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Erratum

An introductory note was inadvertently omitted from the Graham and Holtgrave paper, at 243. It reads: This paper is an edited version of a report prepared under contract for the Congressional Research Service. The second author worked on the report while a Research Fellow in Interdisciplinary Programs in Health at the Harvard School of Public Health and was funded through cooperative agreement CR812699 with the U.S. Environmental Protection Agency. We wish to thank John Blodgett of CRS, Amanda Agnew, William Becker, Eula Bingham, William Burgess, William Clark, Theodore Dinsmore, Thomas Field, Walter Goldberg, Thomas Graham, James Hanbright, William Harnett, Peter Hernandez, Charles Holmes, Joseph Hopkins, Joellen Lewtas, John Martonik, Phil Masciantonio, James McCarthy, Carol Redmond, Steve A. Swanson, Mary Win- O'Brien, Michael Wright and Earle Young - who are, of course, not responsible for our errors or conclusions.

Coke Oven Emissions: A Case Study of Technology-Based Regulation

John D. Graham, David R. Holtgrave*

Introduction

The 101st Congress is considering three major proposals for controlling hazardous air pollution: S.816, H.R.2585 and a proposal by President Bush.¹ Each would require that maximum achievable control technology [MACT] be applied to each major source of emissions. The emissions remaining after MACT is applied (so called "residual emissions") would be treated differently under the plans. President Bush's plan calls for the Environmental Protection Agency [EPA] to apply a discretionary "unreasonable risk" standard to residual emissions whereas S.816 and H.R.2585 would eventually compel major sources to comply with stringent numerical risk levels (so-called "bright lines" of acceptable risk).

Although there are various interpretations of the MACT concept, the general idea is to require each major source of emissions to achieve the lowest level of emissions that has already been achieved by a major source within the same group of industrial sources. Sometimes MACT is interpreted differently for new and existing sources. Note that MACT is not considered to be "technology forcing"; the idea is to proliferate the

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¹ S.816 was introduced on April 18, 1989; H.R. 2585 was introduced on June 8, 1989; the administration proposal was introduced as H.R. 3030 on July 27, 1989.

application of known, demonstrated technology. However, the legislative proposals would be "technology forcing" for those sources whose residual emissions do not satisfy the "unreasonable" or "bright-line" risk tests. For instance, the legislative proposals incorporate health-based standards. The setting of the health-based standards requires the establishment of a bright-line level of acceptable risk. Polluters have a fixed period of time to reduce their output to a level below the bright-line. If they lack the technological means to meet this criterion, they are given five to ten years to develop the requisite technology.

The coke production industry in the U.S. provides an informative case study because it has been subjected to technology-based regulation of fugitive emissions for over 30 years. This report examines how well the approach has worked in the control of coke oven emissions and how it might have worked better. Although the coke production process is complex and unique, we believe it offers some general insights relevant to today's legislative efforts to revise the Clean Air Act.

The Coke Production Process²

Coke is a vital and largely irreplaceable component of the iron and steel production process. Coke is derived from coal. The major steps in coke production are: (1) loading coal into the oven (the "charging" step), (2) heating the coal until it becomes coke ("coking"), and (3) "pushing" the coke out of the oven into cooling and transport cars. The oven operates largely by reusing (burning) gases emitted by the hot coal (hence the name, "by-product recovery"). Over 99% of U.S. coke production makes use of "coke by-product recovery ovens."

² This section is based in part on discussions in U.S. ENVIRONMENTAL PROTECTION AGENCY, COKE OVEN EMISSIONS FROM WET-COAL CHARGED BY-PRODUCT COKE OVEN BATTERIES: BACKGROUND INFORMATION FOR PROPOSED STANDARDS (1987).

In a typical coke oven battery, a number of coke ovens are lined up in a row. This row is called the battery. Each oven in the battery has doors on top and on two sides (the other two sides abut neighboring ovens). Above and to one end of the battery is a coal storage bin. On the top of the battery is a movable "larry car" which is able to take coal from the storage bin and drop it into specific coke ovens. On one side of the battery is a movable "pusher car" which is able to push coke (made from coal) out of the ovens and into a movable "coke car" or "quench car" located on the other side of the ovens.

To be more precise, the first stage of coke oven operation involves loading coal, by conveyor, into the coal storage bunker located above and to one end of the oven battery. Depending on the chemical and physical properties of the coke, the coal may be dried and preheated, or simply used with its natural moisture content. The larry car takes small loads of coal from the bunker and drops them into the coke ovens comprising the battery. This dumping procedure requires that lids on top of the ovens in the battery be automatically or manually opened and shut. After the coal load is dumped into an oven, a leveler bar flattens the pile of coal into a bed. This allows a space for the waste gas to collect while the coal is being heated. The coal is heated from below by a combustion gas system. The gas used is largely air and waste gas taken from earlier cycles of coke production. Virtually all of the gas is recovered and reused in the coke production process. This gas is primarily composed of hydrogen and methane with water vapor, tar, light oils, and heavy hydrocarbons (among other compounds) also present. Steam jets force the gas trapped between the hot coal and the oven top into a collecting gooseneck. Then the gas is sprayed with a "flushing liquid" and cooled somewhat. After the tars, light oils, ammonia, phenol, and hydrogen sulfide are taken from the gas, it is sent back to the coke oven — this time into the side heating units.

When the coal has been heated sufficiently (usually for 1530 hours at around 1000 degrees Centigrade), doors on both sides of the oven are opened. A pusher car then comes along and literally pushes the hot coke out of the oven and into a quench car. The car takes the hot material to a quenching tower. The coke is drenched with water and cooled for transport and size screening. If the coal has been heated for a sufficient length of time, this pushing operation poses little problem. However, if the coal (not yet coke) is prematurely pushed from the oven, flames and large quantities of volatile gases shoot out from the oven. This sort of incident is called a "green push, " or "pushing a bomb. " It can only be avoided and controlled through good brickwork, careful training of coke oven workers, good work practices and maintenance of heating systems.

