are aluminum and plastic, which are being well accepted.

The substitution of aluminum for steel is also having an adverse impact on the demand for steel by beverage container manufacturers. Even though canned beverage consumption continues to increase, steel shipments to the container market peaked in 1974.[31]

Steel faces competition from materials on many fronts. In construction, steel competes with concrete and, to a lesser extent, aluminum. Aluminum has replaced steel in some facets of ship construction. Polyvinyl chloride pipe and tubing is a major competitor to the steel counterparts.[32]

9.1.3 Market Structure

In 1977, there were a total of 396 blast furnaces and steel mill companies. This represents an increase of 64.3 percent from the 241 companies in 1972. From 1967 to 1972, the number of companies increased only 20.5 percent, from 200 in 1967.[3] This is an interesting observation in that apparent steel consumption grew at least as quickly in the earlier 5-year period as in the latter. A possible explanation is market entry in recent years by small companies operating small, EAF mills. This issue is addressed later in Section 9.1.3.2.

9.1.3.1 Geographic Distribution of Plants. The influence of basic supply conditions on market structure is also apparent in the effect on geographic distribution. BOF plants and, to a lesser extent, open hearth plants favor plant integration. In turn, integrated plants are ideally located near sources of coal and iron ore. EAF plants, however, utilize scrap as their major input. Thus, EAF facilities are less tied to coal and ore producing regions of the country.

The geographic distribution of plants bears this out. In 1972, 50.0 percent of all plants were located in five states: Pennsylvania, Ohio, Indiana, Illinois, and Michigan. These states are near coal and ore production sites. In 1977, only 38.9 percent of all plants were located in these same states.[33] [34] As EAF steel production increased from 17.8 percent of the total in 1972 to 24.9 percent of the total in 1977 (see Table 9-2), geographic concentration became less pronounced.

Fully integrated plants, which need coal to produce coke and ore to produce iron, are, as expected, very concentrated in the five states listed above. In 1977, 65.7 percent of all fully integrated plants were located in these five states.

9.1.3.2 Firm Concentration. Basic supply conditions affect industry concentration ratios. The greater the proportion of total output produced by a given number of the largest firms, the more concentrated the industry.

Raw steel production would be expected to become less concentrated as more steel is produced by EAF facilities. This is because EAF facilities are generally smaller and less integrated than open hearth and basic oxygen facilities. Thus, EAF facilities are less costly to build. One estimate places the cost (per ton of annual output) of building an integrated steel mill at near six times that for building a small EAF plant.[35]

The four largest domestic producers of steel mill products together shipped 53.7 percent of total market tonnage in 1974. In 1979, these same producers, still the four largest, accounted for only 49.8 percent of all shipments.[36]

The recent market entrance of small, EAF steel plants is being credited in part with reducing industry concentration. One analyst estimates that the so-called "mini-mills" accounted for 13 percent of domestic steel shipments in 1978; the same analyst forecasts that they will capture at least 25 percent of the market by 1990.[35]

9.1.3.3 Vertical Integration. As indicated previously, certain steel production technologies favor some degree of integration. A plant that produces steel using the basic oxygen process, for example, requires a ferrous charge comprised largely of molten iron. The molten iron can most efficiently be transferred directly from the blast furnace where it is produced, never having cooled. Conversion of iron ore into iron in the blast furnace in turn requires coke. Coke can be purchased from other plants, but is frequently produced in the same establishment.

Production of steel via the electric arc furnace requires little plant integration. As cold scrap is the usual ferrous charge, neither coke nor blast-furnace-produced molten iron is necessary.

The 1977 Census of Manufactures indicates that in 1977 there were 504 plants classified in SIC 3312. This represents an increase of 38.5 percent from 364 plants in 1972. In Table 9-6, the plants classified in SIC 3312 are further classified by degree of integration for the years 1972 and 1977. Plants that produce coke, iron, raw steel, and finished steel are regarded as "fully integrated." Plants that

TABLE 9-6. PLANT INTEGRATION[37,38]

Degree of integration	Percent of total plants 1972	1977
Coke, iron, raw steel, finished steel	10.7	6.9
Iron, raw steel, finished steel	3.6	3.4
Raw steel, finished steel	19.5	16.3
Single product or other combination	66.2	73.4
Total number of plants	364	504

produce iron, raw steel, and finished steel or just raw steel and finished steel might be considered "partially integrated." Plants that produce only one of these four products are called "nonintegrated."

As shown in Table 9-6, the proportion of total plants that were fully integrated declined from 10.7 percent in 1972 to 6.9 percent in 1977. Over the same period, the percent of total plants that were partially integrated declined from 23.1 in 1972 to 19.7 in 1977. Nonintegrated plants, however, increased from 66.2 percent of the total in 1972 to 73.4 percent in 1977.

The trend away from fully and partially integrated plants towards nonintegrated plants is an apparent example of how basic supply (technological) conditions influence market structure. Table 9-2 indicated a substantial increase in the production of steel by the electric arc process since 1972. This trend towards a technology requiring little plant integration may account for the shift away from plant integration.

9.1.3.4. Horizontal Integration. Horizontal integration is defined here as diversification into the production of nonsteel goods or services by steel firms. Integration of this type is evidenced by firms in the steel industry. One estimate indicates that as much as 25 percent of total sales by U.S. steel firms are nonsteel.[39]

Inadequate profit margins in steelmaking, to be discussed later in this profile, are frequently cited as the reason for diversification by steel firms. Petroleum, chemicals, and financial services are among the industries in which steel companies have invested. Diversification is expected to continue. Investment in nonsteel enterprises by steel manufacturers presently accounts for 20 percent of their total investment.[40]

9.1.3.5 Economies of Production.

9.1.3.5.1 Long-run cost structure. An industry is said to have an increasing (decreasing) cost structure if the expansion of industry output over time increases (decreases) the real, average total cost of producing one unit of output. The long-run cost structure of the steel industry is examined here under the assumption that price equals average total cost.

From 1961 to 1979, U.S. raw steel production (in tons) increased at a continuously compounded average annual rate of 1.8 percent.[28 41] During this same 18-year period, the nominal price of steel increased at an average annual rate of 6.2 percent.[42] That part of the nominal price increase attributable to inflation can be removed by deflating the nominal estimate by the increase in the general price level (as measured by the implicit price deflator) over the same period. The implicit price deflator was estimated at 4.8 percent per year over this period; therefore, the real price of steel increased 1.4 percent per year from 1961 to 1979. An increasing long-run cost structure is thus indicated for the steel industry.

9.1.3.5.2 Short-run cost structure.

9.1.3.5.2.1 Economies of scale. The presence or absence of economies of scale is often cited as being partially responsible for determining short-run cost structure. There is general agreement that significant economies of scale do exist in steel production; that is, physical output increases more than proportionately with all inputs. The Office of Technology Assessment of the U.S. Congress states that domestic steel producers, because they have smaller, higher cost plants than their foreign counterparts, are less able to realize economies of scale.[43] The U.S. General Accounting Office says "...bigger is cheaper in integrated steelmaking. Large-scale plants can more efficiently use equipment, labor, and energy than small plants."[44] The same report proceeds to estimate 4 million tons (of raw steel) annually as a minimum economically efficient plant scale.

Economies of scale and minimum efficient scale must not be considered, however, aside from the plant's technology. Many new companies are operating EAF plants with capacities under 0.5 million Mg annually. Far from being uneconomical, these small plants are able to sell raw steel below prices charged by integrated mills and still make a profit.[35] Further advances in steelmaking technology could further reduce the presence of economies of scale.

9.1.3.5.2.2 Production costs and plant vintage. There is a definite link between steel production costs and plant age. In general, per-unit costs of steel production are higher for older plants than for newer plants. The General Accounting Office believes the obsolescence of U.S. steel plants to be the industry's major obstacle in meeting domestic steel demand.[45]

The cost/age relationship is primarily the result of technological advance over time. EAF's can produce steel at a lower cost than the open hearth and basic oxygen furnaces. Newer plants increasingly adopt the electric arc process, which results in lower cost operations.

9.1.3.6 Entry Conditions. The U.S. steel industry has long been regarded as presenting barriers to entry to potential market entrants.[46] Entry is said to be difficult because very large minimum efficient plant scale makes for a substantial initial capital investment. One estimate places the cost of a new integrated steel mill at $1,107 per megagram of capacity, in 1978 dollars.[35] This would put the capital cost of a 4-million-Mg plant at nearly $5 billion (see Section 9.1.3.5.2.1).

That barriers to entry are actually restrictive is not clear from U.S. Bureau of the Census data. In 1967, 200 companies operated one or more establishments classified in SIC 3312. The number of companies increased 20.5 percent from 1967 to 1972, for a total of 241 companies in 1972. Market penetration was even more pronounced from 1972 to 1977. A total of 396 companies operated in SIC 3312 in 1977, an increase of 64.3 percent from 1972.[3]

Much of the dramatic increase in the number of new companies since 1972 is no doubt the result of new, small-scale, EAF plant operations. "Mini-mills" are less expensive to build because blast furnace and coking facilities are unnecessary. An estimate for building a new mini-mill is $192 per megagram of capacity, in 1978 dollars--far under the $1,107 estimate for an integrated mill.[35] Removal of the startup cost barrier is significant. Entry barriers of other types appear to be minimal.

9.1.4 Market Conduct

This section focuses mainly on pricing behavior in the steel industry. The question is whether the steel industry most closely approximate the competitive pricing model, the monopoly pricing model, or some model of imperfect competition. Important factors to be considered include homogeneity of product, degree of industry concentration, barriers to entry, and observed pricing practices.

9.1.4.1 Homogeneity of Product. The degree to which the output of an industry is perceived by demanders to be homogeneous is an important determinant of industry pricing behavior. The more homogeneous the product, the more likely a single market price will be observed. A perfectly homogeneous good is difficult to sell at some price higher than that offered by one or more competitors. Interestingly, in his discussion on this subject, Nicholson suggests steel girders as one tentative example of a strictly homogeneous good.[47]

The degree of product homogeneity in the steel industry is not easily determined. Section 9.1.2.1.1 of this profile suggests there are four major categories of products produced by establishments classified in the blast furnaces and steel mills industry--coke, pig iron, raw steel, and finished steel products. These products differ greatly from one another in use. Coke, for example, is of no interest to a construction firm demanding steel girder. The price for a megagram of coke would not be equivalent to that for a megagram of steel girder; the two are not homogeneous products.

A meaningful discussion of product homogeneity cannot proceed without some reasonable limitation of product definition. Section 9.1.2.1.2.2 of this profile, which discusses production processes employed in SIC 3312, concentrates on the primary output of the industry--raw steel. The same approach will be adopted here. The relevant question is whether raw steel is perceived by buyers to be homogeneous.

In 1979, approximately 85 percent of all raw steel was carbon steel, the remainder being alloy and stainless.[9] Raw carbon steel is produced as ingots, blooms, slabs, billets, and other semifinished shapes. All of these shapes resemble one another in that they are, to varying degrees, square, blocky, solid forms with rounded edges. All are similar in that they are not useful in these forms, but must be rolled, drawn, or otherwise processed into more finished shapes such as girders, rails, bars, rods, sheets, pipes, and plates.

Scherer compares the homogeneity of steel with that of cement and rayon.[48] Any differences in steel, he argues, are superficial. There may be complex differences in finish, temper, packaging, etc., but steel is fairly homogeneous.[49] The Federal Trade Commission says that within each steel product line, steel is relatively homogeneous; the product of one plant is physically substitutable for the product of another.[50]

Homogeneous output alone does not ensure a single pricing model. A strictly homogeneous product can be produced under perfect competition, monopoly, or any other market model.[51] It becomes necessary to investigate other indicators of pricing behavior. However, recognizing the hazards of such a generalization, product homogeneity will be accepted as characterizing steel output.

9.1.4.2 Degree of Concentration. Industry concentration largely determines market pricing behavior. At the one extreme, where all industry output is produced by a single firm, the pure monopoly pricing model is most relevant. The other extreme is an industry characterized by many sellers, with no one firm producing a significant share of total output. A perfect competition pricing model is applicable here. Either extreme is rare, and the steel industry is neither extreme.

The U.S. steel industry is clearly not a pure monopoly. In 1977, there were 396 companies with plants classified in SIC 3312.[3] Whether the existence of 396 companies justifies the use of a perfect competition pricing model is less clear. For perfectly competitive pricing practices to result, it is not sufficient that a large number of firms exist. No one firm must produce a large enough share of industry output to enable it to influence market price by its own actions. In 1979, the single largest domestic steel firm, U.S. Steel, accounted for 20.8 percent of total domestic steel shipments.[52] This large market share of a single producer brings into question the appropriateness of the perfectly competitive pricing model for the industry.

9.1.4.3 Barriers to Entry. The degree to which barriers to entry effectively reduce market penetration by new firms influences industry pricing behavior. Nicholson calls barriers to entry the source of all monopoly power.[53] Section 9.1.3.6 concludes that effective barriers to entry do not exist in the steel industry.

The apparent lack of significant barriers to entry promotes the selection of the perfectly competitive pricing model. "Free" market entry is necessary but not sufficient to support this model. "Free" market entry obtains when the only costs of production incurred by new firms are those incurred by established firms.[54] In the case of the steel industry, economies of scale enjoyed by existing firms once resulted in lower per unit cost of production. Technological advances, especially the development of the EAF, have apparently diminished this technological advantage, as evidenced by recent market entry.

9.1.4.4 Observed Pricing Practices. The purpose of this section is to comment on actually observed pricing practices in the steel market as another aid in selecting an appropriate pricing model. If market participants behave as perfect competitors, a perfect competition model would logically be deemed appropriate. If evidence of imperfect competition behavior is apparent, other market models can be explored. Emphasis will be placed on observed pricing behavior in recent times--the past 20 years.

Selection of the past 20-year period for examining pricing behavior is not entirely arbitrary. Until the 1960's, the U.S. steel industry had a long history of adherence to a pattern of rigid administered pricing. During normal times in the period prior to the 1960's, U.S. Steel Corporation, with a market share exceeding one-half, assumed the role of price leader and its smaller rivals followed.[55]

In the 1960's and 1970's, pricing behavior has been complicated by two factors. First is the competition provided by foreign steel supply. Second is the industry structural change resulting from changing basic conditions, especially technological advance.

Pricing behavior in the domestic steel industry is most frequently said to be characteristic of an oligopolistic market. An oligopoly is a market with relatively few firms producing a homogeneous product. A single firm in an oligopoly can have some effect on the price it will receive for its output because it has a significant market share of the total output.[56]

Smolik cites the U.S. steel industry as being a "... concentrated oligopoly on the basis of concentration ratios and on the basis of its highly knit social structure." The oligopolistic structure, he argues, is further strengthened by the homogeneous nature of most steel products.[57]

Adams (writing in 1977) states:

> The steel industry today is--structurally speaking--an oligopoly and is dominated by a relatively few, large, integrated producers. These, taken together, own or control about three quarters of the nation's . . . ingot and "steel for casting" capacity . . . .[58]

Unfortunately, a tentative conclusion that the American steel industry is an oligopoly makes it more difficult, not easier, to identify a specific pricing behavior model. There are no generally accepted pricing behavior models for oligopolists as there are for perfect competitors and monopolists. Many price/output combinations can result based on various sets of behavioral assumptions. Observation of actual oligopoly markets suggests that almost anything can happen.[59,60]

One generalization that perhaps can be made is that some form of administered pricing behavior will emerge under oligopoly. The outcome of a single firm in an oligopoly changing its output price depends, in part, on the reactions of other firms. A firm stands to suffer if it cannot accurately determine beforehand how its actions will be met by other firms. Prices tend to be fixed until some unifying event can ensure the "appropriate" response by all firms.[61]

A system of price leadership often emerges in oligopoly. If a single firm is recognized as the price leader, price adjustments can occur with some assurance of market order as other firms follow in concert.

Price leadership has been an apparent characteristic of the U.S. steel industry. U.S. Steel Corporation is the usually recognized price leader. All other companies follow the leader's actions closely.[57,62] As recently as 1971, an announcement of a price hike for all mill products by U.S. Steel Corporation was promptly followed by a similar declaration by other major producers.[63] When the U.S. General Accounting Office in 1979 asked steel users why they buy foreign steel, one answer given was that they, as buyers, perceived that many U.S. mills follow suit each time a major steel mill publishes a new price list.[64]

While there is near universal agreement that the domestic steel industry has historically been oligopolistic with U.S. Steel Corporation acting as price leader, trends in recent years indicate the situation is changing or has changed. The reason for this basic change in market conduct is, once again, changes in market structure. Three structural changes have been observed.

First, the Federal Trade Commission reports that since 1960, U.S. Steel Corporation has had to share the leader role with Armco Steel and Bethlehem Steel. Efforts to raise prices by any leader have frequently been ignored unless they reflected basic supply and demand conditions.[65]

A second major structural change has been the dramatic increase in steel output by independent mini-mills. Mini-mills regularly engage big producers in price competition, and are beginning to be a greater threat to historically large steelmakers than are the foreign producers.[35] [66] The success of mini-mills is in turn the result of a successful technological advance--the EAF. This is an example of how changes in basic conditions can, by influencing market structure, ultimately result in changes in market conduct.

The third major structural change is the increasingly significant role of steel imports. In 1961, imported steel mill products accounted for only 4.7 percent of United States consumption. This import market share increased to 13.8 percent in 1970 and reached a peak of 18.1 percent in 1978.[28] [41]

Steel imports may have a significant role in the price behavior of domestic steel firms. If the U.S. steel industry is an oligopoly, the U.S. Steel Corporation is the dominant firm, with steel shipments of 19.0 million Mg in 1979.[52] In that same year, total steel mill imports totaled 15.9 million Mg--83.7 percent of the dominant firm's output.[28] As foreign producers collectively capture more of the U.S. market, domestic firms individually and collectively enjoy less market power.

To summarize, it is not easily concluded that currently observed pricing behavior in the steel industry is oligopolistic. Increasingly, individual firms are setting their own price based mainly on their own cost structures and basic underlying supply and demand conditions.

9.1.5 Market Performance

In a conditions-structure-conduct-performance industry profile, the performance section is of special importance. Market performance is seen as the result of the earlier causal chain. Emphasis in this section will be on three aspects of market performance. First, a financial profile of the steel industry will be presented with comments and comparisons to other industries. Second, recent trends in such industry variables as price, output, employment, and investment will be presented. Third, industry projections will be discussed.

9.1.5.1 Financial Profile of the Steel Industry. The objective of a firm is to maximize shareholders' wealth. It can be shown that a firm that behaves so as to maximize profit maximizes the discounted stream of cash flows to its shareholders.[67] If this is accepted as the primary objective of firms, some measure of success in achieving this objective is surely a relevant measure of financial performance.

Stockholders' equity is the portion of a corporation's assets owned by holders of common and preferred stock. It is equal to the excess of a firm's assets over its liabilities.[68] A ratio frequently used to assess a firm's success in maximizing shareholder's wealth is the ratio of after-tax profit to stockholders' equity. An average of this ratio for firms representing approximately 90 percent of raw steel output over the period 1960-1979 is presented in Table 9-7. As a comparison, the same ratio is presented for firms representing all manufacturing over the same period.

A profit-to-equity ratio of 10 percent or higher is usually regarded as necessary to provide dividends to the holders of stock, as well as funds for future growth.[72] The 20-year average profit-to-equity ratio for all manufacturing, as indicated in Table 9-7, is 13.0 percent. The 20-year average for the steel industry is considerably lower--7.4 percent. In only one year, 1974, was the ratio for

TABLE 9-7. AFTER-TAX PROFIT TO STOCKHOLDERS' EQUITY[69] [70] [71]
(PERCENT)

Year	Steel	All manufacturing
1979	6.8	16.7
1978	7.3	15.9
1977	0.1	14.9
1976	7.8	15.0
1975	9.8	12.6
1974	17.1	15.2
1973	9.3	14.9
1972	5.8	12.1
1971	4.3	10.8
1970	4.1	10.1
1969	7.0	12.4
1968	8.2	13.3
1967	6.9	12.6
1966	8.9	14.2
1965	9.4	13.9
1964	9.0	12.6
1963	7.3	11.6
1962	5.3	10.9
1961	6.5	9.9
1960	7.9	10.6

steel firms equal to or greater than that for all manufacturing. The profitability difference as measured by this ratio between steel and other industry is even more pronounced in recent years. During the period 1970-1979, return to steel stockholders was only 7.2 percent compared to 13.8 percent for all manufacturing stockholders.

