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Sammis Generating Station: Meeting SO_2 and Particulate Standards with Cleaned Ohio Coals

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Sammis Generating Station:
Meeting SO_2 and Particulate Standards with Cleaned Ohio Coals

by

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ABSTRACT

This report discusses the background and issues related to the control of air pollutants emitted by a large coal-burning plant in eastern Ohio. This plant has had a history of severely exceeding the particulate emission limit set forth in Ohio's State Implementation Plan (SIP). Furthermore, the plant's SO_2 emissions have exceeded the limit that Ohio's forthcoming SIP will allow.

One important issue to consider is the extent to which compliance with the SIP will promote the plant's switching from Ohio coals to southern Appalachian coals, which produce fewer particulate and SO_2 emissions, and the consequent disruption to the Ohio coal mining industry. Addressing this issue, the report examines the plant's historical coal usage, the production and characteristics of Ohio and southern Appalachian coals, the relevance of coal-sulfur variability, and, most important, the feasibility and implications of producing and burning cleaned Ohio coals as a strategy for complying with Ohio's SIP.

The report discusses the factors that will affect the relative economics of burning cleaned Ohio coals at the plant in question. The analysis indicates that, by burning cleaned Ohio coals, the plant's largest and newest units (which constitute 60 percent of the plant's total capacity) can increase their consumption of Ohio coal by 50 to 100 percent, depending on the characteristics of the coals and the cleaning processes used.

This report was submitted in fulfillment of the requirements of Work Assignment 3, Task B, of EPA Task Order Contract 68-02-3092 by Teknekron Research, Inc., under the sponsorship of the U.S. Environmental Protection Agency. The report covers the period from March 1979 to July 1979.

CONTENTS

CONTENTS (Continued)

FIGURES

TABLES

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1. INTRODUCTION AND SUMMARY OF RESULTS

1.1 Introduction

This report deals with the feasibility and implications of burning cleaned Ohio coals at the W.H. Sammis Generating Station in eastern Ohio. Sammis's choice of coals is now at issue as a result of state and federal regulations governing the plant's particulate and SO_2 emissions. Because Sammis's particulate emissions have greatly exceeded the limitations set forth in Ohio's State Implementation Plan, Ohio Edison, the owner utility, has been involved in litigation with EPA. And because Sammis will have to comply with SO_2 emission limits starting in October 1979, Ohio Edison plans to substitute low-sulfur (and low-ash) out-of-state coals for the high-sulfur (and high-ash) Ohio coals that have comprised most of Sammis's coal supply in the past.

The strategy of relying mainly on out-of-state coals is expected to have adverse repercussions for Ohio's coal mining industry. Another strategy — one that would counter the decrease in Ohio coal use — is to burn Ohio coals that have been physically cleaned, since physical cleaning can remove a significant fraction of a coal's ash-producing constituents and pyritic sulfur. Whether the burning of cleaned Ohio coals at Sammis is feasible — and what the implications would be for both Sammis and the Ohio coal industry — are the subjects of this report.

The report contains two main sections. In Section 2, which provides background information on Sammis, we discuss: (a) the plant's facilities and historic emissions; (b) environmental, legal, and regulatory issues affecting Sammis's coal choices; (c) characteristics and sources of reserves and the recent production of Ohio coals; and (d) the coals Sammis has burned and the compliance coals currently available.

In Section 3 we discuss physical coal cleaning (PCC), particularly in terms of its meeting Sammis's coal needs, and more generally in terms of its attenuating the decline of Ohio coal production. First (in Section 3.1, but also in the Appendix) we discuss the subject of sulfur variability in Ohio coals in order to relate Sammis's maximum allowable SO_2 emissions to its effective allowable emissions. This analysis is essential in order to assess the actual coal-sulfur levels that must be achieved by PCC to render cleaned Ohio coal use feasible at Sammis. Next (in Section 3.2) we discuss another Ohio plant — C&SOE's Conesville plant — which plans to meet its SO_2 emission standards by cleaning Ohio coals from nearby sources. We then discuss the available data on the cleaning of Ohio coals (Section 3.3) and estimate the quantity of cleaned Ohio coal that Sammis could burn (Section 3.4). In Section 3.5, which deals with the costs and benefits of cleaning Ohio coals, we discuss estimated production costs, estimated boiler-related benefits, and estimated differences between the price of non-Ohio coals that are low in sulfur and ash and the price of high-sulfur, high-ash Ohio coals that can be washed to meet Sammis's requirements. In the final section, 3.6, we mention some of the institutional issues that must be addressed in connection with the production of cleaned Ohio coal.

1.2 Summary of Results

The investigation detailed in Sections 2 and 3 suggests that cleaned Ohio coals can comprise a sizable fraction of the supplies to be burned at Sammis units 5-7 in compliance with applicable emission limitations. The salient points made in this study can be summarized as follows:

- The EPA, under an interim compliance program, has ordered Sammis to reduce particulate emissions so that they do not exceed 0.7 to 0.8 lb particulates per million Btu. (Ohio's SIP specifies a limit of 0.1 lb particulates per million Btu.) A major element of the interim compliance program involves burning coals with less than 10 pounds of ash-producing material per million Btu, a "quality index" that represents considerably lower ash content than that generally found in Ohio coals.

- Sammis's SO_2 emission limitations will be 4.46 lb per million Btu for the three largest and newest units (units 5, 6, and 7), which account for almost 70 percent of the plant's capacity. The SO_2 limit for the remaining units is

1.61 lb SO_2 per million Btu. Units 5-7 have been operating at very low capacity factors due to operational difficulties. If they were to operate at 60 percent of capacity on an annual basis, they would consume almost 4 million tons of coal a year (in 1977 they consumed 2.5 million tons). We show that the fraction of cleaned Ohio coal that units 5-7 can acceptably burn ranges from about 50 to 100 percent, depending on the characteristics of the Ohio coal, the cleaning process used, and the characteristics of a low-sulfur coal that can be blended with the cleaned Ohio coal.

- Assuming that up to two exceedances of the SO_2 standard will be permitted each month, and that more than two exceedances per month will occur only once every two years, the allowable mean SO_2 emissions from coals burned in units 5-7 range from about 3.2 to about 3.8 lb SO_2 per million Btu.

- The estimated costs of producing cleaned coal are divided about equally between the PCC plant costs (capital and operating) and the value of the combustible material discarded during PCC.

- It generally costs more to purchase and clean Ohio coals than to purchase uncleaned out-of-state, low-sulfur, low-ash coals. This cost differential between the use of cleaned Ohio coals and the use of out-of-state coals is expected to decrease, since the costs of low-sulfur compliance coals are expected to escalate faster than the prices of Ohio coals. Moreover, when estimated savings associated with the burning of cleaned coals are considered, the use of cleaned Ohio coals may be economically justified. In the case of Sammis these savings reflect, among other factors, elimination of the need to build additional barge unloading facilities for increased out-of-state coal deliveries.

- A limited set of sulfur-removal measurements taken at one Ohio coal-cleaning plant indicates that PCC at that plant reduces SO_2 emissions (in lb SO_2 per million Btu) by about 25 to 40 percent. A large, new, relatively sophisticated PCC plant that is coming on line near Cadiz, Ohio is designed to remove 50 to 70 percent of the total sulfur. PCC can also reduce the ash content of Ohio coals by about 25 to 75 percent.

- Besides the technological and economic factors relating to the use of cleaned coals, there are important institutional issues associated with the production of such coals in Ohio. Especially important is the fact that many Ohio coal mines are small; they lack the organization and capital to build a PCC plant on an economically viable scale. Also important are the interim arrangements the utility must make with regard to either coal purchases or emission limitations during the period of approximately three years between conception of, and production from, an advanced coal cleaning plant.

2. BACKGROUND INFORMATION

2.1 The Sammis Generating Station: Location and Facilities

The W.H. Sammis Station is located at Stratton in Jefferson County on the eastern border of Ohio. The station is bounded on the east by Ohio Highway 7 — which runs along the Ohio River — and on the west by a rail spur (see Figure 1). Further, there is relatively little available unused space. The available area to the north is used largely for coal storage, conveyance from barge unloading, and ash disposal. The approximately thirteen acres to the south of the main building contain ash-disposal facilities and underground water ducts.

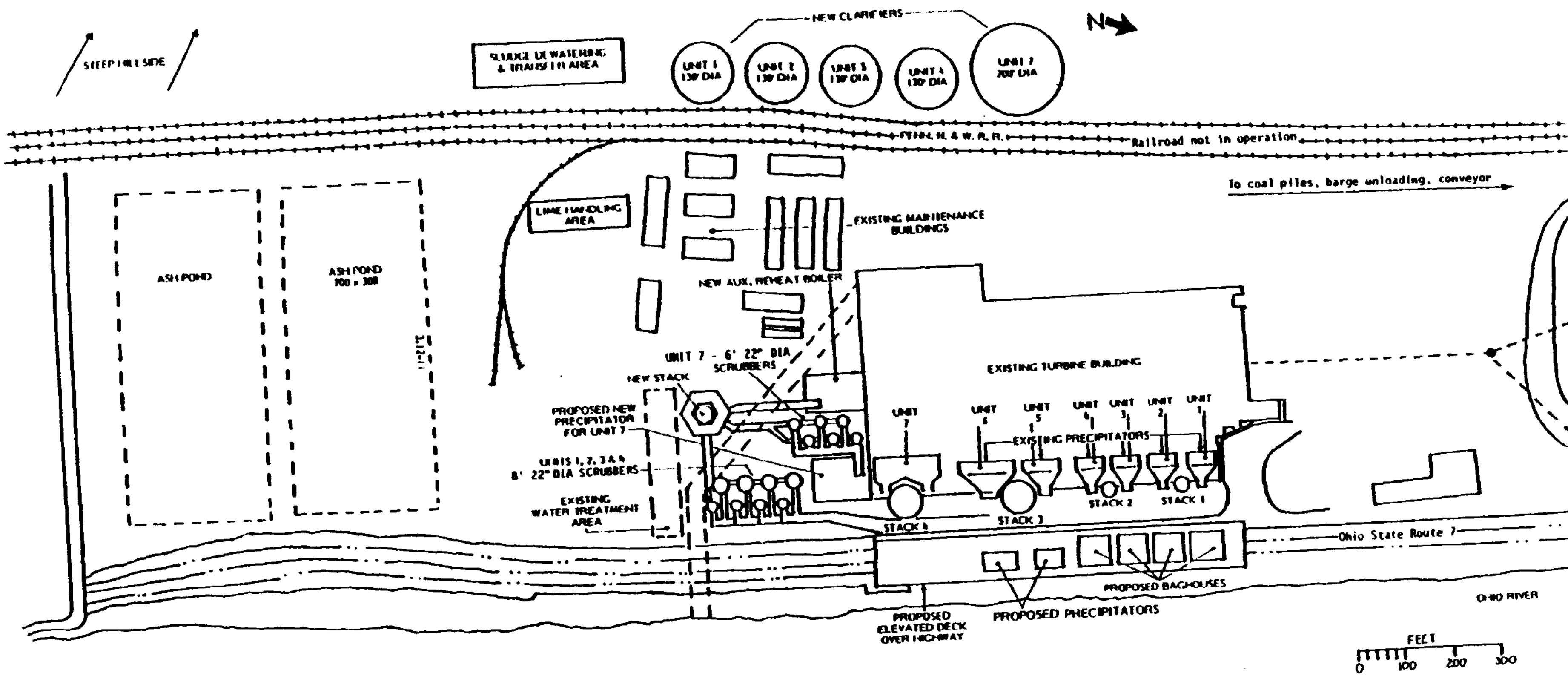
The rated plant capacity is 2,300 MW(e). In recent years the plant has operated at about 1,700 MW(e), burning only coal. The Sammis Station comprises seven units and four stacks. The first six units are owned by the Ohio Edison Company. The seventh unit is owned by a consortium: Ohio Edison (48.0 percent); Duquesne Light Company (31.2 percent); and Pennsylvania Power Company (20.8 percent), of which Ohio Edison owns all the common stock. All seven units comprise dry-bottom, pulverized-coal boilers equipped with electrostatic precipitators.

As can be seen in Table 1:

- Boiler units 1 through 4 — which exhaust into stacks 1 and 2 — were built between 1959 and 1962, while units 5 through 7 — exhausting into stacks 3 and 4 — were built between 1967 and 1971
- Units 1-4 comprise 32 percent of the total plant capacity
- All units together consumed 3.8 million tons of coal in 1977 (Ohio Edison projects 5.8 million tons in 1980 and 5.5 million tons in 2000)
- SO_2 emissions in 1977 exceeded the scheduled SO_2 compliance limitations (a 24-hour standard of either 2.91 lb per million Btu from each unit or an alternative 24-hour

Figure 1

Plant Layout for W.H. Sammis Plant
Ohio Edison Company



Note: Schematics for scrubbers and related facilities refer to hypothetical units.

Table 1

Sammis Plant Characteristics

Unit	Stack	MW (Nameplate)	Year of Installation	1977 Coal Use: Ohio Tons	1977 Coal Use: Non-Ohio Tons	1977 Capacity Factor (%)	Current SO_2 Emissions (lb/10^6 Btu)	SO_2 Limit (lb/10^6 Btu)	Optional SO_2 Limit (lb 10^6 Btu): For FGD Design	Optional SO_2 Limit (lb 10^6 Btu): For Non-FGD Design
1	1	185	1959	364,560	69,440	55.72	5.15	2.91	0.63	1.61
2	1	185	1960	271,150	51,650	40.68	5.15	2.91	0.63	1.61
3	2	185	1961	118,020	22,480	17.18	5.15	2.91	0.63	1.61
4	2	185	1962	412,520	78,580	61.48	5.15	2.91	0.63	1.61
5	3	317.5	1967	397,320	75,680	35.80	5.15	2.91	6.33	4.46
6	3	623	1969	634,700	120,900	28.67	5.15	2.91	6.33	4.46
7	4	623	1971	1,007,240	191,860	45.54	5.15	2.91	0.63	4.46
		2,303.5		3,205,510	610,590					
				(84%)	(16%)					

Source: Acurex Corporation, JACA Corporation, and Professional Construction Management, Inc., Engineering Study for Ohio Coal Burning Power Plants, Final Report 78-311, prepared for U.S. Environmental Protection Agency, Division of Stationary Source Enforcement (Mountain View, Calif.: Fort Washington, Pa.; and Cincinnati, Ohio; March 1979), Table 1, p. 3.9-2.

standard that Sammis chooses to apply: 1.61 lb SO_2 per million Btu from units 1-4, and 4.46 from units 5-7)[2]

Measurements in the vicinity of the Sammis plant have consistently shown concentrations of particulates in excess of the secondary and primary National Ambient Air Quality Standards and of the opacity levels set by Ohio's visibility standards. And particulate emissions have consistently been far in excess of Ohio's applicable emission limitation of 0.1 lb per million Btu. As we indicate later, EPA is establishing interim measures for reducing Sammis's particulate emissions.

Despite the existence of a railroad spur adjacent to the plant site, Sammis does not, and cannot at this time, receive coal by rail. Deliveries are made primarily by barge and truck. Ohio Edison has stated that no more than 50 percent of Sammis's coal deliveries can arrive by barge at the harbor north of the plant on the Ohio River.[1] For this reason, at least half the deliveries at present must come by truck and must therefore consist largely of Ohio coal.[2]

Sammis's tentative plan for 1980 is to blend 0.8 million tons of Ohio coal with out-of-state, low-sulfur coal (the blending will be done by a bulldozer at the plant's stockpiles).[3] This planned quantity of 0.8 million tons for 1980 is substantially lower than the 3.2 million tons of Ohio coal purchased by Sammis in 1977 (see Table 1).

Ohio Edison has had operational problems with units 5, 6, and 7. The boiler-turbine-generator systems used on these units – sharply scaled-up versions of similar systems previously built only cs much smaller units – have experienced an unusual number of unscheduled outages due to failure of generators, turbines, and boilers. According to an ongoing study by Bechtel Associates, the problems that have been encountered in the boiler are aggravated by "the poorer quality coal on the market today, as compared to coal commonly available when the plant was designed."[4]

2.2 Legal and Regulatory Issues Affecting Sammis's Choice of Coals

Four sets of laws and regulations either do or may significantly affect Sammis's choice of coals. First are the regulations in Ohio's State Implementation Plan that limit the emissions of particulates from, and levels of opacity in the vicinity of, Ohio's steam electric power plants. Because particulates and opacity levels from Sammis have exceeded the limits set by the plan, EPA has served several legal notices to the utilities that own Sammis. Second, Sections 110 and 126 of the 1977 Clean Air Act Amendments provide EPA and the states with mechanisms for restricting the interstate transport of pollutants. Several neighboring states attribute significant degradation of their air quality to the transport of particulates and SO_2 from Sammis. Because of this pollutant-transport effect, the state of West Virginia has joined forces with EPA in legal action against Sammis. Third, the state of Ohio, after many delays, now has a plan for limiting emissions of sulfur dioxide from steam electric plants.[5] Sammis's strategy for compliance involves significantly decreasing its current rate of purchase of Ohio coals, which are relatively high in sulfur. This strategy of sharply cutting the use of Ohio coals risks conflict with the fourth regulatory issue – the "local or regional coal" provision in Section 125 of the Clean Air Act Amendments.

Before discussing these legal and regulatory issues in somewhat greater detail, let us look generally at the matter of Sammis's compliance strategies and coal choices. Ohio Edison has indicated that the earliest feasible time at which it will be able to comply completely with Ohio's particulate regulations is the fall of 1986.[6] An EPA consultant, PEDCo, has concluded that compliance will be possible before 1984.[7] Interim and final plans for compliance with the particulate regulations in the Ohio Implementation Plan are still to be submitted by Ohio Edison.

Because of the limited amount of land available at the Sammis plant, Ohio Edison has determined that the construction of new facilities for reducing particulate emissions would necessitate the design and construction of a bridge-like structure over Ohio Highway 7 (which is adjacent to the plant on the east).

Such a structure — which would require approval by the Ohio and U.S. departments of transportation — would of course necessitate adopting safeguards to preclude interference with the flow of traffic on the highway.

Ohio Edison has been advised by a consultant, Gilbert/Commonwealth, that the most reliable and cost-effective method of achieving compliance with both SO_2 and particulate emission limitations would be to purchase low-sulfur coal from West Virginia and eastern Kentucky, to retrofit fabric-filter baghouses on units 1-4, and to install new electrostatic precipitators or baghouses on units 5-7, at an estimated cost of $480 million.[8] PEDCo has estimated the capital cost for installing new particulate control facilities at about $300 million.[9] Ohio Edison has stated that implementing such a strategy (its preferred strategy) would be wasteful if Sammis were subsequently required to retrofit a flue gas desulfurization (FGD) system on any of its units — which would occur if, for example, the Section 125 proceedings were to result in an order to burn only Ohio (high-sulfur) coal. In that case, Ohio Edison argues, (1) some of the particulate control equipment might be rendered unnecessary, and (2) the space used for the particulate control systems might be needed for FGD systems.[10]

In the sections that follow we explore more fully the background and implications of the legal and regulatory issues affecting the Sammis plant.

2.2.1 Particulates: The Ohio Implementation Plan and Interstate Transport

The Ohio Implementation Plan requires that, after June 1975, all large power plants emit no more than 0.1 lb ash per million Btu (AP-3-11). ("Large" power plants are defined as those which, like Sammis, burn fuel at a rate exceeding 1,000 million Btu per hour.) Furthermore, there are limits to the extent to which emissions may affect visibility: the opacity of visible emissions is limited to 20 percent with some periodic allowable exceptions (AP-3-07).

Almost all Ohio utilities are either in compliance with the Ohio regulations for particulates or have agreed to a schedule for final compliance. The exceptions are one unit belonging to Cincinnati Gas and Electric and all forty-seven Ohio units of Ohio Edison, including Sammis.

EPA has charged that the Ohio limit of 0.1 lb ash per million Btu has been exceeded at Sammis by factors ranging from 10 to 80.[11] EPA has also charged that Sammis has violated the opacity levels allowed by AP-3-07 of Ohio's plan and, furthermore, that Sammis has in several instances violated an Emergency Action Plan. That Emergency Action Plan is triggered during periods of high ambient concentrations of particulates and certain meteorological conditions to avoid the buildup of excessive concentrations in vulnerable counties of Ohio, West Virginia, and Pennsylvania. It calls for having low-ash coals available and for burning these coals when an alert is issued. We observe that the plan, which is implemented for relatively short periods (for example, August 23-25, 1978, and November 4-6, 1978), can be interpreted in effect as an "intermittent supplemental control" plan superimposed upon the continuous controls that power plants must apply in order to meet State Implementation Plans or New Source Performance Standards.

The history of legal actions related to Sammis's excessive emissions of particulates began when EPA issued a Notice of Violation to Ohio Edison on 22 September 1976 and a Notice of Violation to Duquesne Light one year later. In a recent action (15 January 1979), EPA filed an Amended Motion for a Preliminary Injunction, in which the State of West Virginia Air Pollution Commission acted as Intervenor. The Amended Motion is less exigent than a previously filed motion for a Preliminary Injunction, which it supersedes. The earlier action, filed in August 1978, sought a final as well as an interim compliance program. The Amended Motion in effect defers the question of final compliance to a time when a full trial will be held to decide the merits of a still-to-be-proposed resolution.

