EPA/310-R-95-005

EPA Office of Compliance Sector Notebook Project

Profile of the Iron and Steel Industry

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Office of Compliance
Office of Enforcement and Compliance Assurance
U.S. Environmental Protection Agency
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Electronic versions of all Sector Notebooks are available on the EPA Enviroene Bulletin Board and via the Internet on the Enviroene World Wide Web. Downloading procedures are described in Appendix A of this document.

Contacts for Available Sector Notebooks

The Sector Notebooks were developed by the EPA Office of Compliance. Particular questions regarding the Sector Notebook Project in general can be directed to the EPA Work Assignment Managers:

Michael Barrette
US EPA Office of Compliance
401 M St., SW (2223-A)
Washington, DC 20460
(202) 564-7019

Gregory Waldrip
US EPA Office of Compliance
401 M St., SW (2223-A)
Washington, DC 20460
(202) 564-7024

Questions and comments regarding the individual documents can be directed to the appropriate specialists listed below.

Document Number	Industry	Contact	Phone (202)
EPA/310-R-95-001.	Dry Cleaning Industry	Joyce Chandler	564-7073
EPA/310-R-95-002.	Electronics and Computer Industry	Steve Hoover	564-7007
EPA/310-R-95-003.	Wood Furniture and Fixtures Industry	Bob Marshall	564-7021
EPA/310-R-95-004.	Inorganic Chemical Industry	Walter DeRieux	564-7067
EPA/310-R-95-005.	Iron and Steel Industry	Maria Malave	564-7027
EPA/310-R-95-006.	Lumber and Wood Products Industry	Seth Heminway	564-7017
EPA/310-R-95-007.	Fabricated Metal Products Industry	Greg Waldrip	564-7024
EPA/310-R-95-008.	Metal Mining Industry	Keith Brown	564-7124
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EPA/310-R-95-010.	Nonferrous Metals Industry	Jane Engert	564-5021
EPA/310-R-95-011.	Non-Fuel, Non-Metal Mining Ind.	Keith Brown	564-7124
EPA/310-R-95-012.	Organic Chemical Industry	Walter DeRieux	564-7067
EPA/310-R-95-013.	Petroleum Refining Industry	Tom Ripp	564-7003
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EPA/310-R-95-016.	Rubber and Plastic Industry	Maria Malave	564-7027
EPA/310-R-95-017.	Stone, Clay, Glass and Concrete Ind.	Scott Throwe	564-7013
EPA/310-R-95-018.	Transportation Equip. Cleaning Ind.	Virginia Lathrop	564-7057

Industry Sector Notebook Contents: Iron and Steel Industry

Exhibits Index

List of Acronyms

AFS -	AIRS Facility Subsystem (CAA database)
AIRS -	Aerometric Information Retrieval System (CAA database)
BIFs -	Boilers and Industrial Furnaces (RCRA)
BOD -	Biochemical Oxygen Demand
CAA -	Clean Air Act
CAAA -	Clean Air Act Amendments of 1990
CERCLA -	Comprehensive Environmental Response, Compensation and Liability Act
CERCLIS -	CERCLA Information System
CFCs -	Chlorofluorocarbons
CO -	Carbon Monoxide
COD -	Chemical Oxygen Demand
CSI -	Common Sense Initiative
CWA -	Clean Water Act
D&B -	Dun and Bradstreet Marketing Index
ELP -	Environmental Leadership Program
EPA -	United States Environmental Protection Agency
EPCRA -	Emergency Planning and Community Right-to-Know Act
FIFRA -	Federal Insecticide, Fungicide, and Rodenticide Act
FINDS -	Facility Indexing System
HAPs -	Hazardous Air Pollutants (CAA)
HSDB -	Hazardous Substances Data Bank
IDEA -	Integrated Data for Enforcement Analysis
LDR -	Land Disposal Restrictions (RCRA)
LEPCs -	Local Emergency Planning Committees
MACT -	Maximum Achievable Control Technology (CAA)
MCLGs -	Maximum Contaminant Level Goals
MCLs -	Maximum Contaminant Levels
MEK -	Methyl Ethyl Ketone
MSDSs -	Material Safety Data Sheets
NAAQS -	National Ambient Air Quality Standards (CAA)
NAFTA -	North American Free Trade Agreement
NCDB -	National Compliance Database (for TSCA, FIFRA, EPCRA)
NCP -	National Oil and Hazardous Substances Pollution Contingency Plan
NEIC -	National Enforcement Investigation Center
NESHAP -	National Emission Standards for Hazardous Air Pollutants
NO_2 -	Nitrogen Dioxide
NOV -	Notice of Violation
NO_X -	Nitrogen Oxide
NPDES -	National Pollution Discharge Elimination System (CWA)
NPL -	National Priorities List

NRC -	National Response Center
NSPS -	New Source Performance Standards (CAA)
OAR -	Office of Air and Radiation
OECA -	Office of Enforcement and Compliance Assurance
OPA -	Oil Pollution Act
OPPTS -	Office of Prevention, Pesticides, and Toxic Substances
OSHA -	Occupational Safety and Health Administration
OSW -	Office of Solid Waste
OSWER -	Office of Solid Waste and Emergency Response
OW -	Office of Water
P2 -	Pollution Prevention
PCS -	Permit Compliance System (CWA Database)
POTW -	Publicly Owned Treatments Works
RCRA -	Resource Conservation and Recovery Act
RCRIS -	RCRA Information System
SARA -	Superfund Amendments and Reauthorization Act
SDWA -	Safe Drinking Water Act
SEPs -	Supplementary Environmental Projects
SERCs -	State Emergency Response Commissions
SIC -	Standard Industrial Classification
SO_2 -	Sulfur Dioxide
SO_X -	Sulfur Oxides
TOC -	Total Organic Carbon
TRI -	Toxic Release Inventory
TRIS -	Toxic Release Inventory System
TCRIS -	Toxic Chemical Release Inventory System
TSCA -	Toxic Substances Control Act
TSS -	Total Suspended Solids
UIC -	Underground Injection Control (SDWA)
UST -	Underground Storage Tanks (RCRA)
VOCs -	Volatile Organic Compounds

I. INTRODUCTION TO THE SECTOR NOTEBOOK PROJECT

I.A. Summary of the Sector Notebook Project

Environmental policies based upon comprehensive analysis of air, water and land pollution are an inevitable and logical supplement to traditional single-media approaches to environmental protection. Environmental regulatory agencies are beginning to embrace comprehensive, multi-statute solutions to facility permitting, enforcement and compliance assurance, education/ outreach, research, and regulatory development issues. The central concepts driving the new policy direction are that pollutant releases to each environmental medium (air, water and land) affect each other, and that environmental strategies must actively identify and address these inter-relationships by designing policies for the "whole" facility. One way to achieve a whole facility focus is to design environmental policies for similar industrial facilities. By doing so, environmental concerns that are common to the manufacturing of similar products can be addressed in a comprehensive manner. Recognition of the need to develop the industrial “sector-based” approach within the EPA Office of Compliance led to the creation of this document.