These figures tend to support the contention by Adams that the steel industry's profit record has been poor in recent years. Adams blames the industry's noncompetitive pricing conduct, leading to technological lethargy and inadequate capacity utilization, for low profitability.[73]

9.1.5.2 Financial Profile of Firms Owning BOF Facilities. Financial data on 18 companies that now own BOF facilities are presented in Table 9-8. From these financial data, three ratios have been calculated for each company. These ratios are presented in Table 9-9.

The liquidity ratio is a measure of the firm's ability to meet current obligations as they come due. A liquidity ratio above one indicates the firm is solvent enough to meet current obligations with little trouble. A firm with a liquidity ratio below 1 may be unable to pay bills on time, a condition which could lead to its eventual demise.[75] The liquidity ratios of BOF-operating firms vary from 1.25 to 2.55.

The profit ratio measures the ability of the firm to pay dividends to stockholders while maintaining adequate funds to ensure growth. A ratio of 10 percent or higher is usually deemed necessary to secure these ends.[72] One firm, U.S. Steel, has a negative profit ratio for 1979. The ratios for the remaining firms vary between 5 percent and 23 percent. Of the 18 companies, 12 have a ratio of 10 percent or higher.

The leverage ratio indicates the relationship between total liabilities, including those owed to stockholders, and stockholders' equity. Because the numerator, total liabilities, is largely comprised of debt owed to bondholders and stockholders' equity, a ratio exceeding 2 is an indication that there is more interest debt outstanding than there is owner-contributed equity. While it is difficult to say what

TABLE 9-8. FINANCIAL INFORMATION ON FIRMS OWNING BASIC OXYGEN FURNACES, 1979[74] (10^3 1979 $)

Company name	Net sales	Current assets	Current liabilities	Net profit	Tangible net worth	Total assets = liabilities
Allegheny Ludlum	1,550,010	526,123	261,973	71,527	485,154	1,140,165
Armco Steel	5,035,127	1,361,643	656,741	221,040	1,715,271	3,260,163
Bethlehem Steel	7,137,200	1,844,200	1,035,900	275,700	2,639,800	5,165,900
CF&I Steel	557,231	130,424	82,552	15,371	213,123	400,217
Crucible Steel (CoH Inds.)	2,140,515	854,182	335,534	111,375	638,479	1,301,619
Ford Motor Co.	43,513,700	11,571,300	9,263,000	1,169,300	10,420,700	23,524,600
Inland Steel	3,635,225	813,687	567,441	131,108	1,321,351	2,725,473
Interlake, Inc.	1,104,588	383,477	221,207	39,735	349,944	733,559
International Harvester	8,392,042	3,265,769	1,873,371	369,562	2,163,900	5,247,475
Jones and Laughlin Steel	3,290,000	741,914	511,268	161,928	1,023,703	2,089,672
Kaiser Steel	975,247	367,930	220,545	48,489	521,416	1,141,273
McLouth Steel	725,099	196,630	136,814	9,368	189,226	465,795
National Steel	4,234,458	1,275,417	732,133	126,466	1,436,825	3,160,279
Republic Steel	3,987,381	923,525	570,117	121,158	1,489,198	2,749,872
Sharon Steel	534,622	597,106	323,763	58,603	257,300	1,110,779
U.S. Steel	12,929,100	3,456,700	2,410,800	-293,000	5,394,600	11,029,900
Wheeling Pittsburgh Steel	1,250,742	374,106	234,918	49,690	397,982	846,645
Youngstown Sheet & Tube	2,259,827	533,089	365,060	66,193	429,219	1,242,740

TABLE 9-9. FINANCIAL RATIOS FOR FIRMS OWNING BASIC OXYGEN FURNACES, 1979

Company name	Liquidity ratio[a]	Profit ratio[b]	Leverage ratio[c]
Allegheny Ludlum	2.01	0.15	2.35
Armco Steel	2.07	0.13	1.90
Bethlehem Steel	1.78	0.10	1.96
CF&I Steel	1.58	0.07	1.88
Crucible Steel	2.55	0.17	2.04
Ford Motor Co.	1.25	0.11	2.26
Inland Steel	1.43	0.10	2.06
Interlake, Inc.	1.73	0.11	2.10
International Harvester	1.74	0.17	2.43
Jones and Laughlin Steel	1.45	0.16	2.04
Kaiser Steel	1.67	0.09	2.19
McLouth Steel	1.44	0.05	2.46
National Steel	1.74	0.09	2.20
Republic Steel	1.62	0.08	1.85
Sharon Steel	1.84	0.23	4.32
U.S. Steel	1.43	-0.05	2.04
Wheeling Pittsburgh Steel	1.59	0.12	2.13
Youngstown Sheet & Tube	1.46	0.15	2.90

[a]Liquidity Ratio $= \frac{\text{Current Assets}}{\text{Current Liabilities}}$

[b]Profit Ratio $= \frac{\text{Net Profit}}{\text{Tangible Net Worth}}$

[c]Leverage Ratio $= \frac{\text{Total Liabilities}}{\text{Tangible Net Worth}}$

the highest satisfactory ratio is, in general the higher the ratio, the more likely that the firm would be unable to meet its long-term obligations. Of the 18 companies 14 have leverage ratios exceeding 2, indicating that they are substantially debt financed.

Table 9-10 lists the simple (unweighted) means of the three ratios for the 18 BOF companies. Also listed are industry average ratios for several arbitrarily selected industries for the same year. While it is difficult to draw meaningful conclusions, observations can be made. Of the five industries compared, only one, petroleum refining, has a lower liquidity ratio. The profit ratio for the BOF steel industry is well below those of the five industries compared. Finally, the leverage ratio for the BOF steel industry is in line with those of the other industries compared.

9.1.5.3 Industry Trends. The purpose of this section is to highlight recent trends in certain steel industry variables. The variable values presented and the related discussion are intended only as an indication of past industry performance. Projections of future performance are presented in Section 9.1.5.4.

9.1.5.3.1 Physical output. The annual physical output of an industry is perhaps the single best indicator of industry performance. In general, a healthy industry is expected to increase physical production in pace with general economic activity. As the population increases and real income increases, the demand for industry output is expected to increase. An annual index of shipments of domestically produced steel mill products tonnage has been constructed and is presented in Table 9-11. In the same table is the total industrial production index of the U.S. Board of Governors of the Federal Reserve System. Both are indexes of actual physical output.

It is clear from Table 9-11 that during the 13 years ending in 1979, steel production did not keep pace with total industrial production. The average annual continuously compounded rate of growth of total industrial output was 3.5 percent, compared with only 1.5 percent for steel mill products. For the period covered, domestic steel shipments peaked in 1973. The 2-year decline in the total industrial

TABLE 9-10. FINANCIAL RATIOS FOR SELECTED INDUSTRIES, 1979[76]

Industry	Liquidity ratio	Profit ratio	Leverage ratio
BOF steel firms[a]	1.69	0.11	2.28
Primary nonferrous metals, NEC--SIC 3339	1.86	0.22	2.32
Aluminum foundries--SIC 3361	2.15	0.22	2.84
Primary metal products, NEC--SIC 3399	2.28	0.24	1.69
Motor vehicles--SIC 3711	1.73	0.17	2.44
Petroleum refining--SIC 2911	1.36	0.26	2.56

[a]Means from Table 9-9.

TABLE 9-11. STEEL MILL PRODUCTS AND TOTAL INDUSTRIAL OUTPUT INDEXES (1967 = 100)[28 41 77 78]

Year	Steel mill products	Total industrial output
1979	119.5	152.5
1978	116.7	146.1
1977	108.6	137.1
1976	106.6	129.8
1975	95.3	117.8
1974	130.5	129.3
1973	132.8	129.8
1972	109.4	119.7
1971	103.7	109.6
1970	108.2	107.8
1969	111.9	111.1
1968	109.5	106.3
1967	100.0	100.0

output index in 1974-1975 marks a recession. Steel output declined as well during those years, but has been far slower to recover than the overall economy.

9.1.5.3.2 Real value of output. Because of the effect of inflation, observation of the value of industry output over time can be misleading. Industry value of output is more meaningful when deflated to constant dollars for some base year.

Table 9-12 presents the real value of output (deflated by the implicit price deflator for GNP) of all establishments classified in SIC 3312 from 1967 to 1977. The annual growth rate for real output of SIC 3312 was 1.8 percent during the period, well below the 2.4 percent growth rate of real GNP.

9.1.5.3.3 Steel mill products prices. The producer price index for steel mill products is compared with the GNP price deflator index in Table 9-13. Steel prices increased at a rate very near the general rate of inflation until 1973. Note that in 1973 the steel index is only four-tenths higher than the GNP index with 1967 = 100. In 1974, however, steel prices increased 26.8 percent over 1973 levels while the implicit price deflator increased only 9.6 percent. Steel prices continued to outpace inflation through 1979.

The increase in the price of steel relative to overall prices from 1973 to 1979 can in part be attributed to an important basic supply condition. Steel production is energy intensive. OPEC-induced energy price increases beginning in 1974 raised the price of this important input to production, which was in turn reflected in increased real price of steel.

9.1.5.3.4 Investment in new plant and equipment. In 1967, new capital expenditures by SIC 3312 firms totaled about $1.7 billion. In 1977, new capital expenditures totaled only $1.2 billion in 1967 dollars.[3] In order to determine the significance of this decline, an index has been constructed of new investment by steel firms and is compared with an index of new investment by all industry in Table 9-14.

Real investment in new plant and equipment by all industry increased at a continuously compounded average annual rate of 1.5 percent during

TABLE 9-12. REAL VALUE OF OUTPUT FOR SIC 3312
(10^6 1967 $)

Year	Real value of output
1977	23,487.6
1976	23,423.5
1975	22,157.2
1974	28,382.8
1973	22,679.4
1972	18,922.7
1971	18,081.9
1970	23,360.0
1969	20,319.8
1968	20,251.8
1967	19,620.6

TABLE 9-13. STEEL PRICE INDEX AND GNP PRICE DEFLATOR (1967 = 100)[42, 79, 80]

Year	Steel price index	GNP deflator
1979	280.4	209.1
1978	254.4	192.2
1977	229.9	179.0
1976	209.8	169.2
1975	197.2	160.7
1974	170.0	146.6
1973	134.1	133.7
1972	130.4	126.4
1971	123.0	121.4
1970	114.3	115.5
1969	107.4	109.6
1968	102.5	104.4
1967	100.0	100.0

TABLE 9-14. INDEXES OF REAL NEW INVESTMENT (1967 = 100)[3 81 82]

Year	SIC 3312	All industries
1977	72.2	115.9
1976	76.1	108.6
1975	77.4	107.0
1974	67.4	116.9
1973	49.9	113.8
1972	45.7	106.7
1971	49.8	102.1
1970	69.3	105.9
1969	86.4	105.2
1968	67.3	99.1
1967	100.0	100.0

NOTE: Investment expenditures were deflated using the GNP implicit price deflator before indexing.

the period 1967-1977. Real expenditures by firms in SIC 3312 declined over the same period at an average annual rate of 3.3 percent.

The American Iron and Steel Institute believes the steel industry's poor investment record is due to general economic conditions and government policy, specifically, high inflation, excessive taxation, and burdensome regulation, which discourage new capital formation.[83] One independent observer, however, blames the poor investment record, not on the inability of U.S. steel firms to invest, but on their unwillingness to compete with foreign steel by investing in new, lower cost techniques.[84]

9.1.5.3.5 Productivity. Productivity is meant to be a measure of technological advance. The most common measure of productivity is output per employee-hour. Table 9-15 compares the index of output per employee-hour for the steel industry with that for all manufacturing for the period 1967-1978. Output per employee-hour increased 28 percent for all manufacturing from 1967 to 1978 while output per employee-hour increased only 21.8 percent for the steel industry.

Increases in labor productivity are often attributed to improvements in capital stock. To the extent it is true that more advanced capital results in greater labor productivity, the relatively slow growth in output per employee-hour in steel is not surprising. As mentioned in Section 9.1.5.2.4, investment in new steel plant and equipment declined in real terms from 1967 to 1977.

9.1.5.3.6 Exports and imports. Much is said about the declining U.S. steel trade balance. There can be little doubt that the domestic industry is losing importance in the world market. Table 9-16 presents data on exports of steel mill products by domestic producers and imports of steel mill products by domestic consumers. During the period 1961-1979, exports of steel mill products changed very little. Exports peaked at 6.4 million Mg in 1970. Over this period imports of steel mill products by domestic consumers increased rapidly, at average an annual rate of 9.5 percent. On balance, the United States was a net importer of steel during the 1960's and 1970's. Net exports declined at an average annual rate of 14.1 percent from 1961 to 1979.

TABLE 9-15. INDEX OF OUTPUT PER EMPLOYEE-HOUR (1967 = 100)[85 86 87]

Year	Steel industry	All manufacturing
1978	121.8	128.0
1977	116.0	127.2
1976	114.5	124.2
1975	107.6	121.2
1974	123.5	129.3
1973	123.5	128.3
1972	112.7	121.5
1971	106.2	115.2
1970	101.3	107.9
1969	104.0	107.4
1968	103.5	104.7
1967	100.0	100.0

TABLE 9-16. STEEL MILL PRODUCTS TRADE[28 41]
(10^3 Mg)

Year	Exports	Imports	Net exports[a]
1979	2,556	15,889	-13,333
1978	2,197	19,169	-16,972
1977	1,817	17,511	-15,694
1976	2,407	12,956	-10,549
1975	2,678	10,895	-8,217
1974	5,291	14,485	-9,194
1973	3,675	13,741	-10,066
1972	2,606	16,037	-13,431
1971	2,564	16,602	-14,038
1970	6,405	12,121	-5,716
1969	4,743	12,729	-7,986
1968	1,968	16,290	-14,322
1967	1,528	10,390	-8,862
1966	1,564	9,753	-8,189
1965	2,264	9,417	-7,153
1964	3,122	5,841	-2,719
1963	2,017	4,940	-2,923
1962	1,826	3,719	-1,893
1961	1,813	2,869	-1,056

[a]Exports minus imports.

9.1.5.4 Steel Industry Projections. The purpose of this section is to present projected values of certain important steel industry variables. Projection can involve much work, and is innately risky--it involves predicting the future. The projections here were developed by Temple, Barker and Sloane, Inc., (TBS) for the U.S. Environmental Protection Agency.[88] All projections assume a continuation of current government policies affecting the steel industry.[89]

9.1.5.4.1 Steel shipments. The total shipment of domestically produced steel mill products is perhaps the variable of most interest. TBS, noting a post-World War II growth rate in domestic steel shipments of 1.2 percent per year and adjusting downward for more recent trends, projects an overall annual growth rate of 1.0 percent.[90] Table 9-17 presents TBS projected steel shipments, incorporating cyclical fluctuations.

9.1.5.4.2 Investment in new plant and equipment. TBS projects capital expenditures for plant and equipment that add to capacity, together with equipment that maintains "efficient" established capacity. The industry's financial limitations in raising capital as well as its unconstrained "needs" are taken into consideration.

The steel industry's total expenditure for capacity addition and capacity maintenance is projected to be $18.4 billion in 1978 dollars for the 10-year period 1981-1990. This is an average annual expenditure of $1.8 billion in 1978 dollars. This compares with an average annual expenditure of $2.3 billion in 1978 dollars for the period 1976-1980.[92] TBS attributes this projected low capital expenditure program to a substantial financing constraint.[93]

9.1.5.4.3 Projections of BOF capacity additions. Projecting BOF capacity additions is complicated by several considerations. These include uncertainties about steel demand in future years, the ability of steel firms to raise capital sufficient to meet investment demands, the rate at which existing furnaces of all types will be retired, and the relative merits of various competing technologies. This last consideration, concerning the future economic desirability of competing steelmaking technologies, seems of some importance currently and is addressed below.

TABLE 9-17. PROJECTED STEEL SHIPMENTS, 1980-1990[91] (10^6 Mg)

Year	Shipments
1980	77.1
1981	82.9
1982	88.7
1983	90.8
1984	91.9
1985	94.6
1986	94.0
1987	94.5
1988	98.0
1989	98.0
1990	96.1

There seems to be general agreement that slow to moderate increases in steel demand in the 1980's, coupled with retirement of open hearth steelmaking capacity during the same period, will inspire the construction of new steel furnace capacity.[12 94 95] The mix of steelmaking technologies that will comprise the new capacity is less certain. Some disagreement exists as to whether the majority of new capacity demand will be met by the construction of electric furnaces.

Several sources support the view that most new capacity in the 1980's will be in electric arc steelmaking. Data Resources, Inc. (DRI) forecasts that increasing BOF steel production through 1984 will involve utilizing existing capacity more fully rather than increasing capacity. New electric furnace capacity, on the other hand, is expected by DRI to be forthcoming. DRI cites the lower capital requirements and lower operating costs of electric furnace facilities as reasons for the forecast of slow additions to BOF capacity.[94] A recent survey of U.S. companies currently operating BOF plants lends credence to this view. None of the firms surveyed indicated they had any current plants to add BOF capacity.[96]

The American Iron and Steel Institute does anticipate construction of new BOF capacity in coming years. The Institute projects that by 1988 all open hearths will be retired and that the retired tonnage capacity will be replaced half by electric capacity and half by oxygen capacity.[12]

TBS has projected steelmaking capacity retirements and additions by furnace type through 1990. Table 9-18 presents the TBS results that are relevant to this study. Based on TBS projections, the industry will build 6.86 million Mg of new BOF capacity from 1981-1986. Of this projected new capacity, approximately 2.6 million Mg can be considered replacement in that this amount of currently existing BOF capacity is projected to be retired during the period.[98]

The TBS new BOF capacity projections are utilized in this report. Several factors contribute to the selection of these projections, and are outlined below.

TABLE 9-18. BASIC OXYGEN FURNACE CAPACITY ADDITIONS, 1981-1990[97]
(10^6 Mg)

1981 - 1984	1985 - 1990	1981 - 1986[a]
6.10	2.28	6.86

[a]Assumes a constant addition of 0.38 Mg a year during the 6-year period 1985-1990.

First, the TBS projections are in agreement with American Iron and Steel Institute estimates that both electric furnaces and oxygen furnaces would replace retiring open hearths through 1988, given sufficient funds.

Second, TBS projections rely on an important assumption which, while not necessarily entirely correct, has some validity. TBS expects the price of scrap steel, the primary metal input to electric steelmaking, to increase over time as more electric furnaces are operated.[99] While there is disagreement over the future availability of scrap and the extent of future price increases, there is general agreement that the price of scrap will rise in future years.[100] To the extent that steel scrap prices do rise, the operating cost advantage of electric steelmaking relative to oxygen steelmaking will dwindle, making BOF investment more attractive than it would be without scrap price increases.

A final reason for accepting the TBS projection of new BOF capacity additions involves the integrated nature of steelmaking. Open hearth furnaces, many of which are expected to be retired by 1986, are necessarily part of an integrated steel plant. Open hearth furnaces utilize a largely hot metal (molten pig iron) charge. Thus, they are operated in plants with blast furnaces which convert iron ore into molten pig iron. These plants frequently have coke ovens as well.

An integrated steel plant with aging open hearth capacity is a plant with several types of independently functioning but interrelated equipment. That is, a single operation such as coking, iron making, or steelmaking can be terminated without technologically affecting the other operations. Termination of a single operation will, however, eliminate or reduce the capacity of the plant as a whole to earn surpluses over operating costs.

In an integrated plant with aging open hearth capacity, a single replacement condition is relevant: an open hearth furnace (or shop) is obsolete when the future savings in operating costs which can be achieved by installing a new steel furnace (or shop) are just sufficient to cover the installed cost and earn a normal rate of return. This comparison must be made in terms of the integrated steel mill as a whole. The rate of return accrues from the sale of the output of the entire plant. It is the surplus of these plant revenues over total plant operating costs that are weighed against the installed capital cost of the new steel furnace operation.[101]

A firm would not seriously consider replacing an aged open hearth furnace with a new open hearth furnace. The operating costs of the open hearth technology is far above that of the oxygen and the electric furnace. At the same time, a firm owning an integrated plant with coking and blast furnace capital in place (a "hot metal" plant) would not necessarily view installation of electric furnaces as a viable option:

> The [electric arc furnace] is relatively inflexible in its ability to utilize molten iron in the charge. It is essentially a 100 percent cold metal user.[102]

Use of an electric furnace shop does not utilize the existing hot metal capacity.

