Pollution Prevention in the Integrated Iron and Steel Industry
and its Potential Role in MACT Standards Development

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DISCLAIMER

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INTRODUCTION

This paper discusses two aspects of air emission pollution prevention in the iron and steel industry. The first half of the paper summarizes major pollution prevention (P²) techniques identified in a scoping study conducted for the U.S. Environmental Protection Agency's Air and Energy Engineering Research Laboratory (AEERL). This project, directed toward identifying air toxics P² opportunities in the integrated iron and steel industry, was part of a series of projects conducted by the AEERL under the Source Reduction Review Project (SRRP). The SRRP is a program through which EPA identifies P² opportunities in categories facing upcoming regulations under the Clean Air Act (CAA), Clean Water Act (CWA), and Resource Conservation and Recovery Act (RCRA).

The second half of this paper discusses some implementation issues and speculation on the future of pollution prevention in rulemaking affecting the iron and steel industry. As EPA continues its focus on pollution prevention as the preferred mode of improved environmental welfare, P² options will increasingly be incorporated into rules and rulemaking across all industries. State and local agencies, too, are increasing their reliance on pollution prevention techniques. Issues facing regulatory agencies and regulated industry will revolve around how P² options are incorporated into rules, and how pollution prevention will be defined. As currently defined by EPA, pollution prevention encompasses practices which reduce the amount of pollutants entering a wastestream or released into the environment prior to recycling, treatment, or disposal. However, it is common practice for many industries to also include recycling, reuse and reclamation within the context of pollution prevention; nonetheless, these practices are excluded from EPA's formal definition. This distinction may have a significant impact on how industry and regulatory agencies develop strategies for environmental compliance.

Several Maximum Achievable Control Technology (MACT) regulations pertaining to the integrated iron and steel industry are scheduled for promulgation in 1997 and 2000. Within the context of EPA's mandate for inclusion of pollution prevention research in regulatory development under the Clean Air Act Amendments of 1990 (CAAA) and the Pollution Prevention Act (PPA), this scoping study was initiated to assess HAPs releases from processes within the industry and to identify P² opportunities within the industry that would affect the release of HAPs as well as criteria pollutants.

Research for the project was conducted via literature search; electronic database search; telephone interviews with industry contacts; and the convention of a one-day focus group meeting with representatives from industry, EPA, and iron and steel industry consultants.

MACT STANDARDS DEVELOPMENT FOR THE IRON AND STEEL INDUSTRY

Criteria pollutant emissions from the iron and steel industry have been studied extensively by
EPA since its inception more than two decades ago; information on HAPs, however, is generally less available. As is the case with many other major source categories, HAPs emissions from the iron and steel industry will be examined in great detail over the coming few years during the development of MACT standards for major process categories within the industry. The draft schedule for issuing MACT standards in 1994, 1997, and 2000.

PROCESS CATEGORIES, HAPS EMISSIONS, AND MAJOR P² OPPORTUNITIES

The integrated iron and steel industry encompasses all the steps included in the manufacture of steel from iron ore and other materials. Major processes in the production of finished steel include coke production, sinter production, ironmaking, steelmaking, alloying, casting and shaping, and finishing.

A 1991 screening study for the Office of Air Quality Planning and Standards (OAQPS) provided a qualitative ranking of HAPs-emitting processes and points in the integrated iron and steel industry. Of the ironmaking and steelmaking processes examined in the study (coke production fugitive emissions were not included), the basic oxygen furnace, sinter plant, electric arc furnace, and hydrochloric pickling lines were considered to have the greatest potential to emit HAPs. Information from that study and other sources is reproduced in Table 1.

Coke Production
Coke is coal from which the volatile components have been removed by heating to high temperatures in the absence of oxygen. Nearly all coke produced in the United States for the integrated iron and steel industry is manufactured using the "byproduct" coke process. Byproduct coke ovens may release volatile organic compounds (e.g.: benzene, butane, butylene, ethane, ethylene, hydrogen cyanide, methane, propane, propylene, toluene, and xylene) through leaks in any part of the system, including the coke oven lids and doors; through the standpipes; and within the plant, itself; and while the coke is being removed, or "pushed," from the oven. Together, these components, "coke oven emissions," are listed as one of the 189 HAPs in Title III of the Clean Air Act Amendments of 1990.¹ The Federal Register notice for the proposed coke oven NESHAPS/MACT standards indicated that pre-MACT emissions from charging and leaks were approximately 810 Mg per year, and emissions from bypass/bleeder stacks were approximately 850 Mg per year.¹ Implementation of the proposed MACT standard is expected to reduce national emissions from charging and leaking by approximately two-thirds, and to reduce emissions from bypass/bleeder stacks by at least 98 percent.¹