As stated above, most of the gas in a coke oven is recycled and reused. However, some emissions do escape during the charging, coking and pushing phases. That is, topside lids, push side doors, quench car side ("coke side") doors, and general cracks do leak to a small extent. The amount of such "fugitive" emissions depends on numerous factors such as the design, age and condition of the battery and the operating and maintenance practices employed. Coke oven emissions are a yellowish-brown gas containing upwards of 10,000 compounds, e.g., gases, vapors, and particulates. Several of these constituents are known carcinogens. Especially problematic are benzene, polycyclic organic matter, respirable particulate matter, and coal tar pitch volatiles. The two major methods for measuring coke oven emissions are (a) measuring the opacity of visible emissions, and (b) measuring concentrations of BSFTPMP (benzene soluble fraction of total particulate matter). It is difficult, however, to correlate these two measurement methods.

There are several methods of controlling fugitive coke oven

emissions. Emission leaks during charging were controlled in the past by using schemes for sequentially charging the ovens in a battery, and by putting scrubbers on larry cars (these scrubbers ride under larry cars, surround open topside lids during charging, and direct the gas to a receptacle on the larry car). Topside leaks which occur while topside lids are closed and the coal is heating are combatted through proper maintenance and operating procedures. Several methods (e.g., coke oven sheds, fume hoods, maintenance and operating procedures) exist for controlling side door emissions, but the most common method is to assure the tight sealing of the doors through various techniques such as wet clay sealing (luting) and metal-to-metal sealing.

New model designs for entire coke ovens are also promising, but of uncertain technological and economic feasibility. Such designs include negative pressure ovens which trap all gases inside the oven by keeping the oven pressure lower than the surrounding air pressure. Brand new designs for coke oven component parts are also promising (these include improvements in virtually every part of the coke oven). Progress is also being made on cleaner methods of dry-coal charging (most procedures now mix the bunker coal with some water), and better methods for recycling the waste gases. In recent years, however, the economics of new or redesigned coke ovens have been so unattractive — in part because of environmental requirements — that very few capital investments in new capacity have been made. Demand for coke has been depressed over much of the last two decades, in concert with the troubled state of the domestic steel industry. Only in the last few years has the steel industry experienced a sustained upturn.

The Health Effects of Coke Oven Emissions

Coke oven emissions can have a deleterious effect on human health. Most of the regulatory action is based on cancer endpoints, and therefore we focus on the evidence linking coke oven emissions to excess human cancer risk.³

Coke oven emissions contain literally several thousand compounds, several of which are known carcinogens and/or cocarcinogens (including polycyclic organic matter from coal tar pitch volatiles, beta-naphthylamine, benzene, arsenic, beryllium, cadmium, chromate, lead, nickel subsulfide, nitric oxide and sulfur dioxide).⁴ However, most regulatory attention has been paid to coal tar pitch volatiles. In particular, the highly toxic benzene soluble organics fraction of the coal tar pitch volatiles has been singled out for intensive study and standard setting.⁵

Coal tar aerosols and air samples taken near coke ovens have been shown to cause lung cancer in laboratory animals and to test positive in mutagenicity tests on bacteria. Urine samples from nonsmoking coke oven workers have also been deemed mutagenic by the Ames test. Coal tar, which condenses from coke oven emissions, has been shown to cause skin tumors in laboratory rodents.

³ For an overview of the limited literature on nonmalignant respiratory effects, *see* U.S. Dept. of Labor, *Exposure to Coke Ovens*, 41 Fed. Reg. 46,748 (1976).

⁴ U.S. ENVIRONMENTAL PROTECTION AGENCY [hereafter EPA], *CARCINOGEN ASSESSMENT OF COKE OVEN EMISSIONS, FINAL REPORT OF OHEA*, (1984).

⁵ Referred to as "BSO" (benzene soluble organics) or "BSTFM" (benzene soluble fraction of total particulate matter).

Table 1⁶

Observed and Expected Deaths for
Selected Causes by Race, 1953 to 1961,
Among Men Employed in Coke Plants in 1953

Cause of Death	Coke Plant			Coke Oven			Non-Oven		
	O	E	SMR	O	E	SMR	O	E	SMR
All Causes (Total)	206	198.9	104	100	96.6	104	106	102.3	104
Respiratory Cancer	25	14.3	175 ^t	20	7.5	267 ^t	5	6.8	74
Digestive Cancer	16	14.8	108	4	6.5	62	12	8.3	45
All Causes (White)	114	121.1	94	25	31.4	80	89	89.7	99
Respiratory Cancer	4	7.5	53	3	1.9	—	1	5.7	18
Digestive Cancer	11	9.8	112	1	2.4	—	10	7.4	135
All Causes (Non-W)	92	77.8	118	75	65.2	115	17	12.6	135
Respiratory Cancer	21	6.8	309 ^t	17	5.7	298 ^t	4	1.1	—
Digestive Cancer	5	4.9	102	3	4.1	—	2	0.8	—

O = Observed Deaths; E = Expected Deaths; SMR = O/E X 100

^t indicates statistical significance at the 1 per cent level

— indicates that SMR is not calculated when there are less than 5 deaths.

There is considerable epidemiological evidence to suggest that coke oven emissions have been carcinogenic to workers. Results from one of the oldest such studies are summarized above in Table 1.