Compliance with the interim terms is expected to reduce Sammis's yearly particulate emissions from 135,000 tons to 30,000 tons. Even with this 73 percent emission reduction, however, Sammis is expected to emit particulates at about seven or eight times the allowable rate. The coals burned at Sammis during the interim period may not exceed a "quality index" of 10 pounds of ash-producing material per million Btu, with the index based on a 30-day weighted, running average. EPA is currently considering whether the interim plan should also include an interim mass-emissions regulation that is more lenient than the state standard of 0.1 lb particulates per million Btu (such as a limit in lb particulates per hour for each unit corresponding to 0.8 lb particulates per million Btu when the unit operates at 100 percent of capacity).[12]

Figure 2 illustrates the proximity of the Sammis Station (in Stratton) to the states of West Virginia and Pennsylvania. The city of New Manchester, West Virginia is in Hancock County, where over 10.5 percent of the total adult population of 25,000 signed a petition submitted with the motion for a Preliminary Injunction.[13]

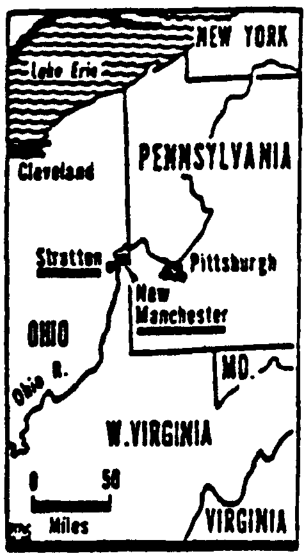


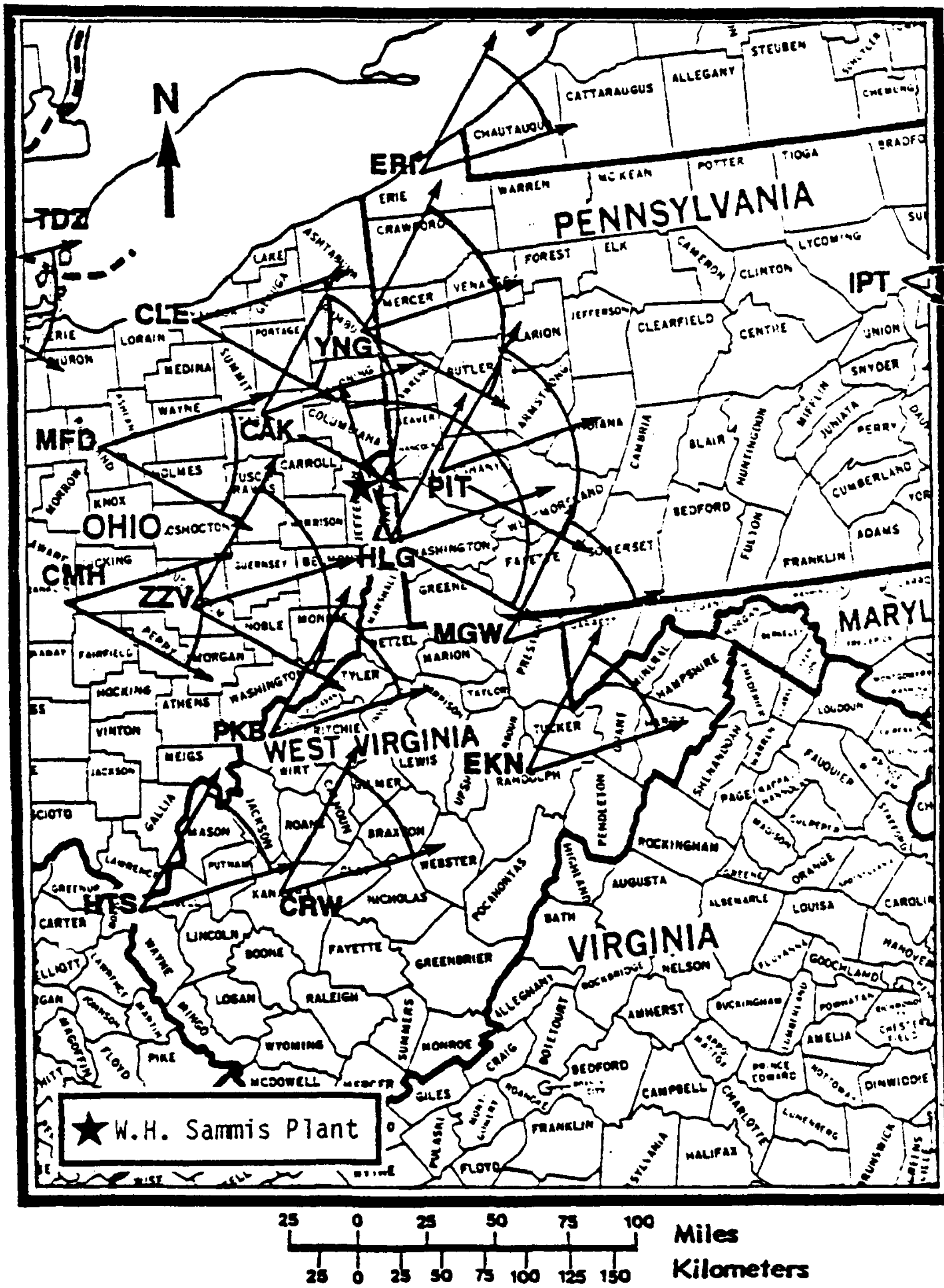
Figure 2

Location of the W.H. Sammis Plant (Stratton, Jefferson County, Ohio)

Figure 3 shows the sectors of persistent winds in the area. Persistent winds can be one of the meteorological mechanisms by which pollutant emissions are transported from their sources to distant locations. The wind directions shown

Figure 3

Sectors of Extremely Persistent Winds in the Upper Ohio River Basin Area



Note: The arrows indicate schematically the direction in which the wind persists for six hours' duration within a radius of 96 miles (155 km) from the origin.

by the sectors in the figure indicate that emissions to the air from Sammis may degrade the air quality in certain communities in West Virginia and Pennsylvania as well as in Ohio counties other than Jefferson.

2.2.2 Compliance with SO_2 Emission Standards

The state of Ohio has had a stormy history with regard to the development and implementation of an approvable and enforceable plan for controlling SO_2 emissions from power plants. The governor of Ohio has twice submitted a plan for SO_2 — and he has twice retracted the plan following challenges by various parties, including EPA. Because Ohio did not adopt an approvable plan, EPA, following its mandate under the Clean Air Act, promulgated SO_2 emission regulations for the state. These regulations were ruled effective as of 17 June 1977 for all but certain rural power plants. Those plants that plan to comply with the regulations by burning low-sulfur coals must be in final compliance by October 1979; those planning to comply by using stack gas scrubbing must meet a deadline of 13 June 1980.[14]

Prior to EPA's promulgation of these regulations, Ohio was the only major industrialized state in the nation totally lacking an enforceable implementation plan. Further, now more than three and one-half years have elapsed since utilities were to have been in compliance with such a plan, according to the Clean Air Act of 1970.

Sammis has chosen the low-sulfur-coal compliance strategy and therefore must comply with the SO_2 plan by 19 October 1979. As it applies to Sammis, the plan calls for limiting emissions to 2.91 lb per million Btu, or alternatively, for adopting a formula allowing different levels of emissions from the different units of Sammis but resulting in an emission level equivalent to 2.91 lb/10^6 Btu on a plantwide basis. Sammis has chosen the alternative, which translates to: 1.61 lb per million Btu for units 1-4, which account for 740 MW(e), or 32 percent of plant capacity; and 4.46 lb per million Btu for units 5-7, which account for the remaining 1,600 MW(e) of total capacity. The compliance emissions of 4.46 lb

SO_2 per million Btu for units 5-7 are not strikingly different from the average 1977 SO_2 emissions shown in Table I: 5.15 lb per million Btu. The compliance emissions for units 1-4, however, are relatively stringent. Sammis's plantwide maximum of 2.91 lb SO_2 per million Btu is also relatively stringent: it can be compared, for example, with the allowed maximum of 8.1 lb SO_2 per million Btu at Ohio Edison's Toronto Plant — also in Jefferson County and near the Ohio River — or with the allowed maximum of 5.66 lb for the Columbus and Southern Ohio Electric plant in Conesville, Coshocton County.

When EPA first published the SO_2 emission limits for Ohio plants,[15] it did not specify methods for demonstrating compliance, nor did it specify averaging periods for sulfur or SO_2 measurements. Later, in February 1978, the Agency described "acceptable fuel sampling analysis methods for demonstrating compliance by SO_2 sources in Ohio."[16] EPA will normally accept a utility's coal-sulfur analyses if the utility has used EPA-approved sampling and analytical methods based on 24-hour averaging; thus, SO_2 stack sampling is not normally required. EPA does, however, reserve the option to require EPA-approved SO_2 stack testing, especially as the basis for any enforcement action. Furthermore, it is expected that Ohio will permit the SO_2 emission limit to be exceeded two days per month.[17]

In its compliance plan, Sammis has rejected the alternative of using flue gas scrubbers. Major deterrents to the use of scrubbers include the additional space that would be needed and the costs. Ohio Edison has estimated the cost of using scrubbers for SO_2 control: investment costs are estimated at about \$837 million; and annual operating costs, at about \$100 million.[18] By contrast, Ohio Edison estimates that the annualized cost to phase in coal in compliance with both SO_2 and particulate standards would be about \$181 million for the period from 1979 through 1984.[19]

2.2.3 SO_2 Compliance and Section 125

Sammis plans to comply with EPA's SO_2 limitations by purchasing about 2.4 million tons of low-sulfur coal from Central Appalachian states. This quantity is equivalent to about 75 percent of Sammis's 1977 consumption of Ohio coals, which was 3.2 million tons. According to a study prepared for EPA, Sammis's shift away from Ohio coals would reduce the employment of coal miners in Ohio by about 720 persons.[20] The same study estimated that the shift from Ohio coal by all the Ohio utilities that plan to comply with the SO_2 plan by burning out-of-state, low-sulfur coal would decrease purchases of Ohio coal by about 15.8 million tons per year, and miners' jobs in Ohio by about 5,300. This loss of jobs represents about 0.3 percent of the state's entire labor force, about 1.9 percent of the workers in the southeastern quarter of the state, an average of about 8 percent of the working force in the four most important coal-mining counties, between 25 and 28 percent of the labor force in one county (Harrison County), and about 39 percent of Ohio's 1977 mining jobs. Additionally, economic "ripples" resulting from the decline of mining activities would, it was estimated, cause the loss of 8,000-10,000 nonmining jobs. The associated unemployment costs would be $36-41 million for 26 weeks, after which time it might be necessary to replace unemployment payments with welfare payments.[21]

While these consequences imposed on the state's economy by the switch to out-of-state coal are considered exaggerated by some (for example, the Council on Wage and Price Stability),[22] the economic and social impacts will undoubtedly be serious for the Ohio mining communities affected by mine shutdowns or slowdowns. As a result, Ohio has been urging the application of Section 125 of the Clean Air Act Amendments. Section 125 provides for corrective action where it is determined — by EPA, the governor of an affected state, or the president of the United States — that a shift from local or regional coal to an alternative fuel would cause significant disruption or unemployment in the community or region. Upon such determination, a utility can be ordered by the governor or president to enter into contracts for local or regional coal.

On 13 July 1978, EPA, in response to petitions by labor groups, Senator Metzenbaum, and Governor Rhodes, instituted proceedings under Subsection 125(a) to determine whether "action may be necessary to prevent or minimize significant local or regional economic disruption and unemployment in Ohio." "Action" would preclude the planned massive switch to non-Ohio coals by the fourteen Ohio plants (including Sammis) that are included in the proceedings, and it would result in the need for some degree of flue gas scrubbing by these plants.

The kinds of questions that the Section 125 proceedings raise are:

- How will utility rates compare under the two options?
- How reliable will retrofitted scrubbers be?
- How significantly will Ohio's gross annual product be affected by the unemployment payments and ripple effects due to the switch away from Ohio coal? (EPA estimates a loss of $400 million, or 0.4 percent of Ohio's total gross annual product)
- Does "local or regional" denote only Ohio, or does it denote also some or all of the other Appalachian states? (A critical question)
- If Ohio plants must adhere to a buy-Ohio policy, how can the benefits to the Ohio mining community be weighed against the losses to the mining communities in the other states?

In support of a buy-Ohio interpretation of Section 125, one preliminary study for EPA concluded that electricity prices would actually be lower in the long run under the option of scrubbing Ohio coal than under the option of burning out-of-state, low-sulfur coal.[23] Ohio utilities, which would rather switch to low-sulfur coal than install FGD systems, see things differently. So do non-Ohio coal producers. A recently formed "Committee to Preserve the Appalachian Coal Market" — consisting of a group of Ohio electric utilities, including Ohio Edison and coal producers from Kentucky in West Virginia — has put forth the following argument: (1) a buy-Ohio policy (and scrubbers) would result in significantly higher rate increases to utility customers in Ohio; (2) the economic disruption to miners in Kentucky and West Virginia would be serious; (3) if scrubbers were required, five to seven years would elapse before they could become operative, during which time either out-of-state, low-sulfur coal would be used (with serious disruptions to Ohio's coal industry) or SO_2 standards would remain unmet. In arguing against a "state" interpretation of the meaning of "regional or local," U.S. senators from West Virginia and Kentucky insist that the original intent of the "local or regional coal" amendment was to preclude massive transport of western coal to the Appalachian region, and not to produce a "monopolistic" buy-Ohio policy.

Another voice sounding the opinion that "Ohio by itself does not represent a distinct region for coal" is the Council on Wage and Price Stability. In support of its opinion, the Council predicts that actions resulting from Section 125 proceedings will have milder employment and economic consequences for Ohio than those suggested by the EPA study, and that these consequences must be weighed both against the resulting economic disruptions to Kentucky and West Virginia and against the higher electricity prices to Ohio consumers. Furthermore, the Council observes, Ohio is already a major importer of coal, currently purchasing over one-half of its coal from other Central Appalachian states.

EPA is expected to clarify the definition of "local or regional" soon. Even if the outcome is contrary to that desired by some or all of the Ohio utilities, the certainty it will produce vis-a-vis SO_2 compliance should be welcome to the utilities.

2.3 Characteristics and Production of Ohio Coals

2.3.1 Recent Production

In 1977, Ohio produced 47 million tons of coal from 445 reporting mines, all in the eastern part of the state (see Figure 4). As can be calculated from Table 2, 59 percent of Ohio's 1977 tonnage was produced in four of the state's 29 coal-producing counties — Belmont (which produced 12 of the 47 million tons),

Figure 4

Ohio Coal Production in 1977, by County

Source: Temple, Barker, & Sloan, Inc., Ohio Section 125 Study: Regional Economic Impact Analysis, report prepared for U.S. Environmental Protection Agency, EPA Contract No. 68-01-4905 (Wellesley Hills, Mass., 14 December 1978), Figure 4, p. III-2, based on data in the State of Ohio's 1977 Division of Mines Report.

Table 2

1977 Ohio Coal Production, by County and Seam
(In short tons)

County	Total	Brookville No. 4	Clarion No. 4a	Lower Kittanning No. 5	Middle Kittanning No. 6	Lower Freeport No. 6a	Upper Freeport No. 7	Mahoning-Groff No. 7a	Pittsburgh No. 8	Redstone No. 8a	Meigs Creek No. 9	Waynesburg No. 11	Other
Total	46,940,131	1,493,746	2,971,145	2,375,644	10,529,210	1,210,105	457,427	24,082	12,502,575	530,247	8,495,833	5,099,248	1,250,869
Athens	96,636	–	–	–	64,699	26,338	5,049	–	550	–	–	–	–
Belmont	11,943,666	–	–	–	–	–	–	–	5,532,454	87,664	2,190,585	3,890,586	242,377
Carroll	310,370	–	–	58,770	128,199	40,225	30,603	24,082	–	–	–	–	28,491
Columbiana	1,173,230	–	–	5,970	953,814	78,002	133,303	–	–	–	–	–	2,141
Coshocton	1,829,929	–	–	146,583	1,683,346	–	–	–	–	–	–	–	–
Gallia	431,599	–	–	–	–	–	–	–	39,275	392,324	–	–	–
Guernsey	963,749	–	–	16,793	3,930	–	125,759	–	811,023	–	6,244	–	–
Harrison	5,989,033	–	–	–	922,505	974,940	467	–	2,257,145	–	1,632,766	60,213	140,997
Hocking	1,153,399	130,013	88,574	54,170	675,519	90,600	–	–	–	–	–	–	114,523
Holmes	680,887	–	–	406,819	274,068	–	–	–	–	–	–	–	–
Jackson	1,045,126	193,552	254,122	347,171	186,320	–	–	–	–	–	–	–	63,961
Jefferson	4,052,713	–	–	–	527,137	–	–	–	2,225,882	50,259	86,070	1,148,449	14,916
Lawrence	242,181	47,340	–	200	–	–	–	–	–	–	–	–	194,641
Mahoning	296,581	198,815	–	40,714	57,052	–	–	–	–	–	–	–	–
Meigs	1,637,367	–	1,637,367	–	–	–	–	–	–	–	–	–	–
Monroe	1,387,303	–	–	–	–	–	–	–	1,387,303	–	–	–	–
Morgan	264,494	–	–	–	–	–	–	–	–	–	264,494	–	–
Muskingum	5,78[illegible],170	–	–	50,074	1,703,305	–	100,443	–	172,282	–	3,759,845	–	1,271
Noble	357,313	–	–	–	–	–	–	–	–	–	357,313	–	–
Perry	2,304,028	–	–	877	2,212,572	–	13,868	–	76,711	–	–	–	–
Stark	702,562	134,086	–	253,576	304,411	–	10,489	–	–	–	–	–	–
Tuscarawas	1,732,068	63,865	–	830,789	708,320	–	25,903	–	–	–	–	–	103,191
Vinton	2,326,289	692,153	991,082	163,138	124,013	–	11,543	–	–	–	–	–	344,360
Washington	198,516	–	–	–	–	–	–	–	–	–	198,516	–	–
Wayne	33,922	33,922	–	–	–	–	–	–	–	–	–	–	–

Source: *State Division of Ohio, Department of Industrial Relations, Division of Mines, 1977 Division of Mines Report (Columbus, Ohio, n.d.), Table 5, p. 7.*

Harrison, Muskingum, and Jefferson; and 67 percent of the 1977 tonnage was produced at three of the 14 minable seams — Pittsburgh, Middle Kittanning, and Meigs Creek. Seventy percent of the 1977 production was strip-mined (Ohio's mines are relatively shallow — less than 400 feet deep).

2.3.2 Sulfur Content

Ohio coal is not low in sulfur. Table 3 shows that essentially none of Ohio's estimated reserves are in the low-sulfur category (less than one percent sulfur by weight), and that 66 percent of the reserves with measured sulfur content are in the high-sulfur category (more than three percent sulfur by weight). By contrast, 36 percent of the estimated coal reserves in West Virginia are in the low-sulfur category. (Fourteen percent of all the estimated eastern bituminous reserves are low-sulfur; and of those reserves, 53 percent are in West Virginia.)

Figure 5 shows the distribution of Ohio coal by sulfur content for reserves and for 1977 deliveries to utilities. While 66 percent of the reserves with measured sulfur content contained more than three percent sulfur (according to Bureau of Mines data), about 77 percent of the Ohio coal delivered to utilities contained more than three percent sulfur. (Subintervals of sulfur content were not specified for the reserves data when sulfur content exceeded three percent.)

Because Ohio coal production generally occurs in mines that are less than 400 feet deep, and because low-sulfur coal is known to have been mined in Ohio prior to 1910, the Ohio Division of Geological Survey undertook a program of exploration in the deepest portions of the Ohio coal basin — particularly in the southeastern counties — to determine whether the state might have significant reserves of low-sulfur coal. The results were not encouraging: none of the samples fell in the low-sulfur range. Only a few of the samples fell in the medium-sulfur range; and of these, only the Lower Kittanning sample was in a core of minable thickness. Most of the samples were in Ohio's "normal" (or high-sulfur) range of 3 to 5 percent.[24]

Table 3

Reserve Base of Eastern Bituminous Coals
(Millions of Tons)

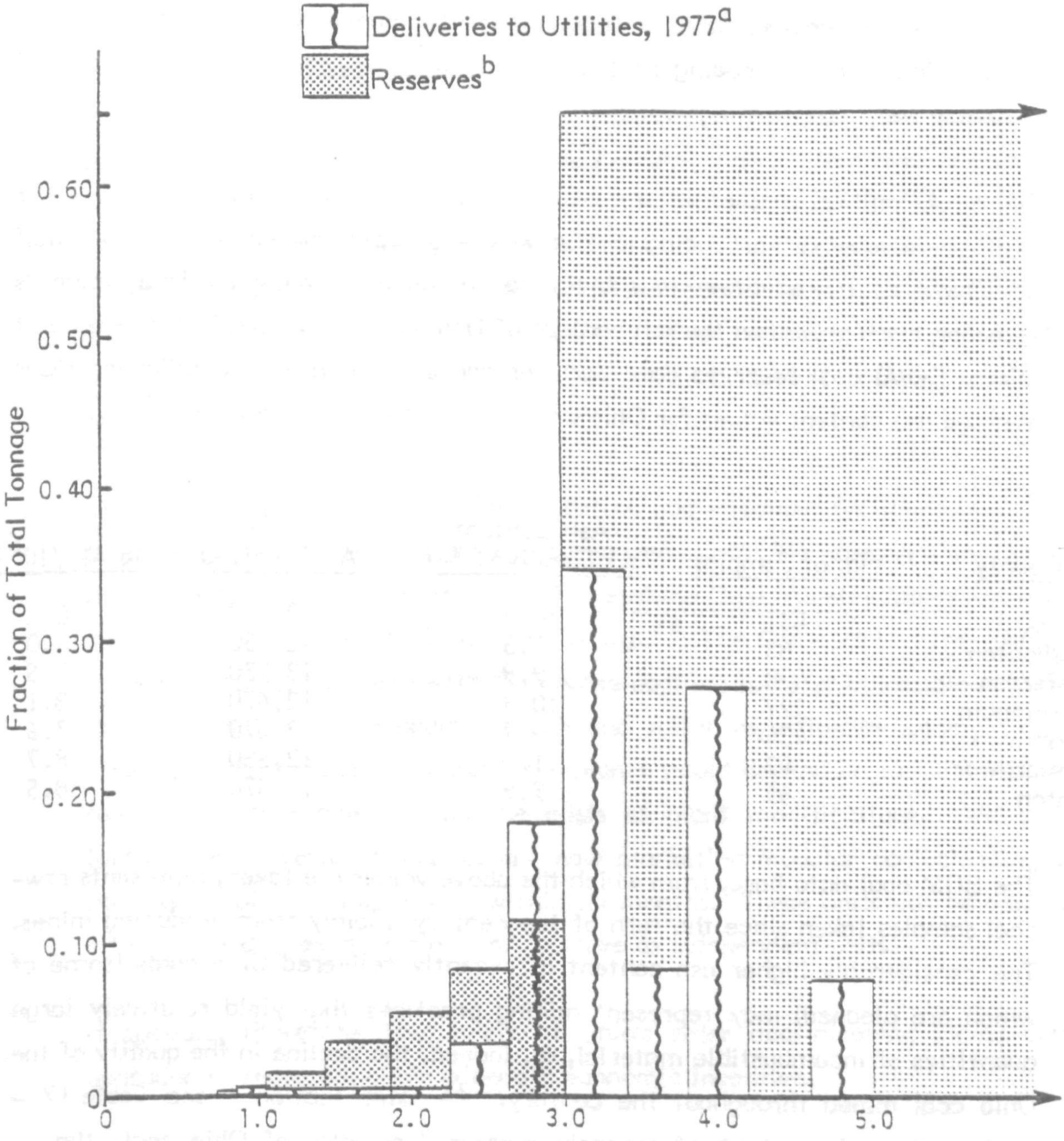
Origin	Production Method	Reserve Base by Sulfur Content (% S by Weight) S ≤ 1.0%	1.0 < S ≤ 3.0%	S > 3.0%	S Content Unknown	Total Reserves
Total Eastern	Deep	21,220	48,461	65,992	25,811	161,516
	Strip	5,302	6,822	15,434	4,936	32,511
Ohio	Deep	115	5,450	10,109	1,754	17,423
	Strip	19	991	2,525	118	3,654
West Virginia	Deep	11,807	12,583	6,553	4,143	34,378
	Strip	3,005	1,423	270	600	5,212

Source: U.S. Bureau of Mines, Reserve Base of U.S. Coals by Sulfur Content, Eastern States, IC 8680, PB-243 031 (Pittsburgh, Pa., May 1975).

