United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/3-78-116
November 1978

Air

EPA

A Review of Standards of Performance for New Stationary Sources - Iron and Steel Plants/ Basic Oxygen Furnaces

EPA-450/3-78-116

A Review of Standards of Performance for New Stationary Sources - Iron and Steel Plants/Basic Oxygen Furnaces

by

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Contract No. 68-02-2526

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Prepared for

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

November 1978

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Publication No. EPA-450/3-78-116

TABLE OF CONTENTS

		Page
LIST OF ILLUSTRATIONS		v
LIST OF TABLES		vi
1.0	EXECUTIVE SUMMARY	1-1
1.1	Best Demonstrated Control Technology for Primary Emissions	1-1
1.2	Revision of the Current NSPS	1-2
1.3	Need for the Development of a Fugitive Emissions Control Standard	1-3
1.4	Future Growth of the BOPF Segment of the Steel Industry	1-4
1.5	Wording of the NSPS Standard	1-4
2.0	INTRODUCTION	2-1
3.0	CURRENT STANDARDS FOR BASIC OXYGEN PROCESS FURNACES IN IRON AND STEEL PLANTS	3-1
3.1	Overview	3-1
3.2	Facilities Affected	3-2
3.3	Controlled Pollutants and Emission Levels	3-2
3.4	Testing and Monitoring Requirements	3-3
3.5	Definitions in 40 CFR 60, Subpart N, Requiring Clarification	3-4
4.0	STATUS OF CONTROL TECHNOLOGY	4-1
4.1	Scope of BOPF Steelmaking Operations	4-1
	4.1.1 Geographic Distribution	4-1
	4.1.2 Technological Trends in Raw Steel Production	4-4
	4.1.3 Technological Trends Affecting the BOPF	4-6
4.2	Basic Oxygen Process for Steelmaking	4-7
4.3	BOPF Particulate Characterization	4-10
4.4	Control Technology Applicable to the NSPS for the BOPF	4-14
	4.4.1 Overview	4-14
	4.4.2 NSPS Control Technology in Current Use	4-14
4.5	Comparison of Levels Achievable with Best Demonstrated Control Technology Under the Current NSPS	4-22

TABLE OF CONTENTS (Concluded)

		Page
5.0	INDICATIONS FROM TEST RESULTS	5-1
5.1	Test Coverage in the EPA Regions	5-1
5.2	Analysis of Test Results	5-1
5.3	Indications of the Need for a Revised Standard	5-4
6.0	ANALYSIS OF THE IMPACTS OF OTHER ISSUES ON NSPS	6-1
6.1	Industry Economics and the Prospects of new BOPF Construction	6-1
6.2	Control of Fugitive Emissions	6-5
	6.2.1 Overview	6-5
	6.2.2 Characterization of Fugitive Emissions	6-6
	6.2.3 Fugitive Emissions Control Technology	6-12
	6.2.4 Regulation of Fugitive Emissions	6-19
7.0	FINDINGS AND RECOMMENDATIONS	7-1
7.1	Findings	7-1
	7.1.1 Economic Considerations	7-1
	7.1.2 Process Emission Control Technology	7-1
	7.1.3 Fugitive Emission Control Technology	7-2
	7.1.4 Definitions	7-2
7.2	Recommendations	7-3
	7.2.1 Revision of the Standard	7-3
	7.2.2 Research and Development	7-3
	7.2.3 Definitions	7-4
8.0	REFERENCES	8-1

LIST OF ILLUSTRATIONS

Figure Number		Page
4-1	Geographical Distribution of the U.S. Iron and Steel BOPF Steelmaking Facilities	4-3
4-2	Raw Steel Production by Process in the United States and Canada	4-5
4-3	Schematic Layout of the Open Hood BOPF Off-Gas Cleaning System Using ESP	4-18
4-4	Schematic Layout of the Open Hood BOPF Off-Gas Cleaning System Using Venturi Scrubbing	4-19
4-5	Schematic Layout of the Closed Hood BOPF Off-Gas Cleaning System Using Venturi Scrubbing	4-20
5-1	BOPF Emission Test Data	5-3
6-1	Raw Steel Production, Capacity, and Process Trends	6-2
6-2	BOPF Generation of Charging Emissions	6-7
6-3	Auxiliary Hood Concept	6-13
6-4	Closure Plate Concept	6-14
6-5	Furnace Enclosure for a 200-Ton Q-BOP	6-17

LIST OF TABLES

Table Number		Page
4-1	BOPF Locations, Design Capacity, Hood Design, and Air Pollution Control Device	4-2
4-2	Typical Particle-Size Distribution of Basic Oxygen Furnace Particulate Emissions	4-11
4-3	Typical Particle-Size Distribution of Particulates from Closed Hood Collection Process	4-12
4-4	Comparison of Particulate Composition from Open and Closed Hood Collection Systems	4-13
4-5	Comparison of Wet and Dry Gas Cleaning Characteristics Dictating Choice	4-16
4-6	Comparison of BOPF Control Technologies	4-21
5-1	BOPF Particulate Emissions Test Data	5-2
6-1	Amount of Fugitive Emissions from BOPFs	6-8
6-2	Composition of Fugitive Emissions from BOPFs	6-9
6-3	Fugitive Emission Particle Size Analysis	6-11
6-4	U.S. BOPF Installations with Furnace Enclosures for Fugitive Emissions Control	6-20

1.0 EXECUTIVE SUMMARY

The objective of this report is to review the New Source Performance Standard (NSPS) for the basic oxygen process furnace (BOPF) in terms of the impact of new developments in control technology, the steel industry economics, and other issues that have evolved since the original standard was promulgated in 1974. Possible revisions to the standard, based on NSPS compliance test results, are also analyzed. The following paragraphs summarize the results and conclusions of the analysis, as well as recommendations for future action.

1.1 Best Demonstrated Control Technology for Primary Emissions

Particulate matter emissions associated with the oxygen blow portion of the BOPF steelmaking cycle are the primary emissions from this process and are generated at the rate of approximately 25 to 28 Kg/Mg (50 to 55 lb/ton) of raw steel. The use of a closed hood in conjunction with a scrubber or an open hood in conjunction with either a scrubber or electrostatic precipitator are the best demonstrated control technologies for controlling BOPF primary emissions.* All BOPFs that have been installed since 1973 incorporate closed hood systems for particulate emission control. The closed hood control

*It should be noted that standards of performance for new sources established under Section 111 of the Clean Air Act reflect emission limits achievable with the best adequately demonstrated technological system of continuous emission reduction (taking into consideration the cost of achieving such emission reduction, and any nonair quality health and environmental impact and energy requirements).

system in combination with a venturi scrubber has become the system of choice of the U.S. steel industry primarily due to this system's energy savings and generally lower maintenance requirements as compared with the older open hood electrostatic precipitator system. The closed hood system conserves energy, since approximately 80 percent less air is required to be cleaned than with the open hood system. The potential exists (only for the closed hood system) for using the carbon monoxide off-gas as a fuel source.

1.2 Revision of the Current NSPS

The rationale for the current NSPS level of 50 mg/dscm (0.022 gr/dscf) for primary stack emissions, as described in 1973, is still valid. As of early 1978 no NSPS compliance tests had been carried out since the promulgation of the standard. However, data are available from emission tests on a limited number of new BOPFs. These tests were carried out using EPA Method 5. The results of these tests indicate that primary particulate emission levels of between 32 mg/dscm (0.014 gr/dscf) and 50 mg/dscm (0.022 gr/dscf) are being achieved using the same control technology as described in the NSPS background document. Therefore, it is recommended that the control level for primary emissions as specified in the current NSPS should not be changed.

1.3 Need for the Development of a Fugitive Emissions Control Standard

Fugitive emissions*, i.e. emissions not captured by the BOPF primary emissions control system, can be generated in significant amounts during various BOPF ancillary operations. One of the principal sources of these emissions, the hot metal charging cycle, can generate amounts of fugitive emissions on the order of 0.25 Kg/Mg (0.5 lb/ton) of charge. These emissions may contain heavy metals (including lead, zinc, and cadmium) and a significant amount of particles $<$ 5 microns in diameter (in the respirable range). These emissions are presently uncontrolled in most of the older BOPFs and only partially controlled in most of the new BOPFs which have come on stream during the last 5 years. Regulation of these emissions is presently minimal.

Control of fugitive emissions not captured in the BOPF hood and stack gas cleaning system from ancillary BOPF operations including hot metal and scrap charging, turndown, and tapping operations is still a developing technology and requires in-depth study to determine the most effective methods of fume capture. The complete furnace enclosure equipped with several auxiliary hoods, a relatively high cost technique, is the only currently demonstrated technology for minimizing or eliminating fugitive emissions from a new BOPF.

*These are also commonly referred to as secondary emissions.

However, several other techniques utilizing auxiliary hoods or devices may be almost as effective as the complete enclosure with a much lower cost.

EPA should continue evaluation of fugitive emission control systems with a view toward incorporating fugitive emissions under the scope of the BOPF NSPS at a later date. As part of this effort, EPA should develop a reliable fugitive emission measurement method which quantifies overall capture efficiencies as well as emission levels. The method should specify averaging times and appropriate adjustments for various BOPF configurations.

1.4 Future Growth of the BOPF Segment of the Steel Industry

The present economic conditions in the U.S. and worldwide steel industry have created a significant excess U.S. BOPF capacity and a tightening of the availability of capital for future expansion. These two factors, coupled with the lack of industry announcements of new U.S. BOPF construction, indicate that no construction of new BOPFs, which would be subject to a revised NSPS, would likely commence before 1980, if then.

1.5 Wording of the NSPS Standard

Ambiguities in the wording of the NSPS with regard to the definition of a BOPF and the component parts of the sampling cycle require clarification. Specifically, the stack emissions averaged over the oxygen blow part of the cycle could be significantly different from the emissions averaged over the entire cycle. The current standard is unclear as to which averaging time should be used. Since no tests to date have come under the NSPS, this has not been an issue. However, interpreting the standard could become a problem in the future.

2.0 INTRODUCTION

In Section 111 of the Clean Air Act, "Standards of Performance for New Stationary Sources," a provision is set forth which requires that "The Administrator shall, at least every four years, review and, if appropriate, revise such standards following the procedure required by this subsection for promulgation of such standards." Pursuant to this requirement, the MITRE Corporation, under EPA Contract No. 68-02-2526, is to review 10 of the promulgated NSPS including the iron and steel industry BOPF.

The main purpose of this report is to review the current BOPF standard and to assess the need for revision on the basis of developments that have occurred or are expected to occur in the near future. This report addresses the following issues:

1. A review of the definition of the present standard.
2. A discussion of the status of the BOPF segment of the steel industry and the status of applicable control technology.
3. Analysis of BOPF particulate emission test results and review of level of performance of best demonstrated control technology for emission control.
4. Review of steel industry economics and projections of new BOPF construction.
5. Discussion of BOPF fugitive emissions and control technology presently available.

Based on the information contained in this report, a set of findings is presented and specific recommendations are made for changes in the NSPS. In addition, recommendations are made for R&D studies on control technology for fugitive emissions.

3.0 CURRENT STANDARDS FOR BASIC OXYGEN PROCESS FURNACES IN IRON AND STEEL PLANTS

3.1 Overview

The principal air pollution emission from iron and steel plants is particulate matter. In the steel industry, the major sources of particulate emissions include the basic oxygen process; operation of open hearth, blast and electric furnaces; and operation of coke ovens and sintering plants. The NSPS under review applies only to the BOPF.

Due to the nature of the basic oxygen steelmaking process, particulate control technology is essential to the operation of the process. Particulate emissions from BOPFs became subject to regulation under NSPS in 1973. The existing state and local regulations designed specifically for BOPFs allowed between two and four times more particulate emissions than the proposed NSPS, i.e., 0.045 to 0.090 gr/dscf as compared with the NSPS of 0.022 gr/dscf. After the promulgation of the NSPS, state limitations submitted pursuant to Section 110 of the Clean Air Act became only slightly less stringent than the standard. (EPA, 1973).

It was estimated that during 1975 the primary metals segment of industrial processes (point source category) accounted for 1.1 million tons or 10.1 percent of the total 10.8 million tons per year of point source particulate emissions. The iron and steel industry is the largest single industrial category producing particulate emissions from primary metal manufacture. In 1975 these emissions were estimated to be 0.37 million tons per year or 33.6 percent of the primary metal segment of the nationwide point source inventory. The BOPF segment of the steel industry is estimated to have particulate emissions of 0.047 million tons per year for 1975 or 12.7 percent of the steel industry total (Barkhau, 1978).

3.2 Facilities Affected

The NSPS regulates BOPFs that were planned or under construction or modification as of June 11, 1973. An existing BOPF is subject to the promulgated NSPS if: (1) a physical or operational change in an existing facility causes an increase in the emission rate to the atmosphere of any pollutant to which the standard applies, or (2) if in the course of reconstruction of the facility, the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost that would be required to construct a comparable entire new facility that meets the NSPS.

3.3 Controlled Pollutants and Emission Levels

Particulate matter is the BOPF pollutant to be controlled by the NSPS, as defined by 40 CFR 60, Subpart N:

> On and after the date on which the performance test required to be conducted . . . is completed, no owner or operator subject to the provisions of Subpart N, 40 CFR 60) shall discharge or cause the discharge into the atmosphere from any affected facility any gases which: (1) Contain particulate matter in excess of 50 mg/dscm (0.022 gr/dscf).