Several P² options reduce emissions of HAPs from coke ovens. Of the techniques available, the most radical change (in terms of costs to implement and difference in operation) is to replace byproduct coke ovens with nonrecovery coke ovens. In nonrecovery coke ovens, the organic compounds released from the coal are not recovered in a byproduct plant but are instead burned within the oven to generate heat. The combustion of organic compounds destroys virtually all
organic HAPs released from the coal. The Jewell Coke plant in Vansant, Virginia, has installed the only nonrecovery coke oven in the United States thus far; however, some coke manufacturers have considered nonrecovery coke ovens in plans for future construction.

Other HAPs opportunities for byproduct coke ovens include improved oven design and maintenance techniques that reduce the amount of HAPs released through lid and door leaks. Inspection and maintenance practices have been incorporated into the new NESHAP/MACT standards for coke ovens. In addition to reducing HAPs releases, these proposed design and maintenance practices also reduce the release of criteria pollutants (e.g., particulate matter) from coke being removed from the oven and from coke that is being cooled prior to transport to the blast furnace.

The Kress Indirect Dry Cooling (KIDC) system is one technique that has been tried at two sites in the United States. The KIDC system is a dry cooling system that allows the coke to cool in closed boxes rather than in open cars, thus preventing the oxidation of hot coal and the release of particulate to the atmosphere. Another technique tried outside the United States uses an inert atmosphere (e.g., nitrogen gas) that prevents oxidation of the coke. Neither the KIDC system nor the inert gas quench system is in current practice within the United States. However, the KIDC system is considered viable for coke oven batteries in the United States. The primary difficulty with the KIDC system at one installation was the need for an open area for movement and storage of the cooling cars. The necessary space was not available at the existing facility but could be included in the design of a greenfield (new construction) plant.

In fulfillment of requirements under the benzene NESHAP rule, existing coke ovens have recently equipped coke byproduct plants with inert gas blanketing systems that eliminate 95-98 percent of benzene emissions, in addition to preventing emissions of other VOCs (including volatile organic HAPs). In this process, an inert gas blanket is placed over various process vessels and storage tanks for reduced emissions.

Sinter Production
Sinter is an agglomerate of materials recovered from the iron and steelmaking process that is recycled into the ironmaking process at the blast furnace. In 1993, approximately ten sintering operations were in production. Many sinter plants have shut down in recent years, in part because of difficulties associated with keeping the sinter operations in compliance with environmental regulations. A wide variety of organic and heavy metal HAPs may be released at the sinter operation; organic HAPs can be released from coal and coke on the sinter grate and from organic solvents frequently found on scrap metals. Heavy metal HAPs may be released (as particulate) from the iron ore. Total HAPs releases from individual sinter manufacturing operations may exceed 10 tons per year. Pollution prevention opportunities for sinter manufacturing may include selecting feed materials to reduce the amount of organics introduced to the sinter process. However, these practices may not be a cost-feasible option, due to the large effort required to identify and segregate oily materials from less-oily materials. Deoiling
of mill scale using caustic solutions may be a better P² option for reducing the oil content in the feed stream before its addition to the sinter grate. Deoiling and dewatering of sludges delivered to the sinter process also reduce the amount of organics released to the atmosphere and reduce the total energy required to produce the sinter from recovered materials.¹ Waste materials generated at iron and steel mills without sinter lines are either sent off-site for processing or landfilled. Off-site processors may take the waste byproducts and separate zinc for reuse elsewhere and iron-rich materials for reuse at the iron and steel mill.

**Ironmaking**

In current U.S. industry practice, coke, iron ore and other materials are heated in a blast furnace to produce molten iron. Most of the HAPs generated in the blast furnace are heavy metals, including cadmium, chromium, lead, manganese, and nickel. Emissions from the blast furnace are controlled by a wet venturi scrubber or another control device and may total several tons per year per blast furnace.¹ Pollution prevention opportunities for the reduction of heavy metals at the blast furnace are somewhat limited, because heavy metals are an inherent part of the iron ore material stream and because iron production is directly proportional to the amount of ore used. However, two changes in ironmaking technology, direct reduction ironmaking (DRI) and pulverized coal injection (PCI), can indirectly reduce HAPs emissions from the industry by reducing or eliminating the need for coke in the ironmaking process. Reducing the need for coke reduces the emission of HAPs from coke manufacturing, since many of the HAPs that could be released (and not recovered) from coal in the coke oven process are instead combusted in the blast furnace. Both of these ironmaking technologies are being incorporated into the industry for their contributions to reducing product cost and air pollution. An additional P² benefit is that these techniques reduce the energy required to produce iron, thereby reducing air pollutant emissions from energy production.¹