In an overview of these studies, the International Agency for Research on Cancer [IARC] stated that all but two of the epidemiological cohort studies provided evidence of significantly raised risk of lung cancer for coke oven workers — although one study showed a deficit of lung cancer among coke oven workers. Comparison

⁶ J. W. Lloyd, *Long-Term Mortality Study of Steelworkers: Part V – Respiratory Cancer in Coke Plant Workers*, 13 J. OCCUPATIONAL MED. 5 (1971).

groups included both general population and non-oven coke production worker samples. IARC states that the increase in lung cancer risk ranges from threefold to sevenfold.⁷

EPA also reviewed the epidemiologic data and came to conclusions similar to that of IARC. In the most methodologically-sound series of epidemiological studies reviewed by EPA, Allegheny County top side coke oven workers were found to have a risk of lung, trachea and bronchus cancer seven times larger than non-oven coke production workers.⁸ The relative risk coefficient for side workers was 1.91, i.e., 1.91 times as many deaths as expected. Allegheny County workers, the top side and coke side relative risk rates were 3.47 and 2.31, respectively. This finding provided the first crude estimation of a dose-response curve for cancer and coke oven emissions. It should be stated, however, that even these exemplary studies suffer from lack of adequate control for smoking status of the workers. While the control groups of workers may have included some smokers, there is no data to prove the comparability of the control group on this critical dimension.

EPA notes the epidemiologic studies conducted in Great Britain do not find such large effects — some find no increased incidence of inhalation pathway cancer. EPA states that these studies suffer from methodological shortcomings, such as small sample sizes and incomplete follow-up.⁹

In a very recent risk assessment, M.H. Dong and his coinvestigators estimate age-specific rates of excess lung cancer for non-white coke oven workers under the assumptions of a multistage model of carcinogenesis. They find that (a) coke oven emissions act as a cancer

⁷ WORLD HEALTH ORGANIZATION, INTERNATIONAL AGENCY FOR RESEARCH ON CANCER, MONOGRAPH ON THE EVALUATION OF CARCINOGENIC RISKS TO HUMANS SUPPLEMENT 7 (1987).

⁸ Lloyd, *supra* note 6, at 53.

⁹ See *supra* note 4, at 98-110.

initiator rather than a late stage promoter, (b) the number of stages in the development of cancer from exposure to coke oven emissions is four (this is not too far off from the commonly assumed number of six), and (c) the lifetime risk for such workers might be as high as four in ten.¹⁰

On the basis of the epidemiological evidence, IARC has stated that there is sufficient evidence to classify coke oven emissions as a known human carcinogen. EPA has likewise placed "coke oven emissions" into its highest category of "evidence for carcinogenesis."

EPA has gone further and estimated a unit risk factor for continuous lifetime exposure to 1 microgram/cubic meter of BSO in the air. (The unit risk factor gives the probability of a person developing cancer from lifetime exposure to the stated concentration.) There is considerable uncertainty about the EPA's estimate. EPA states that the proper range for the estimate is from 1.30×10^{-8} to 1.26×10^{-3} , with the best point estimate being 6.17×10^{-4} . EPA believes that the latter number is a plausible upper-bound estimate.

Using this unit risk factor and various exposure modeling techniques, EPA analysts have estimated how many residents are exposed to coke oven emissions and how much extra risk of respiratory cancer these exposures might generate. Overall, EPA estimates that coke oven emissions are responsible for an additional seven cases of respiratory cancer each year in the U.S., although some residents who live close to such plants may experience very large individual risks.¹¹ (This figure does not include any carcinogenic effects of occupational exposures, which are addressed below.)

EPA estimates of cancer risk from exposure to coke oven emissions

¹⁰ Dong, Redmond, Mazumdar & Costantino, *A Multistage Approach to the Cohort Analysis of Lifetime Lung Cancer Risk Among Steelworkers Exposed to Coke Oven Emissions*, 128 AM. J. EPIDEMIOLOGY 860 (1988).

¹¹ EPA, *Coke Oven Emissions from Wet-Coal Charged By-Product Coke Oven Batteries*, 52 Fed. Reg. 13588;13594 (1987).

should be treated with caution because they are based on some disputable assumptions and questionable data. First, no epidemiological evidence has established a direct link between community (residential) exposure to coke oven emissions and excess rates of respiratory cancer (although it might be difficult to detect such an effect even if it existed). EPA risk estimates are based on extrapolation of epidemiological results from the occupational setting to the general ambient environment. This extrapolation introduces uncertainty because exposure levels in the community are typically several orders of magnitude smaller than they are in the coke oven environment. Furthermore, the chemical composition of the pollutant mixture changes as emissions are transported away from the ovens. EPA also assumes a linear dose-response relationship at low levels, even though the available data are also consistent with a nonlinear dose-response curve (which in this case suggests a much smaller risk at low exposure levels).¹² Second, cigarette smoking is not adequately addressed in the occupational epidemiology, even though smoking could act as a confounder or synergistic agent in producing the reported excess rates of respiratory cancer among coke oven workers. Third, EPA's estimates of community exposure to coke oven emissions are questionable. EPA assumed in 1984 that 43 coke oven plants with 134 operating batteries were in production; the most recent the American Iron and Steel Institute [AISI] survey shows that there are only 30 coke plants with 84 operating batteries — the remainder are either in idle status or have been permanently shut down.¹³ Moreover, EPA's exposure modeling makes numerous simplifying assumptions that tend to exaggerate risk

¹² See Letter from Dr. Steven H. Lamm, Consultants in Epidemiology and Occupational Health, Inc., to Dr. Todd Thorslund, EPA, (Aug. 5, 1983) (Critique of EPA's risk assessment of coke oven emissions).

¹³ See comments of the American Iron and Steel Institute, EPA, Docket No. A-79-15, August 6, 1987.

(e.g., assuming that residents inhale the predicted outdoor concentrations of coke oven emissions for 70 hours a day). Finally, steel producers have performed validation studies that call into question the accuracy of the EPA's Human Exposure Model for purposes of projecting community exposure to coke oven emissions.¹⁴

In summary, coke oven emissions have been shown to cause cancer in highly exposed worker populations. No direct evidence of carcinogenic risk to residential populations has been reported. EPA risk assessors predict that such a risk exists, although their estimates are necessarily speculative.