This standard was derived from test results from five well-controlled plants. These tests indicated that a concentration standard of 50 mg/dscm (0.022 gr/dscf) represented the lowest particulate concentration achievable by control devices for BOPF emissions. In addition, designers and manufacturers of all the control equipment involved can guarantee collection efficiencies that will achieve an average outlet concentration of 45 mg/dscm (0.020 gr/dscf) (EPA, 1973). In Section 5.0, recent non-NSPS emission test results from BOPFs are discussed and compared with the original test results which formed the basis for the standard.

3.4 Testing and Monitoring Requirements

Performance tests to verify compliance with particulate standards for BOPFs must be conducted within 60 days after the plant has reached its full capacity production rate, but not later than 180 days after the initial start-up of the facility (40 CFR 60.8). The EPA reference methods to be used in connection with BOPF testing include:

(1) Method 5 for concentration of particulate matter and associated moisture content.

(2) Method 1 for sample and velocity traverses.

(3) Method 2 for volumetric flow rate.

(4) Method 3 for gas analysis.

Each performance test consists of three separate runs that are each 1 hour long with a sampling rate of at least 0.9 dscm/hr (0.53 dscf/min). The arithmetic mean of the three runs taken is the test result to which compliance with the standard applies (40 CFR 60.8).

Performance test requirements, including provisions for exceptions and provisions for approval of alternative methods, are detailed in 40 CFR 60.8.

No continuous monitoring requirement currently exists for NSPS for BOPFs.

3.5 Definitions in 40 CFR 60, Subpart N, Requiring Clarification

Several terms specifically defining BOPFs and their NSPS testing are given in 40 CFR 60, Subpart N. Two terms require clarification because of ambiguous wording.

> Basic oxygen process furnace (BOPF) means any furnace producing steel by charging a scrap steel, hot metal, and flux materials into a vessel and introducing a high volume of an oxygen-rich gas.

The above definition could also be used to describe an oxygen-lanced open hearth furnace so that any modifications of open hearth furnaces to include oxygen lancing may come under the NSPS for BOPFs.

> . . . the sampling for each run shall continue for an integral number of cycles with total duration of at least 60 minutes. The sampling rate shall be at least 0.9 dscm/hr (0.53 dscf/min) except that shorter sampling times, when necessitated by process variables or other factors, may be approved by the Administrator. A cycle shall start at the beginning of either the scrap preheat <u>or</u> the oxygen blow and shall terminate immediately prior to tapping. (Underline for emphasis.)

The previous definition is ambiguous for BOPF facilities that preheat scrap; i.e., do they have a choice of sampling cycle. Several of these facilities actually preheat scrap external to the BOPF. Scrap preheat could add a significant amount of particulate to the total sampling cycle depending on the quality of the scrap.

4.0 STATUS OF CONTROL TECHNOLOGY

4.1 Scope of BOPF Steelmaking Operations

4.1.1 Geographic Distribution

The U.S. steel industry is composed of 200 companies operating in 38 states. Of the 200 companies, 19 have BOPF steelmaking facilities with a design capacity of about 100 million metric tons per year (110 million tons per year) (U.S. House of Representatives, 1977). Table 4-1 presents an inventory of the location, design capacity, and emission control technology of BOPFs in the U.S. including four BOPFs to be dedicated in 1978 by Bethlehem Steel, U.S. Steel, and Kaiser Steel Corporations. Locations of these facilities are shown in Figure 4-1.

There has been a gradual decentralization trend throughout the country due to the widespread use of the electric arc furnace which converts locally generated steel scrap or iron pellet to raw steel. This grade of steel is then converted to relatively unsophisticated products such as reinforcing bars, which do not require sophisticated finishing processes.

However, a geographic concentration of large integrated steel plants that accounts for 80 percent of the U.S. finished steel production has developed in Illinois, Michigan, Indiana, Ohio, and Pennsylvania, due to the following factors: (1) the proximity of raw materials (about 55 to 60 percent of all coking coal is mined in

TABLE 4-1

BOPF LOCATIONS, DESIGN CAPACITY, HOOD DESIGN, AND AIR POLLUTION CONTROL DEVICE

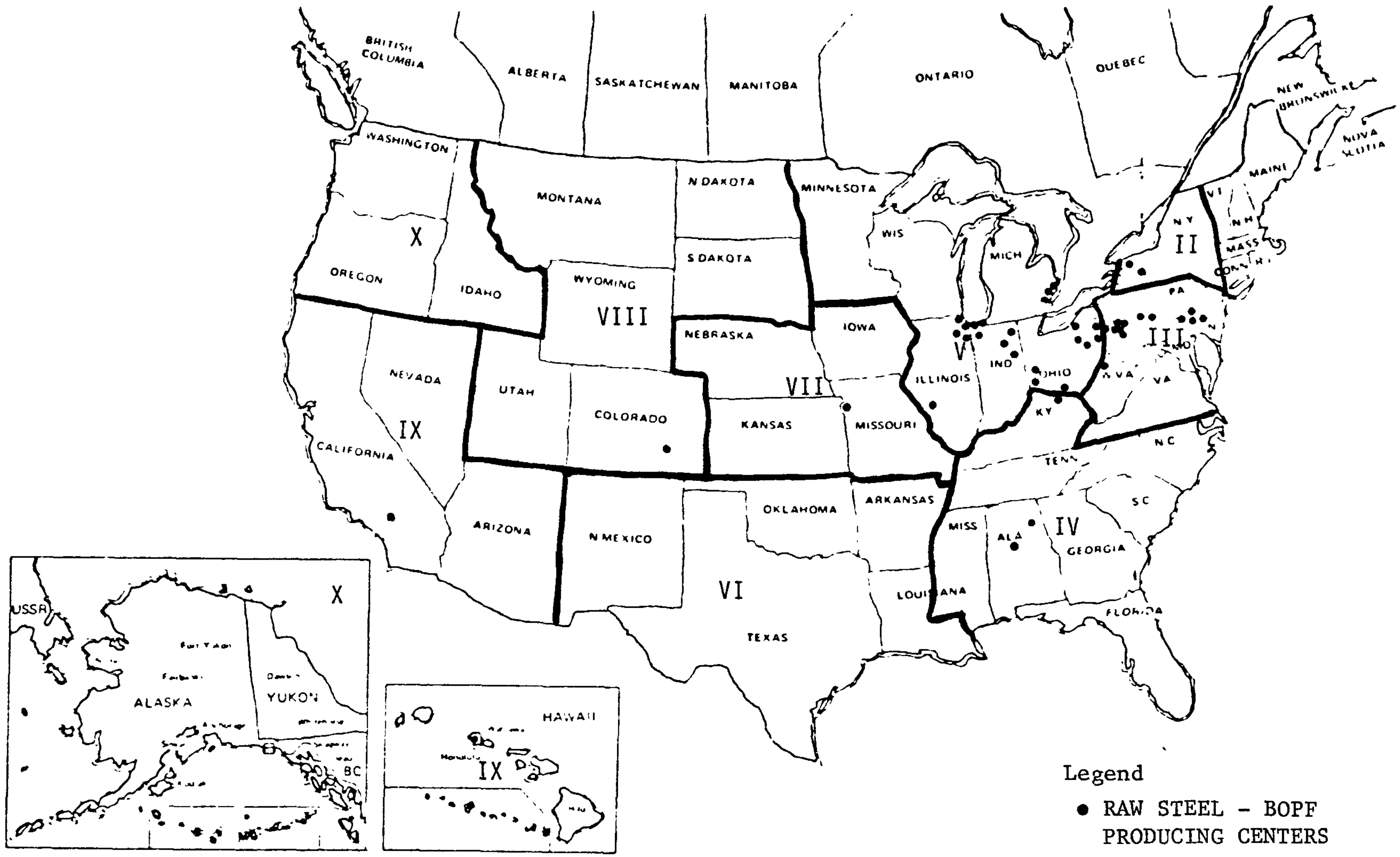
EPA REGION	COMPANY	LOCATION	YEAR INSTALLED	BOP FURNACES NUMBER	BOP FURNACES SIZE-Mg (TONS)	CAPACITY MM Mg/YEAR MM(TONS/YR)	HOOD DESIGN/AIR POLLUTION CONTROL: OPEN HOOD/ PRECIPITATOR	OPEN HOOD/ SCRUBBER	CLOSED HOOD/ SCRUBBER
2	Bethlehem Steel Co.	Lackawanna, N.Y.	1964/66	3	270(300)	4.5(5.0)		X	
	Republic Steel Co.	Buffalo, N.Y.	1970	2	120(130)	0.9(1.0)		X	
3	Alan Wood Steel Co.	Conshohocken, Pa.	1968	2	135(150)	1.8(2.0)	X		
	Alleghany Ludlum Steel Co.	Natrona, Pa.	1966	2	75(80)	0.4(0.5)		X	
	Bethlehem Steel Corp.	Sparrows Pt., Md.	1966	2	195(215)	2.7(3.0)		X	
	Bethlehem Steel Corp.	Bethlehem, Pa.	1968	2	240(270)	3.1(3.5)	X		
	Crucible, Inc.	Midland, Pa.	1968	2	95(105)	0.9(1.0)		X	
	Jones & Laughlin Steel Corp.	Aliquippa, Pa.	1957	2	75(80)	6.0(6.7)	X		
	Jones & Laughlin Steel Corp.	Aliquippa, Pa.	1968	3	170(190)		X		
	National Steel Corp.	Weirton, W.Va.	1967	2	350(320)	5.2(5.8)		X	
	Sharon Steel Corp.	Farrell, Pa.	1974	3[a]	135(150)	1.4(1.6)		X	
	U.S. Steel Corp.	Duquesne, Pa.	1963	2	195(215)	2.2(2.5)		X	
	U.S. Steel Corp.	Braddock, Pa.	1972	2	210(230)	2.2(2.5)		X	
	Wheeling-Pittsburgh Steel Corp.	Monessen, Pa.	1964	2	190(200)	1.4(1.6)	X		
4	Armco Steel Corp.	Ashland, Ky.	1963	2	165(180)	1.8(2.0)	X		
	Republic Steel Corp.	Gadsden, Ala.	1965	2	165(180)	1.3(1.5)	X		
	U.S. Steel Corp.	Fairfield, Ala.	1974/78	3[b]	180(200)	3.2(3.5)			X
5	Armco Steel Corp.	Middletown, Oh.	1969	2	190(210)	2.0(2.3)			X
	Bethlehem Steel Co.	Burns Harbor, Ind.	1969	2	270(300)	4.0(4.5)		X	
	Bethlehem Steel Co.	Burns Harbor, Ind.	1978	1	270(300)	0.9(1.0)			X
	Ford Motor Co.	Dearborn, Mich.	1964	2	225(250)	3.4(3.8)	X		
	Inland Steel Co.	East Chicago, Ill.	1966	2	230(255)	6.0(6.7)		X	
	Inland Steel Co.	East Chicago, Ill.	1974	2	190(210)				X
	Interlake, Inc.	Chicago, Ill.	1959	2	70(75)	0.9(1.1)	X		
	Jones & Laughlin Steel Corp.	Cleveland, Oh.	1961	2	205(225)	2.7(3.0)	X		
	McLouth Steel Corp.	Trenton, Mich.	1958/59	5	100(110)	2.5(2.8)			
	National Steel Corp.	Ecorse, Mich.	1962	2	270(300)	5.2(5.8)	X		
	National Steel Corp.	Ecorse, Mich.	1970	2	215(235)		X		
	National Steel Corp.	Granite City, Ill.	1967	2	215(235)	2.2(2.5)	X		
	Republic Steel Corp.	Warren, Oh.	1965	2	170(190)	1.9(2.2)	X		
	Republic Steel Corp.	Cleveland, Oh.	1966/77	2	220(245)	3.3(3.7)			X
	Republic Steel Corp.	So. Chicago, Ill.	1976	2[b]	180(200)	2.0(2.3)			X
	U.S. Steel Corp.	Gary, Ind.	1965	3	195(215)	7.2(8.0)	X		
	U.S. Steel Corp.	Gary, Ind.	1973	3[b]	180(200)		X		X
	U.S. Steel Corp.	So. Chicago, Ill.	1969	3	180(200)	2.7(3.0)		X	
	U.S. Steel Corp.	Lorain, Oh.	1971	2	205(225)	2.7(3.0)			X
	Wheeling-Pittsburgh Steel Corp.	Steubenville, Oh.	1965	2	260(285)	2.6(2.9)		X	
	Wisconsin Steel	So. Chicago, Ill.	1964	2	110(120)	1.0(1.2)	X		
	Youngstown Sheet & Tube Co.	East Chicago, Ill.	1970	2	255(280)	2.7(3.0)	X		
8	CF&I Steel Corp.	Pueblo, Colo.	1961	2	110(120)	1.2(1.4)	X		
9	Kaiser Steel Corp.	Fontana, Calif.	1958	3	110(120)	1.6(1.8)	X		
	Kaiser Steel Corp.	Fontana, Calif.	1978	2	205(225)	2.1(2.4)			X

Notes:

[a]This facility consists of one standard top-blown BOPF and two Kaldo Process BOPFs, the latter vessels being inclined and rotating during the oxygen blow. The Kaldo units have been virtually supplanted by the standard fixed unit (EPA, 1977).

[b]Q-BOP installation

SOURCES: U.S. House of Representatives, 1977.
EPA, 1977.
Nicola, 1978.



SOURCE: U.S. House of Representatives, 1977.