Direct Reduction Ironmaking (still under development in the United States and in early use elsewhere) represents a radical change in ironmaking practice. DRI creates iron from coal or gas, iron ore, and other materials, eliminating the need for coke in iron manufacture and thereby eliminating virtually all of the HAPs emissions associated with the production of coke that would have been required for ironmaking. However, DRI does not necessarily reduce the amount of metallic HAPs emissions associated with making iron, since the iron ore consumption (from which metallic HAPs are generated) is not changed. In the DRI process, coal, iron ore and limestone are charged into a liquid bath. Carbon and heat reduce the iron ore, generating CO and molten iron. HAPs volatilized from coal during the direct reduction process are presumably destroyed within the ironmaking vessel. DRI processes are being developed internationally, with significant progress in Germany, South Africa, Australia, the United States, and Japan. Different proprietary DRI processes have been or are being developed. In Australia, CRA Ltd. and Midrex Corp. are employing the "HIs melt" process. The "Corex" process is being commercially employed in Germany and South Africa. Corex developers claim that the process reduces operating costs by at least 25 percent. The Corex process has been considered for at least one plant in the United States.
In comparison to the DRI process, pulverized coal injection techniques are a much smaller departure from current ironmaking practice. The PCI techniques nonetheless impact the total amount of HAPs emissions that may be released from the integrated iron and steel making process. PCI techniques currently being used in the industry allow ironmakers to substitute up to 25 percent of the coke with pulverized coal. The pulverized coal is injected into the blast furnace to provide carbon and heat for the reduction of iron ore. In the blast furnace, most of the carbon must be provided in the form of coke because the coke can provide solid yet porous structural support for the blast furnace burden. The structural need for coke limits the amount of pulverized coal that can be substituted in the blast furnace. HAPs volatilized from the coal in the blast furnace are presumably destroyed by the high temperatures in the blast furnace. PCI, first installed at Armco’s Ashland, OH plant, is being used at the US Steel Group plant at Gary, IN; at the USS/Kobe plant at Lorain, OH; and at Inland Steel in Indiana Harbor, IN.¹

In addition to pulverized coal, other fuel injection techniques that reduce coke requirements include natural gas injection and oil injection. A gas injection study sponsored by the Gas Research Institute (GRI) has shown that natural gas can replace 25 percent or more of the coke normally used in a blast furnace. This two-year study was conducted at an Armco Steel blast furnace.¹ Particulate P² opportunities at the blast furnace include the use of covered runners and natural gas flame or nitrogen blanketing to prevent molten iron from oxidizing while being transferred from the blast furnace to the torpedo car.

### Steelmaking

In typical practice at integrated iron and steel operations, steel is made by blowing oxygen into a blend of molten iron and scrap steel in a basic oxygen process furnace (BOF). As in the case for the blast furnace, most of the HAPs generated in the BOF are heavy metals, including cadmium, chromium, lead, manganese, and nickel. Emissions from the BOF are controlled by an electrostatic precipitator or venturi scrubber and may exceed 10 tons per year per BOF.¹ Pollution prevention opportunities for the reduction of heavy metals at the BOF are also somewhat limited, because heavy metals are an inherent part of the iron ore material stream and because iron production is directly proportional to the amount of ore used. Factors affecting HAPs emissions from the BOF include the degree of oxidation of the molten steel and the amount of time required to process the melt. Iron oxide emissions increase with the amount of time the hot metal is exposed to air and agitated by the heating process or during transfer. One P² method in current practice is to use natural gas to suppress oxidation of the steel in the tapping area while the steel is being transferred from the BOF to the transfer ladle.

Some early advances are being made in direct steelmaking, which extends the DRI process from the manufacture of iron to the manufacture of steel. As currently conducted, the final output of the DRI process is iron that must still be converted to steel in a BOF. Direct steelmaking, like DRI, would greatly reduce the need for coke in the manufacture of steel, thereby reducing emissions from coke manufacture. Direct steelmaking also promises to reduce the total energy requirement for steel production.
A recent research project conducted at Lehigh University (sponsored by the AISI) has yielded techniques for rapid, in-situ, spectrophotometric chemical composition analysis using laser-induced plasma. The benefit of the in-situ analysis is that the chemical composition can be determined almost instantly, reducing the BOF steelmaking cycle (typically close to 20 minutes) by two minutes. Conventional techniques require that a molten steel sample be withdrawn from the furnace and moved to a testing station for analysis. The in-situ technique analyzes the chemical composition with a probe inserted into the furnace. Time savings translate to reduced oxide formation (and therefore, reduced emissions) at the BOF. Time savings also reduce energy needs for maintaining the temperature of the hot steel, thereby reducing air pollutant emissions associated with energy production. A current research project being conducted by the Sandia National Laboratory and Bethlehem Steel (sponsored by AISI and the Department of Energy) is exploring the use of optical sensors to determine metal temperature and BOF off-gas temperatures to optimize production of steel.