Evolutions of Regulatory Programs

Coke oven emissions have been a subject of health concern for decades. Both labor unions and environmental groups have been pro-regulation actors, although not always in unison with each other. Agencies at the local, state and federal levels have been active at various times, although again not necessarily in a coordinated fashion. Regulatory policy has been complicated by several key factors: concerns about the health of both coke oven workers and community residents, scientific uncertainty about the magnitude of the health risks (especially in the case of community residents), genuine limitations of knowledge about how to curtail such emissions (short of shutting down batteries), technical disagreements about the feasibility and costs of various proposed emission control strategies, concern for the financial viability of the domestic steel industry generally and the plight of particular firms on the brink of bankruptcy, and the high rate of unemployment in communities that are economically dependent on the steel production industry. The regulatory history that follows is intended to show how, despite such factors, technology-based regulation led to some costly, yet significant environmental improvements.

¹⁴ *Id.*

The Allegheny County Health Department

In the 1960's, before the federal government or the states became active in controlling coke oven emissions, the health department in Allegheny County, Pennsylvania (the Pittsburgh area) became a principle advocate of emission control policies. While many state health departments in America have been mainly concerned with control of infectious and communicable diseases, this department had understandable reasons for being at the forefront of coke oven emissions control. The largest coke plant in the world was operating in the mill town of Clairton, just outside Pittsburgh. Another coke plant was operating on the Monongahela River in close proximity to the Squirrel Hill area of Pittsburgh, an upper class community that was a principal home of Pittsburgh's liberal activists and academics. Grass-roots concern about pollution in the Pittsburgh area also gave rise to GASP (Group Against Smog and Pollution), one of the more ardent and influential local environmental groups in the country. Professor Walter Goldberg, now President of GASP, provided the following commentary on coke oven emissions:¹⁵

"I believe that Pittsburgh has paid, and is paying, a very high price for its failure to control emissions from its coke plants. Hillsides are denuded by the pollution from the Clairton works, and property values in various parts of Allegheny County are drastically decreased by the stench and the dirt from these plants. The odor and haze that our coke plants produce have always contributed to the difficulty in attracting top notch professionals to the area, and this surely has had an adverse effect on the economic welfare of the region."

Much of the key epidemiological research on the carcinogenic risks of occupational exposure to coke oven emissions was performed at the

¹⁵ Personal Communication from Walter Goldberg (Mar. 4, 1989).

University of Pittsburgh's School of Public Health, a professional school with close links to the county health department. At the same time, several domestic steel producers and the United Steel Workers of America [USW] had their headquarters in Pittsburgh, including research and medical staffs concerned with the health of steel workers in general and coke oven workers in particular.

Regulatory action to control coke oven emissions evolved originally from the power of the Allegheny County Commissioners (in consultation with the health department) to deny operating permits for coke oven batteries operating in the county. Later, the County government was empowered to set specific emission standards for manufacturing facilities such as coke batteries. Thus, it is important to recognize that coke oven emissions in the Pittsburgh area were under some regulatory control before federal agencies had interest in the problem.

Occupational Controls¹⁶

In 1967, the American Conference of Industrial Hygienists suggested that a Threshold Limit Value (TLV) for coke oven emissions of 0.2 mg/m³ BSFTPM¹⁷ per eight-hour working day be established. This recommendation was adopted by the U.S. Secretary of Labor in 1969, prior to the passage of the Occupational Safety and Health Act of 1970, when the 0.2 mg/m³ TLV was promulgated as a performance standard under the Walsh-Healey Public Contracts Act. The same standard was later reaffirmed by the Secretary of Labor under the terms of OSHA.

In 1971, AISI petitioned the Labor Secretary for a less stringent standard, and USW petitioned for a more stringent standard. Both

¹⁶ For further discussion of matters summarized here, *see supra* note 3.

¹⁷ *See supra*, note 5.

petitions were temporarily denied by the Labor Department because the National Institute for Occupational Safety and Health [NIOSH] was undertaking a large research program on coke oven emissions. In 1973, NIOSH reported the findings of its research program. The conclusions were twofold: (a) available data were inadequate to firmly establish the adequacy of the 0.2 TLV, and (b) the most effective means of controlling coke oven emissions were engineering controls and good work practices.

During the 1973-1975 period, numerous OSHA citations were issued against domestic steel producers for failure to comply with the 1971 performance standard. These citations were litigated before the OSHA Review Commission and took several years to reach settlement.

Meanwhile, the USW began to raise coke oven emissions as a local issue for collective bargaining. At the time, collective bargaining in steel was governed by the Experimental Negotiating Agreement, which forbade industry-wide strikes in return for guaranteed wage increases and binding arbitration. Since strikes over "local" issues were still permitted, the USW pressured for coke oven emissions control on a plant-by-plant basis. In November, 1974 (two years prior to the final OSHA standard), U.S. Steel Corporation and USW signed an agreement covering coke oven emissions at the Clairton Works. The agreement called for more coke oven workers, extra compensation for specific jobs in coke ovens, and a program to reduce employee exposure to coke oven emissions through engineering controls, improved work practices, and increased use of respirators.

In 1974, OSHA had established — at the urging of the USW — the Advisory Committee on Coke Ovens to reexamine coke oven emissions and suggest control standards. Under the leadership of Dr. Eula Bingham the Committee, in May 1975, recommended — after public Hearings — specific engineering and work practice controls. The Advisory Committee also suggested that coke oven workers be given

periodic medical exams, transferred if necessary to non-oven jobs, and guaranteed their job security and pay rate even if transferred. A minority report of the Committee was signed by several industry members and submitted to the Secretary of Labor. The minority report opposed mandating specific engineering controls.