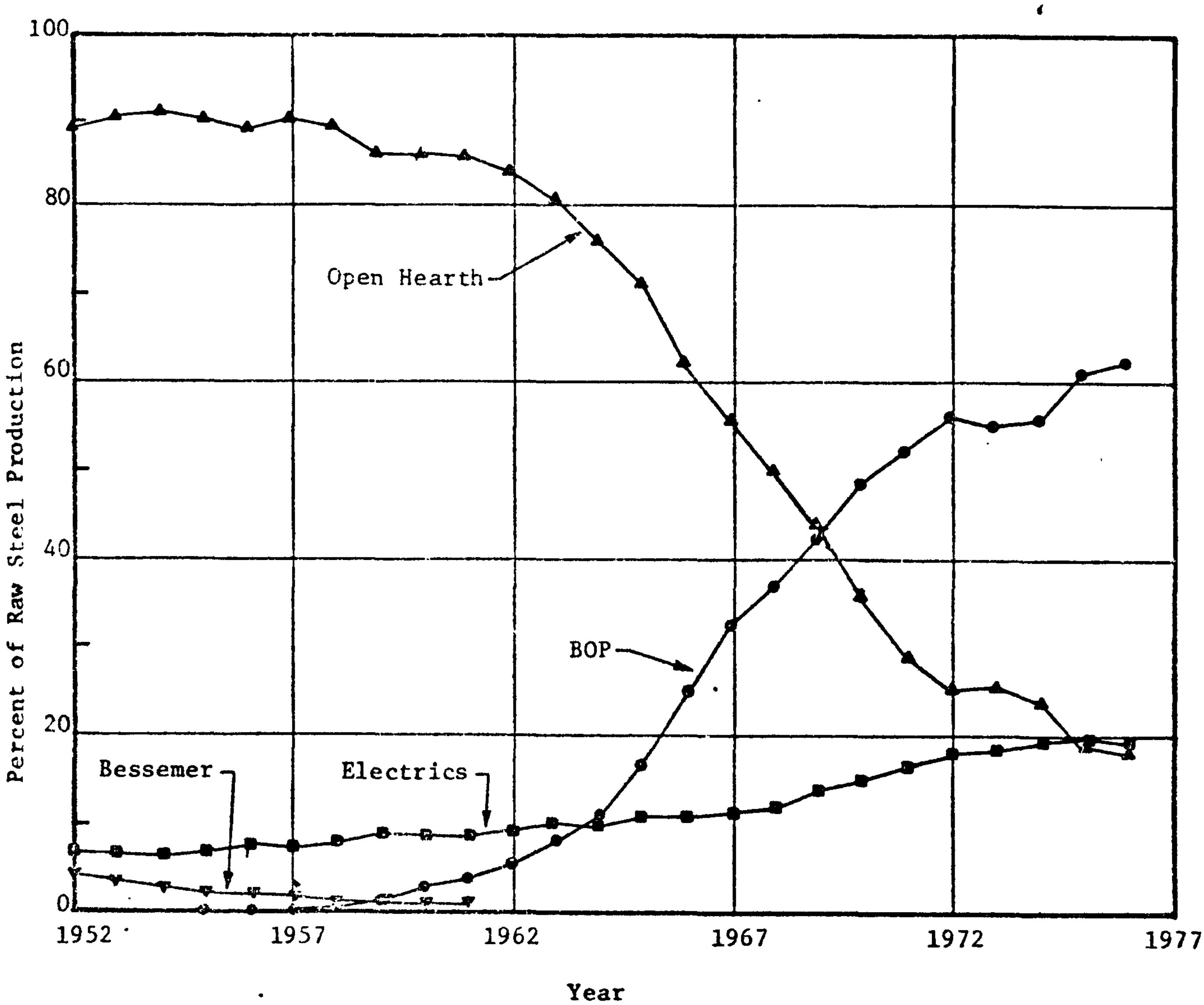
FIGURE 4-1
GEOGRAPHIC DISTRIBUTION OF THE U.S. IRON AND STEEL BOPF STEELMAKING FACILITIES

Pennsylvania, Ohio and Indiana), (2) the easily accessible transportation network, (3) the historic location of large plants dating back to the turn of the century, and (4) the concentration of nearby steel consuming industries.

4.1.2 Technological Trends in Raw Steel Production

Since 1960 a major shift has been underway in the U.S. steelmaking facilities. As illustrated in Figure 4-2, the BOPF has supplanted the traditional open hearth furnace as the predominant process for the production of raw steel. In 1977 the BOPF produced 62 percent of U.S. steel, up from 3 percent in 1960. The open hearth furnace has also fallen behind the electric arc furnace, which produced 22 percent of the total output in 1977. The heavy capital spending for BOPF conversion from open hearth during the 1960s and early 1970s has served to modernize the nation's steel-producing facilities and improve steel quality and industrial productivity. The BOPF, which is a much faster and less labor-intensive process than the open hearth furnace, has been important in increasing output per manhour to the point that U.S. industry is second only to Japan in productivity (U.S. House of Representatives, 1977).

Between 1960 and 1970 new BOPFs were coming on stream at the rate of approximately seven per year. Since 1970 and including the four BOPFs to be dedicated in 1978, this rate of startup has slowed to between two and three per year. Moreover, since the promulgation of the BOPF NSPS in 1974, the rate of new BOPF startup, including



SOURCE: EPA, 1977.

FIGURE 4-2
RAW STEEL PRODUCTION BY PROCESS IN THE UNITED STATES AND CANADA

again the four new BOPFs to be dedicated in 1978, has slowed to between one and two per year. Much of the new BOPF capacity has replaced the corresponding open hearth capacity. Overall raw steel production grew only moderately during this period with much of that growth accounted for by the increased production from electric arc furnaces. As a result of the high degree of conversion to BOPFs already achieved and the unstable economic condition of the steel industry in general, any growth in BOPF capacity will be tied to substantial improvement in economic conditions in the industry. As of July, 1978, no new BOPF facilities had begun construction and none are expected to begin before early 1980, if then (see Section 6.1).

4.1.3 Technological Trends Affecting the BOPF

The open hearth shops remaining in operation are still candidates for eventual BOPF conversion. The process of oxygen-lancing open hearths to increase yield may extend their useful lifetimes. In addition, since open hearth operation is relatively unaffected by the scrap/hot metal ratio in the furnace feed, the future economic conditions of the scrap versus hot metal market may also affect the decision to convert from open hearth to BOPF.

A relatively new BOPF technology that introduces oxygen from below the furnace, rather than from above as in conventional furnaces, is the Quality Basic Oxygen Process (Q-BOP) (described in Section 4.2). Open hearth furnaces at the Fairfield works of U.S. Steel Corporation and at Republic Steel's South Chicago plant have recently been converted to Q-BOPs. The chief advantage of these conversions is in the use of existing open hearth building facilities and a continuity of steel-making operations during conversion.

4.2 Basic Oxygen Process for Steelmaking

In order to discuss the status of control technology required for BOPF particulate emission control, a review of the basic oxygen process and characterization of BOPF emissions is appropriate.

The basic oxygen process for production of steel uses high pressure oxygen to oxidize and remove carbon, silicon, and other undesirable elements from molten iron and scrap steel. The furnace operation is cyclic and the time required for a complete steel production cycle is typically 45 minutes, but can range from about 30 to 75 minutes due to variations in shop operating conditions. The steel production cycle for a BOPF includes five basic operations:

1. Charging of scrap and hot metal
2. Oxygen blowing
3. Testing
4. Tapping
5. Slagging

Generally the material charged to the BOPF consists of 10 to 30 percent scrap and 90 to 70 percent molten pig iron (hot metal). These relative proportions are used so that the heat generated by oxidation of carbon, silicon, and manganese, plus the sensible heat from the hot metal, provides sufficient energy to melt all the scrap and to raise the metal to the correct temperature for tapping. Charging of scrap and hot metal requires only a few minutes. Just after initiation of oxygen blowing and at intervals, as necessary, slag-forming flux materials (lime, limestone, fluorospar, etc.) are added to the vessel to remove undesirable elements such as sulfur, phosphorus, and manganese.

After the vessel is charged, high purity oxygen is blown into the charge materials from above the molten charge using a water-cooled lance. Oxygen is blown generally for about 18 to 20 minutes; but due to variations in conditions (including scrap quality) and the process used, the blowing period can vary from approximately 13 to 26 minutes. The gases emitted from the furnace primarily consist of CO and CO_2 from oxidation of carbon in the metal and oxygen derived from iron oxides. The evolution rate of these gases and attendant iron oxide fumes varies greatly over the entire blowing period.

After blowing of oxygen for a specified period, a sample of the metal is taken for analysis. If the metal is not of correct composition, additional oxygen is blown for a short period. If the steel is of correct composition, the vessel is tapped. Tapping of the BOPF is simply the pouring of molten metal from the vessel into a ladle.

The final operation, slagging, is the removal of slag from the vessel after completion of a tap and before the vessel is charged again. Slag is the fused product formed by the reaction of the flux materials with impurities in the metal. Because slag is of lower density than the metal, the slag floats on top of the molten metal bath and the metal can be tapped from below the slag.

The Q-BOP 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) originated in Europe. 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 modified basic-lined converter which is fitted with bottom tuyeres through which both oxygen and a hydrocarbon gas are injected. Concentric tuyeres are built into the bottom so that the oxygen enters the bath shrouded by a shield of hydrocarbon gas through the larger of two concentric pipes. On entry into the vessel, the hydrocarbon is cracked endothermically, thus absorbing the heat that would otherwise be liberated where the oxygen first contacts the molten metal. This absorption of heat protects the tuyeres from rapid erosion that took place in previous attempts to bottom blow with oxygen. The fact that the oxygen is blown through the bottom rather than from above changes the character of the slag. Powdered lime is blown in through the bottom tuyeres with the oxygen to assist in obtaining a slag that is effective in removing phosphorus and sulfur from the bath. This slag apparently develops a much lower iron oxide content than the slags made in the conventional basic oxygen process.

The benefits of Q-BOP, as compared with conventional top-blown BOPF, are (Pearce, 1976):

- Lower capital investment (greenfield plants* as well as open hearth conversions)
- Lower operating costs
- Higher productivity
- Metallurgical advantages.

Of the 14 BOPFs, which have come on stream in the last 5 years (through 1978), eight are of Q-BOP design. Seven of the eight represent open hearth steelmaking shop conversions, and the eighth (U.S. Steel, Fairfield, Alabama) is a new Q-BOP started up in 1978.

4.3 BOPF Particulate Characterization

Particulate matter emissions from BOPFs 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.

Table 4-2 presents a typical particle-size distribution of BOPF particulate emissions. Other investigations have reported that the mass mean diameter of particulates from top-blown BOPFs varies

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*Greenfield plants represent completely new facilities built in areas where no steel mills existed previously.

between 0.5 and 1.0 micron. Particulates from bottom-blown BOPFs (Q-BOP) are smaller and generally estimated to be about 0.1 micron in diameter (EPA, 1977).

TABLE 4-2

TYPICAL PARTICLE-SIZE DISTRIBUTION OF BASIC OXYGEN FURNACE PARTICULATE EMISSIONS

Particle Diameter (microns)	Weight (percent)
<1	25
1-65	15
65-90	20
90-110	15
>110	25

Source: Skelly, 1966.

A significant change in particle size distribution appears to occur when BOPF emissions are collected in the newer closed hood gas collection systems as compared with the older open hood gas collection system. Table 4-3 presents a typical particle-size distribution from a Japanese closed hood collection system.

TABLE 4-3

TYPICAL PARTICLE-SIZE DISTRIBUTION OF PARTICULATES FROM CLOSED HOOD COLLECTION PROCESS

Particle Diameter (microns)	Weight (percent)
<5	8.7
5-10	9.0
10-20	39.5
20-30	28.8
>30	14.0

Source: Yawata, 1966.

Recognizing that these distributions may vary depending on operating practice and analytical technique, it is probable that a much smaller percentage of the particulates from the closed hood collection system are in the respirable range ($\leq$ 5 microns 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 latter process, the particles consist of an outer surface of hematite surrounding a core of magnetite.

Table 4-4 presents a comparison of the composition of particulates from open and closed hood collection systems.

TABLE 4-4

COMPARISON OF PARTICULATE COMPOSITION FROM OPEN AND CLOSED HOOD COLLECTION SYSTEMS[a]

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.

Source: Cavaghan, 1970.

The particulate generation rate in the basic oxygen process depends on several factors such as: oxygen blow rate, 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. About 50 lb of particulates and 140 lb of carbon monoxide (CO) are produced per ton of raw steel.

4.4 Control Technology Applicable to the NSPS for the BOPF

4.4.1 Overview

Emission control technology for BOPFs is directed at two types of emissions: direct process emissions (primary) and fugitive emissions (secondary). The current NSPS for the BOPF regulates only primary process emissions and does not address fugitive emissions resulting from ancillary BOPF operations.

The status of control technology, which is currently meeting the NSPS for BOPF primary emissions, is discussed in the following paragraphs. All demonstrated control technologies are in use. Fugitive emissions and their control are discussed in Section 6.2.

4.4.2 NSPS Control Technology in Current Use

Only one type of emission control system has been installed on the BOPF since the promulgation of the NSPS. This system is based on suppressing or limiting the combustion of off-gases from the basic oxygen process.

The basic oxygen process off-gases consist largely of carbon monoxide and a small proportion of carbon dioxide. All early BOPFs had full combustion or open hood systems. Large quantities of air were drawn into the hood above the vessel mouth to burn all of the hot CO gas to CO_2 before the gas was cleaned. This technique required that large quantities of heat generated by the combustion of CO be absorbed, and it was necessary to clean not only the furnace gases but also the oxygen and nitrogen from the combustion air drawn into the hood. By limiting the excess air and cleaning only the mixture of CO and CO_2, the gas volume to be cleaned has been reduced by as much as 75 percent. This substantial reduction has been accomplished through the use of a movable skirt positioned during a heat to limit the air drawn into the hood. This arrangement minimizes the mass emission rate of particulate matter from the process.