Note: Reserves included are from coal beds east of the Mississippi River that are more than 28 inches thick and less than 1,000 feet deep. Estimates are for "coal in place"; potential mining losses are not accounted for.

Figure 5

Histograms of Ohio Coal Reserves and Deliveries in 1977



[a] Total deliveries of Ohio coal were 41.6 million tons in 1977. Source: National Coal Association, 1978 Steam Electric Plant Factors (Washington, D.C., 1978).

[b] Reserves of Ohio coal in billions of tons were estimated as: total = 21.1; reserves with > 3% sulfur = 12.6; reserves of unknown sulfur content = 1.87. If the "unknown" are included in the total, reserves with > 3% sulfur account for 60% of the total; if the "unknown" are subtacted, they account for 66%. Source: U.S. Bureau of Mines, Reserve Base of U.S. Coal by Sulfur Content, IC 8680, PB-243 031 (Pittsburgh, Pa., May 1975).

2.3.3 Incombustible (Ash-Producing) Matter

As mentioned earlier, EPA is requiring that Sammis now burn coal with a "quality index" not exceeding 10 lb ash per million Btu, computed on the basis of a 30-day weighted, running average.

Of the 42 million tons of Ohio coal delivered to electric utilities in 1977, the average value of ash-producing matter was 14.3 lb per million Btu[25] (about half of Ohio's coal production is subject to low-level cleaning). That value is considerably higher than the ash content of Ohio coals indicated in the Bureau of Mines (BOM) coal reserves data base, as can be seen from the following BOM average ash content values for Ohio's major coal-producing counties:[26]

County	No. of Samples	Ash Content As-Received (%)	Btu/lb As-Received	lb Ash/10^6 Btu
Belmont	431	10.7	12,500	8.6
Coshocton	83	7.3	12,150	6.0
Jefferson	478	9.9	13,230	7.5
Muskingum	227	10.3	12,670	8.1
Perry	434	9.7	12,670	7.6
Tuscarawas	92	11.0	12,680	8.7
Vinton	59	9.9	11,670	8.5

The BOM coal data base, from which the above values are taken, represents raw-coal samples taken since the turn of the century, mainly from producing mines. The considerably higher ash content of recently delivered Ohio coals (some of which are cleaned) may represent mining practices that yield relatively large quantities of incombustible material, or, indeed, the decline in the quality of the Ohio coal mined throughout the century. (A later section – see Table 12 – depicts the ash content of recently measured samples of Ohio coals tha – according to washability data performed on these samples – are potentially washable to SO_2 compliance levels.)

2.3.4 Coal-Preparation Practices in Ohio

In 1976 almost half the Ohio coals produced were prepared with some degree of "mechanical cleaning," which, on the average, left behind as refuse about 30 percent by weight of the feed coal.[27] Although there are no generally available detailed data on the level and performance of the cleaning processes used, our conversations with Ohio coal-preparation managers and our review of published summaries of the types of coal-cleaning equipment used indicate that the level of cleaning has generally been relatively low. Coarse crushing is generally performed, the degree of removal of the less coarse incombustible material is generally relatively low, advanced technology has not been employed, and sulfur removal has been only incidental. When we asked managers about the objective of their coal-washing operations, their frequent response was: "Just to remove stone."

Can a significant number of Ohio's existing coal-cleaning facilities be upgraded to achieve a higher level of ash and sulfur removal? We observe that eleven of the seventeen plants listed in the 1977 Keystone Coal Industry Manual clean only coarse coal with dense media washers or jigs.[28] The fine coal is either discarded or recombined (uncleaned) with the coarse coal product. It is possible to upgrade these plants to provide additional ash and sulfur rejection by adding fine-coal circuits. The decision to upgrade the plants would depend on the cleanability of the coal being processed and the costs of plant modifications. We observe further that several companies are now marketing modular coal-cleaning units that can be placed in operation within six months. These units can be assembled either to modify existing plants or to serve as independent units.

It appears, therefore, that many of Ohio's older coal-cleaning plants can be upgraded or replaced, given adequate economic incentive.

Ohio PCC plants, like Ohio coal mines, have for the most part operated on a small scale. Until very recently, the only large PCC Plant in Ohio was the Consolidated Coal Company plant near Georgetown, in Brown County. Built in the 1950s, this plant was designed mainly to remove ash from high-ash coals, mainly Meigs Creek coals. There now appears to be a trend in Ohio to build large PCC plants incorporating relatively advanced technology. One such plant, soon to come on line, is located near Cadiz (in Harrison County) and is owned by R&F Coal Company. This plant will process and blend Ohio coals from the Pittsburgh, Meigs Creek, and Waynesburg seams.The three types of coal will be stored in separate silos and blended with variable-speed feeders at rates determined by automatic measuring systems. The 1,000-ton-per-hour plant will have different circuits (including heavy-media and water-only cyclones) for differently sized particles, including fines down to 325 mesh. Located in a nonattainment area for particulates, the plant will not use thermal dryers. It is expected that 50 to 70 percent of total sulfur will be removed, and that ash content will be reduced to about 14.5 percent (in some cases from as much as 25 percent).[29]

Half the product from the R & F facility will be sold under contract to TVA's Colbert plant, whose delivered coal must have a heating value of 11,500 Btu per pound and produce no more than 4.0 lb SO_2 per million Btu. PCC will add $6 per ton to TVA's cost.[29] Negotiations are currently under way for the remaining output (half of 1.6 million tons per year, if we assume that the plant operates 13 hours per day and 250 days per year).

2.4 Coals Historically Used by Sammis and Representative Compliance Coals

2.4.1 Coals Historically Used by Sammis

As indicated earlier, Sammis must burn coal that produces: (1) no more than 10 lb ash per million Btu on a 30-day running average in order to adhere to an interim particulate-emission standard; and (2) no more than 4.46 lb SO_2 per million Btu for about 70 percent of the plant's capacity, and no more than 1.61 lb SO_2 per million Btu for the remaining capacity, both on a 24-hour basis. The coals listed in Table 4 represent about 90 percent of the tonnage delivered to Sammis in May 1978. The entries include the largest deliveries and represent the total tonnage's range of values for uncontrolled sulfur and ash emissions, heating value, and delivered cost for that month. A summary of the May and November 1978 coal deliveries to Sammis – aggregated by state and showing weighted

Table 4

A Representative Selection of Historic Coal Deliveries to Sammis in May 1978[a]

Company	Mine, State	County	Seam	SO_2 (lb/10^6 Btu)[b]	Ash (lb/10^6 Btu)	Btu/lb	Delivered Price (¢/10^6 Btu)	Percentage of Reported May Deliveries
Valley Camp Coal Co.	No. 1, WV	Ohio	Pittsburgh	4.20	9.82	11,911	137.1	5
–	Elkhorn, KY	Floyd	–	1.54	14.01	11,138	156.3	4
Consolidation Coal Co.	Georgetown, OH	Harrison	Pittsburgh	4.06	10.81	11,839	138.5	6
Midwestern Region								
F & F Mining Corp	F & F, WV	Boone & Fayette	–	0.70	14.00	11,432	150.6	1
Valley Camp Coal Co.	Alexander, WV	Marshall	Pittsburgh	6.28	14.23	11,455	134.0	2
Black Hawk Mining Co., Inc.	Black Hawk, KY	Floyd	–	1.56	11.31	11,585	156.2	7
Youghiogheny and Ohio Coal Co.	Nelms No. 2, OH	Harrison	Lower Freeport	4.34	11.31	12,904	115.4	2
–	Buzzard, OH	Jefferson	–	4.52	15.71	10,627	86.3	2
Industrial Mining Co.	Bergholz, OH	Jefferson	Middle Kittanning	4.74	15.39	10,981	90.8	2
Boich Mining Co.	Betsy, OH	Jefferson	Pittsburgh	5.26	13.41	11,411	104.4	6
–	CC & R, OH	Columbiana	–	4.74	14.04	10,967	91.0	2
North American Coal Corp.	Powhaten No. 1, and No. 3, OH	Belmont	Pittsburgh	6.18	16.84	10,987	148.9	7
F & M Coal Co.	F & M, OH	Jefferson	Harlem	5.70	19.39	10,159	86.4	1
–	No. 38, OH	Jefferson	–	5.80	19.92	10,339	84.9	1
–	Monwest, PA	Fayette	–	3.94	16.15	11,146	142.3	5
Schiappa Coal Co., Inc.	No. 43 & No. 56, OH	Jefferson	Pittsburgh	5.34	17.14	10,854	76.0	9
C & W Mining Co.	No. 3 and No. 5, OH	Columbiana	Middle Kittanning	5.72	14.66	11,187	86.5	9
–	Gallatin, PA	Fayette	–	3.56	13.15	11,783	112.5	18

[a] The selections, representing the range of ash and sulfur contents, are from Sammis's May 1978 purchases as listed in the Supplement to Coal Outlook, 28 August 1978.

[b] Assuming all sulfur is emitted as SO_2.

averages of the coal characteristics and delivered prices – is presented in Table 5.

Looking at the percentage of ash in the historic coals listed in Table 4, we observe that these percentages are too high to comply with Sammis's interim requirements. As for sulfur content, only one of the listed coals comfortably meets the more stringent SO_2 limitation of 1.61 lb SO_2 per million Btu: this is the coal from the F & F mine in West Virginia, listed at 0.70 lb SO_2 per million Btu. Two of the other coals – those from the Elkhorn (1.44 lb) and Black Hawk (1.56 lb) mines in Kentucky – are very close to the 1.61 lb limit but surely too close when sulfur variability is taken into account (as it must be for 24-hour averaging). The average SO_2 emissions for five of the listed coals are somewhat below the 4.46 lb limit. Taking into account sulfur variability, however, only one of the coals – that from Gallatin, Pennsylvania – would probably qualify as a compliance coal for SO_2 (see Section 3.1 for a discussion of sulfur variability). The sample coals listed in the table illustrate what is already known – that Sammis cannot comply with particulate or SO_2 limitations by burning only Ohio coal, given existing levels of control and preparation.

The weighted average of ash-producing matter in reported Ohio coal deliveries to Sammis in January 1977 was 16.6 percent.[30] As shown in Table 5, the ash content of coals delivered to Sammis in May 1978 (in pounds of ash per million Btu) was 14 for Ohio and Pennsylvania coals and 12 for West Virginia and Kentucky coals. Ohio Edison has reported that, during the months of December 1978, January 1979, and February 1979, the average ash content of all coals delivered to Sammis was slightly below the interim limit of 10 lb per million Btu on a monthly basis.[31] (The ash reduction was accomplished largely by washing coals from Gallatin, Pennsylvania; see Table 4).[32] All the ash values cited above apply to "as-received" rather than "as-burned" coal. In the present context as-burned coal is coal that has been pulverized and usually also stored for some time. For reasons that are not understood (but tentatively ascribed to different measurement techniques),[33] the ash-quality index of "as-burned" coal at Sammis, measured by Ohio Edison, has been higher than that of the "as-received" coal. At present it is not yet clear whether the interim requirement of an ash-quality

Table 5

Summary of Sammis's May and November 1978 Coal Deliveries by State of Origin

State of Origin	Tons Delivered (10^3)	% of Total Tons Delivered	Sulfur (lb/10^6 Btu)	SO_2 (lb/10^6 Btu)	Ash (lb/10^6 Btu)	Btu/lb	Delivered -Price ($/Ton)
May 1978							
Ohio	367.4	62	2.60	5.2	13.8	11,350	25.13
Pennsylvania	103.8	18	1.82	3.68	14.0	11,610	27.36
West Virginia	53.6	9	2.05	4.1	11.8	11,780	30.27
Kentucky	66.0	11	0.90	1.8	12.0	11,370	34.84
November 1978							
Ohio	291.9	75	2.58	5.16	NA	11,856	27.11
Pennsylvania	52.7	13	2.12	4.24	NA	11,740	25.65
Maryland	15.3	4	2.20	4.40	NA	11,830	25.53
West Virginia	20.6	5	2.28	4.56	NA	11,860	27.32
Kentucky	10.7	3	2.08	4.16	NA	11,490	33.35

Source: National Coal Association, Power Plant Coal Deliveries (Washington, D.C., 1978), except for ash values, which were reported in Coal Outlook, 28 August 1978.

index of 10 will be applied to the as-received or the as-burned measurements. We emphasize that the ash-quality index of 10 for Sammis will result in particulate emissions that exceed by about seven or eight times the emission limit of the Ohio Implementation Plan (0.1 lb per million Btu). Compliance with the statewide standard will require a combination of upgrading the particulate control systems and using coals of lower ash content.

2.4.2 Representative Compliance Coals

Table 6 presents a set of representative low-sulfur and low-ash coals which, we determined recently, are available for delivery on contract terms. Listed in the table are: the sources of the coals, distances by rail and barge from source to Sammis, sulfur and ash contents, heating values, and estimated availability and f.o.b. mine prices.[34] The f.o.b. mine prices listed must be considered tentative. Changing market conditions and actual contract terms may result in negotiated prices that are different. Although prices of quality coal in the early part of 1979 were depressed (even in the spot market), this situation will probably not persist. Similarly, the stated availability (tons per year and number of years) is subject to change.

As can be seen in Table 6, essentially all the compliance coals listed are from states other than Ohio — mainly southern West Virginia but also eastern Kentucky and Pennsylvania. These coals represent the kinds of coals that would comprise the majority of Sammis's deliveries under Ohio Edison's SO_2 compliance strategy. All these coals would be delivered by barge, often after some overland transport. (Again, Sammis currently can handle only about 50 percent of its coal deliveries by barge; hence, its planned compliance strategy would appear to require expansion of the barge unloading and conveyer facilities.) Barge rates, generally not regulated, are lower than the rates for other modes of transport. In May 1979, for example, the rate for the 243-mile barge haul from Charleston, West Virginia, to Pittsburgh, Pennsylvania, was 1.3 cents per ton-mile.[35]

Although not specified as such, some of the compliance coals represented in Table 6 (and some of the delivered coals listed in Table 4) reflect low levels of coal cleaning and thus some degree of sulfur and ash removal.

Table 6

Representative SO_2 Compliance Coals for Sammis

Source of Coal											
Company	County	State	10^6 Tons/Yr Available	Years Available	Transportation Distance (miles)	SO_2 ($lb/10^6$ Btu)[a]	Ash ($lb/10^6$ Btu)	Moisture/ Volatile Matter	Btu/lb	F.O.B. Mine (¢/10^6 Btu)[b]	Reference[c]
Cannelton Industries, W. Va.	Kanawha (loading point)	W. Va.	1	1979, 1980	297 Barge	1.08	10.55	1.57%/ 33.91%	12,315	142.1	1
Classic Coals, Ky.	Lawrence	Ky.	0.15	1979-?	703 Barge	1.16-1.22	6.15-6.50		12,300-13,000	122-104	2
Buckhannon Sales Co., W. Va.	Upshur	W. Va.	0.18-0.24 0.72-0.84	1979 1980-?	86 Rail 60 Barge	3.84-4.22	7.81		12,800-13,000	96.2-97.7	1
Clinchfield Coal, Va. (Raw/Cleaned)	Russell	Va.	0.25		160 Rail 262 Barge	1.12 Raw	12.00 Raw 8.00 Cleaned		12,500	152 Raw 172 Cleaned	2
R.C.B. Coals, Ky.	Carroll (loading point)	Ky.	0.24 0.36-0.48	1979 1980-1983?	485 Barge	4.16	10.00		12,000	104.2	1
Glacial Minerals, Pa.	Clarion	Pa.			100 Rail 70 Barge	3.74	7.78		12,850		2
H&H Mining, W. Va.	Summers	W. Va.	0.50		100 Rail 281 Barge	1.54	7.69	/ 34%	13,000	146	2
Forsyth Coal Exchange, N. C.	Lawrence (loading point)	Ohio	1	1979	277 Barge	4.16	10.00		12,000	105.2	1
CSR, Inc., W. Va.	Upshur, Lewis, Clay	W. Va.	0.10-0.15 0.40	in 3 mo.	152 (Upshur), 152 (Lewis), 53 (Clay) Rail; 281 Barge	3.34			12,000	117	2
Coal Cave, W. Va.	Fayette (loading point)	W. Va.	0.14-0.24	1979-?	303 Barge	1.42	10.52		11,900	71.4	1

[a] Assuming all sulfur is emitted as SO_2.

[b] May include low-level cleaning. Price may be f.o.b. loading point (see Col. 2) or delivered price (if *).

[c] References:

1. Communications during November 1978 with Norman Kilpatrick, director of Surface Mining Research Library, Charleston, W. Va., and consultant to Teknekron Research, Inc.
2. Teknekron's Final Report on Work Assignment 3 (R-011-EPA-79), EPA Task Order Contract 68-02-3092, 26 January 1979.
3. David Large, as affiant for EPA in Civil Action No. C2-78-76, 11 July 1978, p. 7.

Table 6 (Continued)

Source of Coal: Company	County	State	10^6 Tons/Yr Available	Years Available	Transportation Distance (miles)	SO_2 (lb/10^6 Btu)[a]	Ash (lb/10^6 Btu)	Moisture/ Volatile Matter	Btu/lb	F.O.B. Mine (¢/10^6 Btu)[b]	Reference[c]
Bruce Mining, W. Va.	Barbour	W. Va.	0.29 0.50	90 days 180 days	174 Rail 281 Barge	2.30	7.69	/34%	13,000	107.7	2
Vande Linde, W. Va.	Webster	W. Va.	2	in 6 mo.	189 Rail 281 Barge	1.54-1.60	7.69-8.00		12,500- 13,000	108-112	1
Oglebay Norton Co., Ohio	Wyoming (loading point)	W. Va.		1979 stockpiled	164 Rail 264 Barge	0.64	6.58		12,500	128-140	2
Oglebay Norton Co., Ohio	Greenbriar	W. Va.			64 Rail 281 Barge	1.14-1.18	5.71-5.93	/ 25%	13,500- 14,000	161-167	2
Oglebay Norton Co., Ohio	Greenbriar	W. Va.			64 Rail 281 Barge	1.14-1.18	5.71-5.93	/ 25%	13,500- 14,000	143-148	1
Island Creek, Ky.	Logan	W. Va.	1.6	by 1980	85 Rail 264 Barge	1.66	10.00		12,000	125-133.3	2
Island Creek, Ky.	Upshur	W. Va.		by 1980	86 Rail 60 Barge	3.34	8.33		12,000	125	1
Island Creek, Ky.	Upshur	W. Va.	1.5 3	late 1980 by 1981	86 Rail 60 Barge	3.34	8.33		12,000	125-133.3	3
Peabody Coal Co., Ohio	Perry	Ohio	0.12-0.14	Jan. 1979-?	150 Truck	4.18-4.28	8.70-10.71		11,200- 11,500	104.4-107.1*	3
Oglebay Norton Co., Ohio	McDowell	W. Va.	2	6.5	175 Rail 264 Barge	0.64	7.2		15,500	128	3

[a] Assuming all sulfur is emitted as SO_2.

[b] May include low-level cleaning. Price may be f.o.b. loading point (see Col. 2) or delivered price (if *).