The BOF is like the open hearth in its ability to accept a largely hot metal charge. The integrated plant can reasonably be expected to either: (1) convert its existing open hearth shop into a BOF shop; or (2) build a new BOF shop at the hot metal site and scrap the open hearth shop once the replacement criterion is satisfied.

In Table 9-19, the 6.86 million Mg (7.56 million tons) of new BOF capacity expected to be built by 1986 is expressed in terms of numbers of BOF "shops." The 14 shops listed in Table 9-19 are the same as those described in Chapter 6. Reading from the table for case A, for example, the construction of two shops of the type specified in model case A would add 5.8 million Mg (6.39 million tons) capacity. This total is about 1 million Mg (1.1 million tons) shy of the 6.86 million Mg projection. Given the tonnage projection, the maximum number of BOF projects that can be expected from 1981 to 1986 is six. Six separate additions of a single 136-Mg (150-ton) vessel to existing two 136-Mg vessel shops as specified in model case G would generate 7.8 million Mg (8.6 million tons) of new capacity. Of course, actual construction might well consist of a mix of two or more model types.

TABLE 9-19. BASIC OXYGEN FURNACE CAPACITY ADDITIONS BY MODEL CASE, 1981-1986[a]

Model case	Number of model shops	Capacity addition (10^6 Mg)
A	2	5.8
B	3	8.1
C	2	5.8
D	3	8.1
E	2	5.8
F	5	8.0
G	6	7.8
H	2	5.8
J	2	5.8
K	3	8.1
L	2	10.0
N	2	5.8
O	2	5.8
P	3	8.1

[a]Projected new capacity additions total 6.86 million Mg 1981-1986.

9.1.6 Small Business Impacts

The Regulatory Flexibility Act (RFA) requires consideration of proposed regulations on small "entities." This section briefly examines the applicability of the RFA to the proposed NSPS on BOF shops.

The guidelines for conducting a regulatory flexibility analysis define a small business as "any business concern which is independently owned and operated and not dominant in its field as defined by the Small Business Administration Regulations under Section 3 of the Small Business Act." A firm owning plants that operate basic oxygen steelmaking furnaces is classified in SIC 3312. The Small Business Administration has determined that any firm classified in SIC 3312 which employs less than 1,000 workers will be considered small in regard to the Small Business Act.

It cannot be known with certainty whether new or existing companies that might build new BOF facilities in the future would employ fewer than 1,000 workers. It might be expected, however, that these companies would not be much different than companies that currently own and operate BOF facilities as regards employment. Indeed, companies that currently own BOF facilities are among the more likely candidates to construct new BOF shops. Thus, an examination of employment characteristics of existing BOF operating firms is relevant.

A total of 18 independently owned businesses that now operate basic oxygen steelmaking shops can be identified.[96 103] Of this total, the company that employed the fewest workers in 1979 employed a total of 5,862 workers.[104] Even the smallest BOF firm thus does not qualify as a small company under the Small Business Act.

The above investigation reveals that it is not appropriate to conduct a regulatory flexibility analysis for the proposed NSPS on BOF shops. All firms that currently operate BOF facilities, and most likely any that would in the future, are too large to qualify as small businesses under the act.

9.2 ECONOMIC IMPACTS OF REGULATORY ALTERNATIVES

This section presents the estimated impacts of the regulatory alternatives for BOPF shops. As described in Chapter 6, 14 types of model plants are used to represent typical new and modified facilities that might be constructed by the industry in the future. For 272-Mg vessel shops, six model plants represent greenfield facilities, four are additions to existing facilities, one is a conversion of an existing shop to the KMS process, and one is the conversion of an open hearth shop into a Q-BOF shop. For shops using 136-Mg vessels, one model represents a greenfield facility and one is an addition to an existing facility.

Three regulatory alternatives are considered. Regulatory Alternative I is the baseline case from which impacts are computed. Under Alternative I, primary emissions are controlled but secondary emissions are uncontrolled. Alternative II would also control secondary emissions using open hood collection systems. Alternative III, which is more stringent than II, would require the use of closed hood collection systems to control secondary emissions.

Section 9.2.1 summarizes the range of estimated maximum impacts that could result from the NSPS alternatives and presents anticipated impact estimates. Section 9.2.2 presents the discounted cash flows theoretical model employed to compute both net present value and price impacts. Section 9.2.3 presents the full range of maximum impacts on project net present value assuming full cost absorption and the full range of maximum price impacts assuming full cost pass-through. Section 9.2.4 employs a refined model to compute a single set of price impacts and associated output, employment, and import impacts for each alternative. The issue of capital availability is addressed in Section 9.2.5. Section 9.2.6 presents estimates of maximum total costs of industry compliance. Finally, the impacts of achieving baseline are discussed in Section 9.2.7.

9.2.1 Summary

Control of secondary emissions under Regulatory Alternatives II or III imposes additional capital costs on the construction of a BOF project and increases its annual operating cost. It is estimated that Alternative II would increase the cost of producing steel by between \$0.16 and \$1.39 per megagram. These changes represent impacts of between 0.05 percent and 0.44 percent. Alternative III would increase average total cost by between 0.30 percent and 0.69 percent, or by between $0.96 and $2.21 per megagram.

If the computed cost changes were exactly reflected in higher prices, price impacts of 0.04 percent to 0.36 percent would result under Alternative II and impacts of 0.25 percent to 0.58 percent would result under Alternative III. These estimated price impacts would lead to impacts on domestic steel output, domestic steel industry employment, and steel imports. The full ranges of these impacts are presented in Section 9.2.3.

The economic impacts that would actually result from the NSPS depend on which projects are pursued by industry participants and the supply and demand conditions prevalent in the market. The conclusion of this economic analysis, which is based on the premise that model plants A and J most closely typify future BOF construction, is that impacts would occur as changes in the price of carbon steel, reductions in domestic steel production, losses in employment opportunities, and increases in steel imports.

The anticipated steel price impact of Alternative II, measured from baseline, is $0.65 per megagram, or 0.17 percent. The anticipated price impact of Alternative III, also from baseline, is $1.49 per megagram, or 0.39 percent.

The demand for steel is downward sloping. Thus, the price increases presented above are expected to reduce steel demand. It is estimated that 1986 domestic steel production would be 297,228 Mg lower under Alternative II than under Alternative I. This represents an impact of 0.32 percent. The 1986 impact from baseline of Alternative III is computed to be 686,200 Mg, or 0.73 percent.

It is projected that the steel industry in 1986 under baseline will employ 468,120 workers. Under Regulatory Alternative II, it is estimated that there would be 0.32 percent fewer job opportunities in 1986. This represents a total of 1,498 fewer jobs. The employment impact from baseline of Alternative III is computed to be 0.73 percent, or 3,417 jobs. These employment impacts do not take account of possible employment gains that might result in other sectors of the economy. Steel has viable substitutes in many applications, and substitution would likely result in increased employment in those industries producing substitutes such as aluminum, plastics, and concrete. There would also be employment gains in those industries that produce control equipment.

The quantity of steel imported into the United States in 1986 would also be affected by the NSPS alternatives. The import impact of Alternative II is computed to be 0.26 percent. This is the effect of an import increase of 50,313 Mg over the baseline import projection of 19.6 million Mg. The estimated impact of Alternative III is 115,424 Mg, or 0.59 percent, over baseline.

The estimated total cost of control capital for the industry to comply in 1986 with Alternative II is $15.6 million. The estimated compliance cost of Alternative III is $18.4 million. These may be overestimates because they do not account for the estimated quantity adjustments.

9.2.2 Methodology

9.2.2.1 The Discounted Cash Flows Approach. The economic impacts of NSPS on BOPF are estimated using a discounted cash flows (DCF) analysis. Under this approach, the expected future annual net revenue flows generated by an investment in a BOF project are discounted at an appropriate interest rate and summed to determine the net present value of the project. This section describes the DCF theory and methodology in some detail.

An investment is expected to generate a series of cash inflows and outflows during its lifetime. The net cash flow in the first year (year zero) is negative as the cash outflows of the initial investment are not offset by any cash inflows. After the project begins production, it will generate a stream of cash inflows in the form of revenues from the sale of its output and depreciation of the capital equipment, and cash outflows in the form of operating expenses. Beginning with year one and continuing throughout the lifetime of the project, annual cash flows are expected to be positive, but need not be. Although cash inflows and outflows may occur at any time, it is assumed that they will take place at the end of the year. It is also assumed that the only investment in the project takes place at the end of year zero and is followed by a series of net cash inflows. These assumptions guarantee a unique rate of return for each project.[105]

The cash outflow in the first year may be expressed:

$$Y_o = (FCC + WC) - (TCRED \cdot FCC) \qquad (9\text{-}1)$$

where FCC is the principal value of the capital investment, WC is the value of the working capital, and TCRED is the percentage of the capital investment resulting in a direct tax savings, or tax credit, to the firm.

The project generates its first revenues at the end of its first year of production (year two). The net cash flows in this and succeeding years can be expressed:

$$Y_t = (R_t - E_t)(1 - T) + D_t T \qquad t = 1, \ldots, N . \qquad (9\text{-}2)$$

The first term in equation (9-2) represents the net after-tax inflows of the project generated by the sales of the output. Total revenues in year t can be expressed:

$$R_t = (P \cdot Q)_t \qquad (9\text{-}3)$$

where P is the per-unit price of output and Q is the quantity of output sold during the year. Total operating costs in year t can be expressed:

$$E_t = (V \cdot Q + F)_t \qquad (9\text{-}4)$$

where V is the per-unit variable cost of production and F is the fixed annual cost of operating the project. Variable costs include expenditures on material inputs, labor and energy. Fixed costs include such expenses as site rent (explicit or implicit), insurance, and administrative overhead.

Only net revenues are subject to the Federal corporate income tax (T). Thus, annual total operating cost is deducted from total revenue to yield the taxable net revenue. The firm's after-tax net revenue in year t is thus the first term in equation (9-2).

Federal income tax laws allow a deduction for depreciation of the capital equipment. This deduction reduces income tax payments and is thus treated as a cash inflow in the second term in equation (9-2). In this analysis, the straight-line method of capital depreciation is assumed. Thus,

$$D_t T = (FCC/N) \cdot T \qquad (9\text{-}5)$$

where N is the project life in years.[106] The salvage value of the plant is assumed to be zero; there is no additional cash inflow in the last year of the project's life.

The net cash flows represented by equation (9-2) occur at the end of the first through the Nth years, where N is the life of the project. An additional cash inflow actually occurs at the end of the Nth year when the working capital, WC in equation (9-1), is recovered at the end of the project. This inflow is in fact accounted for in the analysis.

The investment project is thus represented as a cash outflow in the first year, followed by N cash inflows and outflows in successive years. Cash flows that occur over a future period must be discounted by an appropriate interest rate to reflect the fact that a sum of money received at some future date is worth less than an equal sum received today. The discounted value of this sum received in the future is called its present value. The discount factor is a function of both time and the interest rate, and can be expressed:

$$DF_t = (1 + r)^{-t} \qquad (9\text{-}6)$$

where DF is the discount factor for year t and r is the interest rate.

An understanding of the discount factor and the selection of an appropriate rate of interest in practice is important. The interest rate r in equation (9-6) can be viewed as the cost to the firm of acquiring funds for the project. The firm can acquire funds in essentially any combination of three ways. It can issue bonds, sell stock, or utilize currently held liquid assets. There is a cost associated with each method. Interest must be paid on bonds, dividends on stock, and there is an opportunity cost associated with utilizing internal funds. A firm typically uses all three methods to finance a project, and the cost of capital becomes a weighted average of all three.

The sum of the discounted cash flows from a project over its life is the net present value (NPV) of the project. The NPV of a project can be expressed most simply as:

$$NPV = \sum_{t=1}^{N} (Y_t \cdot DF_t) - Y_o \qquad (9\text{-}7)$$

where all terms have been defined above. The net present value of a project is thus the sum of the discounted after-tax net revenues minus the initial capital expenditure.

Future cash inflows in equation (9-7) are discounted by a factor reflecting the weighted average cost of capital to the firm. The decision criterion for the firm is to invest in any project with a positive net present value.[107] [108] In practice, however, where a firm's access to funds is limited, the criterion is to invest in the project with the greatest positive net present value.

In this analysis, a steel firm considering investing in a BOF project is assumed to invest in the project with the highest positive net present value. Equation (9-7) can be used to calculate the net present value of each plant under any given regulatory alternative and to evaluate each plant type according to the decision criterion.

In Section 9.1.4.4, it is concluded that recent pricing behavior in the domestic steel industry does not strongly support either a monopoly or an oligopoly market structure. Increasingly, steel prices appear to be more the result of underlying supply and demand conditions than the result of price-setting behavior of any market participant. Thus, in this analysis, competitive conditions are assumed to prevail. In particular, firms are assumed to be price takers.

In this analysis, two types of impacts that could result from the proposed NSPS on BOF facilities are estimated. Equation (9-7) is utilized as stated to estimate the NPV of each project under each regulatory alternative. A different form of the same equation is used to estimate the average total cost of BOF steel production for each plant under each regulatory alternative. This estimate is used in a discussion of steel price impacts.

The NPV calculated in equation (9-7) is the sum of the discounted after-tax net revenues from a project minus the initial capital expenditure. As discussed previously, the objective of a firm is to maximize shareholders' wealth. This is accomplished by maximizing the discounted stream of cash flows to the stockholders. The NPV of an investment is in fact the discounted value of cash flows from the project available as dividends payable to stockholders. Thus, the objective of the firm is to invest in any project with a positive NPV or, where funds are limited, to invest in the project with the highest positive NPV.

9.2.2.2 Net Present Value Impact Methodology. In general, an NSPS increases average total cost (ATC) of production. This can result from additional capital costs for pollution control equipment, increased operating costs, or both. If market demand for the project is perfectly elastic, a situation of full cost absorption prevails--the increase in ATC cannot be passed forward in the form of increased product price. ATC is an expense deducted from gross revenue in equation (9-7). Thus, the NSPS will reduce the NPV of a project if unit price remains unchanged. In a full cost absorption situation, the effect of an NSPS is to reduce the present value of dividends payable to investors.

The nature of the NPV impact on a stockholder depends on whether the stock was purchased before or after the impact was perceived by the market as a whole. The recipients of the loss in NPV are the owners of stock at the time the loss information becomes known. Once it is perceived that the increased ATC resulting from the NSPS will reduce future dividend streams, prices of outstanding stock decline until the new, lower present value of the dividends yields the same rate of return available on other shares of stock.[109] Holders of outstanding stock at the time this price adjustment occurs suffer a one-time wealth loss.

Once stock prices have adjusted downward, the dividend payments yield the same rate of return on these shares as dividend payments on totally unaffected stocks yield. The holders of NSPS affected stock at the time the information is learned receive this same market rate of return on their new, lower priced stock. Moreover, investors who purchase BOF steel firm stock after the market has accounted for the NSPS impact suffer neither a loss in wealth nor a loss in their rate of return. The lower price they pay for stock compensates them for the lower dividend payments they anticipate.

In this analysis, equation (9-7) is utilized to calculate NPV impacts resulting from the proposed regulatory alternatives. The net present values of relevant investment projects under Regulatory Alternatives II and III, which would control secondary emissions, are compared to the NPV's of these same projects under Regulatory Alternative I, which controls only primary emissions. The loss of net present value occurring as a result of the NSPS under a situation of full cost absorption is interpreted as the impact on stockholders' wealth.

9.2.2.3 Steel Price Impact Methodology. An increase in the ATC of BOF steel will be exactly reflected in higher prices in a situation of full cost pricing. Price changes occurring in this manner result in a market with perfectly elastic supply or perfectly inelastic demand.

Price impacts of the proposed regulatory alternatives are calculated assuming that the price change is exactly equal to the change in ATC. This change in ATC is in turn calculated using a revised form of equation (9-7), derived below. In a market situation where price equals average total cost, the NPV of a project is equal to zero. That is, dividend payments in excess of those required to raise capital for the project, which themselves yield the rate r in equation (9-6), are zero. When equation (9-2) is substituted into (9-7) and (9-7) is set equal to zero, (9-7) can be written:

$$\sum_{t=1}^{N} [(R_t - E_t)(1 - T) + D_t T]\, DF_t = Y_o \, . \qquad (9\text{-}8)$$

If revenues and expenses are assumed to be the same over all periods, equation (9-8) can be written

$$(R - E) \cdot (1 - T) \cdot \sum_{t=1}^{N} DF_t + \sum_{t=1}^{N} D_t TDF_t = Y_o \qquad (9\text{-}9)$$

recognizing that (1 - T) is a constant. The sum of the discount factors as t ranges from 1 to N can be written:

$$F = \sum_{t=1}^{N} DF_t = [1 - (1 + r)^{-N}]/r \ . \qquad (9\text{-}10)$$

Substituting equations (9-5) and (9-10) into (9-9) yields:

$$(R - E) \cdot (1 - T) \cdot F + (FCC/N) \cdot T \cdot F = Y_o \ . \qquad (9\text{-}11)$$

Substituting equations (9-3) and (9-1) into (9-11) and rearranging further:

$$(P \cdot Q) - E = \frac{(FCC + WC) - (TCRED \cdot FCC) - DSL}{(1 - T) \cdot F} \qquad (9\text{-}12)$$

where DSL = (FCC/N) · T · F and represents the present value of the tax savings due to straight-line depreciation of the fixed capital.

Finally, Q and E can be moved to the right-hand side of (9-12) to yield:

$$P = \frac{(FCC + WC) - (TCRED \cdot FCC) - DSL}{(1 - T) \cdot F \cdot Q} + \frac{E}{Q} \ . \qquad (9\text{-}13)$$

Where P = ATC, equation (9-13) calculates average total cost. The first term in (9-13) is per-unit capital cost including allowances for the tax credit and depreciation, while the second term is per-unit operating cost.

The cost per megagram of BOF steel is calculated using equation (9-13) for each model project under each regulatory alternative. Assuming that some or all of any additional cost resulting from a proposed NSPS is passed forward in a higher price, price impacts are estimable.

In Section 9.2.3.1, maximum impacts on net present value, price, and other relevant variables are presented for all plants under each regulatory alternative. In 9.2.3.2, an assessment is made of actual expected impacts based on a somewhat refined model and certain simplifying assumptions.

9.2.3 Economic Impacts of Regulatory Alternatives

This section presents ranges of maximum impact estimates for the regulatory alternatives. Maximum impacts on net present value are presented for the case of full cost absorption. The presented range of impacts on steel prices, output, employment, and imports results in a situation of full cost pricing.

Table 9-20 contains cost data for each model project under each regulatory alternative. The costs are taken directly from tables in Chapter 6 except that annual operating cost includes an estimate for the value of hot metal used by the steel furnace equivalent to $223.77 per megagram of hot metal.[110] The hot metal value is included as an operating expense so that the NPV calculated by equation (9-7) is interpretable as the NPV of the BOF project alone, not of the BOF project plus the remainder of the integrated plant. Capital costs in Table 9-20 are employed in the FCC term of equation (9-1) while annual operating costs are employed in the E term in equation (9-4).

Table 9-21 lists the parameter values actually employed to calculate NPV and ATC. A value of working capital equal to 10 percent of the value of the fixed capital and a project life of 15 years are engineering estimates. The currently relevant investment tax credit and Federal corporate tax rate are 10 percent and 46 percent, respectively. Two separate interest rates are employed. The working average cost of capital to the steel industry has been estimated to be 6.2 percent.[111] An alternative interest rate of 10 percent is employed to investigate the sensitivity of the estimates to this parameter. The steel price of $383.15 per megagram is the observed June 1980 producer price for carbon steel billets.[110]

In this analysis, it is assumed that while nominal prices and interest rates are sure to fluctuate in the future, real prices and rates will remain constant. Thus, constant 1980 dollar revenues and expenses are employed in the analysis, along with real interest rates.