Three months later, OSHA proposed a standard which was somewhat at odds with that recommended by the Advisory Committee. The proposed standard allowed industry to use whatever engineering controls they wished. Further, no time limit was placed on implementation of the engineering controls, and employers were permitted to protect workers with "personal protective devices" (respirators) in the interim. Also, the proposed standard dropped the job security and pay rate retention clauses from the Advisory Committee's suggested medical examination procedure. Finally, the proposed standard included a statement that the TLV be set at 0.3 mg/m^3 of "respirable particulate matter."

In late 1975 and early 1976, public hearings were held on the proposed standard. The Oil, Chemical and Atomic Workers Union (OCAWU) and the USW criticized the proposed standard for its weak time limits on controls and for its failure to retain the job and pay rate security mechanism of the Advisory Committee's suggestions. AISI charged that the standard could not realistically be met and would cost the industry \$1.28 billion per year. The Council on Wage and Price Stability (CWPS), in agreement with OSHA, found that the annual costs of implementation would be around \$200 million per year. CWPS disagreed with OSHA, however, on the number of lives saved per year under the proposed standard.¹⁸ OSHA maintained that all 240 employees likely to die from coke oven emissions exposure in a year

¹⁸ Council on Wage and Price Stability, *Exposures to Coke Oven Emissions: Proposed Standard*, Executive Office of the President, May 11, 1976.

(out of about 20,000 total employees) could be saved with the proposed standard. CWPS stated that only 8 to 35 employees were likely to die, although CWPS concurred that all might be saved with the proposed standard. CWPS, concerned with inflation, stated that the lives saved under the proposed standard would come at great cost — far in excess of the \$200,00 and \$1.5 million "life valuations" then used by some professional economists. Therefore, CWPS proposed that society would be better off spending the money on cancer research, and utilizing only respirators as control mechanisms.

After another round of public hearings, OSHA in October, 1979 promulgated a final standard. The standard was set at 0.15 mg/m³ BSFPM per eight-hour working day. Some specific engineering and work practice controls were mandated in the standard. Other detailed regulations concerned (a) areas around the coke oven batteries covered by the standard, (b) monitoring requirements for specific job classifications, (c) protective respirator devices, (d) medical and hygienic facilities and practices, and (e) a time limit for compliance (January, 1980). Industry was required to undertake open-ended research on new control techniques if the required controls proved insufficient to meet the 0.15 mg/m³ standard. The job and pay rate security clauses recommended by the advisory committee were not promulgated.

The final OSHA standard was "technology-based" in two respects. First, it went beyond a performance standard and mandated specific engineering controls and work practices. Progress toward meeting the 1971 performance standard had been slow, thus buttressing the case for design-oriented provisions. Second, the open-ended R&D mandate meant that it was the industry's responsibility to discover new control technologies, if necessary.

AISI and American Coke and Chemical Institute (ACCI) appealed to

both the Secretary of Labor and the federal courts to delay the effective date of the standard, but to no avail. In 1978, AISI and several steel companies petitioned the federal judiciary to overturn OSHA's standard on the grounds of insufficient rationale and infeasibility. The Third Circuit found that OSHA and the Secretary of Labor acted properly in determining that coke oven emissions were carcinogenic, and in establishing the specific standard, time limit and control mechanisms. However, the court ruled that OSHA and the Secretary of Labor had gone too far when it called for open-ended research and development programs.¹⁹

Although the key provisions of the OSHA standard took effect in January, 1980, it is difficult to quantify precisely how effective the OSHA standard has been in protecting worker health. The implementation period was a financially difficult one for steel producers, and many coke oven batteries were shut down for economic reasons. Some states were active in enforcing their own coke oven emission standards, and OSHA maintained a vigilant monitoring program for emissions (citing and fining some companies for gross violations). Mary Win-O'Brien, Assistant General Counsel of USW (and a former OSHA employee) provided the following commentary on OSHA enforcement efforts:²⁰

The bulk of the cases were initiated right after the standard became effective. The lead case was with the USX at Fairless Hills where the ALJ upheld virtually all the OSHA citations, 1978 CCH OSHD 23,052. While the Review Commission reversed some of the items in 1982, 1982 CCH OSHD 26,297, by that time OSHA had inspected a number of coke plants and reached detailed settlements. OSHA set up, at the USWA's insistence, a group of inspectors who were trained to inspect coke ovens.

¹⁹ *Am. Iron & Steel Inst. v. OSHA*, 577 F.2d 825 (3d Cir. 1978), *cert. dis.* 448 U.S. 917 (1980).

²⁰ Personal Communication from Mary Win-O'Brien (March 8, 1989) (Commentary on OSHA enforcement efforts).

Litigations took place at CF&I Steel and virtually all the other companies. Inland Steel was the subject of a series of settlement agreements that resulted in contempt citations in the Court of Appeals for failure to comply with the settlement agreement. That was the first time OSHA had taken that approach to avoid the long delays in litigation before the Review Commission. OSHA is a lot faster than the EPA system and in terms of worker protection, the agency did a good enforcement job from 1977 to 1985. There have been virtually no recent coke oven citations.

In summary, OSHA's technology-oriented standards — while quite costly — were effective in reducing worker exposures to coke oven emissions. The standards were "specification oriented" in the sense that they took what was successful at one battery and required it to be done at other batteries. OSHA did not attempt to compel discovery of new technologies. Vigorous enforcement of standards was a key to success.

Environmental Control Programs

Phase 1: Particulate Regulation

In the mid-1970's, two-thirds of the primary sources of emissions from coke batteries were considered to be from charging (i.e., from dropping coal from a larry car into a coke oven). The other one-third came from pushing operations (i.e., from procedures during which a push car forced the coke out into a quench car). Emissions from cracks during coking were considered negligible contributors to the overall problem. Today, such substantial progress has been made in controlling emissions during charging that leaking lids, doors, and valves during coking are now considered to be almost as important as the residual charging emissions.²¹ Progress during the last twenty years, although substantial, has not been easy or inexpensive. A decade of struggle over how best to control pushing emissions provides a vivid picture of how

²¹ Personal Communication from Earle Young, Vice President, American Iron and Steel Institute (December 17, 1988).

technology-forcing can go wrong.