[c] References:

1. Communications during November 1978 with Norman Kilpatrick, director of Surface Mining Research Library, Charleston, W. Va. and consultant to Teknekron Research, Inc.
2. Teknekron's Final Report on Work Assignment 3 (R-011-EPA-79), EPA Task Order Contract 68-02-3092, 26 January 1979.
3. David Large, as affiant for EPA in Civil Action No. C2-78-76, 11 July 1978, p. 7.

3. PROSPECTS FOR THE USE OF CLEANED OHIO COALS AT SAMMIS

Without physical coal cleaning (PCC), Sammis's proposed strategy of burning low-sulfur coal will mean that most of the plant's supplies will come, not from Ohio, but from southern West Virginia and eastern Kentucky. This may have serious implications for both Sammis and the Ohio coal mining industry. Sammis will have to augment its barge-unloading facilities, which now receive both out-of-state coals and some Ohio coals but currently can handle only about 50 percent of the plant's coal deliveries. Furthermore, Sammis will have to modify some of its existing contracts and purchase coal in a market which, while weak at this time, is bound to become increasingly competitive. As for the Ohio coal mining industry, the decision by Sammis (and other big Ohio plants) to substitute most of the current Ohio coal purchases with out-of-state supplies could lead to the loss of coal-industry jobs (and to associated economic "ripples") as well as to the degradation of coal-production facilities and know-how, particularly in Jefferson and nearby counties. This issue is at the core of the current Section 125 proceedings.

Ohio coal has a relatively high heating value, it is relatively easy to mine, and it is easily transported to Sammis. Moreover, several properties of Ohio coals – for example, grindability index, ash fusion temperature, characteristics of the ash, and moisture content – are generally suitable for the dry-bottom boilers of the Sammis station. But the ash content and sulfur content of Ohio coals are generally too high for existing and proposed emission limitations and control facilities. Since PCC can lower both ash and sulfur content – with some cost in dollars and energy, but with some side benefits as well – we examine the subject of burning cleaned Ohio coal.

In this section we look first at the subject of sulfur variability, including the question of how PCC may affect values of relative standard deviation (RSD) of sulfur content. We next discuss the SO_2 compliance strategy that another Ohio utility has proposed to EPA in regard to a power plant located in the central part of the state: the proposed strategy is to burn cleaned coals from current sources near the plant. We then examine the available data on Ohio coal washability and, from these data, estimate the increase in the use of Ohio coal at Sammis that may result from PCC. Finally, we discuss PCC in terms of its potential costs and benefits and compare the use of cleaned Ohio coals with uncleaned, out-of-state, low-sulfur coals at Sammis units 5, 6, and 7.

3.1 Average Coal-Sulfur Values in Relation to SO_2 Emission Limits and Coal-Sulfur Variability

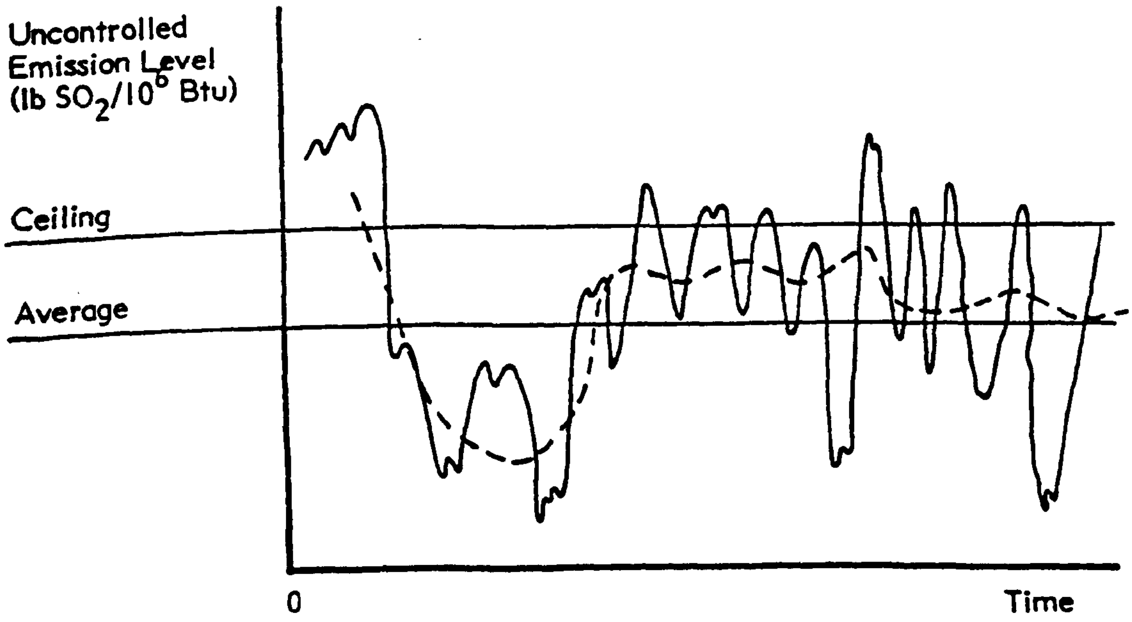
In order to determine the required sulfur content of the mix of coals to be burned, a plant's fuels manager must know not only the SIP's allowable maximum SO_2 emission level for his plant, but also the applicable effective SO_2 emission level. Because of statistical fluctuations, the effective, or mean, SO_2 emission limit will be lower than the maximum allowable SO_2 emissions. How much lower will depend upon such factors as: the variability of the SO_2 emissions, often described by the relative standard deviation (RSD)[36] of SO_2 emissions; the allowable frequency with which the maximum SO_2 emission level can be exceeded; the allowable "confidence level," reflecting an acceptable (small) probability of violating the standard; and the probability distribution (for example, a normal or lognormal distribution) of measured SO_2 emission levels.

In the case of Sammis, the manager's choice of coals must be such that the mean sulfur value of the mix burned in units 1 through 7 — averaged over 24 hours — ensures that the probability of meeting the maximum allowable SO_2 emission level for each unit (with no more than two exceedances each month) will correspond to a designated confidence level. He will need to know the difference between the emission limit and the effective, or mean, level of SO_2 emissions — and, of course, will prefer that this difference be minimal. In this section we mention various factors that affect this difference in general and at Sammis in particular. In the Appendix we present a more detailed discussion of sulfur variability.

A larger RSD means a larger difference between the allowable maximum and mean SO_2 emissions and hence a lower, or more stringent, effective SO_2 emission limit. One of the factors that increases the RSD of the weight percentage of sulfur in a particular coal is a decrease of the lot size of the coal from which measured samples are drawn, since fluctuations are expected to be smoothed with larger lot sizes. Since, for a power plant burning coal at a fixed rate, the lot size to be sampled is related directly to the averaging period, the variance and RSD also decrease with increased averaging periods. The effect of smoothing fluctuations with larger lot sizes (or averaging periods) is illustrated schematically in Figure 6, in which the same coal is sampled at two different intervals. Compared with the solid – and more fluctuating – curve, the dotted – less varying – curve represents sampling at less frequent intervals (that is, larger averaging periods or larger lot sizes). If Ohio power plants were permitted to determine SO_2 emissions on the basis of 30-day composite samples – rather than 24-hour composite samples – the RSD would theoretically be expected to equal the 24-hour RSD divided by $\sqrt{30}$. We observe that the decrease of RSD with increasing lot size implies that the SO_2 limit, for a given averaging period, is effectively more stringent for small boilers than for large boilers.

Figure 6

Illustration of the Effect of Averaging Period on RSD



RSDs of sulfur content vary from coal to coal (for a given lot size). There is no experimental basis for linking RSDs with coal type or sulfur content. The assumption (sometimes made for lack of empirical data) that the RSD per unit weight of a coal is independent of the coal's sulfur content implies a smaller variance and standard deviation for lower-sulfur coals (since the RSD equals the ratio of the standard deviation to the mean).

The RSD of the SO_2 emissions (in pounds per million Btu) will be determined largely by the RSD of the sulfur content, but not entirely. The variability in a coal's heating value affects the RSD of the SO_2 emissions (lb per million Btu) to a small extent; a report on sulfur variability by PEDCo sets the RSDs of SO_2 emissions (lb per million Btu) equal to 1.05 times the RSDs of sulfur content.[37] Two other factors with relatively small effects on the RSD of sulfur emissions are: (1) the variability of sulfur retention in the ash during combustion (the fraction of sulfur retained depends largely upon the coal's alkaline content); and (2) the variability of the small amount of sulfur removal during pulverizing of the coal at the power plant.

An analysis of a limited number of data sets has shown that the RSD of pounds of SO_2 emitted per million Btu decreases as a result of physical coal cleaning (PCC), somewhat more so with somewhat deeper levels of cleaning,[38] but that the RSD of the weight percentage of sulfur in the coal often does not decrease after PCC. These results indicate the importance of the enhancement of the cleaned coal's heating value. They also suggest that — in the raw coal — the RSD of pounds of SO_2 emitted per million Btu is greater for the pyritic SO_2, which is removed by PCC, than for the organic SO_2, which is not removed by PCC (see the Appendix).

An important factor in determining the applicable effective SO_2 emission level is the acceptable <u>confidence level</u>, related to the probability of emissions being above the established maximum SO_2 emission level. The greater the level of confidence that no exceedances (or an allowable number of exceedances) will occur in a specified time, the greater will be the difference between the allowable maximum and mean SO_2 emission levels. Thus, the <u>effective</u> SO_2 limit will be more stringent for a greater confidence level. A confidence level of 95 percent, for example, implies that, for a normal probability distribution (see below), the probability of exceeding the maximum allowable SO_2 emission level is 0.05, or that violations will be tolerated about 18 days per year. A confidence level of 99.87 percent implies that violations will be tolerated about one day in a thousand.

The probability distribution of sulfur measurements also affects the allowable effective level of SO_2 emissions, given a maximum SO_2 emission level and a value of RSD. For convenience, a normal distribution of sulfur content is often used. But, in fact, using a distribution skewed toward higher values — for example, a lognormal or inverted gamma distribution — has provided a good empirical fit to a number of sets of coal-sulfur measurements. A lognormal distribution can be transformed into a normal distribution by setting the mean equal to the natural logarithm of sulfur content in the lognormal distribution and setting the standard deviation equal to the RSD of the lognormal distribution. For a given RSD and confidence level, a coal will have a lower mean sulfur level if its sulfur content is lognormally distributed than if it is normally distributed.

Given a confidence level for a normal distribution, the difference between the mean and the maximum SO_2 emission limit can be expressed as a specified multiple of the standard deviation. This multiple is called the normal variate and can be found in standard tables of "normal curve areas." Here are some examples of normal variates, their corresponding confidence levels, and their implications regarding the number of days per year in which the maximum SO_2 emission limit can be violated.

Confidence Level (%)	Z = Normal Variate (Number of Standard Deviations between the Mean and Limit)	Number of Days per Year of Tolerated Violations
84.13	1.0	58.0
95.00	1.645	18.0
97.72	2.0	8.0
99.87	3.0	0.5

The mean value, m, of a normal distribution is related to the emission limit, max, by:

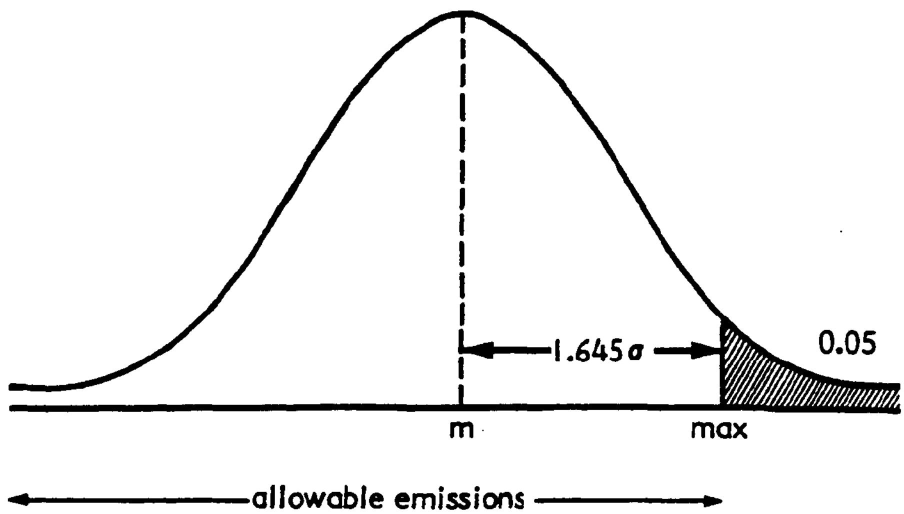
$$max - m = Z \cdot \sigma.$$

or, since RSD = σ/m, by:

$$m = max/(1 + Z \cdot RSD),$$

where σ is the standard deviation and Z is the normal variate, corresponding to a given confidence level.

Diagramatically this relationship is illustrated for a confidence level of 95 percent in the following figure:



It is expected that a confidence level of 99.87 percent (calling for three standard deviations between the mean and the maximum) will be required by EPA.[39]

We will show how the factors mentioned above can determine the effective SO_2 emission level required at Sammis. Before doing so, however, we discuss Table 7, which presents values of sulfur variability as RSD, computed from measurements of sulfur content and heating value in samples of coal from

Table 7

Values of the Relative Standard Deviation (RSD) of Sulfur Content in Ohio Coals

County	Seam Name	Mining Method	Preparation Method	Tons	Average SO_2 Emissions ($lb/10^6$ Btu)[a]	RSD (%)	Number of Samples
Tuscarawas	L. Kittanning / M. Kittanning	Surface	Raw	1,150	7.50	19.47	68
	L. Kittanning	Surface	Raw	1,426	7.26	21.19	362
	L. Kittanning	Surface	Raw	1,213	6.37	16.65	337
	No. 7 & 7A	Surface	Raw	1,248	6.66	20.62	175
	M. Kittanning	Surface	Raw	1,190	6.59	22.26	45
	Unknown	Surface	Raw	–	–	–	–
Jefferson	Pittsburgh	Surface	Raw	1,495	6.00	22.13	116
Harrison	L. Freeport	Underground	Raw	–	–	–	275
	Unknown	Surface	Raw	1,311	6.11	19.64	232
Coshocton	No. 6	Surface	Raw	3,361	8.26	21.71	454
	No. 6	Underground	Raw	2,373	8.72	19.15	455
	No. 6	Underground	Raw	947	9.48	18.86	203
	Waynesburg	Surface	Raw	1,294	6.75	15.82	531
	No. 5	Surface	Raw	1,388	7.15	16.99	262
	No. 5	Surface	Raw	1,044	7.02	23.39	108
	Unknown	Surface	Raw	959	7.13	24.51	33
	Unknown	Surface	Raw	1,181	7.12	14.77	40
	No. 6	Surface	Raw	1,250	8.09	22.56	43
	Unknown	Surface	Raw	1,449	6.84	7.34	8
	L. Kittanning / M. Kittanning	Underground/ Surface	Raw	1,016	5.71	3.15	3
Muskingum	Unknown	Surface	Raw	1,183	6.98	31.33	131
	No. 8	Surface	Raw	1,192	6.68	17.05	103
	M. Kittanning	Surface	Raw	1,568	6.16	21.07	479
	Unknown	Surface	Raw	1,245	6.62	15.09	51
	M. Kittanning	Surface	Raw	924	6.05	8.82	6
Perry	M. Kittanning	Surface	Raw	1,192	6.50	22.34	295
	Unknown	Surface	Raw	1,360	7.49	16.51	11
	No. 6	Underground	Washed	992	4.54	12.07	262
	Unknown	Surface	Raw	1,046	5.84	21.04	53
	Unknown	Surface	Raw	2,025	1.51	–	3
	Unknown	Surface	Raw	512	6.25	14.72	3
Vinton	Clarion	Surface	Raw	989	7.22	15.35	210
	Unknown	Surface	Raw	984	6.77	18.85	251
	Unknown	Surface	Raw	960	6.52	24.66	176
	Clarion / L. Kittanning	Surface	Raw	849	6.71	26.60	78
	Unknown	Surface	Raw	1,040	5.65	–	2

Source: Written Communication from Ray Morrison, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Durham, North Carolina, April 14, 1979.

a Assuming that all sulfur leaves the stack as SO_2.

various lot sizes and from various counties and coal seams in Ohio. The table also indicates the number of samples available in each data set, the type of mining (surface or underground), average values of potential SO_2 emissions, and whether the data set represents raw or washed coal (only one of the coals listed is washed). We note that, in general, the data set for a given coal and lot size can represent either a composite sample of that lot size or the average of individual measurements made on different samples of the same lot size.

Among the 39 Ohio samples listed in Table 7, the range of RSD values is large: from 8.82 to 26.60 percent. (This brackets the value of 15 percent that EPA has used as a typical RSD.) All the SO_2 values are high: none falls below the limit of 4.46 lb SO_2 per million Btu established for Sammis units 5-7, and all are considerably higher than the 1.16 lb limit for units 1-4.

To see if there is any obvious correlation among RSD values for samples taken from the same county, seam, and type of mine, let us examine separately the pairs of samples shown below, all extracted from Table 7:

County	Seam	Mine Type	RSD	Tons	Difference between RSDs
Tuscarawas	L. Kittanning	Surface	21.19	1,425	4.5
Tuscarawas	L. Kittanning	Surface	16.68	1,213	
Coshocton	No. 6	Underground	19.15	2,375	1.7
Coshocton	No. 6	Underground	18.86	945	
Coshocton	No. 6	Surface	21.71	3,360	0.8
Coshocton	No. 6	Surface	22.56	1,250	
Coshocton	No. 5	Surface	16.99	1,390	6.4
Coshocton	No. 5	Surface	23.39	1,045	
Muskingum	M. Kittanning	Surface	21.07	1,570	13.5
Muskingum	M. Kittanning	Surface	8.82	925	
			22.34	1,190	

There is no obvious correlation between the RSDs in each pair of samples. On the basis of the listed RSDs, one cannot conclude that the RSD of a sample from a particular county, seam, and type of mine will be close in value to the RSD of another sample from the same county, seam, and type of mine. There is also no obvious relationship here between RSD and the number of tons in the population represented by a sample. We offer two observations, however. First, since the RSDs in this study seem to vary even among samples of about the same tonnage, it appears that we are not comparing similar values of RSD per unit weight, and therefore that tonnage is not the only variable. Second, the range of tonnages in the above list is relatively small — from about 1,000 to 3,400 tons. (A unit train typically carries about 10,000 tons, approximately the daily consumption at Sammis; Sammis units 5-7 currently burn an average of about 6,700 tons per day.)

In Table 8, we present computed values of the required average SO_2 emissions from coal to be burned at the Sammis units, given Sammis's maximum allowable SO_2 emissions.[40] We have used alternative assumptions regarding the value of the RSD, the confidence level, and the type of probability distribution of sulfur content. Two values of RSD are compared — 0.15, frequently assumed for raw coal fed daily to large power plants, and 0.08, the RSD for the corresponding cleaned coal, according to the best fit computed for nine of the Versar data sets (see Appendix). Two confidence levels are used: 99.87 percent, corresponding to three standard deviations above the mean; and 95 percent, corresponding to 1.645 standard deviations above the mean. Finally, two distributions are considered: a normal distribution and a lognormal distribution.

To the extent that Sammis can burn coal with a higher average sulfur content, its coal choices will include more Ohio coals and more lower-priced coals. How much of a difference do the alternative sets of assumptions in Table 8 make for the allowable mean value of SO_2 emissions (in lb SO_2 per million Btu)? From Table 8 we see that, for the limit of 1.61 lb and a normal probability distribution, the mean SO_2 emissions at the 99.87 percent confidence level with an RSD of 0.15 must be 1.10 lb; with the lower RSD of 0.08, the mean can be higher — 1.29 lb (or 17 percent higher). At the 95 percent confidence level, the highest allowable mean SO_2 emission level corresponding to the RSD of 0.15 is 1.28 lb; and here, again, the allowable mean SO_2 value is higher with the lower RSD of 0.08 — 1.42 lb (or 11 percent higher). Looking at the 4.46 lb limit, the

Table 8

Expected Average SO_2 Emissions for Sammis Units under Different Assumptions of Sulfur Variability[a]

Maximum Allowable Emission (lb $SO_2/10^6$ Btu)	RSD	Confidence[b] Level (%)	Mean Emission (lb $SO_2/10^6$ Btu) Assuming Normal Distribution[c]	Mean Emission (lb $SO_2/10^6$ Btu Assuming Lognormal Distribution[d]
1.61	.15	99.87	1.10	1.02
1.61	.08	99.87	1.29	1.26
1.61	.15	95.0	1.28	1.25
1.61	.08	95.0	1.42	1.38
4.46	.15	99.87	3.07	2.84
4.46	.08	99.87	3.59	3.49
4.46	.15	95.0	3.58	3.42
4.46	.08	95.0	3.94	3.89

a For a given maximum SO_2 emission level, the allowed mean value for a sample of compliance coal will be determined by the RSD (relative standard deviation = standard deviation/mean), the probability distribution of the sampled value, and the required confidence level. The RSDs of .15 and .08 have been assumed to apply to raw and cleaned coals in quantities required daily by a large power plant. No exceedances per month are assumed beyond those implied by the confidence level.

b A 95% confidence level implies that emissions will exceed the emission limit 5% of the time, or one day in twenty. A 99.87% confidence level implies that emissions will exceed the emission limit 0.13% of the time, or less than one day per year.

c Assuming a normal probability distribution, the mean, m, is found by

$$m = \frac{max}{1 + z \cdot RSD},$$

where:

z = 3 standard deviations above the mean for a 99.87% confidence level, and

z = 1.645 standard deviations above the mean for a 95% confidence level; and

max = maximum allowable emission (1.61 or 4.46 lb $SO_2/10^6$ Btu for Sammis's generating costs).

d Assuming a lognormal distribution, the mean, m, is found by:

$$m = e^{m'}, \text{ where}$$

$$m' = \ln max - z \cdot RSD, \text{ or}$$

$$m' = max \quad e^{-z \cdot RSD}$$

(see note c for symbols)

expected average SO_2 emissions are 17 percent higher at the higher confidence level (3.58 lb instead of 3.07 lb) and 11 percent higher at the lower confidence level (3.89 lb instead of 3.49 lb).