The Sector Notebook Project was initiated by the Office of Compliance within the Office of Enforcement and Compliance Assurance (OECA) to provide its staff and managers with summary information for eighteen specific industrial sectors. As other EPA offices, states, the regulated community, environmental groups, and the public became interested in this project, the scope of the original project was expanded. The ability to design comprehensive, common sense environmental protection measures for specific industries is dependent on knowledge of several inter-related topics. For the purposes of this project, the key elements chosen for inclusion are: general industry information (economic and geographic); a description of industrial processes; pollution outputs; pollution prevention opportunities; Federal statutory and regulatory framework; compliance history; and a description of partnerships that have been formed between regulatory agencies, the regulated community and the public.

For any given industry, each topic listed above could alone be the subject of a lengthy volume. However, in order to produce a manageable document, this project focuses on providing summary information for each topic. This format provides the reader with a synopsis of each issue, and references where more in-depth information is available. Text within each profile was researched from a variety of sources, and was usually condensed from more detailed sources pertaining to specific topics. This approach allows for a wide coverage of activities that can be further explored based upon the citations and references listed at the end of this profile. As a check on the information included, each notebook went through an external review process. The Office of Compliance appreciates the efforts of all those that participated in this process and enabled us to develop more complete, accurate and up-to-date summaries. Many of those who reviewed this notebook are listed as contacts in Section IX and may be sources of additional information. The individuals and groups on this list do not necessarily concur with all statements within this notebook.

I.B. Additional Information

Providing Comments

OECA's Office of Compliance plans to periodically review and update the notebooks and will make these updates available both in hard copy and electronically. If you have any comments on the existing notebook, or if you would like to provide additional information, please send a hard copy and computer disk to the EPA Office of Compliance, Sector Notebook Project, 401 M St., SW (2223-A), Washington, DC 20460. Comments can also be uploaded to the Enviroene Bulletin Board or the Environ$ense World Wide Web for general access to all users of the system. Follow instructions in Appendix A for accessing these data systems. Once you have logged in, procedures for uploading text are available from the on-line Enviroene Help System.

Adapting Notebooks to Particular Needs

The scope of the existing notebooks reflect an approximation of the relative national occurrence of facility types that occur within each sector. In many instances, industries within specific geographic regions or states may have unique characteristics that are not fully captured in these profiles. For this reason, the Office of Compliance encourages state and local environmental agencies and other groups to supplement or re-package the information included in this notebook to include more specific industrial and regulatory information that may be available. Additionally, interested states may want to supplement the "Summary of Applicable Federal Statutes and Regulations" section with state and local requirements. Compliance or technical assistance providers may also want to develop the "Pollution Prevention" section in more detail. Please contact the appropriate specialist listed on the opening page of this notebook if your office is interested in assisting us in the further development of the information or policies addressed within this volume. If you are interested in assisting in the development of new notebooks for sectors not covered in the original eighteen, please contact the Office of Compliance at 202-564-2395.

II. INTRODUCTION TO THE IRON AND STEEL INDUSTRY

This section provides background information on the size, geographic distribution, employment, production, sales, and economic condition of the iron and steel industry. The type of facilities described within the document are also described in terms of their Standard Industrial Classification (SIC) codes. Additionally, this section contains a list of the largest companies in terms of sales.

II.A. Introduction, Background, and Scope of the Notebook

The iron and steel industry is categorized by the Bureau of the Census under the Standard Industrial Classification (SIC) code 33, primary metal industries. The industry is further classified by the three-digit codes 331, Steel Works, Blast Furnaces, and Rolling and Finishing Mills, and 332 Iron and Steel Foundries. Since steel works, blast furnaces, and rolling and finishing mills account for the majority of environmental releases, employees, and value of shipments, this profile concentrates on the three-digit SIC 331. The environmental releases associated with foundries are similar to the steel casting and finishing processes included under SIC 331, therefore SIC 332 will not be addressed in this notebook. Some sections of the profile focus specifically on industries in the four-digit SIC 3312, since virtually all establishments producing primary products (iron and steel) under SIC 3312, also produce secondary products that fall under some of the other iron and steel SIC codes under SIC 331.

II.B. Characterization of the Iron and Steel Industry

II.B.1. Industry Size and Geographic Distribution

There are approximately 1,118 manufacturing facilities under SIC 331 according to *1992 Census of Manufactures* data.[1] The payroll totaled $9.3 billion for a workforce of 241,000 employees, and value of shipments totaled $58 billion. Net shipments of steel mill products for all grades including carbon, alloy, and stainless totaled 92.7 million net tons in 1993[2] and 95.1 million net tons in 1994.[3] In terms of environmental issues, value of shipments, and number of employees, SIC 3312 (Blast Furnaces and Steel Mills), is the most significant four-digit code under SIC 331. The 1992 Census data reported 247 establishments under SIC 3312, with an estimated 172,000 employees, a payroll of $7 billion, and a value of shipments totaling $42 billion. For the same year, the American Iron and Steel Institute estimated 114 companies operated 217 iron and steel facilities; this estimate included any facility with one or more iron or steelmaking operation.[4]

The *1987 Census of Manufactures*[5] further categorizes SIC 3312 by the type of steel mill: integrated or non-integrated. A fully integrated facility produces steel from raw materials of coal, iron ore, and scrap. Non-integrated plants do not have all of the equipment to produce steel from coal, iron ore, and scrap on-site, instead they purchase some of their raw materials in a processed form.

SIC Diversity

The Bureau of the Census categorizes the three- and four-digit SIC codes related to iron and steel as follows:

SIC 331 - Steel works, blast furnaces, coke ovens, rolling and finishing mills

- 3312 - Steel works, blast furnaces, and rolling mills
- 3313 - Electrometallurgical products, except steel
- 3315 - Steel wiredrawing and steel nails and spikes
- 3316 - Cold-rolled steel sheet, strip, and bars
- 3317 - Steel pipe and tubes

The remainder of the industries classified under SIC code 33 cover the ferrous and non-ferrous foundries, and smelting, refining, and shaping of nonferrous metals which are not covered in this profile.

Two Steel Industries

In the past fifteen years, the U.S. steel industry has lost over 61 percent of its employees and 58 percent of its facilities. Slow growth in demand for steel, markets lost to other materials, increased imports, and older, less efficient production facilities are largely to blame for the industry's decline. While the integrated steel industry was contracting, a group of companies, called minimills, more than doubled their capacity in the same period and they continue to expand into new markets. Minimills use electric arc furnaces (EAFs) to melt scrap and other materials to make steel products, instead of using coke, iron ore, and scrap as the integrated producers do. In addition to fundamentally different production technologies, other differences between the integrated steel mills and minimill are also significant: minimills have narrow product lines, they often have small, non-unionized work forces that may receive higher pay per hour than a comparable unionized work force, but without union benefits. Additionally, minimills typically produce much less product per facility (less than 1 million tons of steel per year). Lower scrap prices in the 1960s and 1970s created opportunities for the minimill segment of the market to grow rapidly. Initially, the EAF technology could only be used in the production of low quality long products, such as concrete reinforcing bar, but over the years minimill products have improved in quality and have overcome technological limitations to diversify their product lines. Recently, minimills have entered new markets, such as flat-rolled products, however, more than half of the market for quality steel products still remains beyond minimill capability. The EAF producers do face the problems of fluctuating scrap prices which are more volatile than the prices of raw materials used by integrated producers.