Alloying
After steel is removed from the BOF, additional purification and alloying steps can be conducted at a metallurgical station. HAPs emissions from these processes are considered to be relatively low; few HAPs opportunities have been identified. Refinements in the alloying process, particularly the process of ladle-metallurgy, do provide the benefit of reducing energy requirements and reducing wasted steel by virtue of increased accuracy and speed in creating the desired steel composition.

Casting and Shaping
Two principal methods are used to form molten steel into solid form: ingot casting and continuous casting. In ingot casting, molten steel is poured into molds where it cools into an ingot which is later machined into final form. The continuous casting method eliminates the ingot step, thereby reducing the degree of reheating and rolling necessary to manufacture semifinished products. More importantly, continuous casting greatly reduces the amount of energy required to create semifinished steel. Continuous casting saves energy because much less scrap is generated in the manufacture of semifinished steel. Yields from continuous casting are 15 to 20 percent greater than from ingot casting. The largest material savings comes from eliminating crop losses associated with the top and bottom ends of ingots cast in molds. Other benefits include shorter pouring times and transfer times from the BOF to the caster as compared to teeming steel to multiple molds. Also, continuous casting eliminates much of the reheating required to process ingots produced from molds. Most companies in the United States have converted from ingot casting to continuous casting, and more plan to do so in the near future. It is estimated that approximately 80 percent of the semifinished slab steel in the United States is manufactured via continuous casting. In another project sponsored by the AISI, an electromagnetic flow control system to reduce alumina clogging in the steel feed to the continuous caster is being developed by the Westinghouse Science and Technology Center and US Steel. Like other projects, this effort is intended to optimize the casting process to ensure high quality at maximum production efficiency.
Not all steel can or should be manufactured by continuous casting, for reasons such as small batch sizes for specialty steels, or for the desired shape or size of the end product. For those operations that cast steel in molds, some operational changes such as bottom pouring instead of top pouring may reduce total emissions. Bottom pouring exposes much less of the molten steel to the atmosphere than top pouring, thereby reducing the formation of particulate.¹

**Finishing**

Finishing steps include pickling and galvanizing to treat the surfaces of semifinished metal products. Hydrochloric acid (HCl) bath pickling is the most common method used to remove iron oxide from the surface of semifinished steel products; hydrofluoric acid (HF) is also used in some specialty steel applications. Hydrogen chloride is the primary hazardous air pollutant associated with pickling, with emissions from surface pickling typically well over 10 tons per year per facility. Some P² opportunities have been identified for this process area; most have to do with minimizing the use of acid or the prevention of excess HCl or HF losses to the atmosphere. For example, a new pickling product, "Scale Gone," introduced by the Maintenance Equipment and Chemical Sales Corp., is an organic, food-based acid that is reported to be biodegradable and water soluble, and is reported to produce no harmful vapors. Scale Gone is suitable for application in dip cleaning applications, but not in continuous pickling lines, due to its relatively slow cleaning action. No extensive environmental test reports were immediately available for this product.¹

Galvanizing is another finishing process in which steel is coated with zinc to prevent corrosion. Coating can be conducted by passing the steel through molten zinc or by electrodeposition. On-line phase measurement of steel galvanizing techniques using x-ray fluorescence are being developed by the Data Measurement Corp., the Jet Propulsion Laboratory, and Inland Steel. Lastly, on-line temperature measurement of galvanneal steel methods are being developed by the Oak Ridge National Laboratory, the University of Tennessee, and National Steel. In other projects sponsored by AISI, on-line, nondestructive mechanical property measurement techniques using magnetic and ultrasonic methods are being developed by the National Institute of Standards and Technology, the Industrial Materials Institute of Canada, and Armco Steel. All of these "advanced process control" research efforts are dedicated to increasing the efficiency by which steel is made. A benefit of these efficiencies is the reduction of emissions from manufacturing wasted steel and from reducing total energy used in steel manufacture.¹