Table 9-20. MODEL PROJECT COST DATA
(10^6 1980 $)

	Regulatory Alternative					
	I		II		III	
Model case	Capital cost	Annual operating cost	Capital cost	Annual operating cost	Capital cost	Annual operating cost
A	187.5	900.1	-	-	200.1	902.8
B	112.3	734.2	-	-	122.7	736.3
C	188.3	900.4	-	-	202.7	903.5
D	122.1	735.6	132.5	737.6	-	-
E	16.0	896.6	-	-	31.0	899.7
F	97.2	469.4	-	-	106.7	471.5
G	55.7	364.0	-	-	63.3	365.6
H	119.2	900.3	-	-	134.3	903.5
J	190.9	900.8	195.3	902.1	-	-
K	122.7	735.7	123.3	736.0	-	-
L	187.5	1,405.2	-	-	200.1	1,407.9
N	192.0	900.9	196.4	902.2	-	-
O	195.7	904.1	200.1	905.9	-	-
P	117.0	734.4	-	-	127.4	736.4

TABLE 9-21. MODEL PARAMETER VALUES

Parameter	Value
Working capital (WC)	0.1 × FCC
Federal investment tax credit (TCRED)	0.1 × FCC
Federal corporate tax rate (T)	46 percent
Project life (N)	15 years
Interest rate (r)	6.2 percent and 10.0 percent
Steel price (P)	$383.15 per megagram

9.2.3.1 Net Present Value Impacts. Recall that the NPV of a project is the discounted present value of total revenue minus total costs over the life of the project, where total costs include capital recovery. The project NPV is equivalent to stockholders' wealth attributable to the project.

The NPV of each model project under each regulatory alternative is presented in Table 9-22. Each model has a NPV estimate under Regulatory Alternative I, which is baseline. Only one of the two other alternatives is relevant to a particular model project; some table entries are accordingly left blank.

The baseline project net present values range from a low value of $458.8 million for model G to a high value of $1,526.5 million for model L. Thus, all projects are profitable in that they yield a positive NPV at an interest rate of 6.2 percent.

It is evident from Table 9-22 that for each model the NPV is lower under the relevant secondary emissions alternative than under baseline. Project NPV's range from $853.8 million to $952.2 million under Alternative II and from $445.4 million to $1,504.1 million under Alternative III. The reason for this is simple: The control of secondary emissions imposes additional capital and operating costs while leaving the value of marketable output, and hence revenues, unchanged. It must be remembered, however, that the plants under Regulatory Alternatives II and III yield an additional output not produced under baseline--reduced emissions.

Table 9-23 presents the maximum changes in NPV that could occur from baseline primary emissions control to proposed secondary emissions control. The loss in NPV should be interpreted as the reduction in wealth that affected stockholders would experience if a steel firm were to invest in a particular project meeting both the secondary and primary standards instead of the primary standard alone. The impact would be felt as a one-time reduction in affected stock prices.

Moving from baseline to Alternative II results in NPV losses between $2.0 million and $17.3 million, or 0.2 and 2.0 percent. Moving from baseline to Alternative III results in losses of NPV from $13.3 million to $26.6 million, or 2.9 to 2.6 percent.

TABLE 9-22. PROJECT NET PRESENT VALUES ASSUMING 6.2 PERCENT INTEREST RATE (10^6 1980 $)

Model case	Regulatory Alternative		
	I	II	III
A	967.7	-	945.3
B	884.8	-	867.0
C	965.6	-	940.0
D	871.1	853.8	-
E	1,100.0	-	1,073.9
F	480.6	-	463.4
G	458.8	-	445.4
H	1,012.1	-	985.5
J	961.8	952.2	-
K	870.1	868.2	-
L	1,526.5	-	1,504.1
N	960.6	950.9	-
O	941.5	929.3	-
P	880.7	-	863.4

TABLE 9-23. NET PRESENT VALUE REDUCTIONS FROM BASELINE ASSUMING 6.2 PERCENT INTEREST RATE

Model case	Regulatory Alternative II		Regulatory Alternative III	
	10^6 1980 $	Percent	10^6 1980 $	Percent
A	-	-	-22.4	-2.3
B	-	-	-17.8	-2.0
C	-	-	-25.6	-2.7
D	-17.3	-2.0	-	-
E	-	-	-26.0	-2.4
F	-	-	-17.2	-3.6
G	-	-	-13.3	-2.9
H	-	-	-26.6	-2.6
J	-9.7	-1.0	-	-
K	-2.0	-0.2	-	-
L	-	-	-22.4	-1.5
N	-9.7	-1.0	-	-
O	-12.2	-1.3	-	-
P	-	-	-17.3	-2.0

Tables 9-24 and 9-25 present analogous NPV impacts using an interest rate of 10.0 percent. Note that in all cases project NPV is lower than when an interest rate of 6.2 percent is employed. This is because the present value of future net revenues declines as the interest rate rises. However, neither the magnitude changes nor the percentage changes are significantly different when an interest rate of 10.0 percent is used.

To reiterate, these estimated changes in NPV are maximum impacts. They occur only in the extreme case of full cost absorption. The other extreme, the case of full cost pass through, is examined in Section 9.2.3.2.

9.2.3.2 Steel Cost Impacts. The purpose of this section is to present NSPS impacts on the average total cost of producing steel in each of the model plants. Equation (9-13), which is derived in Section 9.2.2.3, is used to calculate the average (per megagram) total cost of producing raw carbon steel in each plant type under each alternative. The difference in the ATC of producing steel in a given plant under the more stringent emissions control alternative is attributable to the added capital and operating costs of the control equipment. In the extreme case where the entire increase is passed forward in higher steel prices, these changes represent maximum steel price impacts.

The average total cost in 1980 dollars of producing 1 Mg of raw steel in each model plant under each regulatory alternative is presented in Table 9-26. Under Regulatory Alternative I, the total cost per megagram of raw steel varies from a low of $309.30 for model plant G to a high of $321.26 for model plant F. The ATC of production increases for all model plants when secondary emissions are controlled. This is because of the additional capital costs that must be recovered plus the increased operating expense associated with the control equipment. The ATC of producing steel varies from a low of $313.27 to a high of $321.25 under Alternative II. Under Alternative III, the range in ATC is between $311.44 and $323.48.

TABLE 9-24. PROJECT NET PRESENT VALUES ASSUMING 10.0 PERCENT INTEREST RATE (10^6 1980 $)

Model case	Regulatory Alternative		
	I	II	III
A	727.5	-	707.1
B	677.9	-	661.6
C	725.7	-	702.3
D	664.9	648.9	-
E	869.3	-	845.4
F	360.4	-	344.7
G	352.0	-	339.8
H	777.4	-	753.1
J	722.1	713.5	-
K	664.0	662.3	-
L	1,170.8	-	1,150.4
N	720.9	712.3	-
O	705.0	694.3	-
P	673.6	-	657.7

TABLE 9-25. NET PRESENT VALUE REDUCTIONS FROM BASELINE ASSUMING 10.0 PERCENT INTEREST RATE

Model case	Regulatory Alternative II		Regulatory Alternative III	
	10^6 1980 $	Percent	10^6 1980 $	Percent
A	-	-	-20.4	-2.8
B	-	-	-16.3	-2.4
C	-	-	-23.4	-3.2
D	-15.9	-2.4	-	-
E	-	-	-23.9	-2.7
F	-	-	-15.7	-4.4
G	-	-	-12.2	-3.5
H	-	-	-24.4	-3.1
J	-8.6	-1.2	-	-
K	-1.7	-0.3	-	-
L	-	-	-20.4	-1.7
N	-8.6	-1.2	-	-
O	-10.7	-1.5	-	-
P	-	-	-15.9	-2.4

TABLE 9-26. AVERAGE TOTAL COST OF RAW STEEL ASSUMING 6.2 PERCENT INTEREST RATE (1980 $/Mg)

Model case	Regulatory Alternative		
	I	II	III
A	318.69	-	320.18
B	311.93	-	313.36
C	318.83	-	320.54
D	313.04	314.43	-
E	309.88	-	311.62
F	321.26	-	323.48
G	309.30	-	311.44
H	315.73	-	317.51
J	319.08	319.73	-
K	313.11	313.27	-
L	317.62	-	318.58
N	319.17	319.81	-
O	320.43	321.25	-
P	312.27	-	313.66

The ATC changes associated with moving from baseline to Regulatory Alternative II or III are more explicity presented in Table 9-27. Moving from baseline to Alternative II increases the ATC of producing steel by between $0.16 and $1.39 per megagram, or by 0.05 to 0.44 percent. Increases in ATC of between $0.96 and $2.21 per megagram, or 0.30 to 0.69 percent, result between baseline and Alternative III.

The ATC data presented above pertain to estimates using an interest rate, or average cost of capital, of 6.2 percent. Analogous estimates using a 10-percent rate are presented in Tables 9-28 and 9-29. The ATC of steel is higher in any given situation when the rate of interest is higher because the higher cost of borrowed funds must be recovered. The differences, however, are slight.

The observed June 1980 producer price for carbon steel billets of $383.15 per megagram is used in NPV equation (9-7).[110] As seen in Table 9-26, however, average total cost tends to hover around $315, depending on the plant and regulatory alternative. It is precisely this spread of approximately $68 per megagram between ATC and market price that yields the positive net present values reported in Section 9.2.3.1.

An understanding of the relationship between costs, price, and NPV is very important. In general, positive net present values are not expected to be observed over any significant length of time. Recall that the investment criterion is to invest in any project that yields a positive NPV at the average cost of capital. In a competitive market with free entry available to potential producers, new firms are expected to drive up the prices of scarce inputs, raising costs, while simultaneously increasing supply relative to demand, lowering market price. The result is that NPV is driven towards zero.[112]

In a market where new entry is restricted, the stock market drives up the price of stock of any firm undertaking a project with positive net present value. The capital stock of such a firm is thus revalued upwards. Excess profits are said to be "capitalized," and the true cost of employing the fixed capital rises until positive NPV is eliminated.[109]

TABLE 9-27. AVERAGE TOTAL COST IMPACTS FROM BASELINE ASSUMING 6.2 PERCENT INTEREST RATE

Model case	Regulatory Alternative II		Regulatory Alternative III	
	10^6 1980 $	Percent	10^6 1980 $	Percent
A	-	-	1.49	0.47
B	-	-	1.43	0.46
C	-	-	1.71	0.54
D	1.39	0.44	-	-
E	-	-	1.73	0.56
F	-	-	2.21	0.69
G	-	-	2.15	0.69
H	-	-	1.77	0.56
J	0.64	0.20	-	-
K	0.16	0.05	-	-
L	-	-	0.96	0.30
N	0.64	0.20	-	-
O	0.82	0.25	-	-
P	-	-	1.39	0.45

TABLE 9-28. AVERAGE TOTAL COST OF RAW STEEL ASSUMING 10.0 PERCENT INTEREST RATE (1980 $/Mg)

Model case	Regulatory Alternative		
	I	II	III
A	322.07	-	323.79
B	314.78	-	316.04
C	322.23	-	324.19
D	315.70	317.32	-
E	310.17	-	312.18
F	324.65	-	327.20
G	311.73	-	314.21
H	317.88	-	319.93
J	322.53	323.25	-
K	315.79	315.96	-
L	319.80	-	320.91
N	322.63	323.35	-
O	323.96	324.86	-
P	314.82	-	316.43

TABLE 9-29. AVERAGE TOTAL COST IMPACTS FROM BASELINE ASSUMING 10.0 PERCENT INTEREST RATE

Model case	Regulatory Alternative II		Regulatory Alternative III	
	10^6 1980 $	Percent	10^6 1980 $	Percent
A	-	-	1.72	0.53
B	-	-	1.66	0.53
C	-	-	1.97	0.61
D	1.62	0.51	-	-
E	-	-	2.01	0.65
F	-	-	2.55	0.78
G	-	-	2.48	0.80
H	-	-	2.05	0.64
J	0.72	0.22	-	-
K	0.17	0.05	-	-
L	-	-	1.11	0.35
N	0.72	0.22	-	-
O	0.90	0.27	-	-
P	-	-	1.61	0.51

In light of this reasoning, one might suspect that the positive net present values reported in Section 9.2.3.1 are overstated either because the observed market price is too high, the ATC estimates are too low, or both. It is quite possible that some of the positive net present value results from the price consideration. Ideally, the price used in equation (9-7) would be a market price for molten, raw steel. The carbon steel billet price actually employed is necessarily higher than the unknown raw steel price since the production of billets requires some further processing. It is also likely that the fixed capital costs employed in the model, being based on historical or accounting costs are leading to underestimates of ATC.

9.2.3.3 Output, Employment and Imports Impacts. Estimates of NSPS impacts on output and employment in the domestic steel industry and on steel imports are presented in this section. Impacts are presented for the year 1986 for all model plants assuming that the real market price of carbon steel increases from its 1980 price of $383.15 per megagram by an amount exactly equal to the change in ATC resulting from the regulatory alternatives. All impacts are computed using the estimated average cost of capital of 6.2 percent.

9.2.3.3.1 Impacts on steel output. Domestic steel shipments are projected to total 94.0 million Mg in 1986 (see Table 9-17). If the real price of domestic steel increases as a result of the NSPS, demand for domestic steel would be expected to decline and industry output would fall below the 94-million-Mg projection.

For a given model plant, the projected change in industry output is computed by multiplying the percentage change in ATC resulting from the relevant secondary emissions alternative reported in Table 9-27 by an estimated own-price elasticity of demand for domestic steel of -1.86.[113] These percentage changes are then multiplied by the 94-million-Mg projection to yield a tonnage reduction estimate. Results of these computations are presented in Table 9-30.

It is computed that 1986 domestic steel shipments would be 90,000 to 830,000 Mg lower under Alternative II than at baseline. This

TABLE 9-30. DOMESTIC STEEL SHIPMENT IMPACTS FROM BASELINE FOR 1986[a]

Model case	Regulatory Alternative II		Regulatory Alternative III	
	10^6 Mg	Percent	10^6 Mg	Percent
A	-	-	-0.88	-0.82
B	-	-	-0.86	-0.80
C	-	-	-1.01	-0.94
D	-0.83	-0.78	-	-
E	-	-	-1.05	-0.98
F	-	-	-1.30	-1.21
G	-	-	-1.31	-1.21
H	-	-	-1.06	-0.98
J	-0.38	-0.35	-	-
K	-0.09	-0.09	-	-
L	-	-	-0.56	-0.53
N	-0.37	-0.35	-	-
O	-0.47	-0.44	-	-
P	-	-	-0.84	-0.78

[a]Average cost of capital = 6.2 percent.

represents a percentage reduction between 0.09 and 0.78 percent. Under Alternative III, shipments would be 560,000 to 1,310,000 Mg lower, or 0.53 to 1.21 percent.

9.2.3.3.2 Steel industry employment impacts. Estimated impacts on domestic steel employment are presented in Table 9-31. They are computed by multiplying the estimated tonnage changes in Table 9-30 by an employment-to-output coefficient of 4,980 workers per million megagrams.[28]

The impact on industry employment resulting from moving from baseline to Alternative II ranges from a loss of 437 to 3,867 jobs. This represents a loss of between 0.09 and 0.83 percent. The employment impact from baseline to Alternative III is between 2,362 and 6,045 jobs, or from 0.50 to 1.29 percent.

It is important to remember that these employment losses are not layoffs. Rather, they are jobs that will not be created by 1986 that otherwise would have been. Also, these computed losses do not take account of any employment increases that might result in other sectors of the economy. For example, because aluminum competes with steel, employment increases might be expected in the aluminum industry. Additional employment gains are expected in industries that produce control equipment.

9.2.3.3.3 Impacts on steel imports. As the real price of domestic steel rises relative to that for imported steel, domestic users are expected to increase their purchases of foreign steel. It has been estimated that a 1-percent increase in the domestic price for finished steel results in a 1.51-percent increase in steel imports.[113] This import elasticity is multiplied by the percentage change in ATC from Table 9-27 to compute the percentage change expected to result in steel imports from the NSPS on BOF secondary emissions.

Steel imports increased at a continuously compounded annual rate of 3.03 percent from 1970 to 1979 (Table 9-16). If this rate of change continues, steel imports would total 19.6 million Mg in 1986. The NSPS-induced percentage change in steel imports estimated as explained above is multiplied by 19.6 million Mg to compute the import impacts. Estimates are presented in Table 9-32.

TABLE 9-31. DOMESTIC STEEL INDUSTRY EMPLOYMENT IMPACTS FROM BASELINE FOR 1986
(Number of workers)

Model case	Regulatory Alternative II	Regulatory Alternative III
A	-	-4,070
B	-	-3,997
C	-	-4,662
D	-3,867	-
E	-	-4,871
F	-	-6,001
G	-	-6,045
H	-	-4,889
J	-1,775	-
K	-437	-
L	-	-2,362
N	-1,755	-
O	-2,216	-
P	-	-3,877

TABLE 9-32. STEEL IMPORT IMPACTS FROM BASELINE FOR 1986[a]

Model case	Regulatory Alternative II		Regulatory Alternative III	
	10^6 Mg	Percent	10^6 Mg	Percent
A	-	-	0.14	0.71
B	-	-	0.14	0.69
C	-	-	0.16	0.81
D	0.13	0.67	-	-
E	-	-	0.17	0.84
F	-	-	0.20	1.04
G	-	-	0.21	1.05
H	-	-	0.17	0.85
J	0.06	0.30	-	-
K	0.01	0.08	-	-
L	-	-	0.09	0.46
N	0.06	0.30	-	-
O	0.07	0.38	-	-
P	-	-	0.13	0.67

[a]Average cost of capital = 6.2 percent.

It is estimated that there would be from 10,000 to 130,000 Mg more steel imported into the United States in 1986 under Alternative II than at baseline. This represents an impact of 0.08 to 0.67 percent. The impact of moving from baseline to Alternative III would be an increase in imports of from 90,000 to 210,000 Mg, or 0.46 to 1.05 percent.

9.2.4 Anticipated Economic Impacts

Section 9.2.3 presented ranges of impacts on NPV assuming full cost absorption and price and other variables assuming full cost pricing. The purpose of this section is to present estimates of impacts on net present value, steel price, and other relevant variables that are considered most likely to result under the proposed alternatives. The impacts that actually occur depend on a number of factors including the types of projects actually built and the extent to which cost increases are passed forward. This first factor is addressed in Section 9.2.4.1, while Section 9.2.4.2 deals with the cost/price mechanism.

9.2.4.1 Model Plant Selection. A total of 14 model projects are described in Chapter 6. They vary in certain respects but are all basic oxygen process steel furnace projects. As seen in Table 9-20, each model has associated with it a unique set of fixed capital and annual operating costs. Accordingly, as evidenced in Tables 9-22 and 9-26, each project has associated with it a unique net present value and average total cost. It is thus clear that the economic impacts that will actually result from the proposed NSPS will depend in part on which types of facilities are actually affected.

Of the model plants investigated in this report, plants A and J typify the project type expected to be most representative of BOF shops to come on line over the next several years. These represent new shops with two 272-Mg top blown vessels.

These models are considered representative of future projects for several reasons. First, they are similar to shops recently built in the United States. Their 272-Mg vessels are well suited to producing high quality carbon steel. Specialty steels, on the other hand, which have sometimes been produced in the smaller 136-Mg vessels of other model shops, are more likely to be produced in electric furnaces in coming years.[114]

9.2.4.2 Estimates of Anticipated Impacts. The economic impacts that are expected to result from the proposed regulatory alternatives are estimated assuming that model projects A and J typify future BOF construction through 1986. Table 9-33 has been constructed from several tables presented earlier in this chapter.

The ATC data in Table 9-33 are a certain result of the NSPS, given that the cost data and model parameter values are correct. That is, the total cost of producing a megagram of raw steel in each model plant is sure to increase as a result of the NSPS. The impact of this change on other relevant variables is less certain. Two extreme results are possible. If the market price of raw steel remains totally unchanged, the NPV of project A would decline to $945.3 million under Alternative III and the NPV of project J would decline to $952.2 million under Alternative II. However, if the market price of steel increases by an amount equal to the change in ATC, the NPV of each project will remain unchanged. A most relevant question thus becomes: What is the mechanism linking ATC to price and what will be the result of this mechanism in this circumstance?

It was stated in Section 9.2.2.2 that if market demand is perfectly elastic, added costs must be fully absorbed and a maximum NPV loss must occur. This is not the case in the steel market, where the estimated elasticity of demand for domestic steel is -1.86. Since the demand for steel is not perfectly elastic, at least some part of any increase in ATC will be reflected in higher price. This is illustrated in Figure 9-1. The demand curve (D) is drawn downward sloping to indicate that demand is neither perfectly elastic nor perfectly inelastic. Two supply curves are drawn for illustrative purposes. S_1 is perfectly elastic and S_2 is upward sloping. It is clear that whatever the shape of the supply curve, an upward shift in supply resulting from an increase in ATC will result in some price increase. The initial

TABLE 9-33. NET PRESENT VALUE AND AVERAGE TOTAL COST DATA FOR MODELS A AND J[a]

	Regulatory Alternative					
	I		II		III	
Model case	NPV (10^6 1980 $)	ATC (1980 $/Mg)	NPV (10^6 1980 $)	ATC (1980 $/Mg)	NPV (10^6 1980 $)	ATC (1980 $/Mg)
A	967.7	318.69	-	-	945.3	320.18
J	961.8	319.08	952.2	319.73	-	-

[a]Average cost of capital = 6.2 percent.