Geographic Distribution

The highest geographic concentration of mills is in the Great Lakes region, where most integrated plants are based (Exhibit 1). According to the *1987 Census of Manufactures*, 46 percent of steel mills are located in six Great Lakes states: New York, Pennsylvania, Ohio, Indiana, Illinois, and Michigan, with a heavy concentration of steel manufacturing in the Chicago area. Approximately 80 percent of the U.S. steelmaking capacity is in these states. The South is the next largest steel-producing region, although there are only two integrated steel plants. Steel production in the western U.S. is limited to one integrated plant and several minimills. Historically, the mill sites were selected for their proximity to water (tremendous amounts are used for cooling and processing, and for transportation) and the sources of their raw materials, iron ore and coal. Traditional steelmaking regions included the Monongahela River valley near Pittsburgh and along the Mahoning River near Youngstown, Ohio. The geographic concentration of the industry continues to change as minimills are built anywhere electricity and scrap are available at a reasonable cost and there is a local market for a single product.

Size Distribution

Large, fully-integrated steel mills have suffered considerably in the last 15 years, largely due to loss of market share to other materials, competition, and the high cost of pension liabilities. In comparing the *1992 Census of Manufacture* data with the data from 1977, these changes are clear. While the number of establishments under SIC 3312 fell by 58 percent from 504 facilities in 1977 to 247 in 1992, the absolute number of integrated mills has always been small, and the reduction is largely due to a drop in the number of small establishments. A more relevant statistic is the reduction in employees during the same time period. The work force for these facilities was dramatically reduced as plants closed or were reorganized by bankruptcy courts. Those that remained open automated and streamlined operations resulting in a 61 percent reduction in the number of production employees over the same 15 year period. Approximately 172,000 were still employed in SIC 3312 establishments in 1992.

The *1987 Census of Manufactures* breaks the SIC code 3312 down into four sub-industries: Fully-integrated (consists of coke ovens, blast furnaces, steel furnaces, and rolling and finishing mills), partially integrated with blast furnace (consists of blast furnaces, steel furnaces, and rolling and finishing mills), partially integrated without blast furnaces (consists of steel furnaces and either rolling and finishing mills or a forging department; includes mini mills), and non-integrated (all others, including stand-alone rolling and finishing mills, and stand-alone coke plants). This division highlights some important characteristics about the size of facilities in this industry. Only 8 percent (20 plants) of the establishments under SIC 3312 in 1987 were fully integrated mills. However, 46 percent of the industry's employees worked in these 20 plants.

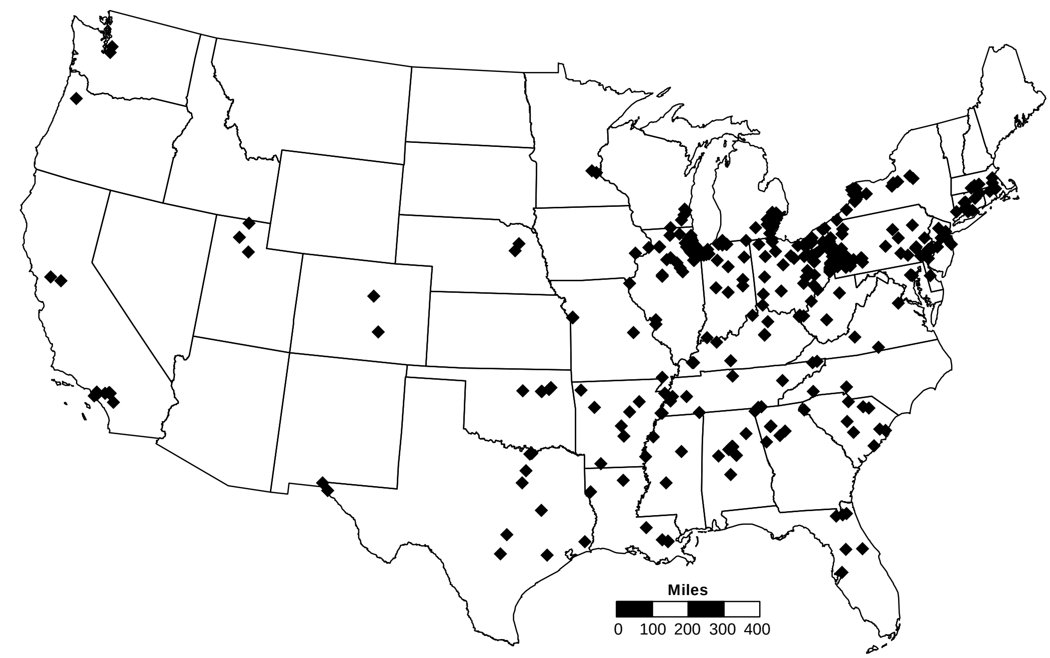


Exhibit 1: Geographic Distribution of SIC 331 Establishments: Steel Works, Blast Furnaces, and Rolling and Finishing Mills

Top Steel Producers

Market Share Reporter, published by Gale Research Inc., annually compiles reported market share data on companies, products, and services. The 1995 edition ranks top U.S. steel producers by 1993 sales in millions of dollars, as shown in Exhibit 2.

Exhibit 2: Top U.S. Iron and Steel Producers

Rank	**Company**	**1993 Sales** (millions of dollars)
1	US Steel Group - Pittsburgh, PA	5,422
2	Bethlehem Steel Corp. - Bethlehem, PA	4,219
3	LTV Corp. - Dallas, TX	3,868
4	National Steel Corp. - Pittsburgh, PA	2,418
5	Inland Steel Industries, Inc. - Chicago, IL	2,175
6	Armco Inc. - Parsippany, NJ	1,595
7	Weirton Steel Corp. - Weirton, WV	1,201
8	Wheeling-Pittsburgh Steel - Pittsburgh, PA	1,047

Source: Market Share Reporter, 1995.

II.B.2. Product Characterization

The iron and steel industry produces iron and steel mill products, such as bars, strips, and sheets, as well as formed products such as steel nails, spikes, wire, rods, pipes, and non-steel electrometallurgical products such as ferroalloys. Under SIC 3312, Blast Furnaces and Steel Mills, products also include coke, and products derived from chemical recovery in the coking process such as coal tar and distillates.

Historically, the automotive and construction sectors have been the two largest steel consuming industries. Consequently, fluctuations in sales and choice of materials in these industries have a significant impact on the iron and steel industry. Over the last two decades, the structure of the steelmaking industry has changed dramatically due to new technologies, foreign competition, and loss of market share to other materials. Many of the large, fully-integrated facilities have closed, and those that are still operating, have reduced their workforce, increased automation, and invested in new technologies to remain competitive.