Table 8 also illustrates that, for an assumed value of RSD, the mean sulfur level to achieve compliance will be lower with a lognormal distribution than a normal distribution of measured sulfur values.

The reduced RSD (0.08) used here for cleaned coals (and the corresponding increases in the average coal-inlet sulfur content) was determined by Versar's best fit of nine coal-data sets representing Levels 2 and 3 of coal cleaning. We point out that (1) the data used were very limited, and (2) Level 4 (more intensive) cleaning may yield a somewhat greater reduction in RSD.

Table 8 is useful because it illustrates a method for calculating the maximum acceptable average sulfur content of the coal burned at a power plant. We emphasize that the actual values used in the calculation must be determined empirically for each individual case. If, for example, measurements indicated that the RSD of the 6,700 tons per day of raw coal delivered to Sammis units 5-7 was 0.20 (rather than 0.15), then — for a confidence level of 99.87 percent and a normal probability distribution — the highest allowable mean SO_2 emissions from this coal would be 2.8 lb per million Btu (rather than 3.1 lb corresponding to an RSD of 0.15).

Implied in the computations of RSD for the cases listed in Table 8 is the assumption that no exceedances of the 24-hour SO_2 standard will be permitted, within a given confidence level. If, in fact, one or more exceedances per month will be permitted, a higher (more easily attainable) mean SO_2 value will be acceptable. Since it is expected that Sammis will be permitted to exceed its SO_2 standard up to two times per month, we have also computed the average sulfur level taking this leeway into account. For the case in which the RSD equals 0.15, the SO_2 standard equals 4.46 lb SO_2 per million Btu, the confidence level is 99.87 percent, and a normal probability distribution is assumed, allowing up to <u>two exceedances per month</u> implies an allowable mean SO_2 level of 3.34 lb

SO_2 per million Btu, which is higher than the mean SO_2 level of 3.07 lb for the same case when the 24-hour standard can never be exceeded (see Table 8). When three exceedances per month are allowed, the mean SO_2 level for the case described here is 3.36 lb SO_2 per million Btu — not very different from the mean of 3.34 lb found with two exceedances per month (see Appendix for computational details).

To summarize, for a confidence level of 99.87 percent and up to two allowed exceedances per month, the allowable mean values for Sammis are as follows:

	Allowable Mean Values (lb $SO_2/10^6$ Btu) for 99.87 Confidence Level and Two Exceedances per Month			
	Limit = 1.61 lb $SO_2/10^6$ Btu		Limit = 4.46 lb $SO_2/10^6$ Btu	
Assumed RSD	Normal Distribution	Lognormal Distribution	Normal Distribution	Lognormal Distribution
.15	1.20	1.15	3.34	3.19
.08	1.37	1.35	3.78	3.73

3.2 One Ohio Plant's Proposal for Using PCC as an SO_2 Compliance Strategy

One plant in Ohio proposes to meet its new SO_2 standard by burning cleaned Ohio coals from currently used sources in four of seven units, with the cleaning to be done in new coal-cleaning facilities. The plant — the Conesville plant near Conesville in Coshocton County (see Figure 4) — is owned by the Columbus and Southern Ohio Electric Company (C&SOE).

According to Ohio's State Implementation Plan, Conesville units 1-4, which represent about 70 percent of the plant's total six-unit capacity of 1970 MW(e), must meet a limit of 5.66 lb SO_2 per million Btu; and units 5 and 6 (which have FGD systems) must meet a 1.2 lb standard. (Compare with Sammis: 4.46 lb

SO_2 per million Btu for units 5-7, and 1.61 lb for units 1-4). Conesville's average SO_2 emissions in 1977 were (in lb per million Btu): 6.95 from units 1-3, 7.32 from unit 4, and 1.10 from unit 5. As of this writing, EPA and C&SOE have agreed that Conesville will comply with the SO_2 emission limit for units 1-4 by burning washed Ohio coals.[41]

At the same time, C&SOE is challenging the 5.66 lb limit on the grounds that it is unnecessarily stringent for plantwide compliance with the National Ambient Air Quality Standards. Whether or not this limit is relaxed, however, the utility prefers the cleaning of nearby Ohio coals as its SO_2 compliance strategy.

At present, all the coal burned at Conesville – about 3.73 million tons in 1977 – originates within about 15 miles from the plant, coming from five seams and 17 mines. About 25 percent comes from plant-site mining areas. Deliveries are by truck or conveyor belt. Since there are no rail or barge facilities, it is infeasible to use distant low-sulfur coal (from, say, eastern Kentucky or southern West Virginia) and especially desirable to continue using nearby Ohio coals.

Twenty percent of the coals currently used at Conesville come from nearby parts of the Lower Kittanning (#5) and Pittsburgh (#8) seams. Since these coals are too high in sulfur, even after washing, the plant would discontinue using them.[42] Eighty percent of the current supply comes from nearby parts of the Middle Kittanning (#6), Meigs Creek (#9), and Waynesburg (#11) seams; C&SOE would clean these coals. On the basis of washability tests it has conducted, C&SOE states that the cleaned coals can meet the 5.66 lb SO_2 standard for units 1-4. C&SOE is also considering the burning of these cleaned coals in the two units with FGDs in order to reduce limestone demand and the generation of scrubber sludge. Further, C&SOE is attracted by the possibility of improving plant performance through the use of PCC.

C&SOE is considering coarse crushing (down to 2 x 0 inches) and a 1.6 specific gravity medium – a relatively low cleaning level often referred to as "Level 2." The company estimated tentatively that the resulting SO_2 level of the washed product will average 5.4 lb. We observe that, if we use an RSD of 0.08 (the lower value in Table 8) for the 7,500 tons per day burned in units 1-4, the average

SO_2 emissions corresponding to the allowable maximum emissions of 5.66 lb are 5.0 lb for a confidence level of 95 percent, and 4.6 lb for a confidence level of 99.87 percent. Therefore, the average post-PCC value of 5.4 lb estimated for the Level 2 cleaning may not allow an adequate design margin to account for sulfur variability. A more intensive level of coal cleaning, or a somewhat greater selectivity of raw coals may, however, bring the product into line.

The Bureau of Mines washability data[43] include two samples from the Middle Kittanning seam in Coshocton County. Middle Kittanning is currently Coshocton's most productive seam, having produced 1.7 million tons in 1977, or about 45 percent of the county's coal output (see Table 2). While it is impossible to determine how representative the Bureau of Mines samples are of the current and future coal production from Coshocton's Middle Kittanning seam (the point values cannot indicate the inevitable variations within seams), it is interesting nevertheless to compare the PCC results for these samples with the results expected by Conesville. The two samples potentially emit 10.3 and 6.7 lb SO_2 per million Btu before cleaning. Results of washability tests of these samples are summarized in Table 9 for two of the Bureau of Mines levels of washing. The first level — "Level 2," which involves crushing to 1½ inch top size and a float-sink medium of specific gravity equal to 1.6 — corresponds to the level of PCC that C&SOE is considering. The second (more intensive) level, which we refer to as "Level 4," involves crushing to 3/8 inch top size and a specific gravity of 1.4.

When the relevant statistical factors require that the mean emissions not exceed 4.9 lb SO_2 per million Btu in order to meet a limit of 5.66 lb, Level 4 cleaning results in enough sulfur reduction from both the coal samples represented in Table 9. When the mean SO_2 emissions cannot exceed 4.5 lb SO_2 per million Btu, Level 2 cleaning allows compliance with the SO_2 standard only for the lower-sulfur coal sample; the higher-sulfur coal would require the more intensive PCC. In addition, several other observations can be made about the results in Table 9:

- The percentage of coal ash drops from 13.5 to 4.7 and 3.2 when Levels 2 and 4 are applied to the first coal, and from 10.2 to 4.8 and 3.4 when they are applied to the second coal.

Table 9

Summary of Results of Bureau of Mines Washability Tests on Two Samples from the Middle Kittanning Seam in Coshocton County, Ohio

	Raw Coal					After Level 2 Cleaning						After Level 4 Cleaning					
				Sulfur %						Sulfur %						Sulfur %	
Sample	Btu/lb	Ash %	lb SO_2/ 10^6 Btu	Total	Pyritic	Btu Loss	Ash %	Btu/lb	lb SO_2/ 10^6 Btu	Total	Pyritic	Btu Loss	Ash %	Btu/lb	lb SO_2/ 10^6 Btu	Total	Pyritic
1	12,300	13.5	10.3	6.4	4.5	8%	4.7	13,590	4.9	3.4	1.5	16%	3.2	13,810	4.0	2.8	1.0
2	12,500	10.2	6.7	4.2	2.3	4%	4.8	13,300	4.2	2.8	1.1	9%	3.4	13,490	3.6	2.5	0.7

Source: Joseph A. Cavallero et al., Sulfur Reduction Potential of the Coals of the United States, Bureau of Mines RI 8118 (Pittsburgh, Pa: U.S. Department of Interior, Bureau of Mines, 1976).

Note: Level 2 here designates crushing to 1½ inch top size and a float-sink medium with specific gravity equal to 1.6. Level 4 designates crushing to 3/8 inch top size and a specific gravity of 1.4.

- The Btu losses resulting from PCC are significantly higher for the more intensive level of cleaning: 16 percent and 9 percent, as compared with 8 percent and 2 percent for the lower level of PCC. (Monetary costs are necessarily attached to the energy losses.)

- The laboratory procedures used in the Bureau of Mines washability tests commonly employ heavy organic liquids to obtain desired specific gravities of separation. Heavy organic liquids promote a greater degree of sulfur removal (for the same specific gravity) than does water (made denser with materials such as magnetite), which is the basic separating medium normally used in commercial PCC operations.

- The heating values and sulfur and ash contents listed in Table 9 are presented on a moisture-free basis, so that they are higher than those for coal on an as-received basis. For lb SO_2 per million Btu, however, the moisture-free and as-received values are not very different.[44]

To put Conesville's proposal — "clean nearby Ohio coals" — in perspective, we list in Table 10 selected characteristics of analytical samples from the Middle Kittanning seam in Coshocton County, as reported by the Ohio Geological Society. Measured heating values and percentages of ash and sulfur (total, pyritic, and organic) are listed in columns 1-5. Computed values of potential emissions of <u>total</u> sulfur and <u>organic</u> sulfur as lb SO_2 per million Btu are shown in columns 7 and 8. Column 9 lists the organic-sulfur SO_2 emissions of column 8 reduced by an assumed value of 10 percent, to reflect an estimated upgrading of 10 percent in the heating value following PCC.[45] Since essentially no organic sulfur is removed by PCC, emissions of only the organic-sulfur component represent <u>the theoretically lowest</u> SO_2 emissions from a cleaned coal, assuming no sulfur retention in the ash. While in practice this theoretical limit will not be achieved, we list it as a guide for understanding Conesville's planning. Certainly, if these theoretically best values were significantly higher than an allowable mean emission (about 4.5 to 4.9 lb SO_2 per million Btu for a clean-coal RSD of 0.08), and if the measured samples were fairly representative of available coal from the Middle Kittanning seam in Coshocton, the proposed coal-cleaning SO_2 compliance strategy would not appear worth considering. Since, however, most of the SO_2 emissions listed in the last column are below the allowable mean limit for units 5-7, PCC does appear to merit consideration.

Table 10

Ash and Sulfur Contents of Coal Samples from Middle Kittanning Seam, Coshocton County, Ohio

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		% Sulfur				lb $SO_2/10^6$ Btu		
Heating Value (Btu/lb)	%Ash	Total	Pyritic	Organic	lb Ash/ 10^6 Btu	Total S before PCC	Organic S before PCC[a]	Organic S after PCC[a]
12880	5.1	3.5	1.22	2.0	4.0	5.4	3.1	2.8
9980	5.0	6.7	3.2	3.25	5.0	13.4	6.5	5.9
12220	4.9	4.2	1.67	2.28	4.0	8.4	4.5	4.1
10510	5.2	8.9	5.19	2.72	4.9	16.9	5.2	4.7
12880	2.7	4.3	2.11	2.16	2.1	6.7	3.4	3.1
12330	3.3	5.4	2.86	2.24	2.7	8.8	3.6	3.3
12580	4.4	3.5	1.3	1.67	3.5	5.6	2.6	2.4
13350	4.5	2.3	0.97	1.27	3.4	3.4	1.9	1.7
10030	7.1	6.5	3.84	1.79	7.1	13.0	3.6	3.3
12300	4.8	3.6	1.59	1.57	3.9	5.9	2.6	2.7
12860	4.0	4.0	1.67	1.77	3.1	6.2	2.8	2.5
12730	3.2	3.6	1.25	1.84	2.5	5.7	2.9	2.6
10270	2.9	4.5	2.17	1.98	2.8	8.8	3.8	3.4
12230	3.6	4.0	1.68	1.83	2.9	6.5	2.9	2.6
11950	5.7	5.3	2.96	2.05	4.8	8.9	3.5	3.2
12800	5.5	3.9	1.76	2.13	4.3	6.1	3.4	3.1
13130	5.4	3.7	1.16	2.47	4.1	5.6	3.8	3.4
9070	5.9	6.7	4.06	2.14	6.5	14.8	4.7	4.3
11980	5.6	4.5	2.15	2.22	4.7	7.5	3.7	3.4

Source: G. Botoman, and B. Smith. Analyses of Ohio Coals, IC No. 47 (Columbus, Ohio: Ohio Geological Survey, 1978).

Note: Samples were taken in 1976. Values listed are for as-received coals.

a Values for lb $SO_2/10^6$ Btu are based on the assumption that all sulfur is emitted as SO_2. Values for organic sulfur after physical coal cleaning are based on the assumption that the heating value of the cleaned coal is 10 percent higher than that of the raw coal; these values represent a lower bound on SO_2 emissions following PCC (i.e., all pyritic sulfur removed by PCC).

The question at this point is "How will the 'theoretically minimum' SO_2 emissions depicted in the last column of Table 10 correspond, in fact, to actual SO_2 emissions from the Coshocton County/Middle Kittanning coals?" The answer, of course, will depend on the particular coal and PCC process. For the data representing the two samples in Table 9, the "theoretically minimum" values would be multiplied by factors of 1.4 and 1.3 for Level 4 PCC. These data, then, suggest that a certain amount of blending of cleaned coal with low-sulfur coal may be required.

To some extent, excess emissions from units 1-4 could be offset by decreases in emissions from the two units with FGD systems, which could result if those units burned some cleaned coal.

While more data and further analysis are needed to determine whether PCC can be the exclusive SO_2 control strategy for Conesville's units 1-4, Table 9 does show that without PCC the use of the nearby Middle Kittanning coals would be out of the question. Certainly PCC would significantly increase the potential for using these coals. C&SOE is attracted further by other consequences of PCC: the removal of incombustible material, the expected decrease in gas flow during combustion, and the possibility of raising the coal's ash fusion temperature. The technical aspects of PCC do, therefore, seem attractive. But there remain a number of insistent and important institutional questions, which relate to the fact that, although SO_2 compliance is required in Ohio by October 1979, the PCC facilities needed by Conesville do not exist:

- Under what institutional arrangement will the needed PCC facilities be built?
- When will they be operational?
- What strategy for SO_2 compliance will Conesville follow until it can use PCC? Will Conesville be allowed a variance in SO_2 emissions during construction of a PCC facility? And if a variance is not granted, what will happen vis-a-vis the disuse of local mines and, possibly, the construction of needed transportation facilities (assuming no FGD) during development of the PCC facilities?

Accounting for the need to acquire relevant information, to carry out feasibility and design studies, and to obtain approval from EPA and other regulatory agencies, Conesville estimates that adequate PCC facilities could not realistically be expected to come on line before about the spring of 1982. Meanwhile C&SOE plans to support studies to determine the optimum ownership, construction, and operational arrangements for PCC. Conesville's preliminary cost estimates suggest that, if Level 2 PCC is implemented and does meet the SO_2 standards, consumers will see about a 2 percent (uninflated) increase in their cost of electricity (reflecting about a 7 percent increase in fuel costs).[46] An analysis of the net costs will necessarily address the following questions:

- What will the levelized capital and operating costs of the PCC facilities be, and what will the associated incremental fuel costs be?
- What power-plant benefits or problems — other than those related to SO_2 compliance — will result from PCC?

3.3 The Washability of Ohio Coals

The Bureau of Mines (BOM) has compiled a computerized data file describing results of a washability study of 587 U.S. coal samples, 455 of which are described in the BOM study report.[47] Two examples of the BOM findings were discussed in the preceding section; here, in Figure 7, we present a sample page of results.

What do these washability data tell us about the physical cleaning of Ohio coals as an SO_2 compliance strategy for Sammis? For units 1-4 (subject to a limit of 1.61 lb SO_2 per million Btu), the data indicate clearly that PCC will not result in SO_2 compliance, but for units 5-7 (4.46 lb SO_2 per million Btu), PCC does seem promising. In Tables 11 and 12 we list 19 of the 57 Ohio samples described in the BOM study. These are the samples for which a fairly intensive level of cleaning ("Level 4")[48] resulted in a product coal with SO_2 emissions not exceeding 3.1 lb SO_2 per million Btu, which, as we pointed out in Section 3.1, is comfortably below the 4.46 lb SO_2 standard. Both tables show the county and coal bed and

Figure 7

A Page of Washability Data from the BOM RI 8118

STATE: OHIO
COUNTY: COLUMBIANA

COALBED: MIDDLE KITTANNING
RAW COAL MOISTURE: 1.5 %

CUMULATIVE WASHABILITY DATA

SAMPLE CRUSHED TO PASS 1-1/2 INCHES

PRODUCT	RECOVERY,% WEIGHT	RECOVERY,% BTU	BTU/LB	ASH,%	SULFUR,% PYRITIC	SULFUR,% TOTAL	LB SO2/M BTU
FLOAT-1.30	68.5	74.2	14217	3.8	.28	.69	1.0
FLOAT-1.40	86.3	91.6	14010	5.2	.43	.98	1.3
FLOAT-1.60	91.3	96.0	13877	6.1	.54	1.03	1.5
FLOAT-1.90	93.3	97.5	13789	6.7	.58	1.16	1.7
TOTAL	100.0	100.0	13153	11.0	1.72	2.35	3.6
EPA STANDARD	83.6	89.2	14051	4.9	.40	.86	1.20

SAMPLE CRUSHED TO PASS 3/8 INCH

PRODUCT	RECOVERY,% WEIGHT	RECOVERY,% BTU	BTU/LB	ASH,%	SULFUR,% PYRITIC	SULFUR,% TOTAL	LB SO2/M BTU
FLOAT-1.30	74.5	80.7	14336	3.0	.07	.51	.7
FLOAT-1.40	86.5	92.7	14188	4.0	.11	.57	.8
FLOAT-1.60	90.4	96.2	14086	4.7	.16	.62	.9
FLOAT-1.90	92.2	97.3	13981	5.4	.21	.66	.9
TOTAL	100.0	100.0	13242	10.4	1.61	2.34	3.5
EPA STANDARD	98.5	97.6	13908	7.9	.40	.82	1.20

SAMPLE CRUSHED TO PASS 14 MESH

PRODUCT	RECOVERY,% WEIGHT	RECOVERY,% BTU	BTU/LB	ASH,%	SULFUR,% PYRITIC	SULFUR,% TOTAL	LB SO2/M BTU
FLOAT-1.30	59.6	76.2	14395	2.6	.06	.48	.7
FLOAT-1.40	83.9	90.7	14217	3.8	.09	.52	.7
FLOAT-1.60	89.5	95.8	14086	4.7	.13	.55	.8
FLOAT-1.90	91.8	97.3	13937	5.7	.17	.59	.8
TOTAL	100.0	100.0	13153	11.0	1.67	2.42	3.7
EPA STANDARD	92.8	97.6	13839	10.4	.38	.81	1.20

STATE: OHIO
COUNTY: COLUMBIANA

COALBED: MIDDLE KITTANNING
RAW COAL MOISTURE: 3.9 %

CUMULATIVE WASHABILITY DATA

SAMPLE CRUSHED TO PASS 1-1/2 INCHES

PRODUCT	RECOVERY,% WEIGHT	RECOVERY,% BTU	BTU/LB	ASH,%	SULFUR,% PYRITIC	SULFUR,% TOTAL	LB SO2/M BTU
FLOAT-1.30	68.5	71.4	13967	5.2	.54	.90	1.3
FLOAT-1.40	91.4	94.3	13775	6.5	.77	1.13	1.6
FLOAT-1.60	96.0	98.3	13687	7.1	.89	1.24	1.8
FLOAT-1.90	97.5	99.0	13613	7.6	.97	1.32	1.9
TOTAL	100.0	100.0	13407	9.0	1.40	1.75	2.6
EPA STANDARD	*****	*****	*****	*****	*****	*****	1.20

SAMPLE CRUSHED TO PASS 3/8 INCH

PRODUCT	RECOVERY,% WEIGHT	RECOVERY,% BTU	BTU/LB	ASH,%	SULFUR,% PYRITIC	SULFUR,% TOTAL	LB SO2/M BTU
FLOAT-1.30	70.3	74.4	14247	3.3	.13	.69	1.0
FLOAT-1.40	90.2	94.0	13967	5.2	.39	.93	1.3
FLOAT-1.60	94.1	97.1	13834	6.1	.50	1.04	1.5
FLOAT-1.90	95.5	98.1	13775	6.5	.57	1.11	1.6
TOTAL	100.0	100.0	13407	9.0	1.31	1.85	2.8
EPA STANDARD	84.7	88.9	14068	4.5	.30	.84	1.20

SAMPLE CRUSHED TO PASS 14 MESH

PRODUCT	RECOVERY,% WEIGHT	RECOVERY,% BTU	BTU/LB	ASH,%	SULFUR,% PYRITIC	SULFUR,% TOTAL	LB SO2/M BTU
FLOAT-1.30	52.7	66.9	14276	3.1	.17	.53	.7
FLOAT-1.40	86.3	90.5	14085	4.4	.22	.57	.8
FLOAT-1.60	92.2	96.5	13996	5.0	.27	.62	.9
FLOAT-1.90	94.4	97.9	13878	5.8	.32	.67	1.0
TOTAL	100.0	100.0	13377	9.2	1.40	1.75	2.6
EPA STANDARD	99.8	98.2	13807	7.8	.47	.82	1.20

Source: Joseph A. Cavallaro et al., Sulfur Reduction Potential of the Coals of the United States, RI 8118 (Pittsburgh, Pa.: U.S. Department of Interior, Bureau of Mines, 1976).