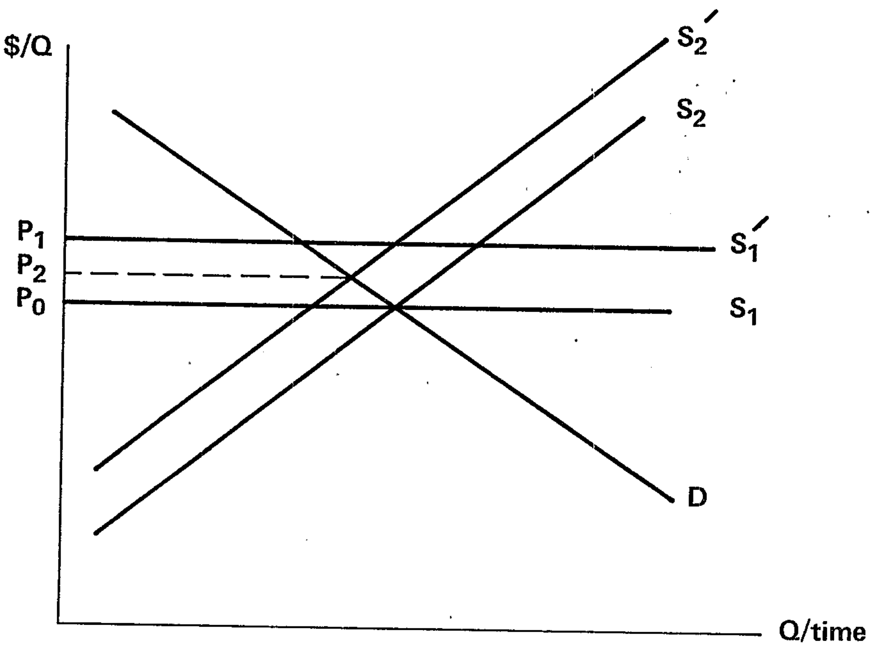

Figure 9-1. Price impacts with downward-sloping demand.

market price P_0 is determined by the intersection of S_1 and D or S_2 and D. An increase in ATC shifts S_1 to S_1', yielding market price P_1. The same change in ATC shifts S_2 to S_2', yielding market price P_2. Given a downward-sloping demand for steel, the extent of the impact on price from a change in ATC is determined by the slope of the supply curve; the more elastic supply, the greater the price impact.

The pricing model adopted for this analysis takes demand as downward sloping--the elasticity of demand equals -1.86. The nature of market supply assumed in the analysis is like that expounded by W. E. G. Salter.[115] At any point in time, the market supply of steel is determined by operating costs of existing plants. A plant will produce steel as long as market price is equal to or greater than its average operating costs. Failure to do so would result in forgone returns to fixed capital. The higher market price is, the more plants there are that have average operating costs (AOC) at or below market price, and the greater market output. The oldest producing plant with the highest operating costs is said to be a marginal plant: market price is equal to its AOC.

In Figure 9-2, market supply is the result of five plants (A-E) having average operating costs at or below market price. The supply from any given plant is perfectly elastic because factor supplies are elastic. Plant A is a modern plant with an AOC well below market price. Plant E is the "marginal plant": price equals $(AOC)_E$.

It has been determined that the proposed NSPS alternatives on BOF steelmaking affect only projects that are as yet unconstructed. A long-run supply criterion is thus relevant; the option to not build is open to the firm. A plant will not be built unless price is equal to or greater than average total cost. The investing firm must anticipate covering not only AOC, but capital costs as well, including a normal return.

In the model described above, a plant will not be built unless $ATC \leqq P$. Recall from Section 9.2.3.2 that in any market, positive net present values are short lived. In a market with unrestricted entry, entering firms increase market output until price falls, eliminating

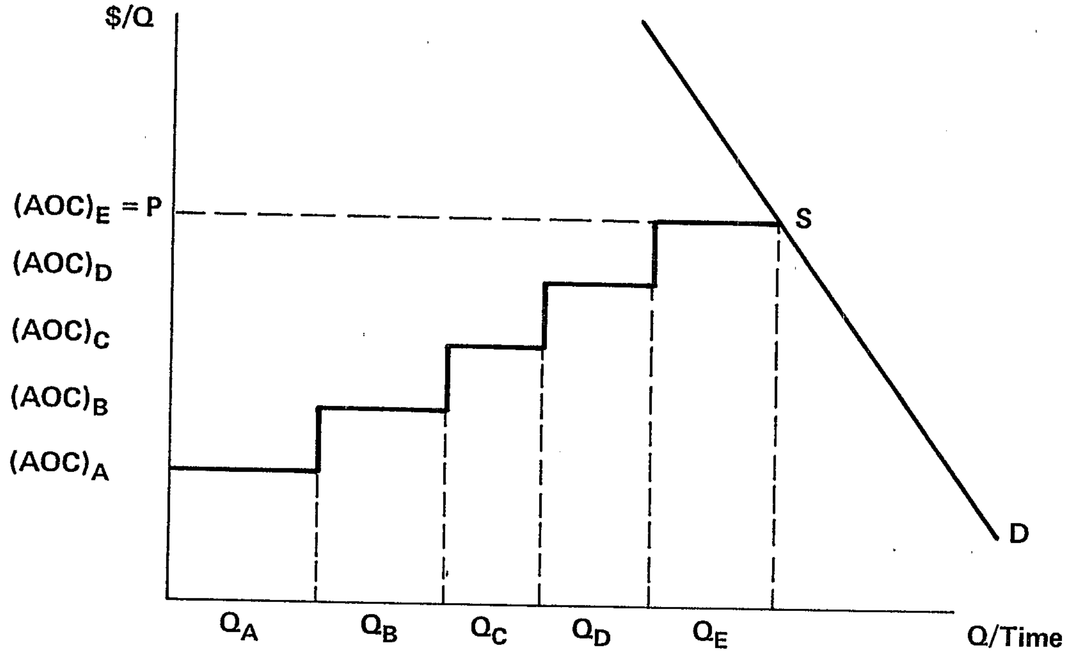

Figure 9-2. Supply from existing plants.

positive NPV. In a restricted entry market, positive NPV is capitalized in higher valued capital stock. In either case the result is the same: market price equals average total cost, properly measured.

Returning to Figure 9-2, plant A has a low AOC. Its capital, however, is technically superior and thus highly valued. So while A has low operating costs, it also has high capital costs. Thus, $ATC_A = P$. At the other extreme, plant E has inefficient capital of little value but high operating costs. In this case, $AOC_E = ATC_E = P$. Indeed, the value of a piece of durable equipment, or a plant, is precisely the present value of the revenues it generates over operating costs. Thus, the ATC of any plant is equal to market price: NPV = 0.

It has been concluded that a project will not be undertaken until market price equals ATC. Also, it has been shown that a necessary result of each alternative is an increase in the ATC of steel production. It thus follows that the new steel facility will not be built until the difference between market price and ATC is eliminated. This could result from a market price increase due to increasing demand or declining supply as older plants are retired. The difference could also disappear over time as new technology reduces the average operating cost of a newer generation model. In either case, a delay is expected in BOF plant construction. Price increases are more likely than operating-cost reductions to eliminate the difference; technological advance is relatively slow.

Table 9-34 summarizes the anticipated economic impacts of Regulatory Alternative II. The price impact of $0.65 per megagram is a 0.17 percent increase. There is no anticipated impact on NPV because project construction will be delayed until the market price has increased to cover the increase in ATC. Domestic output in 1986 would be 297,228 Mg lower under Alternative II than at baseline, a 0.32 percent difference. There would be a corresponding employment impact of 0.32 percent, or 1,498 jobs. Again, this employment impact estimate is a maximum. U.S. steel users would import 50,313 Mg more foreign steel in 1986 under Alternative II than at baseline. The estimated total cost of compliance in 1986 is $15.6 million.

TABLE 9-34. SUMMARY OF ECONOMIC IMPACTS FROM BASELINE OF REGULATORY ALTERNATIVE II[a]

Price impact (1980 $/Mg)	0.65	(0.17%)
NPV impact	-	-
Domestic output impact (Mg)	-297,228	(-0.32%)
Employment impact (jobs)	-1,498	(-0.32%)
Imports impact (Mg)	50,313	(0.26%)
Total cost of compliance (10^6 1980 $)	15.6	

[a]Model parameters: Cost of capital = 6.2%
Baseline price = $383.15/Mg
Baseline output = 94.0 × 10^6 Mg
Baseline employment = 468,120 jobs
Baseline imports = 19.6 × 10^6 Mg
Own-price demand elasticity = -1.86
Import elasticity = 1.51.

The anticipated economic impacts of Regulatory Alternative III are summarized in Table 9-35. BOF project construction would be delayed until the market price of steel increased 0.39 percent, or $1.49 per megagram. Domestic steel output in 1986 would be 686,200 Mg lower than at baseline. There would be 3,417 fewer jobs created by 1986, a 0.73 percent impact. Imports of steel would be 115,424 Mg higher than at baseline, an increase of 0.59 percent. The estimated total cost of compliance is $18.4 million.

9.2.5 Capital Availability

This section investigates how the proposed regulatory alternatives will affect the steel industry's ability to raise capital.

To begin, the capital required to build each model plant under each regulatory alternative is compared. Table 9-36 shows capital requirements by plant type under baseline and under the relevant secondary emissions alternative (Alternative II or III), and the percent change from the baseline to the stricter alternatives. Moving from baseline to the relevant secondary emissions alternative involves increasing capital requirements from between 0.49 percent and 93.75 percent, depending on the model project.

Particular attention should be drawn to the incremental capital requirement for model A, since this is the project considered to be most representative of future projects (see Section 9.2.4.1). The incremental requirement of $12.6 million represents a 6.72 percent increase. It is not felt that an additional capital need of this magnitude would sufficiently impair a firm's ability to raise capital or significantly affect its cost of doing so.

Viewed in a larger respective, incremental capital requirements due to the NSPS on BOF's under consideration are quite small. By 1986, when three new projects of type A might be in place or under construction, incremental capital requirements would be expected to total 3 × $12.6 million = $37.8 million. By the same year, the steel industry is expected to invest $3,276.6 million in new productive capital of all types.[116] The incremental requirement is only 1.2 percent of this total.

TABLE 9-35. SUMMARY OF ECONOMIC IMPACTS FROM BASELINE OF REGULATORY ALTERNATIVE III[a]

Price impact (1980 $/Mg)	1.49	(0.39%)
NPV impact	-	-
Domestic output impact (Mg)	-686,200	(-0.73%)
Employment impact (jobs)	-3,417	(-0.73%)
Imports impact (Mg)	115,424	(0.59%)
Total cost of compliance (10^6 1980 $)	18.4	

[a]Model parameters: Cost of capital = 6.2%
Baseline price = $383.15/Mg
Baseline output = 94.0×10^6 Mg
Baseline employment = 468,120 jobs
Baseline imports = 19.6×10^6 Mg
Own-price demand elasticity = -1.86
Import elasticity = 1.51.

TABLE 9-36. CAPITAL REQUIREMENTS OF REGULATORY ALTERNATIVES

Model case	Capital requirements (10^6 1980 $) Regulatory Alternative			Change from baseline (percent) Regulatory Alternative	
	I	II	III	II	III
A	187.5	-	200.1	-	6.72
B	112.3	-	122.7	-	9.26
C	188.3	-	202.7	-	7.65
D	122.1	132.5	-	8.52	-
E	16.0	-	31.0	-	93.75
F	97.2	-	106.7	-	9.77
G	55.7	-	63.3	-	13.64
H	119.2	-	134.3	-	12.67
J	190.9	195.3	-	2.30	-
K	122.7	123.3	-	0.49	-
L	187.5	-	200.1	-	6.72
N	192.0	196.4	-	2.29	-
O	195.7	200.1	-	2.25	-
P	117.0	-	127.4	-	8.89

One qualification should be discussed. The NSPS on basic oxygen steelmaking is only one of several environmental regulations affecting the steel industry. Others include regulations on coking facilities and on other steelmaking processes. Each is expected to impose additional capital needs on the industry. Taken together these regulations may result in some difficulties in obtaining financing for some companies. Even this is not certain. Table 9-37 presents the "funded-debts-to-net working-capital" ratio (debt ratio) for several industries. Funded debts are all obligations with maturities exceeding 1 year, including bonds, mortgages, and term loans. These are the same instruments that would likely be utilized to finance a new steel project. Net working capital represents the excess of current assets over current liabilities; it represents available liquid funds. The higher the debt ratio, the more difficult it becomes to obtain further capital through debt issue. A ratio in excess of 100 is ordinarily considered excessive.[117]

The debt ratio for the steel industry, 87.2, is a little under the recommended maximum. It is, however, significantly higher than the ratios for other listed industries. This may be some indication that the steel industry has borrowed to its financially practical limit. If this is true, as other studies have reported it is, the imposition of regulations alternatives that require further capital investment could be financially damaging to the industry.[118]

9.2.6 Total Cost of Compliance

The estimated total annualized costs to the steel industry of complying with the regulatory alternatives are presented in Table 9-38. The costs presented are for 1986, at which date an additional annual capacity of 6.86 million Mg of BOF steel shops is projected to be in place (see Section 9.1.5.4.3).

Fourteen separate estimates--one for each model plant--are computed. The estimate for any given model is computed by multiplying the annualized total cost of compliance for a plant of that type by the total number of plants of that type that would have to be built to at least meet the 6.86-million-Mg requirement. Total annualized compliance costs for each plant are obtained from Table 8-2.

TABLE 9-37. INDUSTRY DEBT RATIOS[76]

Industry	Debt ratio[a]
Blast furnaces and steel mills--SIC 3312	87.2
Primary nonferrous metals, NEC--SIC 3339	48.4
Aluminum foundries--SIC 3361	60.6
Primary metal products, NEC--SIC 3399	39.5
Motor vehicles--SIC 3711	41.8
Petroleum refining--SIC 2911	61.2

[a]Debt ratio = $\frac{\text{Funded debts}}{\text{Net working capital}}$

TABLE 9-38. TOTAL COST OF COMPLIANCE, 1986

Model case	Number of projects	Total annual industry capacity (10^6 Mg)	Total cost of compliance (10^6 1980 $) Regulatory Alternative II	III
A	3	8.7	-	27.6
B	3	7.2	-	16.9
C	3	8.7	-	30.2
D	3	7.2	23.1	-
E	3	8.7	-	13.5
F	5	7.5	-	33.3
G	6	7.2	-	24.1
H	3	8.7	-	30.8
J	3	8.7	23.4	-
K	3	7.2	16.4	-
L	2	9.0	-	19.8
N	3	8.7	24.1	-
O	3	8.7	36.9	-
P	3	7.2	-	18.5

As an example, consider model plant A. The annual output of model A is 2.9 million Mg per year. To produce at least 6.86 million Mg of steel, three plants of type A would have to be built (three type A plants have a capacity of 3 × 2.9 million Mg = 8.7 million Mg annually). The total annualized cost of compliance with Regulatory Alternative III for a type A plant is $9.2 million. Thus, if the entire 6.86 million Mg of projected new capacity took the form of the construction of three type A plants, the total cost of compliance with Alternative III would be 3 × $9.2 million = $27.6 million.

The total cost of compliance with Regulatory Alternative II is estimated to be between $16.4 million and $36.9 million. For Regulatory Alternative III, the estimates range from $13.5 million to $33.3 million.

The anticipated total costs for Alternatives II and III are $23.4 million and $27.6 million, respectively. These are maximum impact estimates. As seen in Table 9-19, the construction of only two model A or J plants would nearly meet projected 1986 capacity needs. If only two plants were constructed, total compliance costs for Alternatives II and III would be only $15.6 million and $18.4 million, respectively.

Under certain circumstances, the output adjustment resulting from a proposed regulation is significant enough to reduce plant construction. When this occurs, compliance cost estimates are revised downwards since lower control capital expenditures are required with fewer plants. In the case of the currently proposed NSPS alternatives for BOF steel shops, the anticipated quantity adjustment for the more stringent Alternative III is 686,200 Mg (see Table 9-35). This annual output represents only one-fourth of the total output of a single plant like A or J. It is unlikely that an anticipated quantity adjustment of this magnitude would alter plant construction activity. Thus, compliance costs would be unaffected.

9.2.7 Economic Impacts of Achieving Baseline

Throughout this analysis, Regulatory Alternative I, which includes control of primary emissions, has been used as baseline. This section summarizes the impacts anticipated as the result of achieving primary control; that is, the impacts of moving from no control to baseline.

TABLE 9-39. COST DATA FOR MODEL PROJECT A

	No control	Primary control	Change from no control to primary control	
	(10^6 1980 $)	(10^6 1980 $)	(10^6 1980 $)	(percent)
Capital cost	169.6	187.5	17.9	10.55
Annual operating cost	896.5	900.1	3.6	0.40

TABLE 9-40. ESTIMATED IMPACTS OF MOVING FROM PRIMARY CONTROL TO NO CONTROL

Price impact (1980 $/Mg)	-2.03	(-0.53%)
NPV impact	-	-
Domestic output impact (Mg)	926,652	(0.99%)
Employment impact (jobs)	4,615	(0.99%)
Imports impact (Mg)	156,859	(-0.80%)
Total cost of compliance (10^6 1980 $)	-16.1	(-100.00%)

Recall from Section 9.2.4.1 that BOF projects like those described by models A and J are most likely to come on line in the next several years. For estimation of primary control impacts, model J can also be eliminated since when controlling primary emissions alone it is less costly to use a closed hood collection system. Thus, these impact estimates are based on data for model plant A.

Table 9-39 presents cost data for model A with and without primary control equipment. Capital costs increase by $17.9 million, or 10.55 percent. Annual operating costs increase 0.40 percent from $896.5 million to $900.1 million.

The regulations requiring control of primary BOF shop emissions have been in force for some time. It is thus felt that the current market price of carbon steel and projections of such variables as output, employment and imports account for these control costs. For this reason, the impacts reported in Table 9-40 require a special interpretation. The price impact of $2.03 per megagram is the additional price per megagram currently being paid for carbon steel as a result of primary control. This is an impact of 0.53 percent. Projected 1986 output would be 926,652 Mg higher in the absence of primary control. Accordingly, projected employment in 1986 would be higher by 4,615 jobs. U.S. steel users would purchase 156,859 Mg less of foreign steel if domestic producers were uncontrolled. Finally, the total cost of compliance with the primary standards is an estimated $16.1 million for 1986.

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APPENDIX A

EVOLUTION OF THE PROPOSED STANDARDS

As required by the Clean Air Act, a review of the Standards of Performance for New Stationary Sources--Iron and Steel Plants/Basic Oxygen Furnaces was performed in 1978. This review concluded that there should be no change in the primary emission control level specified in the current NSPS. A recommendation was made to evaluate fugitive emission control systems with the intent of incorporating fugitive emissions in the BOPF NSPS at some future date. Also, a recommendation was made to clarify the period of time during which sampling should be done for determining compliance with the primary emission standard.

In November 1978, Brief Number 78-1534 was filed in the U.S. Court of Appeals for the District of Columbia Circuit by the Group Against Smog and Pollution, Incorporated; Natural Resources Defense Council, Incorporated; and Friends of the Earth, Incorporated. The intent of the brief was to force consideration of an NSPS for BOPF fugitive emission sources. The U.S. Environmental Protection Agency filed a brief in response on December 15, 1978. After reply briefs by both petitioners and respondent, the Department of Justice sent a letter dated October 1, 1979, to the Circuit Court. In this letter, the U.S. EPA agreed to work towards an NSPS for proposal in April 1981.

Subsequent events that have occurred in the development of background information are presented below in chronological order.

<u>Date</u>	<u>Activity</u>
July 6, 1979	Initial project meeting.
December 2, 1979	Plant visit to Kaiser Steel to observe and discuss BOPF secondary emission control system.