**ADDITIONAL PROCESS CATEGORIES AND P² OPPORTUNITIES**

**Metal Coating.** After hot rolling or cold rolling, metals may be coated with various materials containing HAPs (e.g., zinc, chromium, or lead) in solutions containing other HAPs (e.g., chlorine, cyanide, and ethylene glycol). A recent project conducted by Weirton Steel (sponsored by AISI) substituted tin-plating processes which use methane sulfonic acid (MSA) as a more environmentally benign substitute for the halogen solutions currently in use which produce
potassium ferrocyanate as a byproduct. Other tin-plating processes are being modified to substitute hexavalent chromium with trivalent chromium for electroplated chrome coated steel (ECCS).¹

**Dezincing Processes.** Particulate collected from the BOF offgas contains ferrous components that are desirable products for recycle (via the sinter process) to the blast furnace. However, zinc in the BOF particulate is an undesirable element for feeding back into the steelmaking material stream. If the zinc is not removed, the BOF particulate must be landfilled, resulting in the loss of all useful compounds in the particulate, as well as the landfilling of HAPs such as lead, chromium, nickel, and cadmium. Proprietary dezincing processes that can remove zinc, cadmium, lead, and chlorine from BOF (and electric arc furnace) particulate using rotary kilns or calciners have been developed by the Horsehead Resource Development Corp. The remaining iron-rich material (IRM) can then be sent to the sinter process. The zinc and cadmium can be recovered for use elsewhere.¹

**Training Programs**

Steelmakers have made extensive use of employee training for improvements to manufacturing, safety, and the environment. Often, these programs are made within the context of Total Quality Management (TQM) improvement. The USX Corporation's Continuous Improvement to the Environment (CITE) program, initiated at the USX Clairton Works, is a strong example of employee training. The CITE program trains all Clairton employees—workers and managers—in a 40-hour program that educates staff on the impact of their work on the environment and on the quality of USX product. It is generally agreed that well-run training programs are key methods for ingraining P² thinking into the habits of industry employees. Benefits attributed thus far to increased worker training include reduced pollutant releases, higher quality, less downtime, and reduced occurrences of environmental violations.¹

By providing each employee with a holistic perspective of how their actions in one part of the facility affect other parts of the facility and the community, the CITE program encourages proactive thinking. An interesting feature of the Clairton facility CITE program is that it was set up through a partnership between US Steel and a local school, the Community College of Allegheny County. Courses were designed and taught, in part, by retired US Steel employees to increase the quality of instruction and communication. It was understood that these former employees would have the best understanding of the US Steel processes and how to teach them to current employees. By all accounts, employee response to the program has been overwhelmingly positive.¹

It is recognized that implementing total quality management (TQM) programs and similar efforts is not an easy task within any industry, particularly in the iron and steel industry which has not possessed strong financial resources over the last two decades. Nonetheless, these programs are considered means to becoming more profitable and more competitive. Implementation of the CITE program at US Steel has required, in off-site training time alone, 40 hours for each of
1,600 employees. It is estimated that US Steel’s costs to implement the program are on the order of $2.5 million.¹

IMPLEMENTATION ISSUES FOR P² IN THE IRON AND STEEL INDUSTRY

Several issues consistently come up in discussions regarding the inclusion of pollution prevention in rulemaking and rules affecting the iron and steel industry. Frequently mentioned topics include:

- The inherent correlation between steel production volumes and metals emissions
- Concern that EPA rules will mandate specific production techniques (e.g., equipment or material choices) as pollution prevention requirements under MACT rules
- EPA’s interpretation or definition of "process boundaries"
- Economic incentives for pollution prevention

Steel Production and Metals Emissions
In many ways, P² efforts may be more applicable to industries that are trying to reduce materials that are adjunct to the production process (e.g., solvents) than to the iron and steel industry. A key technique for pollution prevention is to reduce the input of materials that eventually become undesired emissions. In the iron and steel industry, however, many pollutants of concern—particularly the heavy metal HAPs such as chromium, lead, and manganese—are inherently present in iron ore, the core element of iron production. In other words, the only way to reduce emissions of species such as manganese from iron production is to reduce the amount of iron manufactured, a non-viable P² option. At this point, it appears that EPA pollution prevention initiatives, recognizing the inherent relationship between product and pollutants in the raw materials, will remain focused on limiting the release of these inherent pollutants rather than the removal of them from the raw material feed. In the iron and steel industry, pursuit of P² techniques that reduce use of pollutant-containing ancillary materials has been historically attended through efforts such as the 33/50 program which has resulted in the elimination of compounds such as 1,1,1-trichloroethane from use in the industry. The following section describes in more detail the challenges associated with incorporating further pollution prevention techniques associated with ancillary materials for the iron and steel industry.