Emission control systems designed according to the principle of limited or suppressed combustion are all of foreign origin. These systems specify a high-energy venturi scrubber for cleaning the combustible gases (to minimize the danger of explosions that could occur in ESP cleaning systems due to the presence of carbon monoxide). The closed-hood system designs also specify that furnaces have a separate gas cleaning system to avoid the danger of "dead spots" in the system and leakage around large valves used to connect two vessels to one gas cleaning system.

Table 4-5 presents a comparison of the significant features of wet scrubber and the dry ESP methods for BOPF particulate emissions removal. In the recent BOPF installations, wet scrubbing as exemplified by the variable throat venturi has become the method of choice by the steel industry due to its superiority over the ESP in terms of maintenance and safety.

TABLE 4-5

COMPARISON OF WET AND DRY GAS CLEANING CHARACTERISTICS DICTATING CHOICE

Precipitator	Scrubber
• The precipitator requires less fan horsepower than that required for a scrubber because a high pressure drop is not required.	• The wet scrubber requires more fan capacity to develop the high pressure drop that is necessary for high efficiency gas cleaning. As a result, the fan power requirements are higher than those for a precipitator.
• The so-called dry precipitator requires about 15 percent moisture in the gas to attain reasonable gas cleaning efficiency.	• Water is required in large quantities. The effluent water as well as the gas must meet all applicable control regulations.
• Maintenance required to keep the precipitator, gas collection, rapping, and discharge systems operating efficiently is more sophisticated than that required for wet scrubbers.	• Maintenance of a scrubber is significantly simpler than a precipitator.
• The precipitator cannot be used on closed hood gas cleaning systems due to CO explosion hazard.	• Only wet scrubbing systems are considered safe by most suppliers for use on closed hood gas recovery systems such as the Japanese system.

Figures 4-3 through 4-5 present schematic flow sheets of typical open and closed hood particulate emission control systems for BOPFs. Table 4-6 presents a comparison of the key features of open and closed hood control technologies.

A review of the NSPS background document (EPA, 1973) indicates that the description of applicable control technologies for BOPF particulate emissions remains unchanged, i.e., closed hood/venturi scrubber or open hood/ESP or venturi scrubber remain the best demonstrated control technologies.

A review of recent installations indicates a strong trend towards closed hood systems for future BOPFs. In the last 4 years (through 1978), six new BOPF installations and one retrofit gas cleaning installation will have been completed, all using closed hood systems. Operational problems with closed hood systems and somewhat higher capital costs, as described in the EPA NSPS background document (EPA, 1973) apparently have not deterred the steel industry from the use of this control technology. In choosing closed hood emission control systems, the industry appears to be influenced by severe maintenance problems with EPSs and the significantly lower energy consumption of the closed hood system as compared with open hood systems. Additionally, the potential for significant energy recovery exists for closed hood systems if the carbon monoxide (which is presently flared) is utilized for its fuel value.

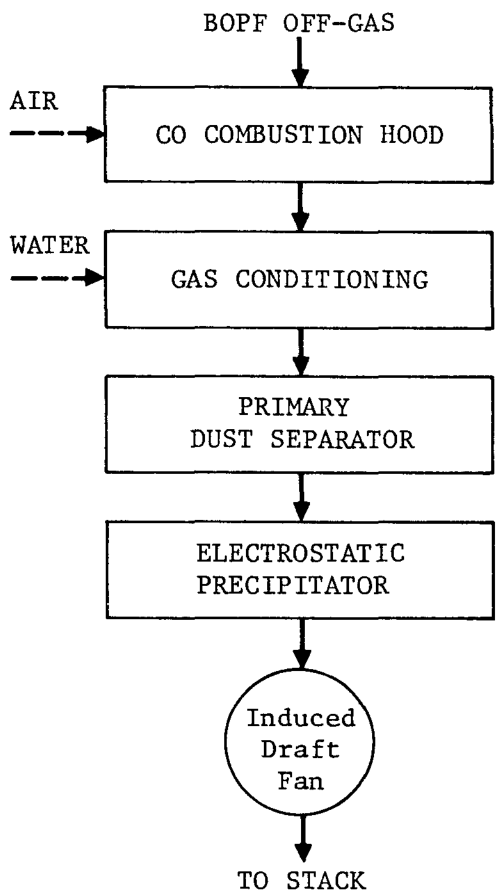


FIGURE 4-3
SCHEMATIC LAYOUT OF THE OPEN HOOD BOPF OFF-GAS CLEANING SYSTEM USING ESP

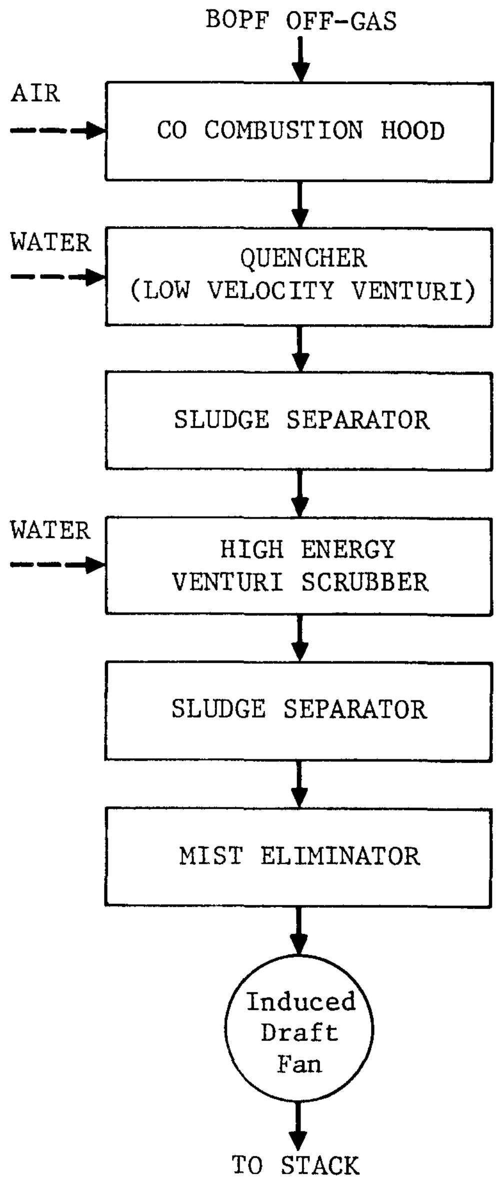


FIGURE 4-4
SCHEMATIC LAYOUT OF THE OPEN HOOD BOPF OFF-GAS CLEANING SYSTEM USING VENTURI SCRUBBING

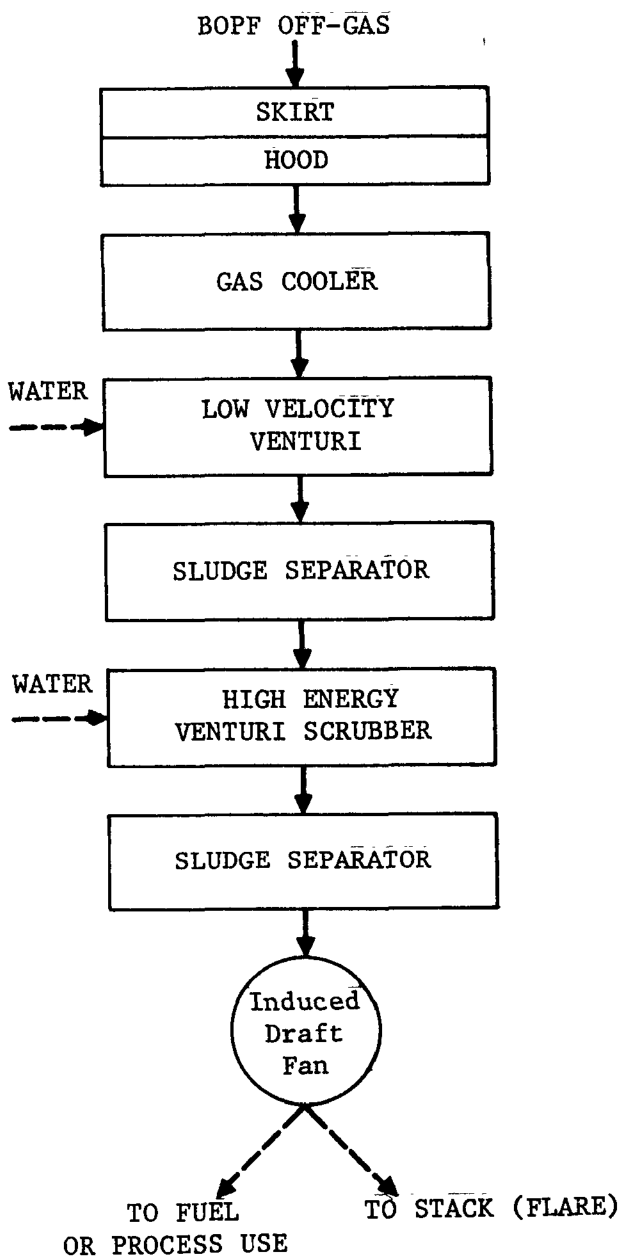


FIGURE 4-5
SCHEMATIC LAYOUT OF THE CLOSED HOOD BOPF OFF-GAS CLEANING SYSTEM USING VENTURI SCRUBBING

TABLE 4-6

COMPARISON OF BOPF CONTROL TECHNOLOGIES

Closed Hood	Open Hood
• CO is not burned in hood: only process gases have to be cleaned. Gas flow only 20-25% of open hood flow.	• Large quantities of air needed to combust process-generated CO -- this requires cleaning of excess combustion air in addition to process off gases.
• Presence of CO in off-gases precludes use of ESP for particulate removal.	• ESP or venturi scrubber can be used for particulate removal.
• Process off-gases require less heat removal in hood due to minimal CO combustion; there is minimal waste heat recovery.	• Large quantities of waste heat required to be removed due to combustion of CO in hood; heat is recoverable as by-product steam.
• Achieves lower mass rate of emissions (lb/hr) than open hood due to lower gas flow rate.	• Higher mass rate of emissions (lb/hr) due to much higher gas flow.
• Particulate removal efficiency is 99% +.	• Particulate removal efficiency (both ESP and venturi) is 99% +.
• Much higher percentage of larger particles sizes.	• Much higher percentage of smaller particles sizes.
• Electricity consumption is 8 KWH/ton of raw steel.[a]	• Electricity consumption is 14 KWH/ton of raw steel.[a]
• Potential energy recovery in CO off-gas is 0.44×10^6 Btu/ton of raw steel.[a]	• No energy recovery from off gas.

[a]EPA, 1976.

4.5 Comparison of Levels Achievable with Best Demonstrated Control Technology Under the Current NSPS

The available data from the testing of BOPFs (see Section 5.2) are not conclusive enough to indicate whether one or the other of the two best demonstrated control technologies (open hood/ESP or venturi scrubber or closed hood/venturi scrubber) is clearly superior. Both control technologies have demonstrated emission control capabilities consistent with the NSPS allowable particulate emission level.

5.0 INDICATIONS FROM TEST RESULTS

5.1 Test Coverage in the EPA Regions

The MITRE Corporation conducted a survey of all 10 EPA regions to gather all available NSPS compliance test data generated since the promulgation of the respective NSPS for each of the 10 categories under study (MITRE Corporation, 1978). No NSPS compliance test data were found for the BOPF category. Since the NSPS was proposed for the BOPF segment of the iron and steel industry, only one basic oxygen furnace has been announced, built, and tested for compliance--that owned by Republic Steel Corporation of Chicago. In this case, however, compliance testing was done for the Illinois EPA to obtain an operating permit for the unit (Kortge, 1977). The test procedure did not meet with the sampling time requirements of 40 CFR 60, Subpart N, i.e., total sampling cycle for primary particulate emissions was approximately 40 minutes (60 minutes is the required time interval). The applicable state emission limit applies to total process particulate emissions (including some secondary emissions) and is approximately four times the allowable NSPS mass emission rate.

5.2 Analysis of Test Results

The results of a number of particulate emission tests on BOPFs are available including test results for the five BOPFs tested in 1971 and 1972, which formed a portion of the rationale for the NSPS. Table 5-1 summarizes these results and Figure 5-1 displays these data.