Section 109 of the Clean Air Act Amendments of 1970²² requires the EPA to develop health-based National Ambient Air Quality Standards [NAAQS] for particulates and other so-called "criteria" pollutants. EPA's regulatory framework calls for each state to submit an implementation plan with sufficient emission controls to bring particulate concentration into compliance with the NAAQS. State and local agencies are permitted, if they desire, to insist on stricter standards than are necessary to meet EPA's NAAQS. Since coke ovens were a significant source of particulate emissions in some "nonattainment" regions of the country, EPA and state officials began in the 1972–75 period to investigate the feasibility of curbing such emissions. By the end of that period, EPA and state officials proposed to require the control of coke oven "pushing emissions."

Subsequent negotiations over consent decrees with the industry became intense during 1975–76; EPA and state officials insisted that pushing emissions had to be controlled — especially in nonattainment regions. Technical experts in the steel industry responded that they knew of no viable techniques for controlling these emissions. They argued further that a major new research, development and testing program was necessary if pushing emissions were to be effectively controlled.

In light of the regulatory interest in pushing emissions, commercial suppliers of pollution control equipment began to propose various solutions, which were generally applications of control systems that had been used in other manufacturing processes or in other facts of the steel production process. A variety of companies proposed specific technical solutions. Each of the solutions shared two components: some type of enclosure that would contain pushing emissions and some type of gas

²² 84 Stat. 1679; codified, with amendments, at 42 U.S.C. § 7409.

cleaning device (stationary or mobile).

In negotiations with individual steel companies, various regulatory agencies (local, state and federal) urged specific control systems, relating proposed reductions to claims of enterprising suppliers. Some industry negotiators felt that some officials appeared to be favoring — at least implicitly — Envirotech's aeronautical mobile scrubber (the "Chemico Car"). In any event, the consent decree process resulted in the majority of the industry's coke batteries being equipped with Envirotech's system. Installing the system cost roughly \$5 million per battery, or over \$250 million in capital investment on an industry-wide basis.²³

Soon after the Chemico Cars were installed, it became apparent that their performance was inadequate and their degree of reliability was unacceptable. Although the systems reduced emissions significantly relative to uncontrolled levels, they did not comply with the particulate standards in state implementation plans.²⁴ Steel industry officials, who felt they had been virtually coerced to purchase the systems, complained both to regulators for relief and to the suppliers about misleading representations about performance and major steel producers filed substantial lawsuits against Envirotech, which took over five years to settle. Millions of dollars were expended in litigation and in efforts to upgrade the system's performance. Although the details of the settlements are confidential, substantial compensation was provided to the major steel producers.²⁵

The fundamental technical problem was that the Envirotech

²³ Personal communication from Theodore Dinsmore, Gaston, Snow, Ely and Bartlett (counsel to an equipment supplier), December, 1988.

Also, personal communication from Phil Masciantonio, Vice President, USX, to authors, April 24, 1989. Although there had been earlier discussions, during a day long meeting at Harvard, virtually all aspects of prior discussions were rehashed.

²⁴ Masciantonio, *supra*.

²⁵ *Id.*

scrubbers were designed for relatively benign metallurgical furnace applications. They had never been tested for coke oven applications.²⁶ Coke batteries are a much harsher environment for such equipment due to factors such as wide fluctuations in temperature and variations in atmospheric conditions. The performance of the systems also varied depending upon the age and condition of the battery, the quality of scrubber maintenance programs, and the quality of the coking job. Although some progress was made in improving the performance and reliability of the Envirotech system, it is no longer considered the control technology of choice. At least one major steel company has recently reached an agreement with the EPA that calls for putting the Envirotech system out of service while beginning construction of an entirely new system to control pushing emissions.²⁷

In summary, technology-based regulation does not always work — especially when regulators try to "leapfrog" technological innovation (so-called "technology-forcing"). In this case, a technology-forcing strategy proved to be both costly and much less effective than regulators had hoped. A phase-in period that allowed for technological experimentation might have been more successful in the long run. Alternatively, regulators might have settled for best available technology and encouraged R&D. Whether these options would have yielded fuller, or more timely, control of emissions is, of course, speculative.

Phase 2: Hazardous Air Pollution Regulation

Aside from their contribution to particulate pollution, coke oven emissions contain numerous toxic constituents that are a potential threat to human health. As a result, the EPA listed coke oven emissions as a hazardous air pollutant in 1984.²⁸ A nationwide control standard (i.e.,

²⁶ Dinsmore, *supra* note 23; also personal communication from Thomas C. Graham, Vice Chairman, USX December, 1988.

²⁷ *Supra* note 23.

a National Emissions Standard for Hazardous Air Pollutants, or NESHAP) was proposed in April, 1987 pursuant to Section 112 of the Clean Air Act Amendments of 1970.²⁹ The proposed control standards cover charging operations and coking leaks from topside lids, side doors, gas offtake systems, and waste gas collection mains.

Due to the fugitive nature of BSFTPM, the EPA prefers not to measure concentrations of that particulate matter. Rather, the EPA relies on visible emissions standards in its regulatory efforts. This measurement methodology involves specifying the percentage of doors leaking during the coking process and the number of seconds emissions are visible during the charging process.