Pollution prevention techniques in EPA rules
Pollution prevention options can generally be characterized in one of three categories:

- Equipment changes (e.g., from byproduct recovery coke ovens to nonrecovery coke ovens)
- Process parameter changes (to borrow from another industry, e.g., lowering temperatures of mixing chambers where solvents are being used; or addition of
cover fluxes to prevent oxidation)

- Work practice changes (e.g., inspection and maintenance programs)

The question of concern to the iron and steel industry is whether and how such pollution prevention options will be included in rules affecting the industry. It is impossible, at this point, to definitively say how pollution prevention will be incorporated into upcoming rules for the iron and steel industry, including MACT rules for HAPs, or for rules under any upcoming amendments to the Clean Water Act. However, a few generalizations can be made on the basis of current and historical rulemaking efforts at EPA.

In short, it does not appear that EPA currently intends to motivate specific equipment or process parameter changes within upcoming MACT regulations for the iron and steel industry. For example, it is inconceivable that EPA rules will specify that "iron and steel mills must install continuous casters for slab metal production; ingot casting will be no longer allowed." It is also inconceivable that EPA rules will specify that "hot metal temperatures within BOFs will not fall below X°F during turndown." Rules as restrictive as these, in which rule language would so specifically constrain the manufacturing operations of the iron and steel industry (or any industry) are recognized to be untenable and ineffective means for maintaining air quality.

It is the case, however, that specific pollution prevention techniques in current industry practice will have some bearing on how MACT rules will be written. EPA is required to base the MACT level of HAPs control (or maximum emission limits) on levels currently being attained by existing sources. For new sources, MACT levels will be predicated on the basis of the "best" performing source in current operation; for existing sources, MACT levels will be predicated on the basis of the five best-performing sources in the industry (for industries with fewer than 30 sources) or on the basis of the best-performing 12 percent of sources in the industry (for industries with 30 or more sources). The new sources and lower-performing sources must match the emission standards of the top-performing sources by whatever means are available to them.

Flexibility for the facility is maintained in that sources may attain MACT standards through traditional add-on control techniques, or through established or new pollution prevention techniques. However, if the top-performing sources are using \( P^2 \) techniques to achieve their level of emissions, then these techniques may become \textit{de facto} the only immediate means for other sources to meet the MACT emission standards if this level cannot be met any other economical way. Nonetheless, all sources would remain free to develop new \( P^2 \) techniques to meet the MACT standards or to use add-on controls if so desired.

As mentioned before, three types of pollution prevention techniques—equipment changes, process changes, and work practice changes—exist that may affect future rulemaking. The following examples illustrate how these three techniques have been or are currently being considered in air quality regulations, and speculate on the future of these techniques in MACT regulations for
the iron and steel industry.

A variety of rules such as the New Source Performance Standards (NSPS) written in the 1980s have all but required some equipment changes. For example, when the primary copper NSPS was being written, the two types of furnaces in use were the flash furnace and the reverberatory furnace. The NSPS performance levels for this industry were written based on the performance level of flash furnaces; consequently, all retired reverberatory furnaces had to be replaced by flash furnaces, since reverberatory furnaces could not meet the new NSPS performance level. In effect, therefore, the NSPS rules did mandate an equipment change. It appears unlikely, however, that major equipment changes of this sort will be incorporated into MACT rules for the iron and steel industry. One reason for this unlikelihood is that the iron and steel production methods in current use are fairly consistent across the United States. Blast furnaces are the standard means for producing iron, and BOFs and EAFs are the standard methods for producing steel. Therefore, the major equipment used by the lower-performing sources is equivalent to the equipment used by best-performing sources and no equipment changes will be required. In the coke production sector, the recent NESHAP/MACT rule allows for new recovery ovens as well as new non-recovery ovens, i.e., the rule does not require industry to abandon byproduct recovery ovens for new construction.

In a second example, process or process-control choices are currently being incorporated into MACT rulemaking for the secondary lead industry, in which HCl is a pollutant of concern. At least three ways of controlling HCl emissions have been evaluated: use of an add-on scrubber, or two potential P2 techniques. Of these three techniques, one of the P2 techniques is not sufficiently commercialized to be considered in setting the MACT standard and the scrubber is considered less cost-effective than the other P2 technique (the use of a fluxing agent). Therefore, use of the fluxing agent will likely be the basis for the MACT emission limit. Nonetheless, secondary lead smelters electing to use different techniques to comply with the MACT rule remain free to do so. This approach, however, in which process-change pollution prevention techniques are evaluated and subsequently used to establish standards, is not immediately foreseen within the iron and steel industry.