II.B.3. Economic Trends

Domestic Market

After years of collapsing markets, bankruptcies, mill closings and layoffs, the steel industry experienced a turnaround in 1993. Shipments were at their highest level since 1981.[6] For the first time since 1989, steelmakers were able to boost their prices. This increase in demand is due in part to the weak dollar, which makes importing foreign steel more expensive than it used to be. The relatively high level of shipments was also attributable to a strong demand from the steel industry's two largest customers - the automotive and construction sectors.[7] Recently, prices for steel sold to the automotive industry have been set in long-term contracts. The prices set in the automotive contracts tend to influence the steel prices of other contract negotiations, such as those with appliance manufacturers. Overall, more than half of all steel sold in the U.S. is covered by long-term contracts; the rest is sold on the spot market.

International Trade

Problems in international steel trade intensified in the last 5 years due in large part to a worldwide weakening in demand. With the exception of China, where rapid economic growth has led to a steady increase in steel demand, the export market has been weak. The "voluntary restraint arrangements" that limited imports in the 1980s expired in 1992. Since then, the U.S. steel industry has discouraged imports by filing complaints that products are being dumped - sold at less than the cost of production. Similar cases have also been filed against U.S. exporters. To address the problems of unfairly traded steel, most major steel-producing countries have participated in multilateral steel agreement (MSA) negotiations under the General Agreement on Tariffs and Trade (GATT).[8]

Steel imports for 1992 totaled 15.2 million metric tons. From 1989 to 1993, the quantity of steel imported was fairly consistent, from 15.7 million metric tons in 1989 to 15.3 million metric tons estimated for 1993. The exception is a slight dip to 14.3 million metric tons in 1991. The forecast for 1994, at 16.3 million metric tons, is a more significant increase than has been seen in the last five years. The export market has seen slightly more variability over the same time period, with a high of 5.7 million metric tons exported in 1991, and 3.8 million metric tons in exports forecast for 1994.[9]

Labor

According to *1992 Census of Manufactures*, there were an estimated 172,000 people employed in SIC 3312 industries, with a payroll of $7 billion. This was a 61 percent decrease from 1977 levels of 442,000 employees, and a 42% reduction from 1982 levels of 295,000 employees. This dramatic reduction in workforce was primarily due to reductions at the large integrated facilities. For example, the U.S. Steel plant in Gary, Indiana, employed 30,000 people during the plant's peak employment in 1953. In 1992, there were about 8,000 employees working at the 4,000-acre facility.

This reduction in workforce, coupled with investments in new equipment, automation, and management restructuring has resulted in the increased productivity that was essential for integrated mills to remain competitive in the face of the severe competitive pressures both from EAF producers in the U.S. and from abroad. With these changes, the U.S. industry has become one of the lowest-cost producers in the developed world. Productivity in steelmaking is often measured in man-hours per ton of finished steel. For every ton produced, American steelmakers spend 5.3 man-hours, compared with 5.6 for the Japanese and Canadian industries, and 5.7 for the British, French, and Germans. The increase in productivity is also reflected in changes in the value added by manufacture, as reported by the Census. During the ten year period where employment in the industry dropped by 42% (1982 - 1992), the value added by manufacture increased by 39% from $11.8 million in 1982 to $16.5 million in 1992.

Problems from such a sizable workforce reduction persist. The industry says one big cost is "legacy costs" - obligations to pay pensions and health benefits to the tens of thousands of retirees and their spouses. Some integrated companies have five retired workers for every active employee. For many of the large, integrated facilities, these pensions are underfinanced. Of the 50 most underfinanced pension plans, five are in the steel industry. This puts the newer minimills, who do not have such legacy costs, at a clear competitive advantage.

In addition to pension payments, major U.S. steel producers are now paying out an average $5.30 per hour worked, 17 percent of total hourly employment costs, for health care. The industry argues that these high costs place it at a disadvantage with its major foreign competitors, some of whom pay no direct health care expenses.

Long-term Prospects

Production of steel products in 1993 totaled 89.0 million net tons which represents an 89.1 percent capacity utilization. Shipments for 1994 rose to 95.1 million net tons and it is forecasted that demand will stay high, with industry capacity utilization increasing through 1995.[10] After years of losing market share to other materials, steel appears to be regaining a competitive position. In the automotive market, some parts that were recently made of plastic, such as fenders, roofs, and hoods, are being returned to steel. The decades-long downtrend in steel content in automobiles appears to have slowed and recently has actually reversed. According to Ford Motor Company, the average vehicle built in 1993 contained 1,726 pounds of steel, up from 1,710 pounds in 1992, marking the second consecutive yearly increase. A further increase is anticipated in 1994 due to new and expanding applications of steel. In addition to increased orders from the automotive sector, the residential construction sector is a potentially rich market for steel producers. Steel framing for houses is being promoted as a light-weight, high strength alternative to wood framing. A galvanized steel frame for a 2,000 square foot house would weigh approximately one-fourth the weight of a lumber structure.

III. INDUSTRIAL PROCESS DESCRIPTION

This section describes the major industrial processes within the iron and steel industry, including the materials and equipment used, and the processes employed. The section is designed for those interested in gaining a general understanding of the industry, and for those interested in the inter-relationship between the industrial process and the topics described in subsequent sections of this profile -- pollutant outputs, pollution prevention opportunities, and Federal regulations. This section does not attempt to replicate published engineering information that is available for this industry. Refer to Section IX for a list of reference documents that are available.

This section specifically contains a description of commonly used production processes, associated raw materials, the byproducts produced or released, and the materials either recycled or transferred off-site. This discussion, coupled with schematic drawings of the identified processes, provide a concise description of where wastes may be produced in the process. This section also describes the potential fate (via air, water, and soil pathways) of these waste products.

III.A. Industrial Processes in the Iron and Steel Industry

In view of the high cost of most new equipment and the relatively long lead time necessary to bring new equipment on line in the steel industry, changes in production methods and products in the steel industry are typically made gradually. Installation of major pieces of new steelmaking equipment may cost millions of dollars and require additional retrofitting of other equipment. Even new process technologies that fundamentally improve productivity, such as the continuous casting process (described below), are adopted only over long periods of time. Given the recent financial performance of the steel industry, the ability to raise the capital needed to purchase such equipment is limited.

Environmental legislation is challenging the industry to develop cleaner and more efficient steelmaking processes at the same time competition from substitute materials are forcing steelmakers to invest in cost-saving and quality enhancing technologies. In the long term, the steel industry will likely continue to move towards more simplified and continuous manufacturing technologies that reduce the capital costs for new mill construction and allow smaller mills to operate efficiently. The companies that excel will be those that have the resources and foresight to invest in such technologies.

Steel is an alloy of iron usually containing less than one percent carbon. The process of steel production occurs in several sequential steps (Exhibit 3). The two types of steelmaking technology in use today are the basic oxygen furnace (BOF) and the electric arc furnace (EAF). Although these two technologies use different input materials, the output for both furnace types is molten steel which is subsequently formed into steel mill products. The BOF input materials are molten iron, scrap, and oxygen. In the EAF, electricity and scrap are the input materials used. BOFs are typically used for high tonnage production of carbon steels, while EAFs are used to produce carbon steels and low tonnage alloy and specialty steels. The processes leading up to steelmaking in a BOF are very different than the steps preceeding steelmaking in an EAF; the steps after each of these processes producing molten steel are the same.