Table 11

Washability Data for Selected Ohio Coals (Sulfur Content)

County	Coal Bed	% Sulfur (S) in Raw Coal		% Moisture in Raw Coal	Lb $SO_2/10^6$		% Btu Recovery
		Pyritic S	Total S		Cleaned	Raw	
Harrison	Sewickley	1.3	1.94	2.1	1.8	3.0	90
Belmont	Sewickley	1.63	3.03	2.7	2.7	4.8	79
Harrison	Sewickley	1.35	2.22	2.1	2.2	3.4	90
Belmont	Waynesburg	2.06	2.85	2.9	2.5	4.8	72
Gallia	Pittsburgh	2.29	3.26	6.1	3.1	5.1	92
Jefferson	Pittsburgh	2.03	2.98	1.4	2.9	4.5	93
Jefferson	Mahoning	0.89	1.48	2.3	1.0	2.2	92
Harrison	Lower Freeport	1.37	2.36	2.3	1.9	3.5	90
Harrison	Lower Freeport	1.64	2.45	1.9	1.5	3.7	91
Mahoning	Brookville	1.65	2.60	3.2	1.5	3.8	90
Columbiana	Middle Kittanning	1.71	2.51	2.3	1.4	3.7	91
Columbiana	Middle Kittanning	1.72	2.35	1.5	0.8	3.6	93
Columbiana	Middle Kittanning	1.40	1.75	3.9	1.3	2.6	94
Muskingum	Middle Kittanning	1.20	2.99	2.4	3.0	1.2	95
Perry	Middle Kittanning	3.32	4.49	5.3	2.9	7.7	77
Perry	Middle Kittanning	0.10	0.65	5.5	1.0	1.1	88
Perry	Middle Kittanning	0.36	1.02	6.4	1.4	1.7	69
Vinton	Middle Kittanning	0.41	0.99	7.2	1.3	1.5	97
Tuscarawas	Lower Kittanning	1.72	2.51	2.1	1.1	3.7	92

Source: Joseph A. Cavallaro et al., Sulfur Reduction Potential of the Coals of the United States, RI 8118 (Pittsburgh, Pa.: U.S. Department of Interior, Bureau of Mines, 1976).

Notes: Selected washability indices for all data shown here: specific gravity of 1.4, crushing to 3/8 inch.

This list includes those of the 57 Ohio samples in RI 8118 that produced no more than 3.1 lb SO_2 per million Btu after cleaning (assuming no sulfur retention in the boiler).

Values of sulfur content and heating value are given on a moisture-free basis. Values of lb $SO_2/10^6$ Btu are comparable on both a moist and moisture-free basis.

Table 12

Washability Data for Selected Ohio Coals (Ash Content)

County	Coal Bed	% Ash		Heating Value (Btu/lb)		% Btu Recovery
		Raw	Cleaned	Raw	Cleaned	
Harrison	Sewickley	10.6	8.0	13023	13410	90
Belmont	Sewickley	13.1	7.9	12622	13377	79
Harrison	Sewickley	10.9	8.5	13002	13336	90
Belmont	Waynesburg	17.4	9.6	11963	13091	72
Gallia	Pittsburgh	8.7	5.3	12829	13303	92
Jefferson	Pittsburgh	9.8	5.9	13346	13916	93
Jefferson	Mahoning	9.3	3.9	13539	14345	92
Harrison	Lower Freeport	9.5	4.1	13380	14179	90
Harrison	Lower Freeport	10.4	4.1	13234	14164	91
Mahoning	Brookville	7.6	3.2	13644	14294	90
Columbiana	Middle Kittanning	9.3	3.9	13497	14300	91
Columbiana	Middle Kittanning	10.4	4.0	13242	14188	93
Columbiana	Middle Kittanning	9.0	5.2	13407	13967	94
Muskingum	Middle Kittanning	6.6	3.9	13208	13590	95
Perry	Middle Kittanning	17.7	5.1	11583	13367	77
Perry	Middle Kittanning	17.9	5.6	11598	13345	88
Perry	Middle Kittanning	16.1	6.3	11827	13195	69
Vinton	Middle Kittanning	3.5	2.7	13652	13870	97
Tuscarawas	Lower Kittanning	7.2	3.5	13515	14063	92

Source: Joseph A. Cavallaro et al., Sulfur Reduction Potential of the Coals of the United States, RI 8118 (Pittsburgh, Pa.: U.S. Department of Interior, Bureau of Mines, 1976).

Notes: Selected washability indices for all data shown here: specific gravity of 1.4, crushing to 3/8 inch.

This list includes those of the 57 Ohio samples in RI 8118 that produced no more than 3.1 lb SO_2 per million Btu after cleaning (assuming no sulfur retention in the boiler).

Values of sulfur content and heating value are given on a moisture-free basis. Values of lb $SO_2/10^6$ Btu are comparable on both a moist and moisture-free basis.

the Btu recovery of each sample. Table 11 also shows the raw coal's moisture content, the raw coal's sulfur content (total and pyritic), and the SO_2 emissions from the raw and cleaned coal (assuming all coal sulfur is emitted as SO_2 from the boiler stack). Table 12 lists the ash content and heating values of the samples both before and after PCC.

The Btu recovery from 14 of the 19 samples equalled or exceeded 90 percent. The Btu recovery from the other five samples ranged from 69 to 88 percent. Again, these data are important, since fuel loss can account for a relatively significant cost factor in PCC.

The major coal beds listed in Tables 11 and 12 are (in order of current levels of production) Pittsburgh, Middle Kittanning, Sewickley (or Meigs Creek), and Waynesburg. We note that within each bed – even within the same county or mine – coal and washability characteristics can vary significantly. On the average, the Pittsburgh seam contains the highest-sulfur coal (estimated at 5.8 percent on a moisture-free basis).[49] For this reason, the cleaning of supplies from the Pittsburgh seam cannot be expected to produce significant quantities of SO_2 compliance coal for Sammis. The Sewickley (Meigs Creek) seam also has a high sulfur content (estimated on the average as 5.5 percent).[50] Furthermore, the ash content is relatively high (about 12 to 20 percent). A number of the Meigs Creek coals are washed (for example, in the large Georgetown Preparation Plant); but, as is true for almost all PCC plants today, the facilities are designed for ash removal, not sulfur removal. While the very high sulfur content may make it impossible for Meigs Creek coals to be cleaned to SO_2 compliance levels for use by themselves, PCC will be able to reduce the sulfur content of these coals sufficiently to increase their use in compliance-coal blends.

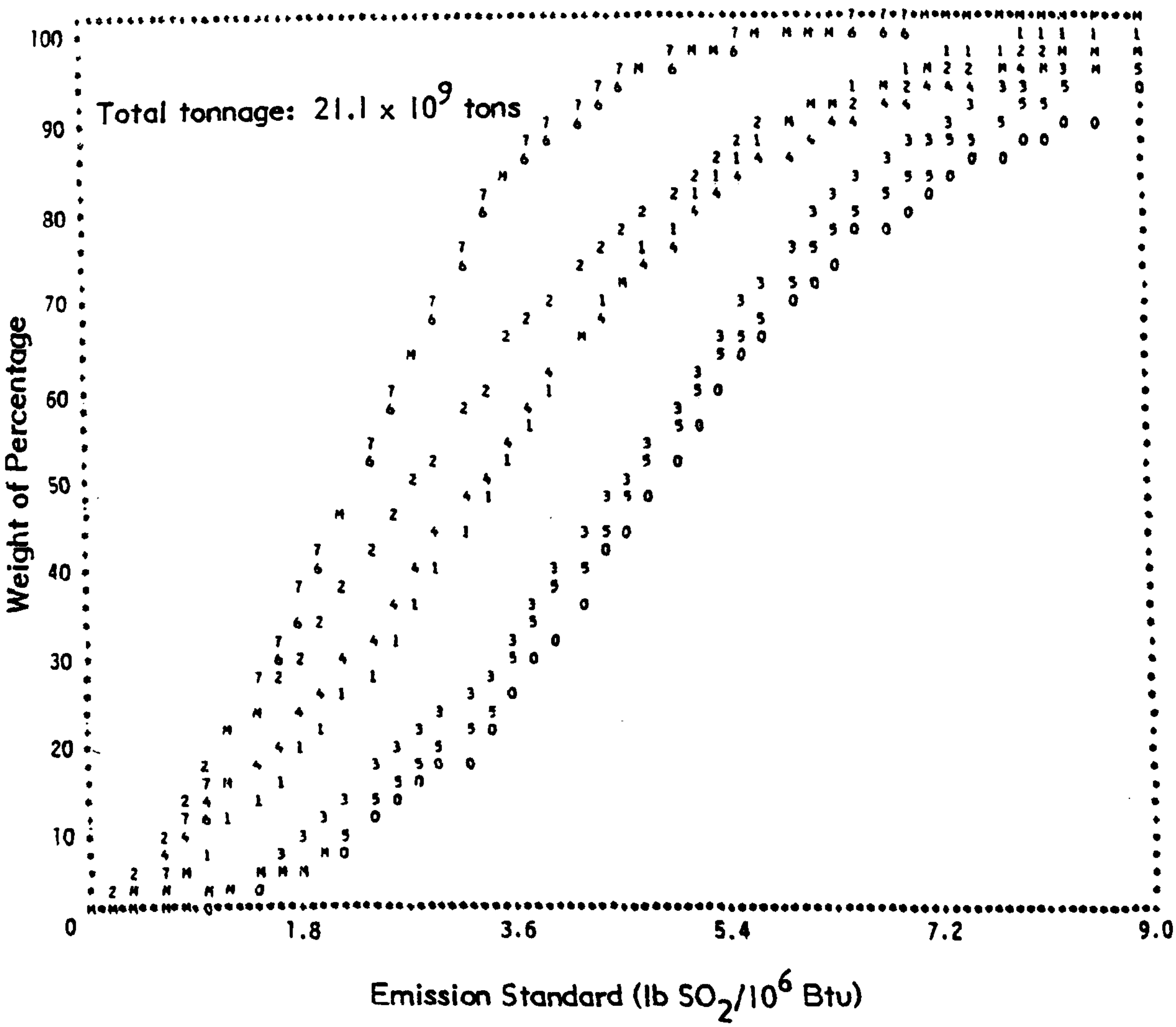
The Bureau of Mines washability data are "point data" from producing coal beds. BOM has not attached values of associated coal reserves or coal production to these data. In order to estimate the quantity of coal reserves represented by the washability samples, EPA's Office of Research and Development has developed a model – the Reserve Processing Assessment Model (RPAM) – to produce overlays of BOM reserves data and analytical data and to match the overlays with the BOM washability data. The objective of the model – which is still in the process of being tested — is to estimate the quantity of coal reserves (in terms of both weight and energy content) capable of meeting alternative SO_2 emission standards. The estimates are made for raw coal and also for coal that has been cleaned with alternative levels of PCC. We have used this model to compute cumulative percentages (by weight) of Ohio reserves that would meet a range of conceivable SO_2 standards. The results are shown in Figure 8.

According to Figure 8, about 44 percent of the total Ohio coal reserves (raw) would produce average emissions of less than 4.46 lb SO_2 per million Btu, and about 20 percent of the raw Ohio reserves would fall under a 3.1 lb limit (which would allow a comfortable margin below Sammis's 4.46 lb limit for sulfur variability). The separate curves in Figure 8 show the reserves' increased availability vis-a-vis these SO_2 standards when alternative levels of PCC are applied. The curve coded by a "2," for example, indicates that an intensive level of cleaning (3/8 inch and specific gravity of 1.3) produces a fairly dramatic increase in the reserves capable of meeting the 3.1 lb SO_2 standard — up to about 58 percent from the corresponding raw-coal availability of about 20 percent.

While the RPAM results depicted in Figure 8 are useful in relating SO_2 standards to coal availability for various levels of PCC, a caveat is in order regarding their use: their accuracy is not known. Although the data used are the best that are publicly available, they contain inherent errors that are not easily quantifiable. Furthermore, there are errors in the matching, or overlay, processes used in (1) partitioning reserves among the analytical point data and (2) partitioning the overlaid reserves and analytical information among the washability point data. The results of the RPAM matching process, where reserves are distributed uniformly among analytical samples within the union of a county and coal bed are, however, identical to those of a BOM matching process using the logistic function. When either process is applied to the same data, 61 percent of the Ohio reserves are found to contain more than 3 percent sulfur. Both matching procedures make the tenuous (but unavoidable) assumption that the distribution of the data is reasonably representative of the coal reserves.

Figure 8

Available Ohio Coal Reserves for Alternative SO_2 Standards and Levels of PCC



<u>Source</u>: EPA's Reserves Processing Assessment Model (RPAM). See text.

<u>Note</u>: The codes represent raw coal and alternative levels of PCC:

- 0: raw coal
- 1: 1½ inch at 1.6 specific gravity (s.g.)
- 2: 3/8 inch at 1.3 s.g.
- 3: 1.6 s.g. on sink of 3/8 inch, 1.3 s.g.
- 4: "Homer City clean" (stringent level of PCC to meet New Source Performance Standard limitations — see discussion at end of Section 3.3)

It is important also to note the discrepancy between the BOM data and recent deliveries of Ohio coal. These deliveries indicate that a higher percentage of high-sulfur Ohio coals are being mined than would be expected from the BOM data if those data are, in fact, representative of the state's reserves. In contrast to the value of 61 percent derived from the BOM data (see preceding paragraph), about 80 percent of the Ohio coal delivered in 1977 contained more than three percent sulfur (see Figure 5). Whether or not these recent deliveries are themselves representative of Ohio reserves is not known.

The PCC performance data discussed in this section came mainly from laboratory tests. What information has been reported on sulfur removed by operational PCC plants? Unfortunately, very little. Some, however, was presented in the Versar study.[51] Here we present the Versar data on a plant using coal from the Middle Kittanning seam in Ohio. The level of cleaning represented is one in which the coal is crushed to 3/8 inch; material greater than 3/8 inch is processed in a jig or dense-medium vessel, and material smaller than 3/8 inch is not processed. Among the six tabulated samples, the reduction of SO_2 emissions ranges from about 25 to 40 percent:

Test Number (Ohio PCC Plant, Middle Kittanning Coal)	lb $SO_2/10^6$ Btu		% Reduction by PCC of lb $SO_2/10^6$ Btu
	Raw Coal	Product Coal	
1	7.4	4.8	35.1
2	6.4	4.6	28.1
3	7.1	4.9	31.0
4	8.3	4.9	41.0
5	7.3	4.9	32.9
6	6.3	4.8	23.8

A new PCC process being developed for commercial use, the Otisca process, is a closed-cycle, heavy-media system that uses an organic medium (as does the BOM in its washability tests). American Electric Power plans to build a 125-ton-per-hour demonstration plant for the Otisca process in Beverly, Ohio, using Ohio coal with a high sulfur content (9-10 lb SO_2 per million Btu) to produce a product coal with emissions of just under 7 lb SO_2 per million Btu. It is reported that as much as 90 percent of the ash may be removed.[52]

Although we have been discussing PCC in terms of sulfur removal, we do not underestimate its value as a technology for ash removal, traditionally its most important objective and one that is especially critical for Sammis in light of the plant's past and present noncompliance with Ohio's emission limitation of 0.1 lb particulates per million Btu. Depending on the level of cleaning, PCC can remove from about 15 to 75 percent of the ash content (or even 90 percent, if the claims for the Otisca prove correct). Lower particulate emissions are not the only benefit of ash removal. The process also results in a product of higher heating value and less variability. Moreover, ash removal reduces boiler unavailability caused by the fouling or slagging problems associated with constituents of the ash.

To date, the largest plant designed and constructed largely for the removal of sulfur from steam coals is the multistream system at the Homer City Generating Station power complex in Homer City, Pennsylvania. This plant is scheduled to process 5.2 million tons of coal per year. Although it is still in the "shakedown" stage and uses Pennsylvania rather than Ohio coal, we present the design performance parameters as an example of the capabilities of an advanced sulfur-removal PCC system (see Table 13). The Homer City plant will produce two streams — one for a higher percentage of sulfur removal to serve Unit 3, which is regulated by the New Source Performance Standards (see "Homer City clean" on Figure 8), and one for units 1 and 2, which are regulated by State Implementation Plan limitations. The product coal is to be transmitted by conveyor to the plants. To eliminate the "blackwater" problem of earlier PCC plants, a closed-circuit system will be used.

3.4 The Potential Consumption of Cleaned Ohio Coal at Sammis

The preceding section indicated that cleaned Ohio coals in many cases can serve as SO_2 compliance coals for units 5-7, for which SO_2 standards are less stringent than they are for units 1-4 (4.46 rather than 1.61 lb SO_2 per milion Btu). That section also suggested that PCC can, to some extent, enhance the prospects of

Table 13

Homer City PCC Plant: Performance Design Values

	Units 1 & 2	Unit 3	Refuse
Weight Recovery (%)	56.2	24.7	19.1
Btu Recovery (%)	61.6	32.9	5.5
Heating Value (Btu/lb)	12,550	15,200	3,400
Ash (Wt. %)	17.75	2.84	69.7
Sulfur (Wt. %)	2.24	0.88	6.15
Sulfur (lb S/10^6 Btu)	1.78	0.58	18.3
Sulfur Removal (Wt. %)	52.6	91.8	

Source: "The Environmental Award," Power (November 1978), p. 214.

burning Ohio coal in units 1-4. Given the assumptions regarding sulfur variability, the effective emission limits for units 1-4 (which represent about 30 percent of Sammis's nameplate capacity) range from about 1.2 to 1.4 lb SO_2 per million Btu (see Section 3.1 and the Appendix).[53] For the Lower Kittanning—Coshocton County coals listed in Table 10, this range of emissions is not attainable, even with complete removal of pyritic sulfur. However, the BOM washability data for Ohio coals (see Table 11) and the data on available representative low-sulfur coals (Table 6) are somewhat more encouraging, indicating that some of the Ohio coals may attain SO_2 compliance levels with deep cleaning even for the relatively stringent SO_2 standards of units 1-4. Despite these indications, in the remainder of this analysis we shall focus our attention upon the more feasible prospect — the use of cleaned coals to satisfy a large fraction of the requirements of units 5-7, which consume more coal than units 1-4 and are much less demanding with respect to SO_2 emissions. We shall surmise that units 1-4 will use low-sulfur, non-Ohio coal from Southern Appalachian states. According to the list in Table 6 such coals will be available over the expected lifetimes of units 1-4. (Of course, cleaning the non-Ohio, low-sulfur coals would somewhat enhance the prospects for using cleaned Ohio coals in units 1-4).

As shown in Table 1, units 5-7 account for 68 percent of Sammis's total nameplate capacity. In 1977 the coal used by these units — almost 2.5 million tons — came to 64 percent of Sammis's coal consumption. Also shown in Table 1 are the relatively low capacity factors of these (newer and larger) units, which have consistently experienced serious operational problems. If these problems were alleviated and the yearly capacity factor were to increase to 60 percent,[54] units 5-7 would increase their annual coal consumption from the 1977 rate of 2.5 million tons to almost 4 million tons.

Reflecting different assumptions about coal-sulfur variability, the effective emission limit of units 5-7 will be from about 3.2 to 3.7 lb SO_2 per million Btu (the higher end of the range corresponds to the assumption that cleaned coals, with lower RSD, are used). If we assume a 30 percent decrease of SO_2 emissions by PCC, these limits imply potential emissions from uncleaned coal of 4.6 to 5.3 lb SO_2 per million Btu (2.4 to 2.8 lb coal sulfur per million Btu).[55] If we assume a 45 percent decrease of SO_2 emissions by PCC (achieved by half the BOM Ohio washability samples in Table 11), then the effective limits imply potential SO_2 emissions of 5.8 to 6.7 lb SO_2 per million Btu from the uncleaned coal (3.1 to 3.5 lb coal sulfur per million Btu). Looking at Table 4 for the levels of the Ohio coals delivered to Sammis in May 1978 (keeping in mind that some of the listed coals may have been washed to some extent), we see that all these levels fall within the allowable range when 45 percent sulfur removal is assumed. Most fall within the allowable range when 30 percent sulfur removal is assumed. Looking also at the potential SO_2 emissions from the list of Ohio coals in Table 7 (and multiplying by 0.95),[56] we see that most of these coals fall within or slightly exceed the range specified above for 45 percent sulfur removal by PCC. It appears, then, that a significant fraction of the SO_2 compliance coals required by units 5-7 can be met by cleaned Ohio coals. What that fraction will be will depend on the raw-coal characteristics and level of PCC. To the extent that cleaned Ohio coals cannot meet all the SO_2 compliance needs of units 5-7, non-Ohio, lower-sulfur coals will have to be mixed with the cleaned Ohio coal. (We continue to assume that Sammis's adopted strategy for SO_2 compliance will be to burn low-sulfur coals.)