The EPA studied several regulatory options and selected the following for its proposal: ten PLD (percent leaking oven doors), three PLL (percent leaking lids), six PLO (percent leaking offtakes), and sixteen seconds of visible emissions per charge. The proposed standard is estimated to reduce the number of nonoccupational respiratory cancers per year due to coke oven emissions from 6.9 to 4.0 and the risk to the maximally exposed individual from 3.4×10^{-2} to 1.4×10^{-2} .³⁰ The standard is estimated to cost \$19.3 million per year. This option was selected over a more stringent proposal that EPA judged to be technologically and economically infeasible. Another option calling for 10 PLD, 3 PLL, 10 PLO, and 25 seconds per charge would have reduced the number of cancers per year from 6.9 to 4.3 at a cost of \$7 million per year to industry. It was also rejected in favor of the more stringent standard.³¹

EPA's current regulatory proposal is likely to undergo a complete

²⁸ 49 Fed. Reg. 36560 (1984).

²⁹ 84 Stat. 1685; codified, with subsequent amendments, at 42 U.S.C. § 7412.

³⁰ The uncertainties associated with these risk estimates are discussed, *supra*, in the section, THE HEALTH EFFECTS OF COKE OVEN EMISSIONS.

³¹ 52 Fed. Reg. 13586-13606 (1987).

overhaul before final promulgation due to the *Vinyl Chloride* case.³² The statutory language in Section 112 calls for EPA to set NESHAP that protect the public health with an ample margin of safety. In the *Vinyl Chloride* case, the U.S. Court of Appeals for the D.C. Circuit ruled en banc that this means that EPA must: (a) determine a safe emissions level, and (b) promulgate an emissions standard at a level which protects the public health with an ample margin of safety [i.e., the promulgated standard may not be less stringent than the safe emissions level determined in (a)]. Cost and feasibility issues may be considered with regard to the latter, but not the former step. The first NESHAP to be promulgated under the *Vinyl Chloride* ruling will be that for benzene; next will come coke oven emissions.

Compared to Phase 1 particulate regulations, the EPA's efforts to control coke oven emissions as a hazardous air pollutant make more direct allowances for issues of cost and technical feasibility. Although the safe emissions level is to be set based on health considerations (as was the NAAQS), the emissions standard may have a very narrow margin of safety if the technology needed to reach the safe emissions level is unreasonably expensive or is nonexistent. Therefore, this type of regulation allows for cost-effectiveness considerations to be directly incorporated into standard setting once the safe emissions level is met.

Coordinating Technology-Based Standards

Lave and Leonard provide a discussion of the contradictions between OSHA and EPA regulatory efforts on coke ovens. They begin by noting the different emissions measurement strategies used by OSHA and the EPA, and go on to claim that the EPA regulations require nothing above and beyond that required by OSHA. "If OSHA had

³² Natural Resources Defense Council, Inc. v. EPA 824 F.2d 1146 (D.C. Cir. 1987).

enforced its own regulation, the EPA would not have found sufficient hazard to justify additional regulation."³³

Lave and Leonard argue that EPA and OSHA need to better coordinate their efforts. Coke oven workers donning respirators cut down on their own exposure, but not on the exposure to the community at large. Early suggestions to construct sheds around coke production facilities might have protected neighborhood residents from exposure to coke oven emissions, but simultaneously might have increased worker exposures. Coke oven emissions must be regulated with occupational and nonoccupational exposures in mind; if this is not done, argue Lave and Leonard, then money, time, effort and public health will be squandered in an inefficient regulatory enterprise.

Our historical review suggests that the coordination problem in technology-based regulation is even more complex than Lave and Leonard suggest. Coke producers must deal with numerous institutional actors with interests in controlling coke oven emissions: (1) the USW — both local and international, (2) the EPA — both regional and national, (3) OSHA — both rule making and enforcement officials, (4) state environmental agencies — acting either in response to EPA requirements or in response to their own desires; and (5) local health departments such as the one in Allegheny County, Pennsylvania. Although in some cases the various actors make good faith efforts to coordinate their activities, they often act independently of each other. There can sometimes be political or bureaucratic incentives to not coordinate with other agencies, for example if an actor may be seeking the credit for cleaning up coke oven emissions.

Whether coke oven emissions might have been regulated more swiftly, comprehensively, and efficiently if the various agencies had a

³³ L. Lave & B. Leonard, *Regulating Coke Oven Emissions* in RISK ASSESSMENT OF ENVIRONMENTAL AND HUMAN HEALTH HAZARDS: A TEXT BOOK OF CASE STUDIES 560 (J. Pausenback ed. 1988).

different set of relationships is an issue Congress could consider. Compared to present relationships, for example, Congress could explicitly direct OSHA and EPA to develop and jointly sign off on any technology-based standard that affects both occupational environmental health. Or, the regulatory review office within OMB could be directed to insist on formal coordination in its review of regulatory proposals. Or, Congress might call for limited federal preemption of state and local authority to regulate hazardous air pollutants, once technology-based standards at the federal level have been established. Such preemption might be in effect for, say, five years after a major federal rule is promulgated. Arguably, while retaining the States' power to set stricter standards in the long run, a limited preemption doctrine might foster more coherent regulatory programs and lead to a more cooperative posture on the part of regulated industries. It is difficult to believe that these alternative arrangements could have taken any longer to achieve control improvements than the present fragmentary system has taken.

Lessons From the Coke Oven Experience

Since the early 1900's dramatic progress has been made in the control of coke oven emissions. The first big step was the transition to contemporary by-product coke ovens — a relatively contained type of system — from the earlier "beehive" technology, a completely uncontrolled coke production process. During the last thirty years, further progress has been made in controlling fugitive emissions from by-product ovens. In the 1960's and 1970's, human exposures to emissions from the "charging" and "pushing" operations were reduced through improvements in work practices, technological advances, and wider use of respirators in the workplace. These improvements were largely the result of OSHA regulation and EPA's control of coke oven emissions as particulate matter (see sections above). In the 1980's fugitive emissions from doors and valves during coking have been a

principal concern of regulatory officials, and a variety of control programs are being considered and implemented. EPA began to exert control over coke oven emissions as a hazardous air pollutant in 1984; the long process from listing a hazardous air pollutant to the promulgating of a NESHAP is still unfolding in the case of coke oven emissions.