December 11, 1979	Plant visit to Republic Steel's Cleveland plant to observe and discuss the BOPF secondary emission control system.
December 12, 1979	Plant visit to Republic Steel's South Chicago plant to observe and discuss the Q-BOP secondary emission control system.
January 25, 1980	Plant visit to Armco Steel's Ashland, Kentucky, plant to observe and discuss hot metal desulfurization emission control system.
February 1, 1980	Plant visit to Inland Steel's East Chicago plant to observe and discuss the No. 2 BOPF shop secondary emission control systems.
February 5, 1980	Don R. Goodwin, Director of Emission Standards and Engineering Division, met with Frances Dubrowski, attorney for the Natural Resources Defense Council, for briefing on project plans for revision of BOPF standards.
February 26-March 3, 1980	Plant visit to Kaiser Steel to make visible emission observations on torpedo car desulfurization facility.
March 4, 1980	A meeting between AISI Environmental Quality subcommittee, EPA Emission Standards and Engineering Division, and EPA contractor to discuss project status.
April 7-11, 1980	Plant visit to Kaiser Steel to make visible emissions observations on BOPF shop secondary emission sources.
April 22, 23, 1980	Plant visit to Armco Steel's Ashland, Kentucky, plant to make visible emissions observations on torpedo car desulfurization facility.
May 12-16, 1980	Plant visit to Inland Steel's East Chicago Plant to make visible emissions observations in the No. 2 and No. 4 BOPF shops.
May 21, 1980	Plant visit to Bethlehem Steel's Bethlehem plant to observe and discuss BOPF charging and tapping emission controls.
June 2-6, 1980	Plant visit to Republic Steel's South Chicago plant to make visible emissions observations at their Q-BOP shop.

June 10-13, 1980	Plant visit to Republic Steel's Cleveland plant to make visible emissions observations at their BOPF secondary emission sources.
June 23-26, 1980	Plant visit to Bethlehem Steel's Bethlehem plant to make visible emission observations at the BOPF open hood secondary emission control system.
December 3, 1980	Presentation of proposed standards to National Air Pollution Control Techniques Advisory Committee.
December 16, 1980	Presentation of proposed standards to EPA working group committee.
January 13, 1981	Plant visit to CF&I BOPF shop in Pueblo, Colorado, to observe and discuss secondary emission control systems.
January 15, 1981	Plant visit to U.S. Steel Q-BOP shop at Fairfield, Alabama, to observe and discuss secondary emissions control systems.
April 9, 1981	Plant visit to J and L Steel BOPF shop at Aliquippa, Pennsylvania, to observe and discuss secondary emission control systems and operating practices.
May 11-27, 1981	Plant visit to U.S. Steel Q-BOP shop at Fairfield, Alabama, to participate in emission test and to observe the operation of secondary emission control equipment.
November 12, 1981	Action memorandum, Preamble and Background Information Document submitted to Steering Committee.
February 1982	Action memorandum, Preamble and Background Information Document submitted for Assistant Administrator concurrence.

APPENDIX B

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

Table B-1 lists the locations in this document of certain information pertaining to environmental impact, as outlined in Agency guidelines (39 FR 37419, October 21, 1974).

TABLE B-1. LOCATIONS OF INFORMATION CONCERNING ENVIRONMENTAL IMPACT WITHIN THE BACKGROUND INFORMATION DOCUMENT

Agency guidelines for preparing regulatory action environmental impact statements (39 FR 37419, October 21, 1974)	Location within the Background Information Document
Background and summary of regulatory alternatives	Chapter 6, Section 6.2
Statutory basis for proposing standards	Chapter 2, Section 2.1
Relationships to other regulatory agency actions	Chapters 3, 7, and 8
Industry affected by the regulatory alternatives	Chapter 3, Section 3.1, and Chapter 9, Section 9.1
Specific processes affected by the regulatory alternatives	Chapter 3, Section 3.2 Chapter 4, Section 4.2

APPENDIX C

SUMMARY OF TEST DATA

The data summaries presented in this section are drawn from the reports of tests conducted at the 10 BOPF shops listed in Table C-1. General descriptions of top blown and bottom blown furnace steelmaking processes are presented in Chapter 3. The steelmaking processes in the test plants do not deviate significantly from the general descriptions. Brief descriptions of the test plants and the control equipment tested are presented below.

C.1 KAISER STEEL, FONTANA, CALIFORNIA

The new (number 2) BOPF shop at Kaiser Steel, Fontana, California, is equipped with two 230-ton top blown furnaces. Each furnace is housed in a complete enclosure designed by Pennsylvania Engineering Corporation. The primary emission control system consists of closed hoods exhausted to separate scrubbers. The primary system exhaust rate during charging, tapping, and turndown is 3,540 m^3/min (125,000 scfm). The draft is reduced to 2,266 m^3/min (80,000 scfm) during the oxygen blow.

Emissions from the BOPF during the oxygen blow are drawn through a two-stage venturi scrubber and demister manufactured by Baumco GMBH, Essen, West Germany. The first stage of the scrubber is the quencher, which has a fixed throat area and a relatively low pressure drop. The second stage has a variable throat area and a high pressure drop of around 70 to 90 in H_2O.

The secondary emission control system consists of a single baghouse serving local hoods at the hot metal transfer and skimming stations and also serves charging and tapping hoods within the furnace enclosures.

The baghouse is a 12-compartment (2 cells each), positive pressure installation with 33,400 m^2 (360,058 ft^2) of gross cloth area. The

TABLE C-1. PLANT AND TEST METHOD SUMMARY
BOPF DATA BASE

Plant	Emissions tested	Type of test	Reference test method
Kaiser Steel, Fontana, CA[1]	Primary Secondary	Particulate loading Visible emissions	5 9
Republic Steel, S. Chicago, IL[2,3]	Secondary	Visible emissions	9
Bethlehem Steel, Bethlehem, PA[4]	Secondary	Visible emissions	9
J&L Aliquippa Aliquippa, PA[5]	Secondary	Visible emissions	9
ARMCO Steel, Middletown, OH[6]	Primary	Particulate loading	5
U.S. Steel, Fairfield, AL[7,8]	Primary	Particulate loading	5
U.S. Steel, South Works Chicago, IL[9]	Primary	Particulate loading	5
CF&I, Pueblo, CO[10]	Primary	Particulate loading	5
Republic Steel Buffalo, NY[11]	Primary	Particulate loading	5
Youngstown Sheet and Tube Indiana Harbor, IN[12]	Primary	Particulate loading	5

gross air-to-cloth ratio is 0.533:1 m/min (1.75:1 ft/min) with a net air-to-cloth ratio of 0.610:1 m/min (2.0:1 ft/min) when three cells are offline. Bag fabric is fiberglass treated with silicon, graphite, and teflon. Bag cleaning is performed by a reverse air system.

The facility is equipped with two fans, each rated at 535,000 m^3/hr (315,000 acfm) at 5 mm of water column and 230° C (450° F). Both fans operate to provide the baghouse design flow of 283 acms (600,000 acfm). Dampers are used to reduce gas flow and energy consumption when full system flow is not required. Air flow is divided among the various secondary hoods according to the needs for each operation. The operations permitted to occur simultaneously depend on whether one or both furnace vessels are being used. Based on design information, hot metal charging requires the largest air flow, or about three-quarters of system capacity. The Kaiser system does not permit hot metal transfer, hot metal skimming, or a hot metal charge to the other vessel while one vessel is being charged. The system does permit oxygen blow, turndown, tapping, or deslagging on the second vessel when one vessel is being charged.

Hot metal transfer or hot metal skimming may occur at any time that neither furnace is being charged. About one-third system flow capacity is required for hot metal transfer or skimming.

The visible emission tests and the particulate tests performed at this facility were conducted in accordance with EPA Reference Methods 5 and 9, respectively.

C.2 REPUBLIC STEEL, S. CHICAGO WORKS, ILLINOIS

This shop is equipped with two bottom blown vessels which have a capacity of 205 Mg (225 tons) each. The secondary emission system at this plant includes full-furnace enclosures with charging hoods at the front of each enclosure. There are no tapping hoods, and neither hot metal transfer emissions nor hot metal skimming emissions are ducted to this system.

Draft for the charging hood at the Republic plant is obtained from the primary fume control system. Each furnace has its own primary gas cleaning system; however, a crossover duct between the two furnaces permits the system for the nonoperating furnace to be used for secondary emission control of the operating furnace. With both gas cleaning system fans drafting the charging hood, the flow rate is about 176 acms at 93° C (373,000 acfm at 200° F) during hot metal charging. During the oxygen blow, the charging hood is drafted continuously through the scrubbing system of the nonoperating vessel. During turndown and tapping, the charging hood is drafted by the scrubbing system of the nonoperating vessel. Fume capture during these latter operations is assisted by drafting the primary hood as well. Fumes captured in the secondary (charging) hood bypass the quencher and pass directly to the venturi in the scrubbing system. The design pressure drop of the venturi during furnace charging is 218 cm (86 in) of water column. The visible emission tests conducted at this plant were performed in accordance with EPA Reference Method 9.

C.3 BETHLEHEM STEEL, BETHLEHEM, PENNSYLVANIA

The BOPF shop at Bethlehem Steel, Bethlehem, Pennsylvania, contains two top blown furnaces rated at 272 Mg (300 tons) each. These furnaces are equipped with open primary hoods which also serve, along with careful work practices, as the control system for secondary furnace emissions.

Each furnace is partially enclosed with side walls, with the charging and tapping sides of the facility remaining open. An awning-like extension has been added to the tapping side of each furnace at the level of the primary hood. This structure acts as a flanged extension of the primary hood and serves to direct the tapping emissions to the hood face. Fugitive charging emissions are minimized by good work practices, which consist of pouring the hot metal slowly and keeping the furnace vessels as upright as possible so that the majority of the emissions are captured by the primary system. As the ladle is emptied, the vessel must be tipped out from under the hood, and it is during this final portion of the charge that some fumes escape. During the charging and tapping, the primary emission control system is evacuated at the rate of 236 acms at 82° C (500,000 acfm at 180° F). During the oxygen blow, this rate is increased to 353 acms at 210° C

(750,000 acfm at 420° F). Gas cleaning is accomplished with an electrostatic precipitator (ESP). The visible emission tests performed at this plant were performed in accordance with EPA Reference Method 9.

C.4 JONES AND LAUGHLIN STEEL, ALIQUIPPA, PENNSYLVANIA

The Jones and Laughlin (J&L) Aliquippa BOPF shop has three furnace vessels with nominal capacities of 188 Mg (207 tons) each. The oxygen blowing rate is about 680 m^3/min (24,000 ft^3/min). The plant is normally operated with two vessels in service which can be blown simultaneously if desired. On an average day with two furnaces in operation, the shop can produce 55 heats of steel; on some days, the production rate runs as high as 61 heats per day.

The gas capture and cleaning system for the shop consists of open, complete combustion primary hoods above each furnace, an evaporation chamber for each furnace, downcomers to a common manifold and damper arrangement, two ESP's, an outlet manifold leading to a draft arrangement with seven fans, and two discharge stacks. The furnace is enclosed on two sides and at the rear (tapping side). While the oxygen blow is in progress, the front or charging side of the furnace may be partially enclosed by means of a curtain mounted on a trolley rail. The curtain can be moved in front of the furnace or away from the furnace as need dictates during the furnace cycle. Curtains have been hung underneath the furnace operating floor to restrict air movement into the partial furnace enclosure from the teeming ladle car side. The design of the evaporation chamber includes provision for steam or water injection to achieve the correct moisture level in the waste gas for proper precipitation.

The damper arrangement provides for isolating the hood at the furnace on which maintenance needs to be done. This prevents wasting the available draft on nonoperating furnaces. Gas flow from the combustion hoods is controlled by louvered dampers between the downcomers and precipitator inlets.

Two precipitators remove particulates from the waste gas streams. Each precipitator has its own stack. One precipitator was built by Western Precipitation and consists of six chambers with five fields per chamber. The total collection surface available in this precipitator is 26,648 m^2 (286,848 ft^2). The second precipitator was built by Research Cottrell. It consists of eight chambers with five fields in the direction of gas flow. The total collection surface area in this precipitator is 44,146 m^2 (475,200 ft^2). With two furnaces in operation, the normal practice is to use six of the eight chambers in the Research Cottrell precipitator with one furnace and the remaining two chambers plus all of the chambers of the Western ESP with the other furnace. The design of the precipitators' damper system is such that a single chamber of a precipitator can be taken out of service for maintenance while the other chambers remain in use.

The seven induced draft fans are normally divided up four and three between the two precipitators. However, the damper arrangement permits the center fan to be used with either of the two precipitators, depending upon the draft needs and whether one of the other fans is out of service for maintenance. There is sufficient draft so that with only six fans the furnaces can continue to operate at full production.

To improve precipitator performance, water conditioning sprays are used to add moisture to the gas stream during the oxygen blowing cycle. Because the flue gas temperature is too low at the beginning of the blowing cycle to evaporate a sufficient amount of water, steam is injected. Steam injection is used during the hot metal charging operation and tapping operations. Steam injection during hot metal charging of the furnace is controlled by a timer and lasts approximately 2 min. The crane operator is not supposed to begin pouring hot metal until he hears the steam turned on. Steam injection at the beginning of the oxygen blow is also controlled by a timer. The steam is turned on as the oxygen lance is lowered into the furnace and continues to flow for about 1½ min into the blowing period. Steam injection is practiced for approximately 15 min per furnace cycle. The steam injection rate is approximately 80,000 lb/hr for the duration of the injection period.

A water ring and water sprays are used to reduce fugitive emissions from the hood during furnace puffing. A water ring is placed on the oxygen lance, and water sprays are placed around the lance hole in the hood. The water ring is a proprietary design of Republic Steel. The function of the water ring and sprays is to partially cool the gases leaving the furnace, especially during periods of puffing, to reduce gas volume and to avoid exceeding the capacity of the system to withdraw these gases. The purpose of the water spray around the lance hole is to reduce fume leakage from the lance hole opening.

To avoid fugitive discharges from the flux chute, a flapper valve has been installed in the chute. It allows flux materials to fall through, but closes to prevent fumes from rising up through the chute at other times.

The visible emission tests performed at this facility were conducted in accordance with EPA Reference Method 9.

C.5 ARMCO, MIDDLETOWN, OHIO

The BOPF shop contains two furnace vessels, each having a capacity of 190 Mg (210 tons). Each vessel is equipped with a closed hood primary emission control system ducted to separate venturi scrubbers. During the 1972 tests, the exhaust rate (inferred from the stack flow rate) ranged from 905 m^3/min (31,996 dscfm) to 1,381 m^3/min (48,787 dscfm). At the time these tests were performed, there was no secondary emission control system in place.

The tests performed on this system were conducted in accordance with EPA Reference Method 5.

C.6 U.S. STEEL, FAIRFIELD, ALABAMA

The U.S. Steel plant at Fairfield, Alabama, is equipped with three 200-ton bottom blown furnaces (Q-BOP's). The primary emission control system for each furnace consists of a suppressed combustion hood ducted to a venturi quencher where the gas is cooled and some of the particulate material is removed. The final cleaning is accomplished with a venturi scrubber, after which the gas stream passes through a demister and into the exhaust stack where the CO gas is burned with a flare.

The exhaust rate design value for the primary system is 5,038 m^3/min at 71° C (177,900 acfm at 160° F). The design pressure drop for the quencher is 2.5 kPa (10 in H_2O) while the venturi scrubber is designed to operate at a pressure drop of 13.7 kPa (55 in H_2O). In actual practice, however, the scrubber is operated in the range of 15 to 17 kPa (60 to 70 in H_2O).

The particulate emissions tests performed at this facility were conducted in strict accordance with EPA Reference Method 5.

C.7 U.S. STEEL, SOUTH WORKS, CHICAGO, ILLINOIS

This plant contains three top blown vessels designated "H", "J", and "K" with design capacities of 180 Mg (200 tons) each. When the test was conducted in 1977, there were no secondary emission controls in place on the furnaces. The primary emission control system consisted of open primary hoods ducted to a common manifold. The manifold lead to a single prescrubber where some of the particulate was removed from the offgas. The single duct leaving the prescrubber branched into three separate ducts, each of which served as an independent scrubber. The total gas flow for the system was 11,385 m^3/min (402,000 scfm). During the tests, the individual scrubbers, designated "A," "B," and "C" handled 3,741; 4,070; and 3,551 m^3/min (132,100; 143,700; and 125,400 scfm), respectively.

The tests performed at this facility were conducted in accordance with EPA Reference Method 5.

C.8 CF&I CORPORATION, PUEBLO, COLORADO

This BOF shop is equipped with two top blown furnaces with design capacities of 110 Mg (120 tons) each. The furnaces are equipped with both primary and secondary emission control systems. The secondary controls consist of local charging hoods and large scavenger hoods located at the roof monitor level of the shop.

The primary emission control system was the subject of the tests in this volume. This system consists of open, complete combustion hoods vented to a dropout chamber and ultimately to a four-unit ESP. Each precipitator was equipped with a knife-edge damper, so that any unit could be isolated at any given time.

The testing conducted at this site was done in accordance with EPA Reference Method 5.

C.9 REPUBLIC STEEL, BUFFALO, NEW YORK

This plant has two 120-Mg (130-ton) furnaces equipped with open, complete combustion primary hoods and EPS's. More detailed descriptions of the plant are not available. Testing conducted at this plant was done in accordance with EPA Reference Method 5.

C.10 YOUNGSTOWN SHEET AND TUBE, INDIANA HARBOR, INDIANA

The Youngstown Sheet and Tube BOPF shop has two vessels with design capacities of 240 Mg (265 tons) of steel each. Heats as large as 259 Mg (285 tons) have been achieved on a regular basis. At the time the test was conducted, scrap preheating was practiced.

The furnaces are not equipped with secondary emission control systems. Primary emissions are captured with open, complete combustion hoods. The captured emissions are ducted to a quench chamber where 11 banks of water sprays can be actuated to cool and condition the gas. Steam is also added to the offgas at a rate of 60,000 lb/hr at 480° F but is shut off as soon as the third bank of spray is actuated. The quenched gases pass into a dropout chamber where large particulates are removed. Final gas cleaning is achieved with four ESP's composed of two chambers each. In normal operation, only seven chambers are used; the eighth chamber is held in reserve. Total gas volume for the system is 36,391 m^3/min at 315° C (1.3 million ft^3/min at 600° F). The tests conducted at this plant were performed in accordance with EPA Reference Method 5.

TABLE C-2. KAISER STEEL, FONTANA, CALIFORNIA
ROOF MONITOR OPACITY OBSERVATIONS
3-MINUTE AVERAGES[1]

Date	Run	Maximum average		Second highest average	
		Observer 1	Observer 2	Observer 1	Observer 2
4/7/80	1	10.4	5.4	4.2	4.2
4/8/80	2	2.1	2.5	0.0	0.0
	3	14.2	13.8	10.0	10.4
	4	10.3	10.4	0.0	10.4
	5	5.0	5.4	3.3	3.8
	6	12.5	16.3	2.9	1.7
	7	7.1	5.8	3.3	3.8
4/9/80	8	7.9	5.4	1.3	0.8
	9	3.3	3.3	0.0	0.0
	10	0.0	0.8	0.0	0.0
	11	8.3	6.3	0.0	0.0
	12	0.0	0.0	0.0	0.0
	13	0.0	0.0	0.0	0.0
	14	0.0	0.0	0.0	0.0
4/10/80	15	17.1	13.3	0.4	0.0
	16	0.0	0.0	0.0	0.0
	17	0.0	0.0	0.0	0.0
	18	5.0	5.4	3.3	0.0
	19	7.9	6.7	0.0	0.0
4/11/80	20	15.0	0.0	0.0	0.0
	21	0.0	0.0	0.0	0.0

TABLE C-3. REPUBLIC STEEL, SOUTH CHICAGO, ILLINOIS
Q-BOP ROOF MONITOR OPACITY OBSERVATIONS[a]
3-MINUTE AVERAGES[2]

Date	Run	Maximum average Observer 1	Maximum average Observer 2	Second highest average Observer 1	Second highest average Observer 2	Third highest average Observer 1	Third highest average Observer 2
6/18/79	1	---	46.3	---	42.5	---	27.5
	2	---	33.8	---	32.1	---	29.2
	3	---	38.8	---	24.2	---	22.9
	4	---	44.6	---	20.4	---	8.8
	5	---	23.8	---	22.5	---	18.8
6/19/79	6	12.5	11.7	12.5	11.3	11.3	10.4
	7	16.7	5.0	6.3	3.3	5.0	2.9
	8	10.8	9.6	5.4	0.0	2.1	0.0
	9	2.3	2.9	0.4	0.8	0.4	0.0
	10	2.5	0.0	0.0	0.0	0.0	0.0
	11	3.8	8.8	1.3	5.8	1.3	5.4
6/20/79	12	10.8	0.8	2.9	0.0	2.1	0.0
	13	15.8	2.5	5.8	2.1	3.8	1.3
	14	0.8	2.9	0.8	2.1	0.4	0.4
	15	4.6	2.1	3.8	0.8	1.7	0.4
	16	3.8	3.8	1.7	0.0	0.4	0.0
	17	11.3	4.2	8.8	0.4	5.4	0.4
	18	8.8	1.3	5.8	1.3	1.7	0.0
6/21/79	19	60.4	---	34.2	---	11.3	---
	20	27.5	5.0	26.3	1.7	2.1	0.8
	21	22.5	12.5	6.7	6.3	6.3	5.4
	22	10.0	4.2	2.5	3.3	2.1	1.7
	23	5.0	0.8	1.3	0.4	0.0	0.0
	24	6.7	1.7	1.3	0.8	0.8	0.4
	25	5.0	3.3	4.6	2.9	4.2	0.4
6/22/79	26	30.8	18.3	21.7	9.2	12.9	3.8
	27	45.4	13.8	20.8	13.3	12.5	12.9

[a]Tested by GCA Corporation.