When making steel using a BOF, cokemaking and ironmaking precede steelmaking; these steps are not needed for steelmaking with an EAF. Coke, which is the fuel and carbon source, is produced by heating coal in the absence of oxygen at high temperatures in coke ovens. Pig iron is then produced by heating the coke, iron ore, and limestone in a blast furnace. In the BOF, molten iron from the blast furnace is combined with flux and scrap steel where high-purity oxygen is injected. This process, with cokemaking, ironmaking, steelmaking, and subsequent forming and finishing operations is referred to as fully integrated production. Alternatively, in an EAF, the input material is primarily scrap steel, which is melted and refined by passing an electric current from the electrodes through the scrap. The molten steel from either process is formed into ingots or slabs that are rolled into finished products. Rolling operations may require reheating, rolling, cleaning, and coating the steel. A description of both steelmaking processes follows:

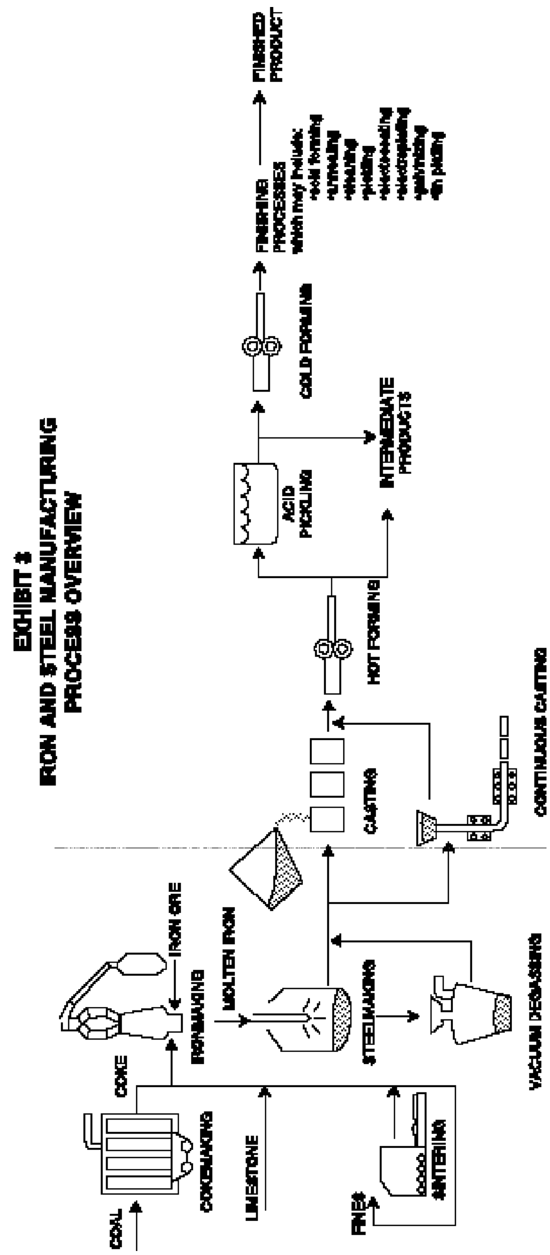


EXHIBIT 3
IRON AND STEEL MANUFACTURING
PROCESS OVERVIEW
COAL
COKEMAKING
COKE
LIMESTONE
FINES
SINTERING
IRON ORE
IRONMAKING
MOLTEN IRON
STEELMAKING
VACUUM DEGASSING
CASTING
CONTINUOUS CASTING
HOT FORMING
ACID PICKLING
INTERMEDIATE PRODUCTS
COLD FORMING
FINISHING PROCESSES which may include:
FINISHED PRODUCT

III.A.1. Steelmaking Using the Basic Oxygen Furnace

The process of making steel in a Basic Oxygen Furnace (BOF) is preceded by cokemaking and ironmaking operations. In cokemaking, coke is produced from coal. In ironmaking, molten iron is produced from iron ore and coke. Each of these processes and the subsequent steelmaking process in the BOF are described below.

Cokemaking

Coal processing in the iron and steel industry typically involves producing coke, coke gas and by-product chemicals from compounds released from the coal during the cokemaking process (Exhibit 4). Coke is carbon-rich and is used as a carbon source and fuel to heat and melt iron ore in ironmaking. The cokemaking process starts with bituminous pulverized coal charge which is fed into the coke oven through ports in the top of the oven. After charging, the oven ports are sealed and the coal is heated at high temperatures (1600 to 2300°F) in the absence of oxygen. Coke manufacturing is done in a batch mode where each cycle lasts for 14 to 36 hours. A coke oven battery comprises a series of 10 to 100 individual ovens, side-by-side, with a heating flue between each oven pair. Volatile compounds are driven from the coal, collected from each oven, and processed for recovery of combustible gases and other coal byproducts.[11] The solid carbon remaining in the oven is the coke. The necessary heat for distillation is supplied by external combustion of fuels (e.g., recovered coke oven gas, blast furnace gas) through flues located between ovens.[12] At the end of the heating cycle, the coke is pushed from the oven into a rail quench car. The quench car takes it to the quench tower, where the hot coke is cooled with a water spray. The coke is then screened and sent to the blast furnace or to storage.

In the by-products recovery process, volatile components of the coke oven gas stream are recovered including the coke oven gas itself (which is used as a fuel for the coke oven), naphthalene, ammonium compounds, crude light oils, sulfur compounds, and coke breeze (coke fines). During the coke quenching, handling, and screening operation, coke breeze is produced. Typically, the coke breeze is reused in other manufacturing processes on-site (e.g., sintering) or sold off-site as a by-product.[13]

The cokemaking process is seen by industry experts as one of the steel industry's areas of greatest environmental concern, with air emissions and quench water as major problems. In efforts to reduce the emissions associated with cokemaking, U.S. steelmakers are turning to technologies such as pulverized coal injection, which substitutes coal for coke in the blast furnace. Use of pulverized coal injection can replace about 25 to 40 percent of coke in the blast furnace, reducing the amount of coke required and the associated emissions. Steel producers also inject other fuels, such as natural gas, oil, and tar/pitch to replace a portion of the coke.

Quench water from cokemaking is also an area of significant environmental concern. In Europe, some plants have implemented technology to shift from water quenching to dry quenching which eliminates suspected carcinogenic particulates and VOCs. However, major construction changes are required for such a solution and considering the high capital costs of coke batteries, combined with the depressed state of the steel industry and increased regulations for cokemaking, it is unlikely that new facilities will be constructed. Instead, industry experts expect to see an increase in the amount of coke imported.

Ironmaking

In the blast furnace, molten iron is produced (Exhibit 4). Iron ore, coke, and limestone are fed into the top of the blast furnace. Heated air is forced into the bottom of the furnace through a bustle pipe and tuyeres (orifices) located around the circumference of the furnace. The carbon monoxide from the burning of the coke reduces iron ore to iron. The acid part of the ores reacts with the limestone to create a slag which is drawn periodically from the furnace. This slag contains unwanted impurities in the ore, such as sulfur from the fuels. When the furnace is tapped, iron is removed through one set of runners and molten slag via another. The molten iron is tapped into refractory-lined cars for transport to the steelmaking furnaces. Residuals from the process are mainly sulfur dioxide or hydrogen sulfide, which are driven off from the hot slag. The slag is the largest by-product generated from the ironmaking process and is reused extensively in the construction industry.[14] Blast furnace flue gas is cleaned and used to generate steam to preheat the air coming into the furnace, or it may be used to supply heat to other plant processes. The cleaning of the gas may generate air pollution control dust in removing coarse particulates (which may be reused in the sintering plant or landfilled), and water treatment plant sludge in removing fine particulates by venturi scrubbers.