The original test data for the NSPS included three open hood controlled BOPFs and two closed hood controlled BOPFs. The additional

TABLE 5-1

BOPF PARTICULATE EMISSIONS TEST DATA

Facility	Nominal BOPF Capacity Mg(tons)	Particulate Collection Hood Design	Method of Oxygen Blowing	Test Date	Particulate Removal Method	Test Method	Average Primary Stack Emissions Mg/Nm^3 (gr/dscf)	Reference
Bethlehem Steel Bethlehem, Pa.	200(220)	Open	Top	1972	ESP[a]	EPA 5	61(.027)	EPA, 1973
National Steel Wierton, W. Va.	295(325)	Open	Top	1971	VS[b]	EPA 5	57(.025)[e]	EPA, 1973
Alan Wood Steel Conshohocken, Pa.	127(140)	Open	Top	1971	ESP	EPA 5	15.9(.007)	EPA, 1973
Armco Steel Middletown, Ohio	182(200)	Closed	Top	1971	VS (45"Δp)[c]	EPA 5	27(.012)	EPA, 1973
U.S. Steel Lorain, Ohio	200(220)	Closed	Top	1971, 1972	VS (~55"Δp)	EPA 5	11(.005), 7(.003)[f]	EPA, 1973
Inland Steel E. Chicago, Ill.	191(210)	Closed	Top	1975	VS	EPA ?	18(.008)	McDowell, 1978
Bethlehem Steel Burns Harbor, Ill.	273(300)	Open	Top	1974	VS (55"Δp)	EPA 5[d]	50(.022)	McDowell, 1978
Kaiser Steel Fontana, Cal.	109(120)	Open	Top	1972	ESP	Unknown	14(.006)	McDowell, 1978
Interlake Steel Chicago, Ill.	73(80)	Open	Top	1975	ESP	Unknown	20(.009)	Interlake, 1975
U.S. Steel Fairfield, Ala.	205(225)	Closed	Bottom (Q-BOP)	1974	VS (57"Δp)	EPA 5	32(.014)	McDowell, 1978
Republic Steel Chicago, Ill.	228(250)	Closed	Bottom (Q-BOP)	1977	VS	EPA 5	50(.022)	Kortge, 1977

[a] Electrostatic Precipitator

[b] Venturi scrubber

[c] Venturi scrubber pressure drop, inches of water

[d] Industrial Gas Cleaning Institute (IGCI) method extrapolated to EPA Method 5

[e] Estimated by EPA from an EPA Method 5 total average particulate catch of 84 Mg/Nm^3 (.037 gr/dscf)

[f] Retest

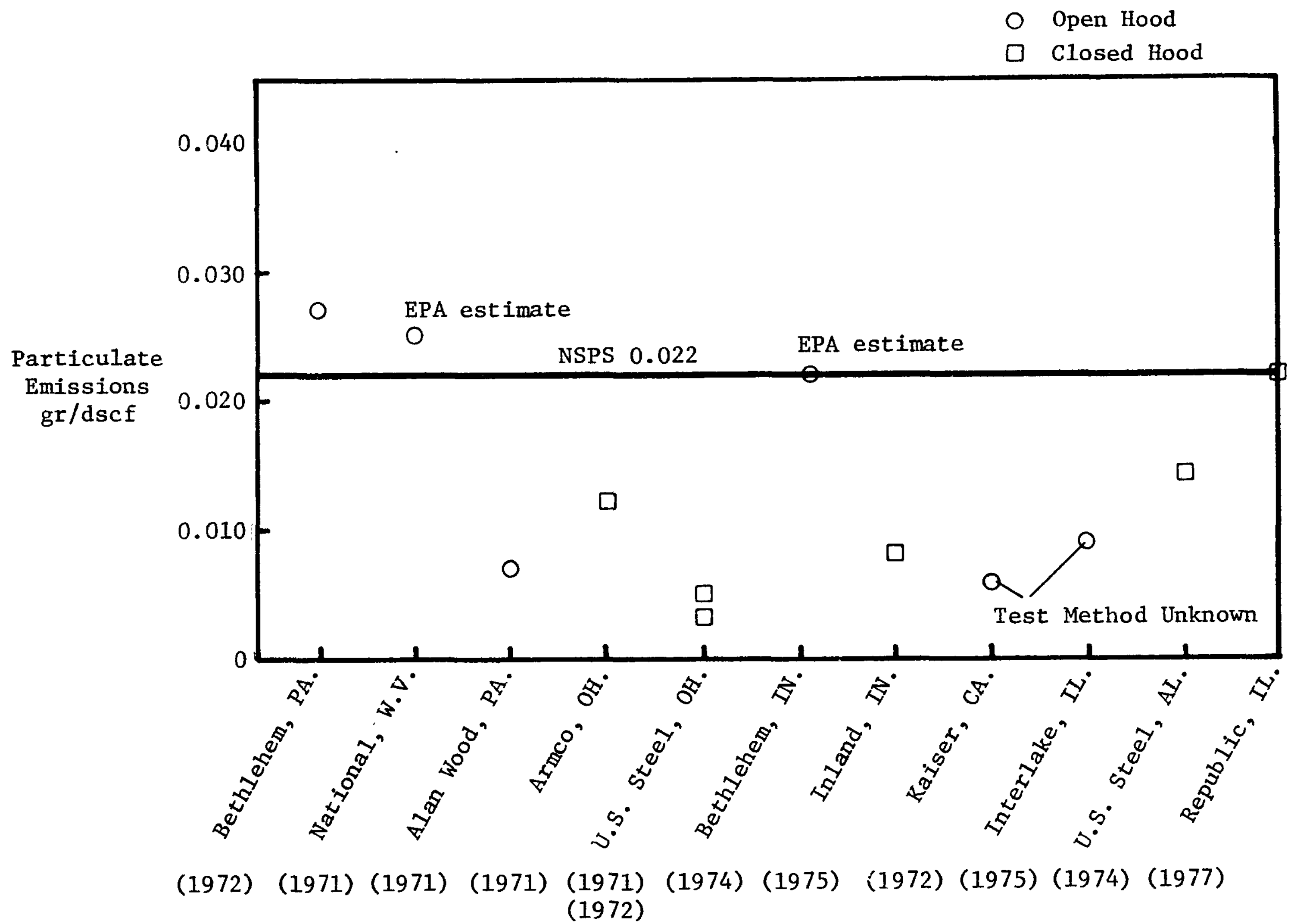


FIGURE 5-1
BOPF EMISSION TEST DATA

data include three closed hood controlled BOPFs and three open hood controlled BOPFs. The available test data, therefore, encompass a total of six open hood and five closed hood control units. Based on an evaluation of these data, there is no discernible trend insofar as the improvement of efficiency of particulate removal by the best demonstrated control technology (as compared with the original NSPS test data). Although data are insufficient to draw a definite conclusion, it appears that closed hood technology may provide a better emission control capability.

While the recent emissions data presented in this report are not the result of NSPS compliance testing, some of the data were developed through the use of EPA Method 5 (a requirement for NSPS testing). Based on this limited information, control technology capable of meeting the standard is clearly available to the industry.

5.3 Indications of the Need for a Revised Standard

At this time, there is not sufficient justification for revision of the present NSPS, based on the following considerations:

1. The best demonstrated control technology is being used in all new BOPFs.
2. There is a lack of NSPS compliance test data.
3. The limited amount of particulate emissions test data available do not show a conclusive trend that would warrant consideration of an adjustment to the standard.

Economic factors, which also play a key role in the decision not to revise the NSPS at this time, are discussed in Section 6.1.

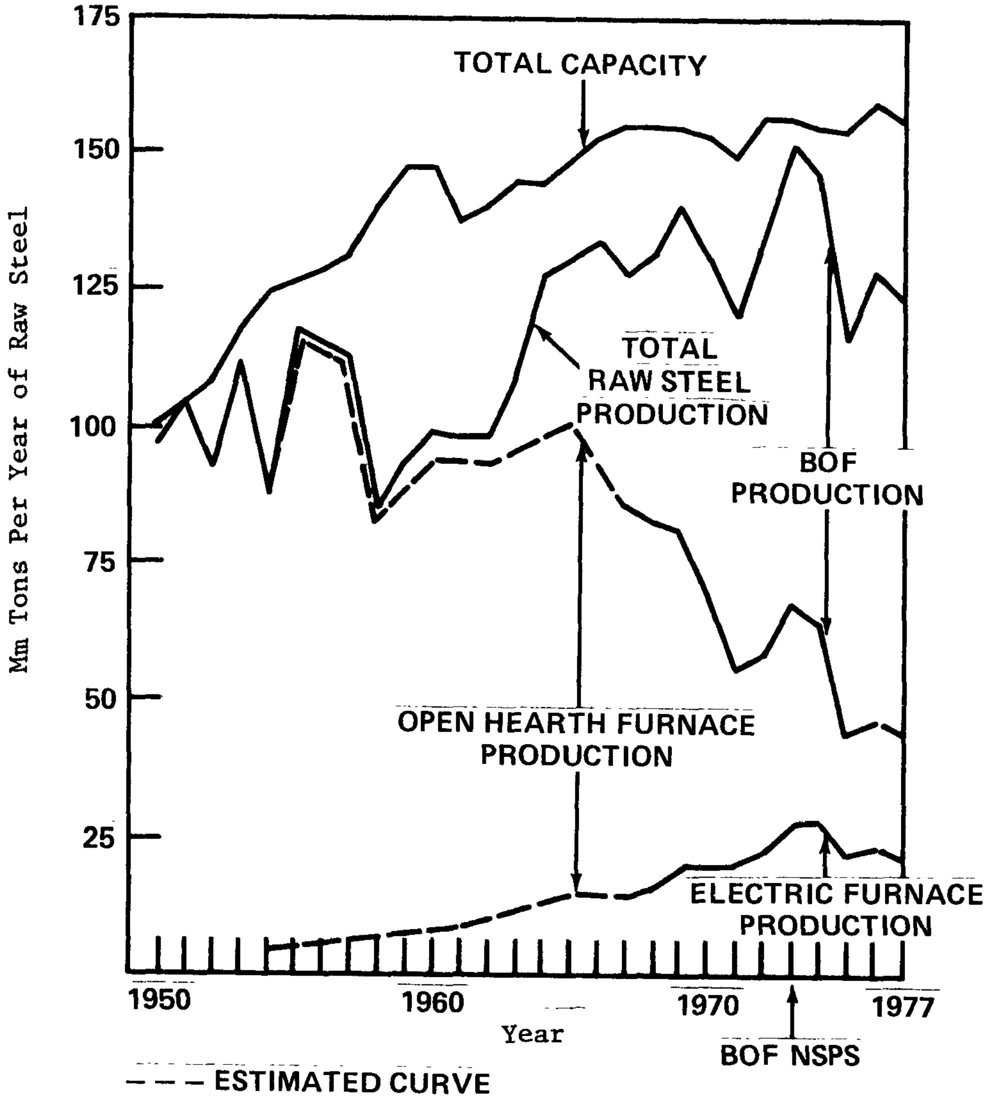
6.0 ANALYSIS OF THE IMPACTS OF OTHER ISSUES ON NSPS

6.1 Industry Economics and the Prospects of New BOPF Construction

Lead time for construction of new BOPFs ranges from 3 to 5 years, depending on whether the new units are added to existing steelmaking facilities or whether they are part of a greenfield plant. Since construction of new BOPFs requires large capital investment, it is important to consider the current overall economic and production conditions within the domestic and world steel industry to ascertain the probability of future new BOPF installations.

Figure 6-1 describes the trends in domestic raw steel production by type of process as well as the overall production and utilization rate since 1950. From Figure 6-1 it is apparent that since 1965, U.S. raw steel production has been subject to increasingly larger oscillations, reflecting the fluctuating U.S. and world economies.

Last year, production was at the same level as it was in 1965, although overall steelmaking capacity had increased slightly. Since the current BOPF NSPS went into effect in 1973, unused capacity has increased. Thus, schedules for the introduction of new BOPF facilities in the U.S. have been cancelled or postponed. In fact, as of the end of 1977 only one BOPF facility subject to NSPS regulation has come on stream (Republic Steel, South Chicago, Illinois). In 1978, Bethlehem Steel (Burns Harbor, Indiana), Kaiser Steel (Fontana, California), and U.S. Steel (Fairfield, Alabama) will have a total of four BOPFs coming on line which will be subject to NSPS testing. Three of



SOURCES: U.S. House of Representatives, 1977a.
U.S. House of Representatives, 1977b.
Iron and Steel Engineer, 1978.
EPA, 1978.

FIGURE 6-1
RAW STEEL PRODUCTION, CAPACITY, AND PROCESS TRENDS

these units had been scheduled to start up in 1974. Several planned BOPFs have been either delayed or cancelled, including a Bethlehem Steel BOPF facility in Johnstown, Pennsylvania, a Jones & Laughlin facility in Pittsburgh, a National Steel facility in Portage, Indiana, and a Youngstown Sheet and Tube Company facility in Campbell, Ohio. The total capacity of these plants would have added approximately 9 million Mg/year (10 million tons/year) in BOPF capacity in 1979 if they had been built (EPA, 1977). Furthermore, during 1977 Bethlehem Steel reduced its overall steelmaking capability by 10 percent (2.3 million Mg/year) through the shutting down of facilities at Johnstown, Pennsylvania and Lackawanna, New York. The Alan Wood Steel Company BOPF facility has closed down permanently. It had a capacity of 1.0 million Mg/year (U.S. House of Representatives, 1977).

Several companies, besides those described above, appear to be actively considering construction or modification of BOPF facilities. These include a complete greenfield facility for U.S. Steel at Conneaut, Ohio, for which a draft environmental impact statement was recently published (Corps of Engineers, 1978). The total of all the proposed construction mentioned above would result in an approximate increase of 18 percent in raw steel capacity by 1985 and 15 new BOPFs. Construction of these BOPFs would not be expected to commence before early 1980 even if improved economic conditions prevail (Bloom, 1978). However, it is unknown whether construction of some of these units will be further delayed or cancelled.

In September, 1977 the U.S. House of Representatives held hearings on the current trends and problems associated with the domestic and world steel industries (U.S. House of Representatives, 1977). The current economic problems of the U.S. and world industry were described as follows:

> ...slow growth in the world economy and consequent depressed demand, excess capacity, unemployment and low profits and prospects on the immediate future are for more of the same.... (U.S. House of Representatives, 1977)

Worldwide excess capacity has affected the U.S. steel industry through highly competitive pricing of foreign imports which have reached 18 percent of total domestic consumption during the first quarter of 1978 (Wall Street Journal, 1978). As an outgrowth of the hearings the Department of the Treasury established a set of "trigger prices" for imported steel products. The trigger prices would establish minimum price levels for imported steel products below which an antidumping action would be implemented if necessary. The effect, if any, of the trigger price on the production of U.S. steel will be felt beginning with the second quarter of 1978 (42 FR 65214, 1977; 43 FR 1463, 1978).