TABLE C-4. REPUBLIC STEEL, SOUTH CHICAGO, ILLINOIS
Q-BOP ROOF MONITOR OPACITY OBSERVATIONS[a]
3-MINUTE AVERAGES[3]

Date	Run	Maximum average		Second highest average		Third highest average	
		Observer		Observer		Observer	
		1	2	1	2	1	2
6/2/80	1	29.6	----	5.0	----	3.3	----
	2	5.8	4.6	2.5	3.3	0.8	0.8
6/3/80	3	40.0	37.9	14.2	14.6	14.2	12.9
	4	35.0	28.8	23.3	25.8	21.3	17.1
	5	17.1	46.3	8.3	14.6	4.6	11.7
	6	29.2	32.1	24.6	21.7	21.7	17.5
6/4/80	7	9.6	7.9	3.8	1.7	3.3	1.7
	8	12.1	10.8	8.3	7.1	7.9	2.5
	9	9.2	5.8	5.8	4.6	5.0	4.6
6/5/80	10	1.3	2.1	0.8	1.7	0.0	0.8
	11	23.3	23.3	7.5	8.8	0.0	0.8
	12	59.2	41.7	37.5	19.2	16.7	14.6
	13	42.1	32.1	8.3	5.0	7.1	4.6
	14	40.8	43.8	39.6	36.3	30.0	15.8
	15	27.5	28.8	22.1	14.6	14.6	8.3

[a]Tested by Clayton Environmental Consultants.

TABLE C-5. BETHLEHEM STEEL, BETHLEHEM, PENNSYLVANIA
ROOF MONITOR OPACITY OBSERVATIONS
3-MINUTE AVERAGES[4]

Date	Run	Maximum average		Second highest average	
		Observer 1	Observer 2	Observer 1	Observer 2
6/23/80	1	0.83	1.25	0.83	0.42
	2	3.75	2.50	0.0	0.0
	3	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0
	5	0.0	0.42	0.0	0.0
6/25/80	6	0.0	0.42	0.0	0.0
	7	6.67	5.83	0.0	0.0
	8	0.0	0.0	0.0	0.0
	9	0.0	0.0	0.0	0.0
6/26/80	10	1.25	0.42	0.0	0.0
	11	5.0	3.33	3.75	1.67
	12	0.83	1.25	0.0	0.42

TABLE C-6. J&L STEEL, ALIQUIPPA, PENNSYLVANIA
ROOF MONITOR OPACITY OBSERVATIONS
3-MINUTE AVERAGES[5]

	No. 2 furnace		
Date	Run	Maximum average	Second highest average
10/6/80	1	3.8	3.3
10/7/80	2	3.3	2.1
	3	5.0	1.7
	4	2.1	0.4
	5	0.0	0.0
	6	0.0	0.0
	7	0.0	0.0
10/8/80	8	5.0	1.7
	9	1.3	0.0
	10	5.8	4.2
	11	9.6	5.0
	12	3.3	2.1
10/9/80	13	6.7	5.8
	14	5.8	0.0
	15	11.7	3.3
	16	11.3	2.5
	17	1.3	0.0
	18	10.4	8.3
10/10/80	19	2.1	1.3
	20	0.8	0.4
	21	2.1	0.4
	22	2.1	0.0
10/13/80	23	1.7	1.7
	24	2.1	0.0
	25	11.7	5.4
10/14/80	26	2.1	0.0
	27	5.0	1.7
	28	4.2	3.8
	29	2.9	2.5
	30	4.2	2.5
	31	4.6	4.2

TABLE C-7. J&L STEEL, ALIQUIPPA, PENNSYLVANIA
ROOF MONITOR OPACITY OBSERVATIONS
3-MINUTE AVERAGES[5]

Date	No. 3 furnace		
	Run	Maximum average	Second highest average
10/6/80	1	2.1	0.8
10/7/80	2	0.0	0.0
	3	1.7	0.8
	4	2.1	0.4
	5	0.0	0.0
	6	0.0	0.0
	7	0.0	0.0
10/8/80	8	5.0	1.7
	9	5.8	4.2
	10	5.0	4.6
	11	9.6	4.6
	12	3.3	3.3
10/9/80	13	2.1	1.3
	14	0.4	0.4
	15	5.8	2.1
	16	11.7	3.3
	17	2.5	2.5
	18	7.1	0.8
10/10/80	19	1.3	0.0
	20	2.1	0.8
	21	2.1	0.0
10/13/80	22	1.7	1.7
	23	2.1	0.0
	24	11.7	0.0
	25	5.4	2.1
10/14/80	26	0.8	0.0
	27	2.1	0.0
	28	1.7	1.3
	29	4.2	3.8
	30	4.2	2.9
	31	4.6	3.8
	32	5.4	4.6

TABLE C-8. SUMMARY OF PARTICULATE TEST DATA FOR CLOSED HOOD BOPF's, KAISER STEEL COMPANY, FONTANA, CALIFORNIA, VESSEL NO. 5

	Run number			
	1	2	3	Average
Date	12/16/78	12/18/78	12/18/78	
Test time (min)	74.1	84.1	76.5	78.2
Steel produced (lb/hr)	630,591	475,263	614,240	573,365
Stack effluent				
Flow rate (dscfm)	82,312	86,978	90,422	86,571
Temperature (°F)	171	171	169	170
Water (% bv)	14.7	12.1	13.5	13.4
CO_2 (% bv)	10.9	10.3	10.6	10.6
O_2 (% bv)	14.9	15.8	14.9	15.2
CO (% bv)	6.3	6.9	7.7	7.0
Emissions - particulate				
Probe + filter catch				
gr/dscf	0.0090	0.0072	0.0077	0.0080
gr/acf	--	--	--	--
lb/hr	6.44	5.46	6.02	5.97
Total catch[a]				
gr/dscf	0.0104	0.0087	0.0094	0.0095
gr/acf	--	--	--	--
lb/hr	--	--	--	--
Percent isokinetic	98.9	93.9	98.5	97.1

[a]Excludes $H_2SO_4 \cdot 2\ H_2O$

--Indicates no data in test report.

TABLE C-9. SUMMARY OF PARTICULATE TEST DATA FOR CLOSED HOOD BOPF's, KAISER STEEL COMPANY, FONTANA, CALIFORNIA, VESSEL NO. 6

	Run number			
	1	2	3	Average
Date	12/14/78	12/14/78	12/16/78	
Test time (min)	71	66.6	98.7	78.8
Steel produced (lb/hr)	699,375	818,350	588,303	702,009
Stack Effluent				
Flow rate (dscfm)	78,915	67,669	82,902	76,495
Temperature (°F)	177	184	180	180
Water (% bv)	13.8	20.4	11.6	15.3
CO_2 (% bv)	11.9	13.6	9.1	11.5
O_2 (% bv)	14.6	12.8	16.3	14.6
CO (% bv)	8.5	7.0	7.5	7.7
Emissions - particulate				
Probe + filter catch				
gr/dscf	0.0068	0.0059	0.0052	0.0060
gr/acf	--	--	--	--
lb/hr	4.68	3.48	3.75	3.97
Total catch[a]				
gr/dscf	0.0089	0.0079	0.0066	0.0078
gr/acf	--	--	--	--
lb/hr	--	--	--	--
Percent isokinetic	98.4	106.7	94.2	99.8

[a]Excludes $H_2SO_4 \cdot 2\ H_2O$

--Indicates no data in test report.

TABLE C-10. SUMMARY OF PARTICULATE TEST DATA FOR CLOSED HOOD BOPF's
ARMCO STEEL CORPORATION, MIDDLETOWN, OHIO

	Run number 1	Run number 2	Run number 3	Average
Date	10/20/71	10/21/71	10/23/71	
Test time (min)	222.4	255.0	224.0	233.8
Steel produced (tons/heat)	202.4	200.5	204.0	202.3
Stack effluent				
Flow rate (dscfm)	37,065	31,996	48,787	39,283
Temperature (°F)	153.9	161.2	128.5	147.9
Water (% bv)	10.5	12.7	13.4	12.2
CO_2 (% bv)	10.4	9.5	10.8	10.2
O_2 (% bv)	8.7	9.7	7.5	8.6
CO (% bv)	27.2	25.2	36.7	29.7
Emissions - particulate				
Probe + filter catch				
gr/dscf	0.0119	0.0145	0.0112	0.0125
gr/acf	0.00913	0.0106	0.00858	0.0094
lb/tons of steel produced	0.0115	0.0140	0.0141	0.0132
Total catch				
gr/dscf	--	0.0164	0.0125	0.0145
gr/acf	--	0.0120	0.00957	0.0108
lb/tons of steel produced	--	0.0158	0.0158	0.0158
Percent isokinetic	--	--	--	--

--Indicates no data in test report.

TABLE C-11. UNITED STATES STEEL, FAIRFIELD, ALABAMA
CANOPY HOOD AND SOUTH MIXER BAGHOUSE

Date	Time Start	Time Stop	Number of 3-minute averages	Opacity (percent)
Observer: Howison				
5/11/81	1434	1533	20	0.0
	1542	1635	18	0.0
5/12/81	0937	1000	8	0.0
5/13/81	1200	1259	10	0.0
			3	0.4
			2	1.3
			2	1.7
			2	2.1
			1	2.5
	1310	1409	9	0.0
			6	0.4
			3	1.3
			1	2.1
			1	4.2
	1420	1519	19	0.0
			1	2.5
5/14/81	0930	1029	20	0.0
	1200	1259	16	0.0
			2	0.4
			2	1.3
	1310	1409	16	0.0
			2	0.4
			2	0.8
	1420	1519	19	0.0
			1	0.4
	1530	1629	20	0.0
5/15/81	1345	1444	19	0.0
			1	0.8
	1455	1554	20	0.0
	1605	1634	10	0.0
Observer: Clark				
5/11/81	1433	1532	20	0.0
	1542	1632	18	0.0
5/12/81	0937	1000	7	0.0
5/13/81	1200	1259	14	0.0
			5	0.8
			1	1.3
	1310	1409	14	0.0
			2	0.4
			2	0.8
			1	3.3
			1	5.0

(continued)

TABLE C-11. (con.)

Date	Time		Number of 3-minute averages	Opacity (percent)
	Start	Stop		
5/13/81	1421	1520	19	0.0
			1	2.5
	1530	1617	16	0.0
5/14/81	0930	1029	20	0.0
	1200	1259	18	0.0
			1	1.3
			1	1.7
	1310	1409	17	0.0
			3	0.4
	1420	1519	30	0.0
	1530	1629	20	0.0
5/15/81	1345	1444	20	0.0
	1455	1554	20	0.0
	1605	1634	10	0.0

TABLE C-12. UNITED STATES STEEL, FAIRFIELD, ALABAMA, NORTH MIXER BAGHOUSE

Date	Time		Number of 3-minute averages	Opacity (percent)
	Start	Stop		
Observer: Howison				
5/12/81	1115	1156	11	0.0
			1	0.8
			2	0.4
5/13/81	0930	1029	20	0.0
	1040	1139	20	0.0
5/14/81	1045	1144	20	0.0
5/15/81	0930	1029	20	0.0
Observer: Clark				
5/12/81	1115	1156	10	0.0
			1	1.7
			1	2.5
			1	4.2
			1	0.4
5/13/81	0930	1029	20	0.0
	1029	1138	20	0.0
5/14/81	1045	1144	20	0.0
5/15/81	0930	1029	20	0.0
	1040	1139	20	0.0

TABLE C-13. SUMMARY OF PARTICULATE TEST DATA FOR CLOSED HOOD BOPF's UNITED STATES STEEL CORPORATION, FAIRFIELD, ALABAMA, Q-BOP "X"

	Run number			
	1	2	3	Average
Date	12/13/78	12/14/78	12/15/78	
Test time (min)	66	58	58.5	60.8
Steel produced (tons/heat)	200 tons/heat nominal			
Stack effluent				
Flow rate (dscfm)	78,552	76,098	74,629	76,426
Temperature (°F)	164	159	159	161
Water (% bv)	16.4	15.3	15.2	15.6
CO_2 (% bv)	--	--	--	18.2
O_2 (% bv)	--	--	--	0.8
CO (% bv)	--	--	--	--
Emissions - particulate				
Probe + filter catch				
gr/dscf	0.0188	0.0236	0.0206	0.0210
gr/acf	--	--	--	--
lb/hr	12.67	15.39	13.21	13.76
Total catch				
gr/dscf	--	--	--	--
gr/acf	--	--	--	--
lb/hr	--	--	--	--
Percent isokinetic	107.9	104.6	102.8	105.1

--Indicates no data in test report.

TABLE C-14. SUMMARY OF PARTICULATE TEST DATA FOR CLOSED HOOD BOPF's UNITED STATES STEEL CORPORATION, FAIRFIELD, ALABAMA, Q-BOP "C"

	Run number			
	1	2	3	Average
Date	10/17/78	10/18/78	10/19/78	
Test time (min)	60	60	60	60
Steel produced (tons/heat)		200 tons/heat nominal		
Stack effluent				
Flow rate (dscfm)	74,597	76,643	77,640	76,293
Temperature (°F)	162	164	163	163
Water (% bv)	16.9	19.9	20.2	19.0
CO_2 (% bv)	--	--	--	14.3
O_2 (% bv)	--	--	--	0.6
CO (% bv)	--	--	--	--
Emissions - particulate				
Probe + filter catch				
gr/dscf	0.02122	0.02108	0.02311	0.02180
gr/acf	--	--	--	--
lb/hr	13.58	13.86	15.43	14.29
Total catch				
gr/dscf	--	--	--	--
gr/acf	--	--	--	--
lb/hr	--	--	--	--
Percent isokinetic	96.9	98.4	100.8	98.7

--Indicates no data in test report.

TABLE C-15. SUMMARY OF PARTICULATE TEST DATA FOR CLOSED HOOD BOPF's, UNITED STATES STEEL CORPORATION, CHICAGO, ILLINOIS, "A" SCRUBBER

	Run number				
	1	2	3	4	Average
Date	7/1/77	7/1/77	7/1/77	7/1/77	
Test time (min)	36	36	36	36	36
Steel produced (tons/heat)	200 tons/heat nominal				
Stack effluent					
Flow rate (dscfm)	127,800	135,000	138,300	127,400	132,125
Temperature (°F)	91	91	101	101	96
Water (% bv)	3.9	3.5	3.5	3.6	3.6
CO_2 (% bv)	--	--	--	--	--
O_2 (% bv)	--	--	--	--	--
CO (% bv)	--	--	--	--	--
Emissions - particulate					
Probe + filter catch					
gr/dscf	0.00729	0.00722	0.00515	0.00520	0.00621
gr/acf	--	--	--	--	--
lb/charge	--	--	--	--	2.04
Total catch					
gr/dscf	--	--	--	--	--
gr/acf	--	--	--	--	--
lb/hr	--	--	--	--	--
Percent isokinetic	97.5	94.8	101.3	98.2	98.0

--Indicates no data in test report.

C-16. SUMMARY OF PARTICULATE TEST DATA FOR OPEN HOOD BOPF's, UNITED STATES STEEL CORPORATION, CHICAGO, ILLINOIS, "B" SCRUBBER

	Run number				
	1	2	3	4	Average
Date	6/29/77	6/29/77	6/29/77	6/29/77	
Test time (min)	36	36	33	33	34.5
Steel produced (tons/heat)	200 tons/heat nominal				
Stack effluent					
Flow rate (dscfm)	148,200	150,000	122,400	154,200	143,700
Temperature (°F)	95	95	95	95	95
Water (% bv)	3.9	3.7	4.0	3.8	3.9
CO_2 (% bv)	--	--	--	--	--
O_2 (% bv)	--	--	--	--	--
CO (% bv)	--	--	--	--	--
Emissions - particulate					
Probe + filter catch					
gr/dscf	0.00617	0.00553	0.00490	0.00442	0.00526
gr/acf	--	--	--	--	--
lb/charge	--	--	--	--	1.86
Total catch					
gr/dscf	--	--	--	--	--
gr/acf	--	--	--	--	--
lb/hr	--	--	--	--	--
Percent isokinetic	99.3	96.6	104.4	96.8	99.3

--Indicates no data in test report.

TABLE C-17. SUMMARY OF PARTICULATE TEST DATA FOR OPEN HOOD BOPF's, UNITED STATES STEEL CORPORATION, CHICAGO, ILLINOIS, "C" SCRUBBER

	Run number				
	1	2	3	4	Average
Date	6/27/77	6/27/77	6/27/77	6/27/77	
Test time (min)	36	36	36	36	36
Steel produced (tons/heat)	200 tons/heat nominal				
Stack effluent					
Flow rate (dscfm)	122,700	126,600	128,300	128,100	126,425
Temperature (°F)	108	108	112	112	110
Water (% bv)	4.4	4.4	5.0	5.2	4.8
CO_2 (% bv)	--	--	--	--	--
O_2 (% bv)	--	--	--	--	--
CO (% bv)	--	--	--	--	--
Emissions - particulate					
Probe + filter catch.					
gr/dscf	0.0039	0.0038	0.0045	0.0038	0.004
gr/acf	--	--	--	--	--
lb/charge	--	--	--	--	1.24
Total catch					
gr/dscf	--	--	--	--	--
gr/acf	--	--	--	--	--
lb/hr	--	--	--	--	--
Percent isokinetic	101.4	97.4	100.4	96.2	98.9

-- Indicates no data in test report.

TABLE C-18. SUMMARY OF PARTICULATE TEST DATA FOR OPEN HOOD BOPF's, CF&I STEEL CORPORATION, PUEBLO, COLORADO

	Run number					
	1	2	3	4	5	Average
Date	4/10/78	4/11/78	4/11/78	4/12/78	4/12/78	
Test time (min)	75.3	75.4	82.7	78.5	72.4	76.9
Steel produced (tons/heat)	100 tons/heat nominal					
Stack effluent						
Flow rate (dscfm)	169,900	151,500	165,600	154,800	156,000	159,560
Temperature (°F)	249	271	265	289	289	273
Water (% bv)	18.6	20.7	20.2	22.9	22.8	21.0
CO_2 (% bv)	3.7	3.9	3.5	11.4	10.4	6.6
O_2 (% bv)	18.5	18.7	18.4	13.8	13.6	16.6
CO (% bv)	0.0	0.0	0.0	0.0	0.0	0.0
Emissions - particulate						
Probe + filter catch						
gr/dscf	0.022	0.0098	0.0115	0.0097	0.00935	0.013
gr/acf	0.011	0.0047	0.0056	0.0044	0.0043	0.006
lb/hr	32.2	12.7	16.3	12.9	12.7	17.4
Total catch						
gr/dscf	--	--	--	--	--	--
gr/acf	--	--	--	--	--	--
lb/hr	--	--	--	--	--	--
Percent isokinetic	92	96	92	99	100	95.8

--Indicates no data in test report.