Sintering is the process that agglomerates fines (including iron ore fines, pollution control dusts, coke breeze, water treatment plant sludge, coke breeze, and flux) into a porous mass for charging to the blast furnace.[15] Through sintering operations, a mill can recycle iron-rich material, such as mill scale and processed slag. Not all mills have sintering capabilities. The input materials are mixed together, placed on a slow-moving grate and ignited. Windboxes under the grate draw air through the materials to deepen the combustion throughout the traveling length of the grate. The coke breeze provides the carbon source for sustaining the controlled combustion. In the process, the fine materials are fused into the sinter agglomerates, which can be reintroduced into the blast furnace along with ore. Air pollution control equipment removes the particulate matter generated during the thermal fusing process. For wet scrubbers, water treatment plant sludge are generally land disposed waste. If electrostatic precipitators or baghouses are used as the air pollution control equipment, the dry particulates captured are typically recycled as sinter feedstock, or are landfilled as solid waste.

Steelmaking Using the Basic Oxygen Furnace

Molten iron from the blast furnace, flux, alloy materials, and scrap are placed in the basic oxygen furnace, melted and refined by injecting high-purity oxygen. A chemical reaction occurs, where the oxygen reacts with carbon and silicon generating the heat necessary to melt the scrap and oxidize impurities. This is a batch process with a cycle time of about 45 minutes. Slag is produced from impurities removed by the combination of the fluxes with the injected oxygen. Various alloys are added to produce different grades of steel. The molten steel is typically cast into slabs, beams or billets.

The waste products from the basic oxygen steelmaking process include slag, carbon monoxide, and oxides of iron emitted as dust. Also, when the hot iron is poured into ladles or the furnace, iron oxide fumes are released and some of the carbon in the iron is precipitated as graphite (kish). The BOF slag can be processed to recover the high metallic portions for use in sintering or blast furnaces, but its applications as a saleable construction materials are more limited than the blast furnace slag.

Basic oxygen furnaces are equipped with air pollution control systems for containing, cooling, and cleaning the volumes of hot gases and sub-micron fumes that are released during the process. Water is used to quench or cool the gases and fumes to temperatures at which they can be effectively treated by the gas cleaning equipment. The resulting waste streams from the pollution control processes include air pollution control dust and water treatment plant sludge. About 1,000 gallons of water per ton of steel (gpt) are used for a wet scrubber. The principal pollutants removed from the off-gas are total suspended solids and metals (primarily zinc, and some lead).[16]

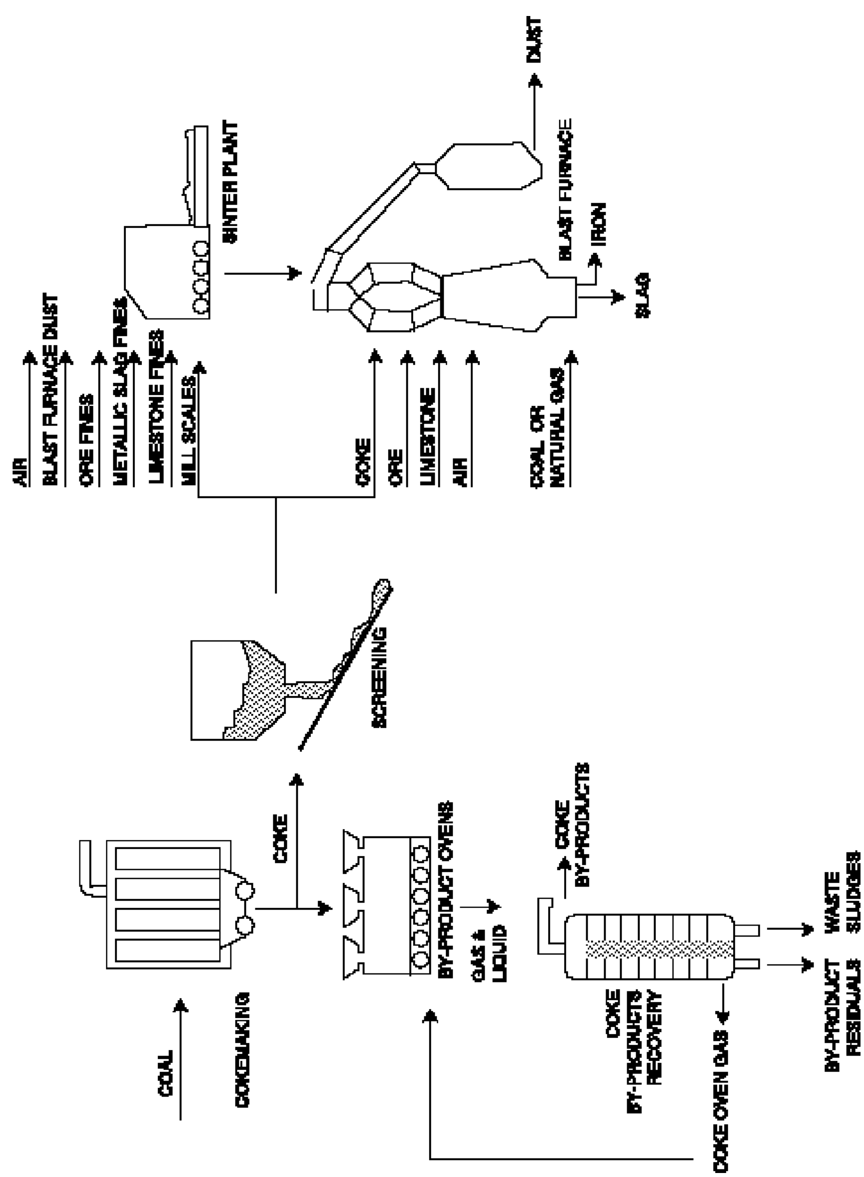
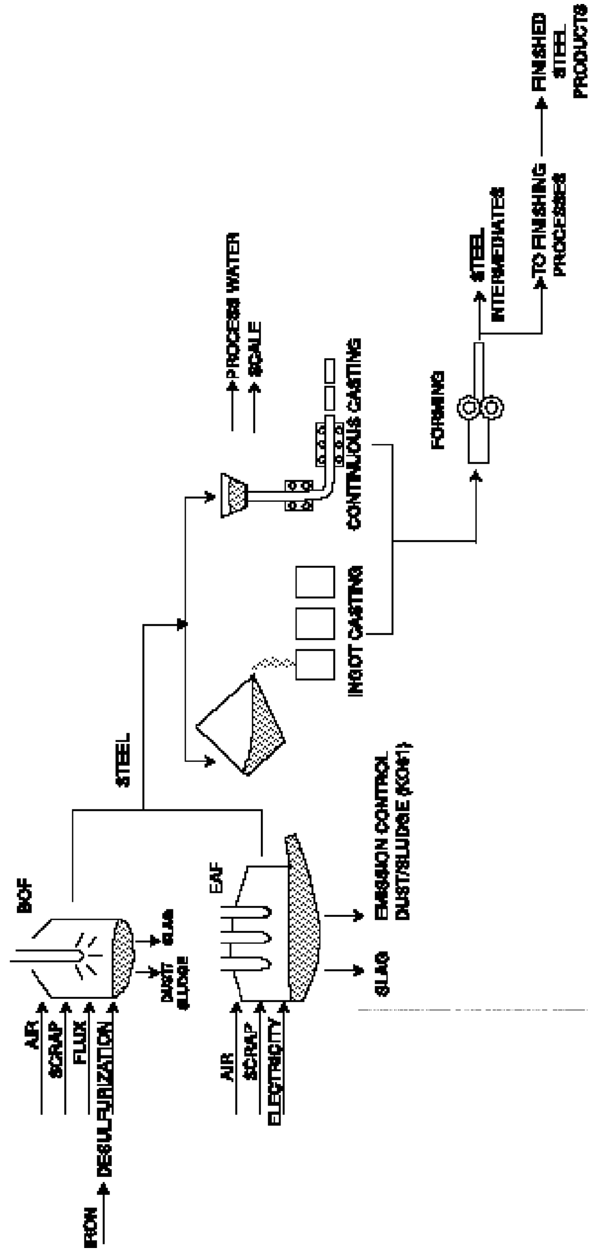