The development of technology-based regulations by local, state and federal agencies has been an important factor in the emission control improvements made since the advent of by-product coke ovens. Armed with epidemiological studies of excess cancer among coke oven workers and supportive toxicological evidence from the laboratory, regulatory officials have set specific standards that are intended to curb risks to worker and community health. Examples of these regulatory efforts include the (above-reviewed) actions of the Allegheny County Health Department, OSHA and EPA. For the most part, these standards have survived intensive political, economic and judicial scrutiny. This scrutiny has come in the form of public debate, negotiated consent decrees and Appellate rulings. Compliance with these standards has been somewhat uneven due to the severe financial difficulties within the domestic steel industry. All parties agree that on the whole, though, substantial progress has been made even though it is not possible to exactly quantify the magnitude of health benefits. More progress is anticipated in the years ahead due to EPA and state programs and USW's continuing efforts to enforce the OSHA standard.

As Congress considers a legislative strategy aimed at controlling 200-odd hazardous air pollutants emitted throughout America's industrial economy, it is important to recognize what the potential problems with technology-based regulation are, what adverse societal consequences they cause, and how — where possible — the problems can be avoided. This is especially important because the current standard

setting for hazardous air pollutants requires the setting of a safe emissions level which is blind to cost and feasibility issues; this is true even though the setting of the margin of safety around the safe emissions level can consider cost and technological feasibility.

Technology-forcing regulation, by its very nature, induces tension between regulators and regulatees. Government, concerned with health protection, is put in the position of saying, "yes, more emission control is essential"; while regulatees, concerned with costs, tend to say, "no, we've done all we can." The stakes in the game may include the public health and the economic viability of particular industries. Over time, the process can lead to cynicism and mistrust among key people in government and industry.

Many believe the adversarial culture works to the detriment of environmental progress because it undermines the mutual respect that is necessary to achieve successful technical collaborations on complex environmental control problems. They argue that as long as EPA emphasizes application of proven technology, and avoids a "technology-forcing" posture, the adversarial culture can be managed successfully. Environmentalists, among other, argue that public health is an overriding value; they contend that any lack of adequate control technology reflects industry's disregard for public health and its failure to invest in needed research and development of control technology. In this view, technology-forcing requirements are the price of violating health-based standards.

The coke ovens experience suggests that forcing technology can lead to less effective than anticipated control efforts, at great expense. The Chemico car is a case in point. Congress appears to recognize this point, since MACT is typically defined in a way that permits consideration of costs. Given the globalization of the world's industrial economy, greater efforts could be made to avoid costly, industry-wide experiments with

untested, emission control equipment. The case study reveals how the domestic steel industry — despite intense import competition and deteriorating steel-making facilities — expended \$250 million on mobile scrubbing equipment that was not yet ready to be applied to pushing emissions in coke batteries.

Arguably, allowing enough time for pilot testing at several plants before industry-wide compliance was demanded would have provided operating experience on which requirements could have been based. Indeed, rigorous quasi-experiments can be conducted in the field the efficacy of new control devices. Even a single plant can be used to conduct an interrupted time-series experiment on a new device's field-worthiness. In the long run, gradual introduction of innovative technologies forced by the need to meet standards may achieve more successful emission control at lower economic cost than an industry-wide standard with tight deadlines. A more "technology-inducing" approach — tax breaks for innovators and participants in field experiments, or waivers for firms that achieve voluntary progress ahead of schedule — might also facilitate a less adversarial relationship between industry and government, thus minimizing the collaborative problem cited earlier.

In hindsight, at least, it appears that a portion of the significant regulatory and industrial resources expended in the coke ovens experience resulted in technological controls that failed to meet expectations. While such investments may be worthwhile in certain cases, Congress might consider allowing regulators some flexibility to authorize and encourage pilot testing, and to exempt particular sources from such standards when it can be demonstrated that health risks are negligible and that the costs to society will be grossly disproportionate to the expected health or environmental benefits. A strict cost/benefit test is not appropriate because it would engender additional delays and

"paralysis of analysis." However, based on the coke ovens experience, one might conclude that a "technology-based" approach to clean air legislation needs to be accompanied with some regulatory discretion to consider the magnitude of benefits and costs to be expected from regulation — often called an "unreasonable risk" approach.

Congress may also wish to consider whether it makes sense to have numerous regulatory offices tackling the same emissions problem. The coke ovens experience raises the question of whether a more coordinated regulatory approach might have achieved the same — or even a greater — degree of emission control at a lower societal cost. Overly ambitious technology-based standards can divert scarce capital from more effective control strategies and from promising R&D programs. Industry's need for a predictable regulatory environment is especially great when expensive technology-based rules are to be applied to capital-intensive firms that face concerted import competition. Once the federal government applies a technology-based standard, a period of preemption could be observed by all regulatory actors before yet another round of regulation is considered — as for example, Clean Water Act permits imply no more stringent controls during the period of permit, except in unique situations.

Requiring maximum achievable control technology appears to be a pragmatic approach to reducing emissions of hazardous air pollutants. The control of the residual emissions is a more difficult challenge. While some criticize the treatment of residual emissions in the Bush Administration's plan as vague and discretionary, others argue that the "bright lines" contained in S.816 and H.R.2585 may represent an impractical form of "technology-forcing." The coke ovens experience suggests that forcing technology beyond what is demonstrated and achieved in practice can lead to costly and possibly less effective control efforts, while a more planned approach to testing and implementation

might have achieved superior emission control results at equal or lower cost to society. Regardless of what legislative plan is enacted, industries that expect to have significant residual emissions should launch major programs of research and development to discover superior emission control strategies.