Lastly, unlike equipment change requirements, work practice pollution prevention requirements are already being incorporated into MACT rules for the iron and steel industry. Work practice requirements include a training program for coke plant operators; formalized door-inspection, -adjustment, -repair and -replacement programs; leak-identification and repair programs; and other similar requirements. However, it has been questioned whether pollution prevention techniques that consisted of training programs or enhanced inspection and maintenance efforts would be effective elements of any regulation because compliance with the technique could not be precisely correlated to reduced emissions. It has been stated by some that numerical targets for emission reduction "by whatever means," (i.e., allowing industry to develop and choose its own pollution prevention techniques) would be a more powerful means of both reducing emissions and encouraging effective use of all pollution prevention techniques. Future
rulemaking will likely incorporate both work practices and emission limits.

**Economic Incentives for Pollution Prevention**

Clearly, economic conditions guide the viability of any P2 technique at a given time. Example economic drivers include the costs of waste treatment and disposal, costs of different P2 techniques, costs of substitute materials or processes, and the market prices of steel products.

As currently conceived, the Title V permit fees (fees per ton of pollutant emitted) are not large enough to significantly influence industry's choice of manufacturing or pollution abatement techniques. For example, Title V regulations call for operating permit fees on the order of $25 per ton of regulated criteria pollutant, with the fee applied to the first 4,000 tons per year. At this rate, the total potential fees associated with criteria pollutant emissions are less than $1 million per year. Fee reductions associated with fractional reductions of criteria pollutant emissions are unlikely to be on par with capital costs typically associated with pollution control or prevention techniques.

**EPA's Interpretation or Definition of Pollution Prevention and "Process Boundaries"**

On May 28, 1992, EPA's Deputy Administrator, F. Henry Habicht II, released a memorandum providing EPA's definition of pollution prevention. The memorandum provided that pollution prevention (or source reduction) includes:

"...equipment or technology modifications, process or procedure modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control.

"Under the Pollution Prevention Act, recycling, energy recovery, treatment, and disposal are not included within the definition pollution prevention. Some practices commonly described as 'in-process recycling' may qualify as pollution prevention."  

The importance of this definition lies in the distinction between pollution prevention and recycling. There are several ways in which this definition is relevant to the iron and steel industry, some of which have greater impact than others. In some cases, the distinction is clear: pollution prevention techniques prevent the formation or release of a pollutant from the process; in contrast, recycling techniques are exemplified by the emission of a pollutant from a process (e.g., coke oven dust), its later recovery (e.g., in a baghouse) and its recycling back into the process. However, there can be a vague line between pollution prevention and recycling depending on where the process boundary is drawn. In the next paragraphs, two processes are used as examples of how the line can be drawn to interpret practices as either pollution prevention or recycling. These examples are given before further discussion of the impact of the EPA pollution prevention definition.
The sintering process recovers coke fines and iron-bearing material from various processes within the mill. The issue of interpretation applies when determining whether sintering is an "in-process recycle" (if the entire iron and steelmaking effort is considered a single "process") and therefore a pollution prevention measure; or if the sintering process is not to be considered pollution prevention, but is instead designated a recycling step because the cokemaking, ironmaking, steelmaking, and sintering operations are considered separate processes.

A second example of a possible in-process recycling operation is the treatment of used HCl solutions from pickling lines. Like the sintering process, treatment of HCl solutions may be viewed as an integrated part of iron and steelmaking, and therefore considered pollution prevention; or it may be designated a separate recycling step. A rationale for excluding off-site recycling from the pollution prevention definition is that the necessity of transporting wastes to a recycling facility, and the risks associated with the recycling process, make recycling a less desirable alternative than in-process recycling on-site.

Pollution prevention in rulemaking. The two examples above can be used to discuss the relevance of the pollution prevention definition as applied to rulemaking, rules, and reporting. In rulemaking (the process by which rules are developed, as distinct from the rules, themselves), the sintering example could be interpreted in one of two ways. If the EPA were to interpret sintering as "in-process recycling" (and thereby, pollution prevention) and were to develop a multi-media, bubble-type rule that evaluated total reductions in wastes released from the facility, then facility-wide emissions could be reduced by the use of the sinter plant. However, if EPA were to define rules based on more limited definition of process release points (as has historically been the case for air pollution regulations), then the sinter plant might be evaluated as a source (with corresponding emission limits and rules) rather than a source-reduction technique.