EXHIBIT 4
IRON AND STEEL MANUFACTURING
COKEMAKING AND IRONMAKING

EXHIBIT 5
IRON AND STEEL MANUFACTURING
STEELMAKING



III.A.2. Steelmaking Using the Electric Arc Furnace (EAF)

In the steelmaking process that uses an electric arc furnace (EAF), the primary raw material is scrap metal, which is melted and refined using electric energy. During melting, oxidation of phosphorus, silicon, manganese, carbon and other materials occurs and a slag containing some of these oxidation products forms on top of the molten metal.[17] Oxygen is used to decarburize the molten steel and to provide thermal energy. This is a batch process with a cycle time of about two to three hours. Since scrap metal is used instead of molten iron, there are no cokemaking or ironmaking operations associated with steel production that uses an EAF.

The process produces metal dusts, slag, and gaseous products. Particulate matter and gases evolve together during the steelmaking process and are conveyed into a gas cleaning system. These emissions are cleaned using a wet or dry system. The particulate matter that is removed as emissions in the dry system is referred to as EAF dust, or EAF sludge if it is from a wet system and it is a listed hazardous waste (RCRA K061). The composition of EAF dust can vary greatly depending on the scrap composition and furnace additives. The primary component is iron or iron oxides, and it may also contain flux (lime and/or fluorspar), zinc, chromium and nickel oxides (when stainless steel is being produced) and other metals associated with the scrap. The two primary hazardous constituents of EAF emission control dust are lead and cadmium.[18] Generally, 20 pounds of dust per ton of steel is expected, but as much as 40 pounds of dust per ton of steel may be generated, depending on production practices.[19] Oils are burned off "charges" of oil-bearing scrap in the furnace. Minor amounts of nitrogen oxides and ozone are generated during the melting process. The furnace is extensively cooled by water; however, this water is recycled through cooling towers.

III.A.3. Forming and Finishing Operations

Whether the molten steel is produced using a BOF or an EAF, to convert it into a product, it must be solidified into a shape suitable and finished.

Forming
The traditional forming method, called ingot teeming, has been to pour the metal into ingot molds, allowing the steel to cool and solidify. The alternative method of forming steel, called continuous casting accounted for more 86% of raw steel produced in the U.S. in 1992[20], compared with approximately 30 percent in 1982. The continuous casting process bypasses several steps of the conventional ingot teeming process by casting steel directly into semifinished shapes. Molten steel is poured into a reservoir from which it is released into the molds of the casting machine. The metal is cooled as it descends through the molds, and before emerging, a hardened outer shell is formed. As the semifinished shapes proceed on

the runout table, the center also solidifies, allowing the cast shape to be cut into lengths.
Process contact water cools the continuously cast steel and is collected in settling basins along with oil, grease, and mill scale generated in the casting process. The scale settles out and is removed and recycled for sintering operations, if the mill has a Sinter Plant. Waste treatment plant sludge is also generated.[21]

The steel is further processed to produce slabs, strips, bars, or plates through various forming operations. The most common hot forming operation is hot rolling, where heated steel is passed between two rolls revolving in opposite directions. Modern hot rolling units may have as many as 13 stands, each producing an incremental reduction in thickness. The final shape and characteristics of a hot formed piece depend on the rolling temperature, the roll profile, and the cooling process after rolling. Wastes generated from hot rolling include waste treatment plant sludge and scale.

In subsequent cold forming, the cross-sectional area of unheated steel is progressively reduced in thickness as the steel passes through a series of rolling stands. Generally, wires, tubes, sheet and strip steel products are produced by cold rolling operations. Cold forming is used to obtain improved mechanical properties, better machinability, special size accuracy, and the production of thinner gages than hot rolling can accomplish economically.[22] During cold rolling, the steel becomes hard and brittle. To make the steel more ductile, it is heated in an annealing furnace.

Process contact water is used as a coolant for rolling mills to keep the surface of the steel clean between roller passes. Cold rolling operations also produce a waste treatment plant sludge, primarily due to the lubricants applied during rolling. Grindings from resurfacing of the worn rolls and disposal of used rolls can be a significant contributor to the plant's wastestream.

Finishing

One of the most important aspects of a finished product is the surface quality. To prevent corrosion, a protective coating may be applied to the steel product. Prior to coating, the surface of the steel must be cleaned so the coating will adhere to the steel. Mill scale, rust, oxides, oil, grease, and soil are chemically removed from the surface of steel using solvent cleaners, pressurized water or air blasting, cleaning with abrasives, alkaline agents or acid pickling. In the pickling process, the steel surface is chemically cleaned of scale, rust, and other materials. Inorganic acids such as hydrochloric or sulfuric acid are most commonly used for pickling. Stainless steels are pickled with hydrochloric, nitric, and hydrofluoric acids. Spent pickle liquor may be a listed hazardous waste (RCRA K062), if it contains considerable residual acidity and high concentrations of dissolved iron salts. Pickling prior to coating may use a mildly acidic bath which is not considered K062.

Steel generally passes from the pickling bath through a series of rinses. Alkaline cleaners may also be used to remove mineral oils and animal fats and oils from the steel surface prior to cold rolling. Common alkaline cleaning agents include: caustic soda, soda ash, alkaline silicates, phosphates.

Steel products are often given a coating to inhibit oxidation and extend the life of the product. Coated products can also be painted to further inhibit corrosion. Common coating processes include: galvanizing (zinc coating), tin coating, chromium coating, aluminizing, and terne coating (lead and tin). Metallic coating application processes include hot dipping, metal spraying, metal cladding (to produce bi-metal products), and electroplating. Galvanizing is a common coating process where a thin layer of zinc is deposited on the steel surface.