The technology of coal blending can be fairly sophisticated and highly automated. For example, the Navajo Mine in the Four Corners area of New Mexico, which supplies about 2.5 million tons per year of highly variable coal, ensures uniformity of product by use of a blending system that includes ten separate storage piles of crushed coal, each built with a specially designed stacker. A running inventory is automatically indicated while a pile is being built, to allow for the adjustment of loading schedules. Reclaiming the coal from the piles also involves special equipment. Sometimes special storage equipment, such as silos, are used.

Blending may be performed at the mine, at a preparation plant, at a coal transhipping terminal, or as part of the user's coal handling system. The characteristics of the blended product must, of course, be compatible with the user's facilities.

The cost of a large, automated blending system was estimated in 1977 to be about \$1.50 per ton for a 4-million-ton-per-year blending operation.[57] This translates to about 6 cents per million Btu for Ohio coals.

Because of the space limitations at Sammis, we assume that only two streams will be combined for use in units 5-7: the low-sulfur coal stored primarily for units 1-4, and the cleaned high-sulfur coal. The combined product must result in SO_2 compliance. We assume further that these two streams will be combined by means of only "ordinary mixing," and not by a sophisticated "blending" system. Sammis has reported plans to store the low-sulfur coal for units 1-4 in a new coal-pile area served by a new conveyor belt system.[58] The need for this second coal pile is based not only on the different SO_2 emission requirements of the two sets of units but also on the need for additional coal storage.

Assuming fixed-ratio mixing of two coal streams at Sammis, we ask now what fraction and what quantity of cleaned Ohio coals can be used at Sammis units 5-7. To answer we apply the formula:

$$E_{max}/(2 \cdot 0.95) = S_L (1 + 2.17\,RSD_L)(1 - f_H)$$

$$+ S_H (1 + 2.17\,RSD_H)(f_H),$$

where the factor 2.17 corresponds to the normal variate (the number of standard deviations between the mean and allowable maximum E_{max}) for two exceedances per month and 99.87 percent confidence level (see Appendix), and:

f_H	is the fraction of cleaned high-sulfur coal;
E_{max}	is the emission limit for units 5-7 (4.46 lb SO_2 per million Btu), and $E_{max}/(2 \cdot 0.95)$ is the corresponding coal-sulfur content, assuming 5 percent retention of coal sulfur during combustion;
S_L and S_H	are mean values of lb sulfur per million Btu in the low-sulfur coal and high-sulfur coal (after cleaning), respectively; and
RSD_L and RSD_H	are the RSDs for the low-sulfur and cleaned high-sulfur coals (0.15 and 0.08), respectively, assuming the low-sulfur coal is not cleaned.

Solving for f_H (the fraction of cleaned high-sulfur coal in the mix), we have:

$$f_H = \frac{E_{max}/2 \cdot 0.95 - S_L(1 + 2.17\,RSD_L)}{S_H(1 + 2.17\,RSD_H) - S_L(1 + 2.17\,RSD_L)}$$

We observe that mixing is necessary ($f_H < 1$) only if the maximum probable SO_2 emissions from the "high-sulfur" coal exceed E_{max}, that is:

$$S_H(1 + 2.17\,RSD_H) > E_{max}/2 \cdot 0.95.$$

Or substituting the values given for RSD_H and E_{max},

$$S_H(1.174) > 4.46/2 \cdot 0.95, \text{ or}$$

$$S_H > 2.0 \text{ lb sulfur per million Btu.}$$

We now apply the formula for f_H to determine the fraction of cleaned high-sulfur coal. Values of f_H are shown in Table 14 for two values of S_L, corresponding to mean emissions from the low-sulfur coal of 1.2 and 1.4 lb SO_2 per million Btu (representing the previously described range of allowable mean emissions from units 1-4).

For S_L equal to 1.2, the fraction of cleaned Ohio coal ranges from 0.52 (when S_H corresponds to the high mean emission level of 6.1 lb SO_2 per million Btu) to 1.0 (when S_H = 2.0, corresponding to the lower – but in many cases attainable – mean emission level of 3.8 lb SO_2 per million Btu). For S_L = 1.4, the fraction of clean high-sulfur coal is not very different: 0.49 when S_H corresponds to mean emissions of 6.1 lb SO_2 per million Btu, and 1.0 when S_H corresponds to values not exceeding 3.8 lb SO_2 per million Btu (the upper limit is, of course, independent of S_L).

To translate these fractions into actual annual quantities of cleaned Ohio Coal for units 5-7, we recall that these units burned almost 2.5 million tons in 1977, and that, if the capacity factor of these units were increased to about 60 percent, the annual consumption would be almost 4 million tons per year.

Table 14

The Allowable Fraction of Cleaned High-Sulfur Coal at Sammis Units 5-7[a]

Low-Sulfur Coal[b]		Cleaned High-Sulfur Coal[b]		
Mean Emissions (lb $SO_2/10^6$ Btu)	S_L	Mean Emissions (lb $SO_2/10^6$ Btu)	S_H	Fraction, f_H
1.2	0.63	3.8	2.0	1.00
1.2	0.63	4.0	2.1	0.93
1.2	0.63	5.0	2.6	0.68
1.2	0.63	6.1	3.2	0.52
1.4	0.74	3.8	2.0	1.00
1.4	0.74	4.0	2.1	0.92
1.4	0.74	5.0	2.6	0.66
1.4	0.74	6.1	3.2	0.49

a Based upon the formula and assumptions described in the text.

b S_L and S_H are values of sulfur content (lb sulfur per million Btu) in the low-sulfur and high-sulfur coals. The mean emissions listed are based on the assumption that five percent of the sulfur in these coals is retained in the boiler ash.

3.5 The Costs of Coal Cleaning

A utility will perceive the net monetary cost of PCC, for specifed PCC levels and coals, in terms of two main sets of factors. The first set translates into an incremental price of delivered coal, which reflects mainly (1) the capital and operating costs associated with the PCC plants, and (2) the loss of Btu during PCC, and (3), to a lesser extent, other items such as reduced transportation costs and reduced payments for miners' benefits. The second set of factors relates to the combustion of cleaned rather than raw coal at the power plant (for given environmental regulations and operating conditions): burning cleaned rather than raw coals generally results in monetary benefits (often difficult to quantify) having to do with the pulverizers, the boiler, and the particulate control equipment, and storage and disposal requirements. At Sammis, the use of PCC may reduce the need for constructing new barge-unloading facilities; and at Conesville (see Section 3.2), it may reduce the need for building rail facilities. Further, any reduction in sulfur variability resulting from PCC will increase the coal purchaser's options and therefore his bidding position. Finally, there is the argument that PCC may reduce the need for unemployment or welfare payments by enhancing the competitive position of locally produced coal.

In the following section we discuss estimates of the unit cost of PCC for a high-sulfur eastern coal, considering several different levels of cleaning. In Section 3.5.2 we discuss the (generally advantageous) effects that the removal of mineral matter by PCC may have upon various power-plant operations. Finally, in Section 3.5.3 we discuss the factors that must be balanced in order to determine the point at which the use of cleaned Ohio coals at Sammis units 5-7 will be economically competitive with the use of non-Ohio, naturally low-sulfur coals. To the extent possible, we quantify these factors — but, unfortunately, many of the data needed for a definitive comparison are not available.

3.5.1 Estimated Costs of Cleaning High-Sulfur Eastern Coal

The unit cost of producing cleaned coal will be the sum of processing costs (including the disposition of refuse) and the value of the combustible material lost during processing. Some credit will accrue when PCC takes place at the mine, because of lower payments for miners' benefits (the tonnage of the coal received per energy content is reduced by PCC, and miners' benefits are based upon tonnage sold).

To suggest approximate PCC costs for Ohio coal, we present here engineering estimates developed by Versar, Inc., for "high-sulfur Eastern coal" (see Table 15); these estimates were prepared for EPA as background material relating to studies on a New Source Performance Standard for industrial boilers. We caution that the processing costs will depend on the PCC site, the PCC process, and the coals used. No generalizable PCC cost model has yet been developed, and, as mentioned earlier, experience with intensive sulfur removal is still limited.

Table 15 shows the estimated costs associated with five levels of PCC applied to a coal with about 12,000 Btu per lb, 23 percent ash, and 3.4 percent sulfur (2.8 percent pyritic sulfur). The main performance parameters — the reduction in weight and energy, the reduction in ash and sulfur contents, the increase in heating value and required ancillary energy — are shown. The annualized cost of preparation is \$2.00 per ton of product for Level 2 cleaning (which, in this example, reduces pounds of SO_2 per million Btu by 17 percent, and ash content by 15 percent). The cost is \$6.00 per ton of product for the two-stream, intensive Level 5 process (similar to the Homer City design), which reduces SO_2 emissions by 75 percent and 85 percent, respectively, in the two output streams. We note that the levels of sulfur removal depicted for the higher PCC levels are unrealistically high for most Ohio coals: the percentage of pyritic sulfur in the total sulfur of Ohio coals is rarely as high as 82 percent, the value that applies to the example in Table 15.

The annualized cost presented in Table 15 is the sum of first-year operating and maintenance (O&M) costs and a fixed annual capital charge (based here on a 10 percent discount rate, a 20-year plant life, and four percent for taxes, insurance, and G&A). By not levelizing O&M costs (significant for PCC), the costs are underestimated, since O&M cost escalation is not accounted for.

Table 15

Annual Physical Coal Cleaning Costs (1978 $) for a High-Sulfur Eastern Coal[a] (8,000-ton-per-day plant)[b]

	Levels of Cleaning				
	1	2	3	4	5[c]
Yield: wt. %	98	85	75	70	78
Recovery: % energy	100	92	85	87.5	92
Btu content of clean coal (Btu/lb)	11,974	12,678	13,265	14,674	13,852
Weight % ash reduction	4	15	51	68	75 and 52
% lb $SO_2/10^6$ Btu reduction	3	17	53	69	75 and 58
Hourly output, clean coal, tons/hr	603	523	462	431	480
Total turnkey costs, $	3,962,000	9,506,400	16,634,400	19,010,400	28,989,600
Land cost, $	120,000	180,000	264,000	720,000	480,000
Working capital, $	170,800	365,200	555,600	714,300	933,800
Grand total capital investment, $	4,252,800	10,051,600	17,454,000	29,444,700	30,403,400
Total annual costs (excluding coal cost), $[d]	1,572,400	3,377,500	5,409,200	6,635,300	9,393,100
Cost of preparation (excluding coal cost), $/ton of clean coal	0.80	1.99	3.60	4.74	6.02
Average energy requirement, Kw (10^6 Btu/hr)	250 (0.8)	650 (2.2)	1,000 (3.4)	1,300 (4.5)	2,300 (7.9)

Source: Versar, Inc., Individual Technology Assessment Report for Physical and Chemical Coal Cleaning and Low Sulfur Coal in Support of NSPS for Industrial Boilers, Draft Report, vol. 2 (Springfield, Va., 1979).

[a] Raw coal characteristics include: Heating value = 11,740 Btu/lb; weight % ash = 23.4; weight % total sulfur = 3.4; weight % pyritic sulfur = 2.8; lb $SO_2/10^6$ Btu = 5.79.

[b] Based on 13 hr/day, 250 days/year operation.

[c] The plant will generate two product streams: a very high Btu stream, and a middlings stream. The heating value applies to the combined product.

[d] Based on first-year operating costs and annualized investment costs (10 percent discount rate, 20-year PCC plant life, and 4 percent of depreciable investment for taxes, insurance, and G&A).

In Table 16 we calculate three sets of costs for Levels 2, 3, and 4: (1) the process costs (see Table 15); (2) the value of the Btu loss that occurs during processing, based on an assumed current raw-coal cost of $1 per million Btu; and (3) a credit for reduced miners' payments based on the reduced tonnage per Btu after PCC. Interestingly, the value of Btus lost during PCC (even for the relatively efficient PCC processes indicated in Table 15) is comparable in each case to the annualized PCC cost. The credit for miners' benefits is relatively small, from 0.04 to 0.09 dollars per million Btu in the first year.

The values for each set of costs in Table 16 (in dollars per million Btu) are given in terms of (1) current costs, and (2) levelized costs based on a 20-year period, reflecting the escalation of costs and the cost of capital. (To levelize the processing cost, the levelized O&M cost is added to the annualized capital cost.) Based upon the assumptions indicated in the table, the total first-year costs for Levels 1, 2, and 3, respectively, are 0.16, 0.31, and 0.29 dollars per million Btu; and the total levelized costs, again for the three levels respectively, are 0.26, 0.49, and 0.45 dollars per million Btu.

3.5.2 Cost Advantages of Burning Cleaned Coal

To what extent does PCC reduce operation and maintenance (O&M) costs at a particular power plant? Work is proceeding on this complex question, but estimates reported so far are tentative and not readily applied to specific plants. Nevertheless, we mention several general observations and some recent estimates to give some idea of how the removal of mineral matter by PCC may affect plant costs.

The removal of mineral matter is expected to have its greatest effect on: (1) furnace-wall slagging and fouling; (2) pulverizer wear; (3) convection pass fouling; (4) coal handling and storage; (5) ash handling, storage, and disposal; and (6) particulate control devices.

Table 16

Summary of the Cost of Producing Cleaned Coal[a]

	Level of PCC[b]								
	2			3			4		
		Current Cost	Levelized Cost[c]		Current Cost	Levelized Cost[c]		Current Cost	Levelized Cost[c]
Processing Cost[b]									
$/ton	1.99			3.60			4.74		
$\$/10^6$ Btu		0.078	0.107		0.136	0.182		0.162	0.219
Btu loss									
fractional loss[b]	8/92			15/85			12/88		
$\$/10^6$ Btu[d]		0.87	0.157		0.176	0.318		0.136	0.246
Miners' Benefits									
Increase in Btu/lb[b]	938			1,526			2,963		
Change in $\$/10^6$ Btu paid[e]		(0.004)	(0.007)		(0.007)	(0.013)		(0.009)	(0.016)
Total ($\$/10^6$ Btu)		0.161	0.257		0.305	0.487		0.289	0.449

a Values pertain to a unit of PCC product coal.

b See Versar's values in Table 15.

c Costs are levelized on the following basis: All cases represent a 20-year period and a discount rate of 11.5 percent per annum. Base costs for coal and miners' benefits are multiplied by 1.81, representing escalations of 7.5 percent per annum. Base costs for the O&M costs for PCC are multiplied by 1.66, representing escalations of 6.5 percent per annum. The O&M costs are the difference between the annual costs and the product of (1) the total capital investment, and (2) the factor of 0.15 (see Table 15).

d Assuming a coal price of $\$1.00/10^6$ Btu for the value of rejected Btu.

e Miners' benefits are $1.39 per ton of coal sold (1978 National Bituminous Wage Agreement of the United Mine Workers).

Tentative "typical" cost benefits have recently been put forward, but with the emphatic reminder of "the necessity to analyze each potential situation independently.[59] Most significant among the estimated benefits are the following, expressed in units of cleaned coal:

Benefit Area	Typical Benefit ($/ton)	($/$10^6$ Btu @ 13,000 Btu/lb)
Ash Disposal	0.20	0.008
Boiler Availability	0.40	0.015
Boiler Efficiency	0.70	0.029
Boiler O&M	0.50	0.027

Slagging and fouling tendencies will change as a result of PCC, usually (but not always) favorably, largely because of the reduced quantity of ash but also because of the selected reduction of some chemical constituents. In particular, the removal of iron (in the pyrite removed by PCC) will generally result in less slagging and fouling. However, this effect may be offset somewhat if the product coal is contaminated by iron-containing materials, such as magnetite, used in dense-media PCC.

In the case of Sammis, the low capacity factors of units 5-7 reflect serious O&M problems attributed partly to poor coal quality. Referring to these problems, a consultant to Ohio Edison reported that "the poorer quality coal on the market today as compared to coal commonly available when the plant was designed, is aggravating plant problems."[60] In light of this situation, coal ash removal may play an important role in improving plant availability at Sammis. To the extent that PCC can effectively increase boiler capacity or make it unnecessary to add new boiler capacity, its contribution to plant economics will be especially valuable (new large coal-fired plants may require a capital investment of as much as one million dollars per megawatt).

In a recent report on TVA's experience and analysis, the increase of rated plant capacity by PCC was determined to have a high monetary worth: $3.02 per ton of product coal ($0.13 per million Btu for a heating value of 13,000 Btu/lb).[61] This value was determined for a high-ash, high-sulfur, western Kentucky coal (20.5 percent ash and 7.0 percent sulfur before PCC; 10.5 percent ash and 4.5 percent sulfur after PCC; and a raw-coal heating value of 10,400 Btu per pound).

Because PCC increases a coal's heating value (as illustrated in Table 15), cleaning can lower the costs — on a unit-energy basis — of transporting coal. In the case of Sammis, this effect may not be significant if cleaned Ohio coals are compared with uncleaned out-of-state coals. Although cleaning would permit the use of considerably more Ohio coal, and the Ohio coals originate much closer to Sammis (up to about 150 miles, but usually within 50 miles) than do the out-of-state, low-sulfur coals (see Table 6), the Ohio coals are hauled to Sammis by truck, whereas the eastern Kentucky and southern West Virginia coals are hauled mainly by barge and, in some cases, also by rail. Barge rates are considerably lower than truck rates (in many cases by a factor of about one-tenth); rail rates are also lower. Furthermore, the Southern Appalachian coals are often lower in ash content than are the Ohio coals (see Tables 4 and 6). The increased use of Ohio coals, therefore, will not obviously result in direct coal transportation savings. If, however, the comparison is made between transporting cleaned coal and transporting raw coal within Ohio, the transportation savings may be significant: about $0.35 to $0.40 per ton for an average 50-mile haul, assuming a truck rate of $0.06 per ton-mile and a post-PCC weight loss per energy unit of approximately 15 percent. Recalling our discussion of Sammis's restricted coal choices, we note that the comparison between hauling cleaned and uncleaned Ohio coal applies realistically to only a small fraction of the coal that Sammis will burn; the amount of Ohio coal burned at Sammis must be severely reduced unless it is cleaned.

One last point — perhaps the most important — must be made in connection with transportation costs: the cleaning of Ohio coals can significantly reduce the need for constructing new barge unloading facilities at Sammis.

PCC may have an important effect upon the plant's particulate collection devices, especially since Sammis must install new devices — baghouses or electrostatic precipitators (ESPs) — to bring about the dramatic increase in particulate emissions needed to comply with the Ohio standard of 0.1 lb particulates per million Btu (see Section 2.2). With cleaned coal, the reduced particulate loading into the collection device can significantly reduce the required capacity — and consequently the cost — of the new control devices. The reduction in the cost of an ESP is roughly half the reduction in required capacity; if, for example, PCC reduces ash content by 50 percent, the cost of the control device can be expected to be reduced by roughly 25 percent — roughly $0.01 per million Btu of cleaned coal.[62]

Although the efficiency of an ESP is sometimes reduced by lower coal-sulfur levels, it should not be affected by the sulfur removal that would result from PCC for Sammis units 5-7, which would burn coal of about 3.5 lb sulfur per million Btu. At this level there would be adequate concentrations of SO_3 in the flue gas to ensure proper conductivity in the ESP. Furthermore, it is not unlikely that competitive bidding for contracts to build Sammis's new particulate collection facilities will result in similar cost estimates for ESPs and fabric-filter baghouses — and the efficiency of baghouses does not depend on coal sulfur content.

All the cost estimates mentioned in this section are for current costs. To derive levelized costs, the current costs must be multiplied by a levelization factor (such as 1.81, the factor applied to the coal costs shown in Table 16).

We have mentioned here some of the cost advantages of burning cleaned coal at the power plant. In some cases there are also advantages in producing the coal. When it is known that the coal will be cleaned, it is sometimes possible to use cruder — and cheaper — mining methods, as, for example, in mines where partings are difficult to remove with conventional processes. This effect will become more important as lower-quality seams are mined, especially by underground mining methods.