In comparative analyses of the Japanese and American steel industries conducted for setting the trigger prices, a significant lag in processing efficiency of U.S. steel plants as compared with Japanese plants was noted with respect to conversion of raw steel to finished products (43 FR 1463, 1978). It is likely that future expansion of capacity by the U.S. industry will emphasize modernization of the processing of raw steel similar to its prior emphasis on open hearth conversion to BOPF in the 1965-1975 period. In its forecast of future capital expenditures, Iron and Steel Engineering (January, 1978) confirmed this trend of no new BOPF construction and increased emphasis on finishing modernization.

In summary, the world economic climate and the status of current domestic raw steel production resources indicate that little, if any, expansion of U.S. BOPF capacity will take place over the next few years. The uncertainty of new BOPF construction minimizes the necessity of NSPS revision at this time. However, EPA can review the NSPS at any time, i.e., before the next mandatory review in 1982, should circumstances dictate.

6.2 Control of Fugitive Emissions

6.2.1 Overview

Inasmuch as the primary emissions from the BOPFs appear to be adequately controlled, collection of secondary (fugitive) emissions has now become the major particulate control problem for this source category. The problem arises from the difficulty of efficiently collecting significant amounts of fumes generated during several distinct operational phases of the basic oxygen steel production cycle both from top-blown BOPFs, i.e., charging and tapping, and bottom-blown BOPFs (Q-BOPs), i.e., charging, turndown and tapping. Once these fumes escape from the source into the building, they are almost impossible to control and create a visible emission that leaves the

BOPF building via the roof monitor. Possible major sources of fugitive emissions within the BOPF building include: (1) the operating furnace (puffing during oxygen blow), (2) charging mechanisms for lime and other process (flux) additives, (3) scrap charging, (4) hot metal charging, (5) slagging and (6) tapping. These emissions contain lead and zinc oxides and hydrocarbons depending on the nature of the scrap used.

In the following sections, data are presented on the characterization of the BOPF fugitive emissions (including data on amounts and composition) and the state-of-the-art with respect to fugitive emission control technology. This is followed by a discussion of the problems entailed in developing a standard for the regulation of fugitive emissions.

6.2.2 Characterization of Fugitive Emissions

A significant quantity of fugitive emissions is generated during turndown of the BOPF and during charging of hot metal into the furnace already holding a charge of scrap. During charging of scrap and hot metal to the vessel prior to the oxygen blowing operation, the vessel must be tilted out from beneath the hood system (generally 25° to 30° from the vertical) to provide access to the charging mechanisms. Emissions generated during this charging period are not captured effectively by the main hood system (Figure 6-2).

Several studies have attempted to determine amounts and composition of fugitive emissions leaving the BOPF. Results of these studies are tabulated in Tables 6-1 and 6-2, respectively.

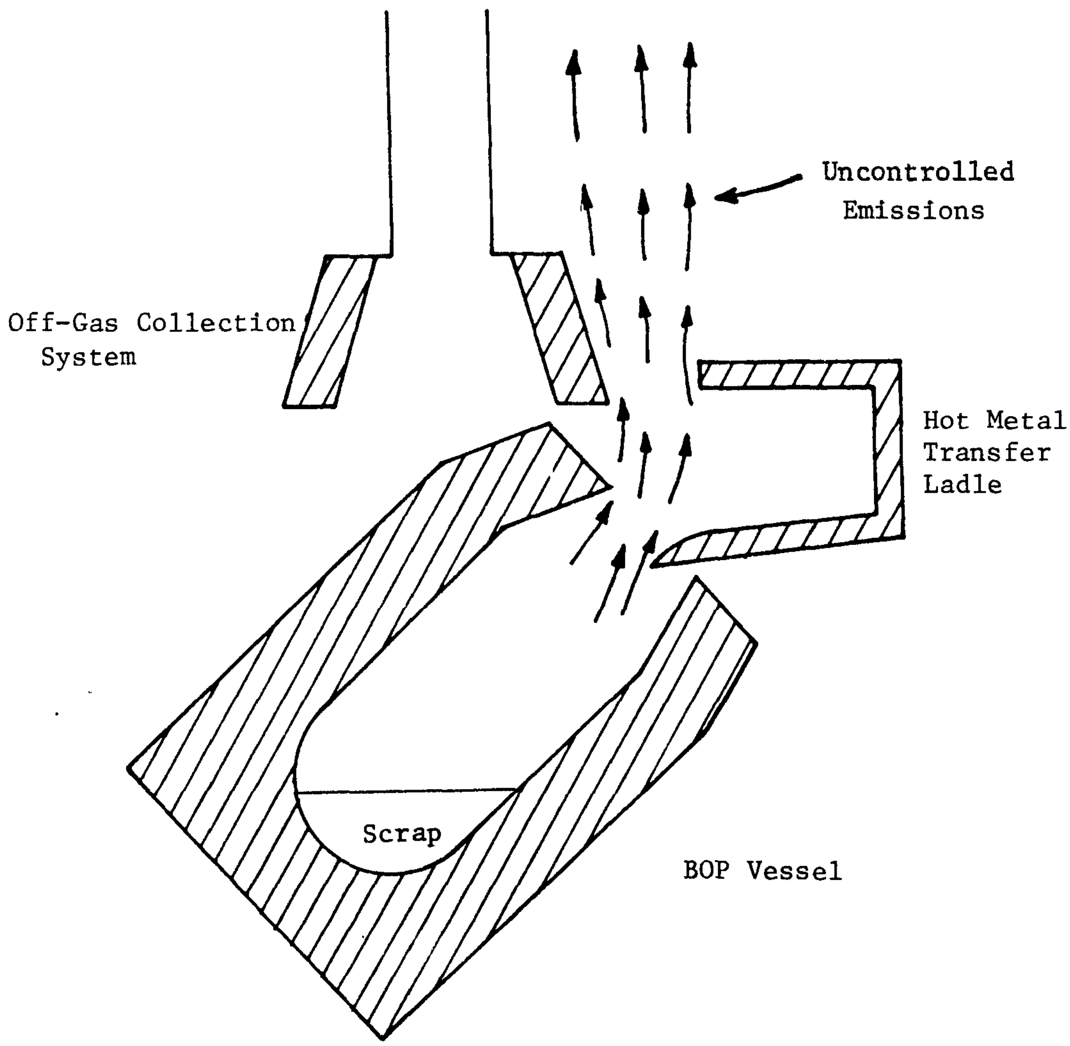


FIGURE 6-2
BOPF GENERATION OF CHARGING EMISSIONS

TABLE 6-1

AMOUNT OF FUGITIVE EMISSIONS FROM BOPFS

Facility	Nominal BOPF Size Mg(ST))	Average Production Rate[b] Mg/day(ST/day)	Total Fugitive Emission Rate Kg/day(lb/day)	Total Fugitive Emission Rate Kg/Mg charged (lb/ton produced)	Fugitive Emissions Capture Rate Kg/day/lb/day	Fugitive Emissions Capture Efficiency (percent)	Reference
U.S. Steel Fairfield, Ala.	205(225)[a]	5870(5600)	1454(3200)[c]	0.28(0.57)	465(1024)[m]	32	Gibbs, 1978
Republic Steel Chicago, Ill.	228(250)[a]	6990(7680)	Unknown	Unknown	121(266)	Unknown	Kortge, 1977
Interlake Inc. Chicago, Ill.	73(80)	2180(2400)	366(806)[d]	0.17(0.34)	None	None	Interlake, 1975
Colorado Fuel & Iron Pueblo, Colorado	109(120)	2620(2880)	1538(3400)[e]	0.43(0.86)	Unknown	Unknown	Seton et al., 1976
			215(474)[f]	0.06(0.12)	Unknown	Unknown	Seton et al., 1976
National Steel Wierton, W.Va.	325(360)	11,270(12,380)	4075(9000)[g]	0.34(0.68)	None	None	EPA, 1977
			2680(5900)[h]	0.23(0.45)	None	None	EPA, 1977
			10,730(23,600)[i]	0.80(1.79)	None	None	EPA, 1977
			9900(21,800)[j]	0.83(1.65)	None	None	EPA, 1977
Nippon Steel Oita, Japan	340(374)	14,360(15,785)	18,600(41,000)[k]	1.3(2.6)	18,500(40,600)[n]	99	McCutchen, 1977
Japanese BOPF Practice				0.2-0.3(0.4-0.6)[l]			Nicola, 1976

[a] Q-BOP process

[b] Based on a 24 hour day and the appropriate cycle time for each plant.

[c] Amount measured at the roof monitor plus capture by fugitive emission hood-baghouse system. These were measured only during the hot metal charging period and do not include emissions from tapping, slagging or turn-down periods.

[d] Amount measured at the roof monitor.

[e] Not including a limited amount of fugitive emissions captured by an auxiliary hood.

[f] Hot metal charging emissions only measured at the roof monitor (total based on 45 minute cycle, 2 minute hot metal pouring time).

[g] Hot metal charging emissions only based on 45 second average pour time; clean scrap used.

[h] Hot metal charging emissions only based on 45 second average pour time; galvanized scrap used.

[i] Hot metal charging emissions only based on 45 second average pour time; oily scrap used.

[j] Hot metal charging emissions only based on 45 second average pour time; No. 2 scrap (principally galvanized sheet) used.

[k] Design basis of fugitive emission collection system.

[l] This range of values given for hot metal pour cycle fugitive emissions only.

[m] As of April 1975, this system has been subsequently modified to improve fugitive emissions capture efficiency.

[n] Design basis of fugitive emissions hood and baghouse system.

TABLE 6-2

COMPOSITION OF FUGITIVE EMISSIONS FROM BOPFS

Facility	Source of Fugitive Emissions	Fe	FeO	Fe_2O_3	CaO	MgO	SiO_2	PbO	ZnO	MnO	C	Cd	Benzene Soluble Organics	Reference
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			EPA, 1977
	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			EPA, 1977
	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)	EPA, 1977
	d) No. 2 Bundles in Initial Charge (large % of galvanized sheet scrap)	3.8	17.6	10.5	1.7	0.5	2.8	1.8	12.0	0.6	41.5			EPA, 1977
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	Love, 1976
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		Love, 1976

[a]Gaseous methane averaged 61 ppm.

Inspection of these two tables permits several conclusions:

1. The quantity of fugitive charging emissions appears to average approximately 0.25 kg/Mg (0.5 lb/ton) of BOPF charge, except in the case of "dirty" scrap in which a significant increase in the amount of charging emissions occurs. There are no definitive U.S. data available on the total fugitive emissions from the BOPF. The total fugitive emissions given for one Japanese BOPF cited is based on the design emission collection rate for the secondary hood collection system and is probably a highly conservative value. Incidentally, the Japanese BOPFs have been operating with 90 to 100 percent charging of hot metal in combination with 10 to 0 percent in-house scrap as compared with the typical 30 percent scrap, 70 percent hot metal charge used in the U.S. As a result, the composition of fugitive emissions from Japanese and U.S. BOPF operations differs substantially. Particulate matter collected from Japanese BOPF operations can be recycled; particulate matter from the U.S. operations is presently disposed of due to the high zinc content.*

2. The percent of zinc oxide in fugitive charging emissions increases significantly when "dirtier" grades of scrap are used. There is a limit on the amount of high quality scrap available, and the usage of lower quality scrap containing impurities which result in additional charging emissions will increase as the world market for steel increases. The need for effective secondary emission control will, therefore, become more imperative during the next 5 to 10 years.

3. The data available with which to judge the effectiveness of control of fugitive emissions by existing secondary control systems are meager at present. Further studies are needed in this area to fully evaluate the collection efficiencies of various control configurations.

4. Composition of fugitive emissions is quite variable, but this material appears to be predominantly carbon and oxides of iron with lesser amounts of calcium oxide, silicon dioxide, zinc oxide and lead oxide. Oily scrap in the initial BOPF

*Processes to recycle particulate matter from BOPF emission collection operations after separation of the zinc values, are available (Georgieff, 1978). However, the steel industry does not consider processing of high zinc-bearing waste particulate economically feasible at this time (Jackson, 1978).

charge will lead to the presence of significant hydrocarbon levels in the fugitive emissions.

Limited data from one study indicate that the average median diameter of charging emissions determined from several tests is 2 to 3 microns, independent of the type of scrap used in the initial charge (EPA, 1977). In another study, particle size range analyses were made on fugitive emissions leaving the building monitor, as well as on particulate matter collected in the secondary emission collection baghouse hopper. These results are shown in Table 6-3.

TABLE 6-3

FUGITIVE EMISSION PARTICLE SIZE ANALYSIS

Building Monitor Particulate		Baghouse Hopper Particulate	
(Percent)	(Microns)	(Percent)	(Microns)
5 - 50	<0.5	3.6	0.70
30 - 70	<1	13.7	0.70 - 1.41
80 - 99	<5	30.3	1.41 - 2.82
<14	>10	19.6	2.82 - 4.23
		12.5	4.23 - 5.64
		7.1	5.64 - 7.05
		3.8	7.05 - 8.45
		3.3	8.45 - 9.87
		3.7	9.87 - 14.1
		2.3	15.5
		Largest Particle - 16.9 microns	

Source: Love, 1976.

As evidenced by the particle size analysis, the test results indicate that 80 to 90 percent of the particulate material escaping from the building roof monitor and collected by the existing baghouse system is estimated to be in the range of 5 to 10 microns in diameter and/or respirable in nature.