TABLE C-19. SUMMARY OF PARTICULATE TEST DATA FOR OPEN HOOD BOPF's, REPUBLIC STEEL COMPANY, BUFFALO, NEW YORK

	Run number			
	1	2	3	Average
Date	10/20/75	10/21/75	10/22/75	
Test time (min)	140	140	140	140
Steel produced (tons/heat)	130 tons/heat nominal			
Stack effluent				
Flow rate (dscfm)	226,738	258,023	251,595	245,452
Temperature (°F)	207.5	207.5	202.3	205.8
Water (% bv)	18.5	19.8	19.5	19.3
CO_2 (% bv)	9	--	--	--
O_2 (% bv)	16	--	--	--
CO (% bv)	--	--	--	--
Emissions - particulate				
Probe + filter catch				
gr/dscf	0.012	0.013	0.012	0.012
gr/acf	--	--	--	--
lb/hr	22.5	27.9	26.4	25.6
Total catch				
gr/dscf	--	--	--	--
gr/acf	--	--	--	--
lb/hr	--	--	--	--
Percent isokinetic	108.7	103.6	100.6	104.3

--Indicates no data in test report.

TABLE C-20. SUMMARY OF PARTICULATE TEST DATA FOR OPEN HOOD BOPF's, YOUNGSTOWN SHEET AND TUBE, INDIANA HARBOR, INDIANA

	Run number			
	1	2	3	Average
Date	6/12/78	6/13/78	6/14/78	
Test time (min)	36	36	36	36
Steel produced (tons/heat)	354.6	355.8	350.8	353.7
Stack effluent				
Flow rate (dscfm)	458,976	449,150	449,514	452,547
Temperature (°F)	271	274	300	282
Water (% bv)	20.0	21.3	22.7	21.3
CO_2 (% bv)	0.3	6.3	8.1	4.9
O_2 (% bv)	20.5	17.0	15.6	17.7
CO (% bv)	--	--	--	--
Emissions - particulate				
Probe + filter catch				
gr/dscf	0.0133	0.008	0.012	0.033
gr/acf	--	--	--	--
lb/hr	52.8	31.1	45.1	43.0
Total catch				
gr/dscf	--	--	--	--
gr/acf	--	--	--	--
lb/hr	--	--	--	--
Percent isokinetic	110.0	109.0	109.2	109.4

--Indicates no data in test report.

C.11 REFERENCES

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2. GCA Corporation. Assessment of Air Emissions From Steel Operations, Republic Steel Corporation, Chicago District Q-BOP Shop Emission Evaluation. U.S. Environmental Protection Agency, Washington, DC. Contract No. 68-01-4143, Task No. 58 Report. September 1979.

3. Clayton Environmental Consultants. Steel Processing Fugitive Emissions--Emission Test Report, Republic Steel Company, South Chicago, Illinois. U.S. Environmental Protection Agency, Research Triangle Park, NC. EMB Report 80-BOF-7. September 1980.

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12. Acurex Corporation. Particulate Emission Rates for BOF Operations at Youngstown Sheet and Tube, East Chicago, Indiana. U.S. Environmental Protection Agency, Chicago, Illinois. EPA Contract No. 68-01-4142, Task 9. Acurex Report TR-78-123, Volumes 1 and 2. August 1978.

APPENDIX D

BOPF SHOP FUGITIVE EMISSIONS MEASUREMENT AND CONTINUOUS MONITORING

D.1 EMISSION MEASUREMENT METHODS

EPA Methods 9 and 22 are used currently for measuring visible emissions. In Method 9, a trained and certified observer visually determines and records the percent opacity of the emission plume of interest. In Method 22, an observer times and records the duration of visible emissions during an observation period suitably defined for the process of interest. Method 22 observers are not required to have opacity certification but are required to have a basic understanding of and experience in the use of visible emissions testing techniques.

The two methods were used to assess basic oxygen process furnace (BOPF) fugitive emissions because these emissions do not enter the atmosphere in a manner that can be practicably quantified by conventional mass sampling techniques. In addition, fugitive emissions from processes essentially related to BOPF operations were measured by Methods 9 and 22. Emphasis was placed on measuring the visible emissions from the principal BOPF shop roof monitors. Simultaneous visible emissions tests were conducted inside the shop at the furnace vessel to provide more detailed information on fugitive furnace emissions that were not captured by the control systems. Related steel processes that were also tested included iron desulfurization, slag skimming, and hot metal transfer. In order to characterize fume exhaust capacities, duct velocity measurements were made by EPA Method 2 where suitable testing accessibility was available at the secondary control devices. Certified observers conducted all EPA Method 9 testing throughout the test series.

The first emission test was conducted at an iron desulfurization facility[1] from February 26 through March 4, 1980. Initially, only Method 22 was used. When the first few test runs indicated high results, one observer was asked to conduct Method 9 observations simultaneously. (The quantity of uncaptured emissions at this plant appeared to be directly proportional to the degree of overfilling of the hot metal cars.) The scales used to weigh the charged torpedo cars were inoperable because of recent heavy rains. Consequently, many of the cars were filled to overflowing to ensure a full charge for desulfurization. Eighteen iron desulfurization tests were made by Method 22 and 15 tests were made by Method 9. The presence of high Method 22 results continued, so a modified Method 22 was used on the last two tests in which the observers timed only those emissions that exceeded 15-percent opacity. The results of the modified method were slightly less than those for Method 22. The modified Method 22 results were similar because most of the emissions observed were significantly higher than 15-percent opacity.

Visible emissions testing at the BOPF shop at the first plant[1] was completed April 7-11, 1980. The roof monitor was tested for 19 hours by Method 9 and for 16 hours by Method 22. During the roof monitor observations, 21 furnace heats were tested indoors by Method 22. A typical BOPF heat consists of several distinct operations. Furnace visible emissions observations were structured to cover the individual operations to aid in specific identification of the emissions source. These separate operations included: scrap charging, hot metal charging, blowing, turndown, tapping, and deslagging.

Method 22 recommends a maximum observation period of 30 minutes to prevent observer eye fatigue. A typical BOPF heat lasted about 45 minutes and required constant observation. During the first three heats it was noted that the blowing operation produced no emissions; therefore, the observers were asked to discontinue readings during blowing except to note any emissions on subsequent heats.

Ten hot metal transfers and two slag skimming operations were tested by Method 22. The skimming tests were interrupted because the test personnel were needed to perform additional testing at the BOP furnace to determine any effect of high winds which occurred on the last day of testing. A Santa Anna wind produced velocities up to 60 mph on April 11, 1980. This high wind did not cause any discernable effect on the level or duration of furnace or roof monitor emissions; however, it caused significant interference for the outdoor observers testing at ground level at the hot metal transfer station.

An iron desulfurization station at a second plant[2] was tested during April 24-26, 1980. Ten desulfurization tests were conducted by Method 22. Because the Method 22 emission frequencies were high, Method 9 was used by one observer for the last six tests. Exhaust velocity was measured using Method 2 for eight traverses at the baghouse outlet.

The physical configuration of the desulfurization station at this plant did not permit visible emissions observers to maintain proper sun angle positioning in the late afternoon. The observers could not read from the south side of the building because it was enclosed from the ground level to the roof. This enclosure is designed to minimize emission capture interference caused by the prevailing winds. Whenever the observers were forced to face the sun, they were always standing well within the shadow of the building which effectively prevented any observational interferences caused by the improper sun angle.

Two BOPF shops at a third steel plant[3] were tested during May 12-16, 1980. Testing at the Number 2 shop included 24 hours each of Method 9 and Method 22 observations of the roof monitor, 19 heats inside at the furnace by Method 22, and 12 velocity traverses by Method 2 at the inlet to the secondary scrubber control. Indoor emissions for all segments of the heat cycle were tested for the first three heats. No emissions were observed; therefore, during normal blowing for the first three heats, testing of this process segment was discontinued for all subsequent heats to be consistent with the procedure established at the first indoor furnace testing for this industry.

Testing at this plant's Number 4 BOPF shop included three iron desulfurization tests by Method 22, 12 hot metal transfers by Method 22, 12 velocity traverses at the secondary baghouse outlet by Method 2, 6.5 hours of roof monitoring testing by Method 9, and 3 hours of roof monitor testing by Method 22.

The roof monitor over the Number 2 BOPF shop at this plant is open on only one side. The open side was not visible from the observation location used for the afternoon readings; consequently, the observers could not see the origin of any emissions rising over the top edge of the monitor. To document possible interfering emissions from other sources, two additional observers were assigned to read simultaneously from the opposite side of the shop. A comparison of the data taken simultaneously from both sides of the shop indicated that any emissions seen from the west location originated from the Number 2 shop. The extra observers were located facing the sun since they were opposite the primary observers who carefully positioned themselves with the sun in the required 140° arc behind them. Both sets of observers switched locations at around 2:00 p.m. from morning to afternoon positions. Data collected by the additional readers at the Number 2 shop cannot be used for standard setting in this industry because an improper sun angle was used. These data are summarized in Tables 2.2, 2.3, 2.4 and 2.5 of the referenced emissions test report.[3]

Emissions from extraneous sources interfered with visible emissions observations at this plant. A coke plant adjacent to the Number 2 BOPF shop produced a periodic steam plume which occasionally completely obscured the BOPF shop roof monitor. Emissions from a small lower roof monitor over the teeming aisle and from the primary scrubber stacks interfered with testing at the Number 4 BOPF shop. The interferences at the Number 4 shop were more consequential than those at the Number 2 shop and much more testing time was lost to these extraneous plumes. The presence and times of these interferences were noted on the field data forms. The inherent chronology of Method 9 was used to record observation times lost to the various interferences. The occurrence of visual interference during roof monitor testing was addressed by summarizing the data in different forms to provide a variety of options for data analysis for this plant. The same type of summaries were used for all subsequent tests at other plants where significant periods of visual interferences were encountered.

Overall averages for the Number 2 and Number 4 BOPF shop tests were computed using all the roof monitor data for Methods 9 and 22. Averages were also computed for both methods using only those data sets without interferences. The Method 9 roof monitor data were reduced two ways to accommodate the periods of interference. In the first procedure, sets of 24 consecutive readings were computed as prescribed by the reference method where periods of interferences were skipped when counting the sets. The intervals of interference recorded by the paired Method 9 observers did not always match; therefore, a direct comparison of the two readers' observations is not assured by the 24 consecutive reading mode of reduction. In the second procedure, Method 9 data were divided into successive 6-minute segments that included the periods of interference. Averages for each 6-minute set were calculated based on the number of actual readings recorded for the set. This second mode of Method 9 reduction provides a continuing comparison of opacity data between the two observers.

Fugitive emissions testing was performed at a fourth steel plant[4] during June 2-6, 1980. The BOPF shop roof monitor was tested for 24 hours by Method 9 and for 23 hours by Method 22. Indoor furnace emissions were tested for 10 heats by Method 22, and nine velocity traverses were conducted at the inlet to the secondary collector. Significant quantities of emissions during the blowing segment of the furnace heat were observed at this shop; therefore, the entire heat was tested by Method 22. The problem of observer eye fatigue was addressed by having the observers read only alternate heats; every other heat was used as a break period. The only accessible ports for duct velocity traverses at this shop were directly above the furnaces. Plant safety requirements prohibited any use of these ports during furnace operations; therefore, the velocity traverses were made before furnace operations began. Because three modes of secondary fume exhaust are used at this shop, "cold" velocity traverses were made in all three modes. A wind shift on the fourth day of testing prevented roof monitor observations from the preferred locations. The observers moved to an alternate position which faced the long dimension of the roof monitor and forced the use of an improper sun angle; therefore, the roof monitor readings from 1:00 to 5:00 p.m. on June 4, 1980, should not be included in the data base for this series.

A testing program for fugitive emissions was conducted at the fifth steel plant[5] during June 9-16, 1980. Roof monitor observations were made for a total of 29 hours by Method 9 and 26 hours by Method 22. Eleven hot metal transfers were tested by Method 22, and 13 furnace heats were observed by Method 22. Rainy weather on the first day of testing produced marginal conditions for reading the roof monitor. Periods of interference caused by the weather were noted on the field data forms. Furnace operation at this plant produced significant emissions during blowing so that entire heats were read. The observers tested only on alternate heats to avoid excessive eye fatigue. Lighting inside the BOPF shop building at this plant was noticeably lower than at previous shops tested in the series. Light level measurements were below the 10-foot candle minimum recommended by Method 22 for indoor testing. This condition probably caused underestimated observations because the testers reported difficulty in seeing faint emissions.

The sixth plant in the BOPF series was tested during June 23-27, 1980.[6] The roof monitor was observed for 24 hours by both Methods 9 and 22. The BOP furnace was tested for 20 heats by Method 22. Emissions observed during blowing at this plant necessitated testing during the entire furnace heat. Typical furnace operations here included a 15 to 20-minute delay between heats. The indoor observers used this time as a break to avoid undue eye fatigue.

A seventh BOPF facility was tested during May 11-15, 1981.[7] Emissions observations by Method 9 were conducted at the outlets of two separate baghouses controlling secondary emissions. One of these units was used to control fugitive emissions from a Q-BOP furnace and emissions generated in the transferring of hot metal. The two types of hot metal transfer involved were pouring fresh cast metal into a large capacity mixer and pouring from the mixer to ladles for furnace charging. The second baghouse was used to control only the two hot metal transfer processes.

D.2 MONITORING SYSTEMS AND DEVICES

No instrumental or automated systems are available for suitably quantifying the mass of fugitive emissions from secondary BOPF control devices. These emissions are uncontained; therefore, they are not suitable for representative sampling by any material capture technique. These difficulties apply to the emission sources around the steel processing hardware and to emissions passing through the roof monitor.

Opacity transmissometers could be considered for measuring roof monitor emissions; but application of this type of instrument is highly questionable because of practical problems. A long path transmissometer mounted to cover the full length of a roof monitor could be used to monitor opacity, but the values measured would have to be instrumentally or mathematically corrected to the short dimension of the roof monitor. Since multiple plumes of varying opacities are typical at these sources, any correlation between Method 9 observations and transmissometer output would be highly questionable.

The exhaust velocity in the secondary control device ducting for steel processing plants could be monitored if required. These measurements could be obtained by periodic manual velocity traverses or by commercially available flow detection devices. The cost of velocity monitoring could range from about $100 for a half-day series of manual velocity tests to about $5,000 for an automated electronic flow detector. The cost of instrumental flow detectors ranges from less than $500 to around $5,000, depending upon the degree of precision and length of performance desired. Compatibility with either chart type recording devices or digital data acquisition systems is probably available on the more expensive flow measuring instruments.

Field experience with automated velocity measuring projects in the iron and steel industry has shown that blockage of the probe and sampling lines from duct contaminants is the greatest problem. This problem especially occurs when measurements are attempted in a control device inlet duct. A probe-sample line purge and routine maintenance cleanout are recommended to enhance continuous operation of a stack velocity monitor.

D.3 PERFORMANCE TEST METHODS

Method 9--"Visual Determination of the Opacity of Emissions from Stationary Sources"--and Method 22--"Visual Determination of Fugitive Emissions from Material Processing Sources"--are recommended as appropriate for determining the level of visible emissions from BOPF shop roof monitors and baghouses. No method can be recommended for characterizing visible emissions from buildings or structures such as the iron desulfurization facilities tested where emissions escaped from the sides of the facility rather than from a roof monitor.

Both of these methods have inherent advantages and disadvantages. Method 9 can be used to quantify the intensity of the fugitive emissions as the various opacity levels are determined. Since Method 9 is applied at only 15-second intervals, it does not necessarily provide an indication of the duration of emissions. Consequently, fugitive emission plumes that last less than 15 seconds might not be recorded by this method. Experience gained from the six fugitive emissions test programs indicates that most of the emissions observed from the roof monitors lasted more than 15 seconds and typically lingered for 1 to 2 minutes. Therefore, the Method 9 requirement that readings be taken at 15-second intervals does not pose a serious problem to its application for roof monitor testing at BOPF shops.

Method 22 is designed to provide quantitative determination of the duration of fugitive emissions without measuring plume opacity. This method is quite suitable to processes that produce intermittent visible fugitive emissions, and it is also more suitable than Method 9 for sources of multiple fugitive plumes because the observer does not have to select the plume of highest opacity but merely records the total time that any emissions are observed. Method 22 is the preferred method for sources that simultaneously produce multiple fugitive plumes.

Test data obtained at six BOPF shops in the steel industry indicate that visible emissions test methods are applicable to the various process sources as follows:

BOP Furnace - Method 22; furnace emissions are highly intermittent and originate indoors; therefore, the level of lighting does not permit an accurate determination of opacity. Establishing the observation period for Method 22 by individual process operation is recommended.

Iron Desulfurization - No method can be recommended for measuring visible emissions from iron desulfurization facilities not located inside the BOPF building. Although fume escape can be detected by Method 22, the present data base is insufficient for recommending this method. Because of poor conditions and the multiplicity of locations where fumes escaped, no reliable measure exists for determining percent opacity that is consistent with EPA methods and techniques.

Hot Metal Transfer - Method 22; process stations for this operation can be located indoors or outdoors. When the stations are indoors, lighting levels are too low for Method 9, and when they are outdoors, the equipment configuration typically gives very poor background options for opacity determinations.

Skimming - Method 22; this operation is usually performed indoors; therefore, opacity measurements are impractical because of low lighting levels.

BOPF Shop Roof Monitors - Method 9 or Method 22; typical roof monitors over BOPF shops are suitable for either method of visible emissions observations. Method 9 observers must position themselves to read across the shortest dimension of the roof monitor and not through the long dimension from the end of the monitor. Failure to observe this precaution in positioning would result in a high bias in opacity determinations. Consideration could be given to using both Methods 9 and 22 for combined performance testing of roof monitors. A two-method test of this type would provide a more comprehensive coverage of emission monitoring, but the cost effectiveness of such an approach is questionable. Application of both methods for roof monitor testing would essentially double the cost of a performance test. Method 9 is recommended for performance tests at BOPF shop roof monitors because it is a better quantifier of roof monitor emissions, and field testing applications have indicated its suitability for this source of emissions.

Any modification of the time base for averaging Method 9 roof monitor data should be considered for statistical accuracy prior to implementation. A statistical analysis of Method 9 data reduction options indicated that either a 6-minute or 3-minute average is suitable for an accurate determination of opacity levels.[8]

Secondary Emission Control Device Outlets - Method 9; this method is applicable for either stack or roof monitor outlets from secondary control devices. When multiple stacks are encountered, the number of stacks will determine the number of observers required. One observer can provide sufficient coverage for up to eight multiple stacks if the control efficiency is high and emissions are infrequent (less than 5 minutes per hour). Frequently emitting multiple stacks could require one observer for each pair of stacks. When long rectangular roof monitor outlets on secondary control devices are tested, the observers need to position themselves so that readings are made through the shortest dimension of the roof monitor. It is recommended that Method 9 observers be paired for testing these sources to provide corroborative emissions data.

Secondary Emission Exhaust Systems - Methods 1 and 2; exhaust gas velocities in the secondary steel processing control devices can be tested by these two reference methods. Any instrumental or automated flow measuring devices cannot be used for testing until a procedure for demonstrating the accuracy of such a system relative to Reference Methods 1 and 2 and performance specifications for such a device have been established.

Costs for conducting performance tests of steel processing fugitive emissions are estimated to range between $3,000 and $10,000, exclusive of travel expenses. Variations in costs depend primarily upon the number of sources that require testing at a given plant. Testing costs can be minimized if observations are limited to the BOPF shop roof monitor by Method 9 alone. Related processes that are not under the same roof monitor would require separate testing. An example breakdown for a test of a roof monitor and iron desulfurization unit follows:

Assignment	Number of Persons	Number of Days	Man-days
Presurvey	1	0.5	0.5
Field work	4	3	12
Data reduction	1	3	3
Report preparation	1	3	3
Management	1	0.5	0.5
Total	8	10	19.0

D.4 REFERENCES

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(Please read Instructions on the reverse before completing)

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16. ABSTRACT

A New Source Performance Standard for secondary emissions from basic oxygen process furnace (BOPF) steelmaking shops is being proposed under authority of Section 111 of the Clean Air Act. The purpose of the proposed standard is to minimize BOPF secondary particulate emissions to the level attainable with the best demonstrated technology. Revisions to the existing BOPF primary standard (40 CFR 60.140, Subpart N) are also being proposed. These would clarify the definition of a BOPF and the sampling time used to determine compliance.

17. KEY WORDS AND DOCUMENT ANALYSIS

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