III.B. Raw Material Inputs and Pollution Outputs

Numerous outputs are produced as a result of the manufacturing of coke, iron, and steel, the forming of metals into basic shapes, and the cleaning and scaling of metal surfaces. These outputs, categorized by process (RCRA waste code provided where applicable), include:

Cokemaking

Inputs:

- Coal, heat, quench water

Outputs:

- Process residues from coke by-product recovery (RCRA K143, K148)
- Coke oven gas by-products such as coal tar, light oil, ammonia liquor, and the remainder of the gas stream is used as fuel. Coal tar is typically refined to produce commercial and industrial products including pitch, creosote oil, refined tar, naphthalene, and bitumen.
- Charging emissions (fine particles of coke generated during oven pushing, conveyor transport, loading and unloading of coke that are captured by pollution control equipment. Approximately one pound per ton of coke produced are captured and generally land disposed).
- Ammonia, phenol, cyanide and hydrogen sulfide
- Oil (K143 and K144)
- Lime sludge, generated from the ammonia still (K060)
- Decanter tank tar sludge (K087)
- Benzene releases in coke by-product recovery operations
- Naphthalene residues, generated in the final cooling tower
- Tar residues (K035, K141, K142, and K147)

- Sulfur compounds, emitted from the stacks of the coke ovens
- Wastewater from cleaning and cooling (contains zinc, ammonia still lime (K060), or decanter tank tar (K087), tar distillation residues (K035))
- Coke oven gas condensate from piping and distribution system; may be a RCRA characteristic waste for benzene.

Ironmaking

Inputs:

- Iron ore (primarily in the form of taconite pellets), coke, sinter, coal, limestone, heated air

Outputs:

- Slag, which is either sold as a by-product, primarily for use in the construction industry, or landfilled
- Residual sulfur dioxide or hydrogen sulfide
- Particulates captured in the gas, including the air pollution control (APC) dust or waste treatment plant (WTP) sludge
- Iron is the predominant metal found in the process wastewater
- Blast furnace gas (CO)

Steelmaking

Inputs:

- In the steelmaking process that uses a basic oxygen furnace (BOF), inputs include molten iron, metal scrap, and high-purity oxygen
- In the steelmaking process that uses an electric arc furnace (EAF), the primary inputs are scrap metal, electric energy and graphite electrodes.
- For both processes, fluxes and alloys are added, and may include: fluorspar, dolomite, and alloying agents such as aluminum, manganese, and others.

Outputs:

- Basic Oxygen Furnace emission control dust and sludge, a metals-bearing waste.
- Electric Arc Furnace emission control dust and sludge (K061); generally, 20 pounds of dust per ton of steel is expected, but as much as 40 pounds of dust per ton of steel may be generated depending on the scrap that is used.
- Metal dusts (consisting of iron particulate, zinc, and other metals associated with the scrap and flux (lime and/or fluorspar)) not associated with the EAF.
- Slag.
- Carbon monoxide.
- Nitrogen oxides and ozone, which are generated during the melting process.

Forming, Cleaning, and Descaling

Inputs:

- Carbon steel is pickled with hydrochloric or sulfuric acid; stainless steels are pickled with hydrochloric, nitric, and hydrofluoric acids.
- Various organic chemicals are used in the pickling process.
- Alkaline cleaners may also be used to remove mineral oils and animal fats and oils from the steel surface. Common alkaline cleaning agents include: caustic soda, soda ash, alkaline silicates, phosphates.

Outputs:

- Wastewater sludge from rolling, cooling, descaling, and rinsing operations which may contain cadmium (D006), chromium (D007), lead (D008)
- Oils and greases from hot and cold rolling
- Spent pickle liquor (K062)
- Spent pickle liquor rinse water sludge from cleaning operations
- Wastewater from the rinse baths. Rinse water from coating processes may contain zinc, lead, cadmium, or chromium.
- Grindings from roll refinishing may be RCRA characteristic waste from chromium (D007)
- Zinc dross

III.C. Management of Chemicals in the Production Process

The Pollution Prevention Act of 1990 (PPA) requires facilities to report information about the management of TRI chemicals in waste and efforts made to eliminate or reduce those quantities. These data have been collected annually in Section 8 of the TRI reporting Form R beginning with the 1991 reporting year. The data summarized below cover the years 1992-1995 and is meant to provide a basic understanding of the quantities of waste handled by the industry, the methods typically used to manage this waste, and recent trends in these methods. TRI waste management data can be used to assess trends in source reduction within individual industries and facilities, and for specific TRI chemicals. This information could then be used as a tool in identifying opportunities for pollution prevention compliance assistance activities.

From the yearly data presented below it is apparent that the portion of TRI wastes reported as recycled on-site has increased and the portions treated or managed through energy recovery on-site have decreased between 1992 and 1995 (projected). While the quantities reported for 1992 and 1993 are estimates of quantities already managed, the quantities reported for 1994 and 1995 are projections only. The PPA requires these projections to encourage facilities to consider future waste generation and source reduction of those quantities as well as movement up the waste management hierarchy. Future-year estimates are not commitments that facilities reporting under TRI are required to meet.

Exhibit 6 shows that the iron and steel industry managed about 1.3 billion pounds of production-related waste (total quantity of TRI chemicals in the waste from routine production operations) in 1993 (column B). Column C reveals that of this production-related waste, over half (52%) was either transferred off-site or released to the environment, and most of this quantity was recycled off-site (typically in a metals recovery process). Column C is calculated by dividing the total TRI transfers and releases by the total quantity of production-related waste. In other words, about 48%

of the industry's TRI wastes were managed on-site through recycling, energy recovery, or treatment as shown in columns E, F and G, respectively. The majority of waste that is released or transferred off-site can be divided into portions that are recycled off-site, recovered for energy off-site, or treated off-site as shown in columns H, I and J, respectively. The remaining portion of the production related wastes (15% for 1993), shown in column D, is either released to the environment through direct discharges to air, land, water, and underground injection, or it is disposed off-site.

Exhibit 6: Source Reduction and Recycling Activity for Iron and Steel Industry (SIC 331) as Reported within TRI

A	B	C	D	On-Site			Off-Site		
				E	F	G	H	I	J
Year	Quantity of Production-Related Waste (10^6 lbs.)[a]	% Released and Transferred[b]	% Released and Disposed[c] Off-site	% Recycled	% Energy Recovery	% Treated	% Recycled	% Energy Recovery	% Treated
1992	1,301	40%	10%	32%	2%	16%	34%	1%	5%
1993	1,340	52%	15%	24%	1%	17%	35%	1%	6%
1994	1,341	---	15%	23%	1%	18%	37%	1%	6%
1995	1,357	---	15%	22%	1%	18%	38%	1%	6%

[a] Does not include any accidental, non-production related wastes.
[b] Total TRI transfers and releases as reported in Section 5 and 6 of Form R as a percentage of production related wastes; this value may not equal the sum of the percentages released and transferred due to reporting errors in Section 8.
[c] Percentage of production related waste released to the environment and transferred off-site for disposal.