6.2.3 Fugitive Emissions Control Technology

A literature survey has been conducted to develop information on charging emissions control technology on both new and existing BOPFs (EPA, 1977). Of the eight U.S. BOPF fugitive emission control systems described in the literature, seven employ auxiliary hoods located near the charging area, tied into the main process emissions cleaning system, i.e., connected into the main hood exhaust system upstream of the EPS or venturi particulate removal device. The effectiveness of these systems depends largely on the available fan capacity of the main hood system (since much larger volumes of the emission-laden BOPF room air are required to be removed as compared with the primary emissions system), and the location of auxiliary hoods with respect to the points of discharge of the charging, reladling and tapping fugitive emissions. The eighth system described in the literature features the use of the Gaw patented damper. In this system, the main hood is partially blocked by a sliding damper which increases the velocity in the charging emission area, thereby increasing the effectiveness of the primary hood system. The Gaw system is currently being evaluated at one BOPF installation. Figures 6-3 and 6-4 illustrate the auxiliary hood and Gaw damper concepts, respectively.

Little or no data were reported in the literature on the success of auxiliary hood systems in recovery of fugitive emissions from the BOPF. This, coupled with the wide diversity of hood configurations

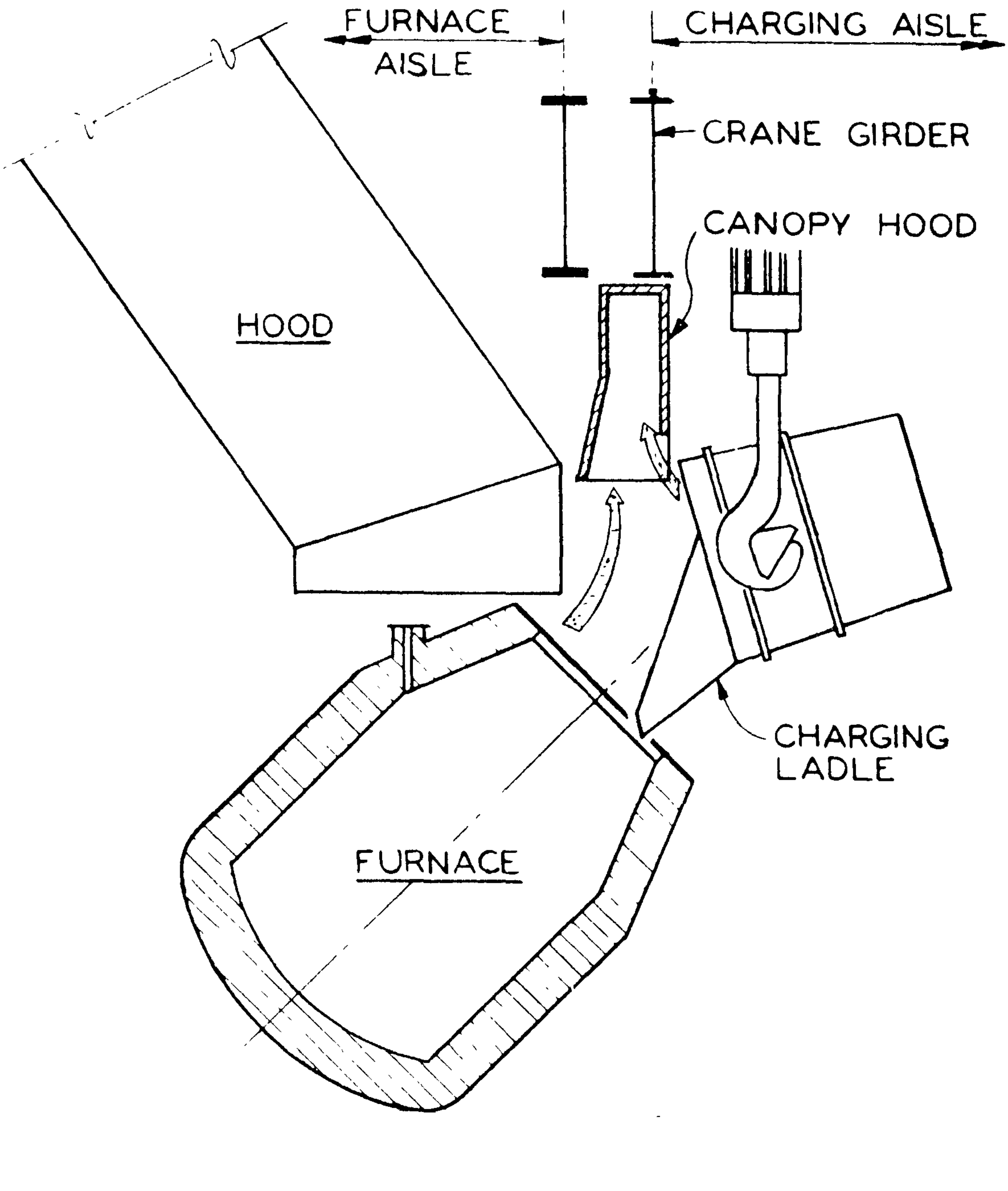


FIGURE 6-3
AUXILIARY HOOD CONCEPT

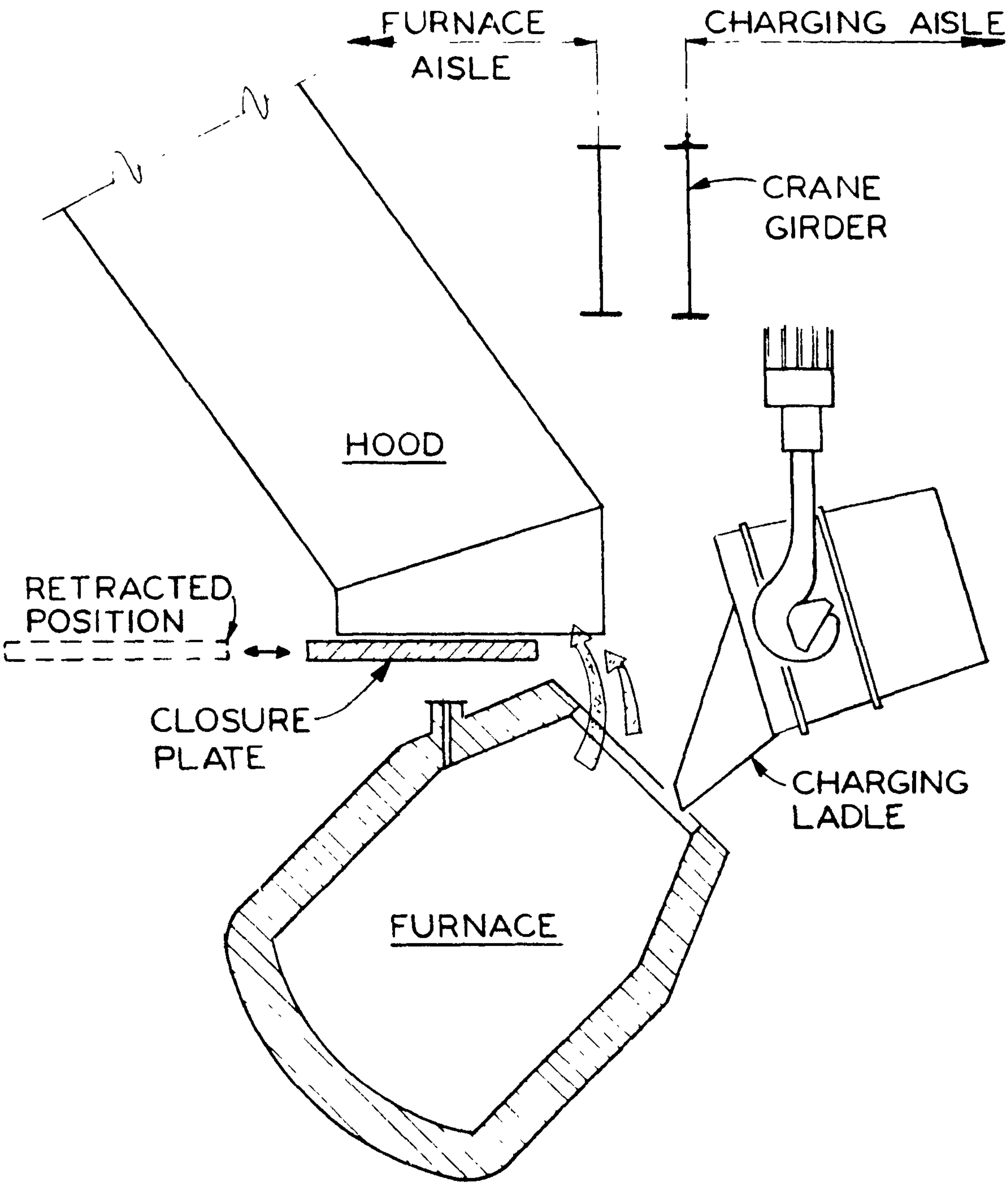


FIGURE 6-4
CLOSURE PLATE CONCEPT

reported, prevented a definitive conclusion about the utility of auxiliary hoods for fugitive emissions capture.

Application of the auxiliary hood, e.g., canopy hood concept to an existing (retrofit) or new BOPF installation for charging emissions control will require accurate prediction of fume volumes and velocities for a variety of hot metal charging operations. Since these conditions are not completely predictable, the design of canopy hood systems to capture charging emissions from BOPF furnaces would be difficult. Available data indicate that the emission volume rate required divided by the vessel tonnage should be in the range of 33 to 81 m^3/min/Mg (1,100 to 2,600 cfm per ton) (EPA, 1977). It is apparent from the over twofold variation of this number, that design of canopy hood systems at this time is highly empirical, and a large margin of safety in hood design is required to assure achievement of design control level. The application of a canopy hood requires consideration of the type of air pollution control system and fan capacity needed, and dimensional restrictions and operating clearances unique to individual shops. Due to the distance of these hoods from the emission source, consideration must also be given to the adverse effects of cross drafts in the shop which affect collection efficiency. Major advantages of the canopy hood concept are that it involves minimum constraints and changes to operating practices, and that auxiliary mechanical or electrical devices are not required in the immediate vicinity of the furnace.

Collection of BOPF fugitive emissions by means of a total furnace enclosure appears to offer a comprehensive solution to this problem, since it allows collection of emissions at the source and prevents their escape into the atmosphere. With properly designed total furnace enclosures, it should be possible to effectively control scrap charging, hot metal charging, furnace tapping, ladle alloy additions, furnace slagging, and puffing emissions with relatively low exhaust volumes.

Figure 6-5 shows a typical schematic arrangement and design of a BOPF enclosure in which the enclosure essentially forms a gas-tight seal when the biparting doors are closed. Since the furnace enclosure extends below the charging floor, the only openings are for the ladle car. However, these openings can be effectively reduced by the addition of a vertical shield on the end of the ladle car, which will also increase the efficiency of the furnace enclosure.

Enclosures of this type were initially developed to control emissions from the Q-BOP process. However, the original enclosure designs have been modified to effectively collect the charging, tapping and slagging emissions generated during the oxygen steelmaking process, in addition to puffing emissions during the oxygen blowing period (Nicola, 1976).

Present furnace designs incorporate a secondary hood inside the furnace enclosure with sufficient volume for efficient charging emission control. At present, systems of this type are effectively

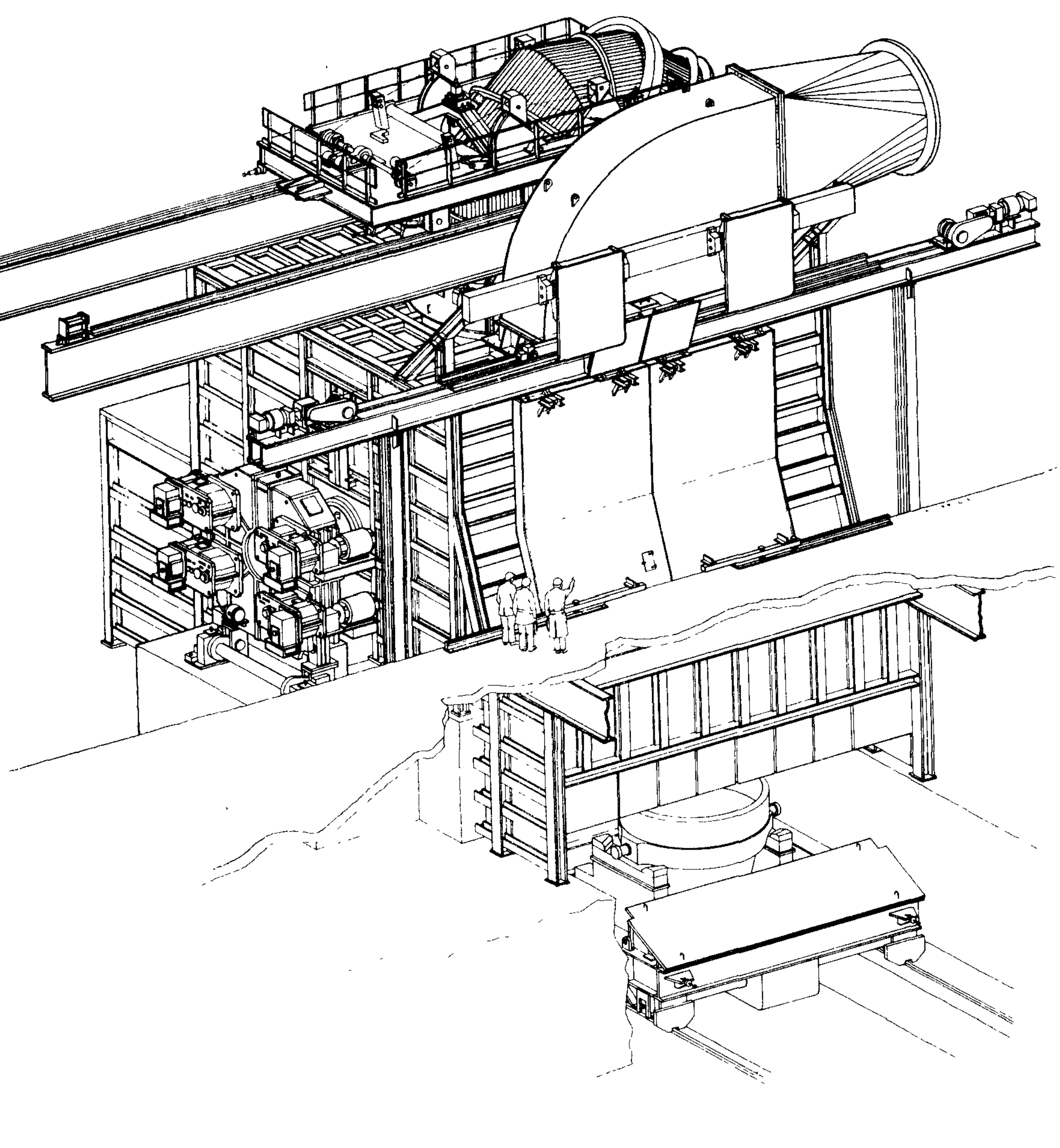


FIGURE 6-5
FURNACE ENCLOSURE FOR A 200-TON Q-BOP
(REPUBLIC STEEL CORPORATION
SO. CHICAGO, ILLINOIS)

controlling fugitive emissions with exhaust volumes of approximately 350,000 acfm (Nicola, 1976).