EPA's mandate to include pollution prevention techniques in new rulemaking makes it all the more important to examine the way in which process-boundaries are evaluated in order to create optimal environmental rules. One handicap facing pollution prevention in MACT rulemaking is that manufacturing facilities release air pollutant emissions to the atmosphere directly from each stack, vent, or fugitive process at a site. Therefore, rules must be written that account for each release. In contrast, effluent guidelines for wastewater release and guidelines for solid waste release can allow more flexibility, since waste generated within the facility can be aggregated and extensively reused and treated within the facility before their release from the plant at one or more points at the fenceline. Perhaps the most important change that may come to environmental rulemaking will be the development of a multimedia (i.e., air, water, and solid waste) regulatory framework in which tradeoffs between pollution in different media are fully evaluated, and in which bubble rules and netting are normal means for achieving environmental compliance. But while some efforts have been made in this direction (i.e., cluster rules for the pulp and paper industry and upcoming "sector" activities for other industries), full attainment of this goal at EPA is in the unforeseen future.
Mandated Pollution Prevention Plans. The definition of pollution prevention comes into play, again, in various federal requirements under RCRA and in numerous state pollution prevention programs. Under RCRA, major treatment, storage, and disposal facilities (TSDFs) are required to develop a pollution prevention plan for reducing or limiting the release of hazardous wastes. Facilities submitting these plans must do so using pollution prevention techniques under the EPA definition as interpreted in the Habicht memorandum. Recycling techniques submitted under the pollution prevention plan are not considered satisfactory. Increasingly, state environmental laws are also requiring facilities to generate pollution prevention plans. Individual state rules may, however, use a broader definition of pollution prevention than the EPA definition. Also, facilities reporting to the Toxic Release Inventory System (TRIS) must distinguish between wastes released from a process and subsequently recycled (these wastes would be reported as releases) and wastes immediately reprocessed through in-process recycling techniques (not reported as releases). Lastly, pollution prevention plans are frequently being used as parts of compliance plans or Supplemental Environmental Projects (SEPs) for facilities negotiating compliance strategies with EPA. In these instances, the definition of pollution prevention may again be important.

CONCLUSION
Within the integrated iron and steel industry, numerous opportunities for process improvements are being explored to continuously improve the efficiency through which iron and steel are manufactured. Many of these improvements are, by definition, pollution prevention opportunities in that they reduce the amount of emissions, material waste, and energy used in the production of finished steel. Nonetheless, it should be kept in mind that pollution prevention in the iron and steel industry is largely tied to efficiencies in production rather than through the substitution, reduction, or removal of specific materials from the product stream. Nearly all the materials used in the industry are part of the final product rather than ancillary materials (e.g., solvents) used to make the product. Many pollution prevention approaches in other industries are based on reducing the introduction of non-integral materials to the process stream. In the production of iron, most materials that become contaminants (e.g. magnesium or chromium) are introduced to the process in fixed proportion to the amount of desired finished product. Pollution prevention will continue to have a role in the iron and steel industry. However, given these constraints, the current status of radically different production approaches (such as direct ironmaking), and the timetable for producing MACT regulations for the industry, it appears unlikely that upcoming MACT rulemaking will make extensive use of pollution prevention as a means of reducing emissions of hazardous air pollutants.

REFERENCES


DISCLAIMER

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The views expressed within this paper are those of the author and not of TRC Environmental Corporation.
Table 1. Process listing by annual HAPs emission estimates¹

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<thead>
<tr>
<th>Processes with substantial HAPs emissions</th>
<th>Coke oven fugitives</th>
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<tbody>
<tr>
<td></td>
<td>Basic oxygen furnace (steelmaking)</td>
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<tr>
<td></td>
<td>Sinter plant</td>
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<tr>
<td></td>
<td>Electric arc furnace (steelmaking)</td>
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<tr>
<td></td>
<td>Pickling (finishing)</td>
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</tbody>
</table>

| Processes with potential as major HAPs emission sources | Blast Furnace (ironmaking) |

<table>
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<tr>
<th>Processes unlikely to be major HAPs emission sources</th>
<th>Coke oven battery stack</th>
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<tbody>
<tr>
<td></td>
<td>Hot metal transfer</td>
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<tr>
<td></td>
<td>Hot metal desulfurization (steelmaking)</td>
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<td></td>
<td>Slag skimming</td>
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<td></td>
<td>Ladle metallurgy (alloying)</td>
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<td></td>
<td>Scarfing (finishing)</td>
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<td></td>
<td>Galvanizing (finishing)</td>
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<table>
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<tr>
<th>Processes for which no HAPs emission data were available</th>
<th>Open dust sources</th>
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<tbody>
<tr>
<td></td>
<td>Scrap cutting</td>
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<td>Casting</td>
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