For controlling emissions during the blow and tapping periods, the biparting doors are closed, forming an essentially gas-tight seal while the fumes are evacuated from the enclosure through the main or secondary hood. During charging, the biparting doors are opened while charging scrap or pouring hot metal and the fumes are collected through the secondary hood located inside the enclosure directly above the furnace mouth (Nicola, 1976).

With a properly designed furnace enclosure (including appropriate secondary hoods), it is possible to collect secondary emissions from the basic oxygen process with approximately 90 percent efficiency, provided the charging of the hot metal into the furnace is done at a controlled rate and the scrap is relatively clean (Nicola, 1976).

Seven new BOPF vessels that have been installed in the U.S. in the past 7 years have incorporated a partial or full furnace enclosure for collection of fugitive emissions as part of the original particulate emission control system. Since the early furnace enclosure designs had many deficiencies, these systems are operating today with varying degrees of success. Six new furnace enclosure installations (due to commence operations in 1978) including four on new BOPFs and two retrofit installations will incorporate a secondary hood inside the furnace enclosure with sufficient volume for fugitive emission control. These systems should be capable of effectively collecting the oxygen steelmaking fugitive emissions under controlled conditions. Table 6-4 lists the recent known BOPF furnace enclosure installations.

6.2.4 Regulation of Fugitive Emissions

Fugitive emissions, e.g., emissions not captured by the BOPF primary emissions control system, can be generated in significant amounts during various BOPF ancillary operations. During the hot metal charging portion of the BOPF production cycle, fugitive emissions can amount to 0.25 Kg/Mg (0.5 lb/ton) of charge while total fugitive emissions may amount to 0.5 to 0.75 Kg/Mg, (1-1.5 lb/ton). Therefore, a NSPS should be considered for control of these emissions.

Regulation of fugitive emissions is presently minimal, i.e., insofar as is known there are no specific Federal or state BOPF fugitive emission control regulations. However, Section 173 of the Clean Air Act requires, among other things, that a new or modified source constructed in an area in violation of the National Ambient Air Quality Standards (NAAQS), e.g., in a non-attainment area, must reduce emissions to the level which reflects the "lowest achievable emission rate" (LAER) for such category of source as defined in Section 171(3). When a source is constructed in an attainment area, the source becomes subject to the "prevention of significant deterioration" (PSD) air quality provisions of the act (Part C). An example of these requirements being applied to a new BOPF in a non-attainment situation is the U.S. Steel Q-BOP at the Fairfield, Alabama plant. This BOPF has had a fugitive emission standard applied of 0.01 gr/dscf. This

TABLE 6-4

U.S. BOPF INSTALLATIONS WITH FURNACE ENCLOSURES FOR FUGITIVE EMISSIONS CONTROL[a]

Facility	No. of Units Enclosed	BOPF Nominal Size Mg(tons)	Type of Furnace Enclosure	Year of Furnace Enclosure Installation	Effectiveness of Fugitive Emissions Capture	Remarks
Inland Steel E. Chicago, Ill.	2	190(210)	Partial	1975	Fair	Tapping emissions capture remains a problem.
U.S. Steel Gary, Ind.	3	180(200)	Complete	1971	Fair	No secondary hood available for charging emissions capture.
U.S. Steel Fairfield, Ala.	2	180(200)	Complete	1973	Fair	Secondary hood for charging emissions installed outside of furnace enclosure .
U.S. Steel Fairfield, Ala.	1	180(200)	Complete	1978	Not yet operating	EPA consent decree requires installation of secondary charging emissions hood inside furnace enclosure tied to a 200,000 CFM baghouse system.
Republic Steel Chicago, Ill.	2	180(200)	Complete	1977	Good charging emissions. Poor-tapping emissions[b]	Secondary charging emissions collection hood installed inside furnace enclosure tied to primary exhaust system.
Bethlehem Steel Burns Harbor, Ind.	1	270(300)	Complete	1978	Started operations Spring, 1978	Secondary charging emissions collection hood installed inside furnace enclosure tied to primary exhaust system.
Kaiser Steel Fontana, Cal.	2	205(225)	Complete	1978	Starting operations Fall, 1978	All fugitive emissions processed through a 600,000 CFM baghouse system. Secondary charging emissions collection hood installed inside furnace enclosure.
Colorado Fuel & Iron Pueblo, Col.	2	110(120)	Complete	1978	Starting operations Fall, 1978	Retrofit system; vendor claims that there has been no interruption of steel production from the BOPF during installation of furnace enclosure.

[a]Nicola, 1978, unless otherwise indicated.

[b]Miller, 1978.

standard resulted from a March 31, 1978 consent decree and does not become effective until system revisions and performance testing are complete. U.S. Steel has until August 31, 1980 to achieve compliance (United States District Court, 1978).

Several engineering/economic areas should be further researched before a fugitive standard is promulgated. For instance, because the NSPS can apply to a new BOPF vessel in an existing location, variations in space and operating constraints may require many different control techniques to meet a common standard, with a resultant wide spread in capture efficiencies and control costs. To date, experimentation with fugitive emission control techniques that, in existing locations, require a minimum of space and new equipment have not yielded satisfactory emission control and/or have had unreliable performance.

When an entirely new BOPF shop is to be built, it appears that complete furnace enclosures with modern seals and separate venting and removal equipment (e.g., baghouses) may provide good control of fugitive emissions. A minimal amount of emissions information is available on the effectiveness of this approach to fugitive emissions control. Several locations starting up in 1978 will incorporate complete furnace enclosures for fugitive emissions control as an integrated part of the BOPF facility and should supply information for quantification of an emissions level.

A fugitive emissions standard would also require an applicable measurement technique if based on a quantitative grain loading. An EPA method that normalizes fugitive emissions would be required to ensure a fair system of measurement due to the many different physical variations in facilities and the dispersed nature of the emissions. A standard based on emissions levels from a control device should also incorporate a capture efficiency measurement. For example, a baghouse system should operate with a very low emissions rate. However, if the majority of the fugitive emissions escape the collecting hood leading to the baghouse system, such a standard would be ineffective in its intent to control these emissions.

It is recommended that a fugitive emissions standard not be considered during this review period, based on the following: (1) there appears to be a lull in new BOPF construction due to the financial status of the steel industry and the almost completed conversion from aging open hearths to BOPFs, (2) further research and development is required on fugitive emission measurement techniques; and (3) information on relative costs versus control effectiveness is required (this should be forthcoming within the next 1 to 2 years). However, as data are developed EPA should reexamine the promulgation of such a standard earlier than the required 4-year NSPS review period. In the interim, EPA should monitor the effectiveness of new plant controls and further research measurement and control techniques applicable to fugitive emissions from new BOPFs.

7.0 FINDINGS AND RECOMMENDATIONS

The primary objective of this report has been to assess the need for revision of the existing BOPF NSPS including the possible need to develop a standard applicable to BOPF fugitive emissions. The findings and recommendations developed in these two areas are presented below.

7.1 Findings

7.1.1 Economic Considerations

- The large conversion from open hearth furnaces to BOPF occurred during the 1960 to 1970 period.
- The present economic conditions in the U.S. and worldwide steel industry have created a significant excess U.S. raw steel capacity and a tightening of the availability of capital for future expansion.
- Since the promulgation of the BOPF NSPS, there has been a significant slowdown in new BOPF construction due to the economic condition of the industry. Three of the four units scheduled for startup in 1978 had been planned to begin production in 1974.
- No new BOPF construction activity is expected before early 1980. Even this date is subject to slippage if economic conditions in the steel industry do not improve significantly.

7.1.2 Process Emission Control Technology

- Since the promulgation of the NSPS for the BOPF, no NSPS compliance tests have been performed on BOPFs.
- The best demonstrated control technologies described in the NSPS background document have not changed in the last 4 years.
- Limited emissions test data available from recent BOPF installations show particulate emission levels between 32 mg/dscm (0.014 gr/dscf) and 50 mg/dscm (0.022 gr/dscf).

- Emission levels lie in the same range as the data used as part of the rationale for the original NSPS of 50 mg/dscm (0.022 gr/dscf).

7.1.3 Fugitive Emission Control Technology

- Fugitive emissions from BOPFs are primarily generated from three distinct operational phases of the basic oxygen steel production cycle: charging, turndown and tapping.

- The largest amounts of fugitive emissions occur during the hot metal charging portion of the BOPF production cycle.

- The total quantity of fugitive emissions appears to range from 0.5 to 1 kg/Mg BOPF charge (1 to 2 lb/ton), depending on the degree of contamination of the metal scrap charge. Zinc and lead oxides and hydrocarbons can be present in significant levels in fugitive emissions when "dirty" grades of scrap are used.

- Design of hoods for collection of fugitive emissions from existing BOPFs has so far been highly site-specific. This is due to limitations on available space and exhaust capacity. Local hoods for collection of these emissions appear to have had only limited success to date.

- Fugitive emission control from the ancillary BOPF operations is still a developing technology and will require in-depth studies to determine and develop the most effective methods of fume capture.

- The complete furnace enclosure is the only currently demonstrated control technology exhibiting the potential for minimizing or eliminating fugitive emissions from a new BOPF.

7.1.4 Definitions

- Ce[illegible]in ambiguities exist in the definition of the affected fa[illegible]lity and in the testing requirement contained in 40 CFR 60 Subpart N.

7.2 Recommendations

7.2.1 Revision of the Standard

At this time, there is not sufficient justification for revision or inclusion of fugitive emissions under the present NSPS, based on the following considerations:

- The best demonstrated control technology for process emissions is being used on all new BOPFs.
- The limited amount of particulate emission test data available does not show a conclusive trend which would warrant consideration of an adjustment to the primary emission standard.
- There is as yet insufficient data with which to make a judgment as to the availability of a satisfactory method for quantitative measurement of fugitive emissions from a BOPF.
- Definitive data on a best demonstrated control technology for efficient fugitive emission capture from new BOPFs have not yet become available.
- The impact of any revised NSPS would be very small due to the low growth rate of the industry.

7.2.2 Research and Development

EPA should continue evaluation of fugitive emission controls for BOPFs with a view toward incorporating fugitive emissions under the scope of the standard at a later date. In addition, an EPA measurement standard technique must be devised to include capture efficiencies and normalization for various physical configurations and to specify averaging times.

7.2.3 Definitions

EPA should review and, as appropriate, revise or clarify certain definitions and testing requirements contained in 40 CFR 60, Subpart N.

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TECHNICAL REPORT DATA *(Please read Instructions on the reverse before completing)*		
1. REPORT NO. EPA - 450/3-78-116	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE A Review of Standards of Performance for New Stationary Sources-Iron and Steel Plants/Basic Oxygen Furnaces		5. REPORT DATE November 1978 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Marvin Drabkin and Richard Helfand		8. PERFORMING ORGANIZATION REPORT NO. MTR-7324
9. PERFORMING ORGANIZATION NAME AND ADDRESS Metrek Division of the MITRE Corporation 1820 Dolley Madison Boulevard Mc Lean, VA 22102		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. 68-02-2526
12. SPONSORING AGENCY NAME AND ADDRESS DAA for Air Quality Planning and Standards Office of Air, Noise, and Radiation U. S. Environmental Protection Agency Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE EPA 200/04
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

This report reviews the current Standards of Performance for New Stationary Sources: Subpart N - Iron and Steel Plants/Basic Oxygen Furnaces. It includes a summary of the current standards, the status of current applicable control technology, and the ability of plants to meet the current standards. No changes to the existing standard are recommended, but EPA will continue evaluation of fugitive emission controls for BOPFs with a view toward incorporating fugitive emissions under the scope of the standard at a later date.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Basic oxygen process oxygen blown converters steel making iron and steel industry performance standards regulations		13B
18. DISTRIBUTION STATEMENT Release Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 76
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

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