3.5.3 Costs of Cleaned Ohio Coal versus Out-of-State Low-Sulfur Coal for Units 5-7

Whether Sammis units 5-7 burn cleaned Ohio coal or low-sulfur, non-Ohio coal will depend largely on the comparative effective costs of the two options. To make the comparison, one must examine each option's major cost factors, which will involve a number of considerations, including alternative sources of the coal, types of PCC facility and operation, and institutional agreements. Applicable cost factors include:

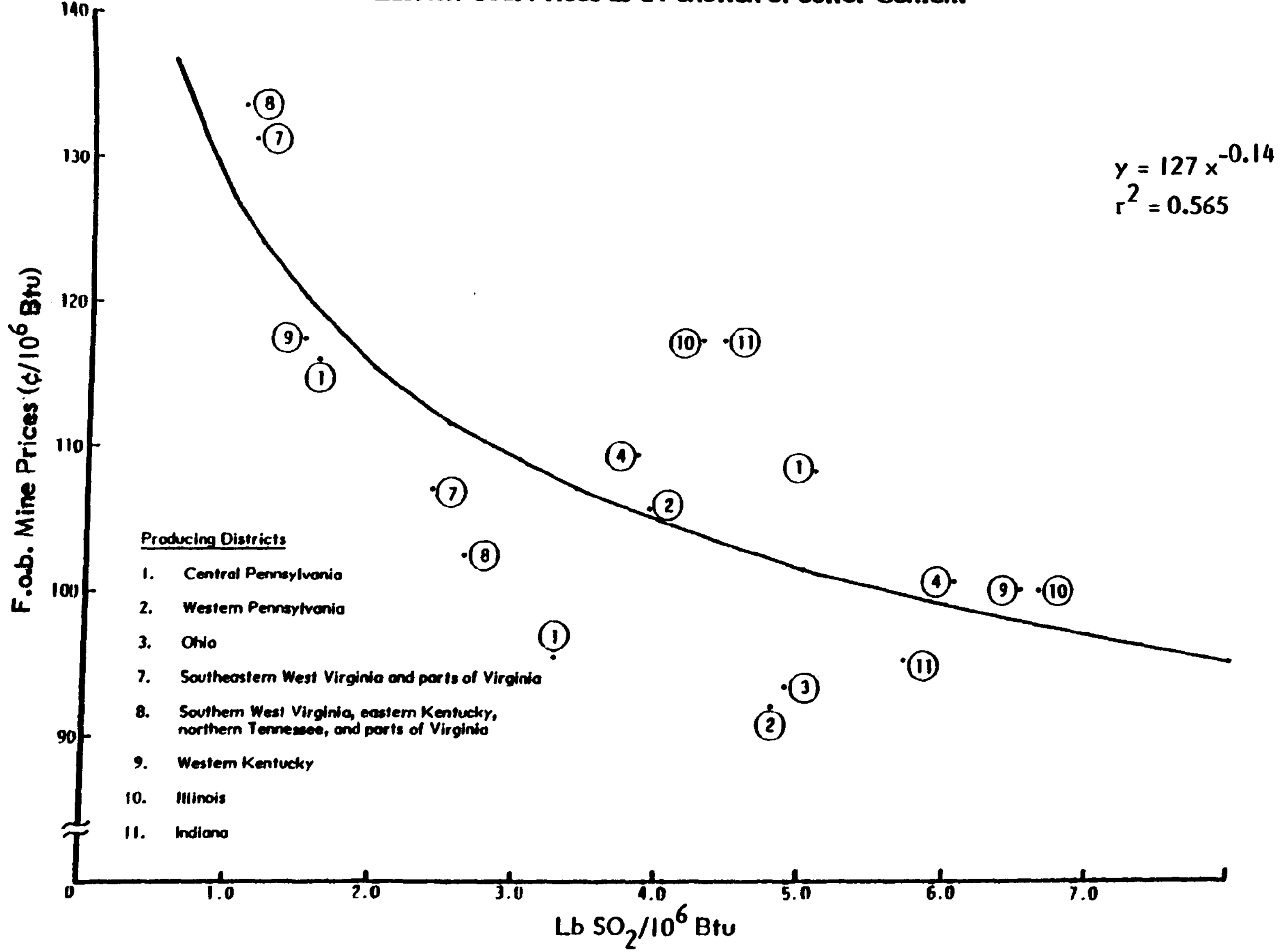
Cleaned Ohio Coals	Low-Sulfur, Non-Ohio Coals
Coal prices, f.o.b. mine	Coal prices, f.o.b. mine
PCC production costs	
Transportation (by truck)	Transportation (by barge and possibly by rail)
Contractual arrangements	Contractual arrangements
Benefits at the power plant due to removal of mineral matter (see Section 3.5.2)	

We consider first the difference between the raw-coal prices of the cleaned Ohio coals and the low-sulfur, out-of-state coals (keeping in mind the allowable sulfur levels for units 5-7), and then we compare this difference with the costs incurred by the PCC process. Again, we caution that generalizations are risky. Because of the anticipated changes in coal purchases by Ohio's utilities, the market price of lower-sulfur coals, which has been depressed lately, is expected to escalate faster than the market price of Ohio (high-sulfur) coals. It is largely in anticipation of increased demand and higher prices for their supplies that producers of lower-sulfur, Southern Appalachian coal are currently reluctant to enter into long-term contracts.

With this caveat in mine, we look at Figure 9, which shows a "best fit" curve drawn through points representing a set of eastern coal prices (early 1979) as a function of potential SO_2 emissions. The function represented by the curve — for which the coefficient of determination is only 0.565 — is one in which one

Figure 9

Eastern Coal Prices as a Function of Sulfur Content



Source: Coal prices and characteristics from Coal Week, 9 April 1979.

price is more sensitive to changes in sulfur content at the lower levels of sulfur content. From the curve we read current coal prices corresponding to the range of average SO_2 emissions allowed for units 5-7, which is 3.2 to 3.8 lb SO_2 per million Btu (as determined in Section 3.1 on the basis of the limit of 4.46 lb SO_2 per million Btu and stated assumptions about sulfur variability). This range implies that, for a 30 percent reduction of SO_2 emissions by PCC, allowable average emissions from the raw coals must be 4.6 to 5.3 lb SO_2 per million Btu, and that, for a 45 percent reduction of emissions by PCC, allowable average emissions from the raw coals must be 5.8 to 6.7 lb SO_2.

We read the raw-coal prices for the uncleaned coal and then find the difference between these prices and those for naturally low-sulfur coals that correspond to (1) 30 percent SO_2 reduction by PCC, and (2) 45 percent SO_2 reduction by PCC. We then multiply these differences by a levelization factor[63] and compare the resulting differences (levelized savings attributable to PCC) with the levelized costs of PCC. The PCC costs for 30 percent and 45 percent SO_2 reduction are found from Table 16 by linearly interpolating between Level 2 (17 percent SO_2 reduction) and Level 3 (53 percent SO_2 reduction). This comparison between the savings in raw-coal costs by using PCC and the expenses incurred in producing cleaned coals is summarized in Table 17.

According to Table 17, the costs of PCC outweigh the savings that are due only to the difference in costs of the raw coal used with and without PCC — the PCC costs are about \$0.25 per million Btu higher. We note that, although we have assumed here that the maximum reduction in SO_2 emissions is 45 percent, a greater reduction is possible in some cases. The new R & F PCC plant near Cadiz, for example, is designed to reduce SO_2 emissions from Ohio coals by about 80 percent (see Section 2.3.4).

If we add to the raw-coal savings the savings in the power-plant operations mentioned in Section 3.5.2, then the savings from using PCC in fact outweigh the costs of PCC. The savings, in dollars per million Btu, attributed to increased plant capacity by TVA (0.13) and to lower boiler O&M by PEDCo (0.027), when multiplied by the levelization factor of 1.81, equal 0.28 dollars per million Btu.

Table 17

Summary of Costs versus Savings with PCC

	No PCC	30% Sulfur Removal by PCC	45% Sulfur Removal by PCC
Allowable raw-coal SO_2 emissions from units 5-7	3.2-3.7 lb $SO_2/10^6$ Btu	4.6-5.4 lb $SO_2/10^6$ Btu	5.8-6.9 lb $SO_2/10^6$ Btu
Savings in levelized raw-coal costs with PCC (from Figure 9)	–	0.06 x 1.81 = 0.11 $\$/10^6$ Btu	0.09 x 1.81 = 0.16 $\$/10^6$ Btu
Levelized costs for PCC production (interpolated from values in Table 16)	–	0.34 $\$/10^6$ Btu	0.43 $\$/10^6$ Btu
Difference between PCC costs and raw-coal costs savings	–	0.24 $\$/10^6$ Btu	0.27 $\$/10^6$ Btu

This more than cancels the debit of 0.25 dollars per million Btu indicated above, where PCC costs are compared only with raw-coal savings. Further, to the extent that low-sulfur coals increase more rapidly in price than high-sulfur coals, the raw coal savings from PCC will increase. Other savings postulated for the burning of cleaned coals — related to such factors as ash disposal, boiler efficiency, particulate controls, pulverizer wear and capacity, and, in the case of Sammis, elimination of the need to build new barge unloading facilities — are not added here to the cost-savings side of the equation.

We emphasize that the cost analysis presented here suggests the kind of procedure that must be followed in order to determine the economic competitiveness of using cleaned Ohio coals. Many of the illustrative values we have used, however, must be replaced by hard data, to which we do not have access.

Ohio Edison can be expected to have many of these data; other data, however, can be determined only empirically, and still others can be determined from negotiations in the marketplace (or on the basis of existing contracts).

Judging from what we have been able to show, it appears that PCC for units 5-7 may be economically justifiable. Given this conclusion — and given the indications that PCC can minimize the negative effects that a switch away from Ohio coals will have on the state's coal industry — it appears prudent to recommend that the needed information be acquired for a decisive economic analysis of the cost of PCC for Ohio plants in general and Sammis in particular. The importance of the consequences that will result from a decision to adopt or reject PCC dictates that such an analysis be carried out.

3.6 Institutional Barriers to Implementing PCC in Ohio

In the preceding section we showed that PCC may represent an economically viable SO_2 compliance strategy for Sammis units 5-7. And in earlier sections we indicated that PCC can prevent the shutdown of a large fraction of Ohio's mines (80 percent of which may close as a result of SO_2 limitations). There are, however, several barriers obstructing the adoption of PCC in Ohio. We mention the major barriers here.

First, many Ohio mines are too small to produce the input required by the smallest economically feasible PCC plant (about 100 tons per hour).[64] Next, the coal preparation engineers and contractors needed to build advanced-technology PCC plants are often in short supply. Further, PCC plants will be subject to environmental constraints (the effects of which include the need for closed-circuit water systems and, in some cases, the prohibition of thermal dryers). Finally, there will be a time lag of at least 2.5 to 3 years between inception and completion of a PCC plant.

The time lag in the production of cleaned coals raises a barrier against the use of PCC (one mentioned in discussing the Conesville plant, in Section 3.2): What will utilities do to meet their SO_2 standard while waiting for PCC to become available? If they burn out-of-state, low-sulfur coal during the interim, many of the potential producers of cleaned Ohio coal may suffer irreversible financial problems and loss in production capability. If, on the other hand, the utilities burn noncompliance coal from Ohio, they will need a temporary waiver of environmental standards.

While these barriers are not insurmountable, they do exist — and some effort will be needed before they can, in fact, be overcome.[65]

APPENDIX

SULFUR VARIABILITY AND A COMPARISON OF THE EFFECTIVE AND MANDATED SO_2 EMISSION LIMITATIONS

This appendix develops a number of topics alluded to in Section 3.1 ("Average Coal-Sulfur Values in Relation to SO_2 Emission Limits and Coal-Sulfur Variability") and should be read in conjunction with that section. The topics include:

- Effect of lot size on the relative standard deviation (RSD) of coal sulfur content
- Effect of coal cleaning on RSD[36]
- Effect on RSD of the number of daily exceedances allowed per month

Effect of Lot Size on RSD

In a recent study for EPA,[66] PEDCo examined the variation of RSD with lot size on the basis of sulfur-content measurements from a data set representing coals with less than one percent sulfur. Computed RSDs were compounded statistically for the case where unit trains (8,400 tons) were sampled at the rate of four per week to obtain RSDs for lot sizes representing a unit train for periods of one week, one month, three months, six months, and one year — that is, for lot sizes from 8,400 to more than one million tons.

PEDCo's results are shown as data points on the solid curve of Figure A-1, where RSDs for sulfur (percentage by weight) are plotted against the $\log_{10}$ of lot size (or averaging period). The curve indicates a decreasing function that approaches zero as the lot size exceeds several million tons. For smaller lot sizes, a straight-line extrapolation was used:

$$RSD = 0.289 - 0.0341 \log_{10} T,$$

where T represents the lot size in tons. Extended to the very small lot size of 50 lbs (a typical core size), the RSD according to this formula reaches the very high value of 0.34.

The curve indicates that the RSD for a lot size of 10,000 tons — approximately the daily average coal feed for Sammis — is about 0.15. By contrast, the RSD for 100 tons of coal (the daily consumption of a small industrial boiler of about 100 million Btu per hour at 100 percent capacity) would be twice as high — 0.30.

The curve of RSD versus the $\log_{10}T$ in Figure A-1 is based on data sets for coals with less than one percent sulfur and for which RSD decreases with increasing lot size. In some instances in the PEDCo study the RSD remained unchanged or even increased slightly with increasing lot size. These instances were attributed to either "aberrations in data or the fact that samples were not truly representative of the entire lot."

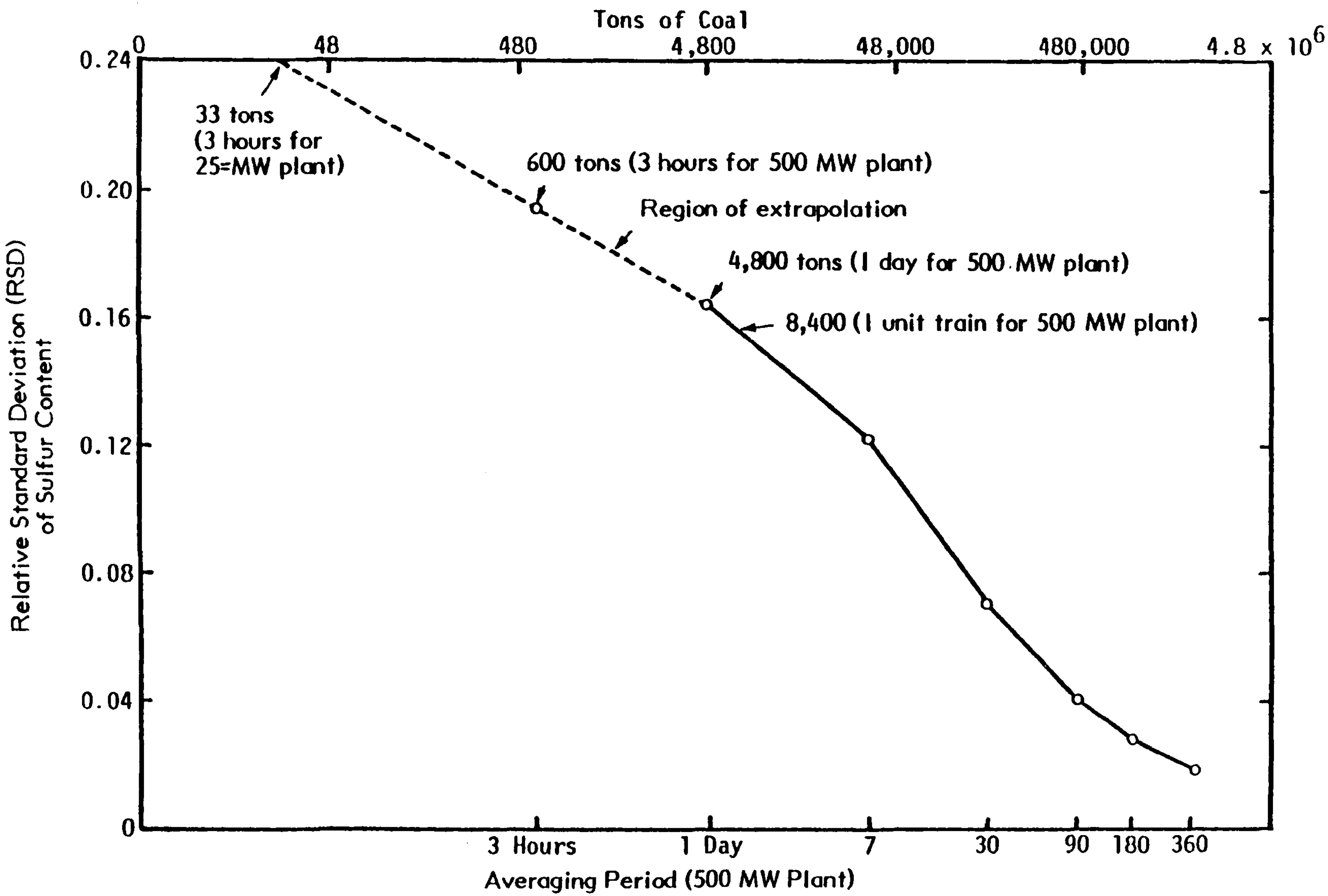
It should be stressed that a coal user must empirically determine the RSD for any particular coal he will be using. In this regard the PEDCo report explicitly states:

> It is emphasized that the values [see Figure A-1] are based on a collection of coal data made available by selected companies. Each company using the approach presented herein is urged to use its own data in estimating the variability of sulfur content for specified times or tonnages.

It is impossible to generalize about the RSDs of either raw or cleaned coal, even for coals from a single county and seam. While the overall trend of the data analyzed in the abovementioned report does support the intuitive notion that RSD decreases as lot size increases, in a local sense it may not be possible to verify any functional relationship or even trend between RSD and lot size. One important reason for aberrations in the trend is that the RSD per unit weight may in fact be different among different types of coal, as suggested by the data in Table 7 in Section 3.1. In particular, the RSD of washed coal is almost always smaller than that of the corresponding raw coal (we shall say more about this later).

Another report for EPA, this one by Versar,[67] computed RSDs from measured values of percent sulfur and heating value. The values — representing various

RSD of Sulfur Content versus Averaging Period (Lot Size)



Source: PEDCo, Inc., Preliminary Evaluations of Sulfur Variability in Low-Sulfur Coals from Selected Mines, EPA-45013-77-044, prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina (Cincinnati, Ohio, November 1977).

Note: Values represent Appalachian coals containing up to one percent sulfur. They are estimated to apply to coals with up to 1.5 percent sulfur.

raw and cleaned coal types and both mechanical and manual sampling – were provided mainly by coal companies but also by two EPA studies. The emphasis was on comparing RSDs of coals before and after coal cleaning.

To examine the functional relationship of RSD and lot size, the Versar study took 25 data sets (each comprising from 23 to 26 samples and representing a raw or cleaned coal from a given county and bed), partitioned them into three or four lot-size ranges, and constructed 25 plots of RSD versus lot size, each with three or four points. Two further plots – one of 20, the other of 13 points – were constructed, each an aggregate of computed RSDs for all data sets from a particular coal seam and state. These representations did not indicate a trend of decreasing RSD with increasing lot size. We offer two explanations for the absence of this trend. First, the sample sets in the Versar study were relatively small: the aggregated plots represented ranges of 3.5 to 26, and 1.3 to 8.1, thousand tons. (By contrast, the range of lot sizes in the PEDCo study represented several orders of magnitude.) A marked trend of decreasing RSD with increasing lot size may be apparent only over a wide range of lot sizes. Second, there is the heterogeneity of coals within a seam: different coals may have different RSDs (per lot size). This fact emerged as a number of multiple-valued RSDs when RSDs of different data sets within a coal seam and state were plotted against lot size. Thus, it is obvious that RSD is not a function of lot size alone. In particular, assuming that RSD does not change with the mean sulfur content implies that there is less sulfur variability for low-sulfur than for high-sulfur coals (since RSD is the ratio of the standard deviation to the mean sulfur content). No available data do, in fact, substantiate this assumption.

The Effect of Coal Cleaning on RSD

An important result of the Versar analysis concerns the reduction of RSD of lb SO_2 per million Btu as a result of coal preparation. A straight-line fit to data points from nine coal-preparation plants, each operating on a different seam, relates the RSD of the uncleaned coal (RSD_{uc}) to the RSD of the cleaned coal (RSD_c):

$$RSD_c \simeq .836\ RSD_{uc} - .051.$$

Although it must be stressed that the actual reduction of RSD with physical coal cleaning will have to be tested against the specific raw-coal type and cleaning process used,[68] it is interesting to examine the implications of this equation. For an uncleaned coal with an RSD equal to 0.15 — the RSD that can be deduced from the PEDCo plot for Sammis's approximate 24-hour coal use, and also the value used in a number of EPA reports — the RSD of the cleaned coal would be only 0.08.

Since organic sulfur is bound to the coal and not generally removed by PCC, while the pyritic sulfur is associated with the incombustible (ash-producing) material and is removed by PCC, a lower value of the RSD of lb SO_2 per million Btu suggests that, in a raw coal, the values of RSDs (lb SO_2 per million Btu) are higher for pyritic sulfur than for organic sulfur. While reported coal sulfur values are not generally separated into pyritic and nonpyritic sulfur, the washability data prepared by the Bureau of Mines do include mean values and standard deviations of measurements of both pyritic and total sulfur for raw and cleaned coals within a county and coal bed. In examining these data to compare the RSDs of pyritic and organic sulfur (lb SO_2 per million/Btu), we found that, indeed, the raw-coal RSDs were usually higher for pyritic sulfur than for total sulfur. Further, as can be seen in Table A-1, when these data are aggregated on a regional basis, the raw-coal RSDs for pyritic sulfur are consistently higher than those for total sulfur.

Additional data and results of analyses pertaining to RSDs will become available from a number of ongoing EPA studies of sulfur variability.

Effect on RSDs of the Number of Daily Exceedances Allowed per Month

Implied in the computations of relative standard deviation for the cases listed in Table 8 (Section 3.1) is the assumption that the 24-hour SO_2 standard will never be exceeded. If, in fact, one or more exceedances per month will be permitted,

Table A-1

Total Sulfur and Pyritic Sulfur Content: Comparison of Variability

Coal Region	Number of Samples	Sulfur Content of Raw Coal					
		Pyritic Sulfur (%)			Total Sulfur (%)		
		Mean %	Sigma	RSD	Mean %	Sigma	RSD
N. Appalachian	227	2.01	1.3	0.65	3.01	1.6	0.53
S. Appalachian	35	0.37	0.4	1.08	1.04	0.6	0.58
Alabama	10	0.69	0.8	1.16	1.33	0.9	0.68
Eastern Midwest	95	2.29	1.0	0.44	3.92	1.2	0.31
Western Midwest	44	3.58	1.9	0.53	5.25	2.3	0.44
Western	44	0.23	0.3	1.3	0.68	0.3	0.44

Source: Joseph A. Cavallero et al., Sulfur Reduction Potential of the Coals of the United States, RI 8118 (Pittsburgh, Pa.: U.S. Department of the Interior, Bureau of Mines, 1976).

Note: RSD is the ratio of the standard deviation (sigma) to the mean.

a higher mean SO_2 value will be acceptable. Since Sammis may be permitted to exceed its SO_2 standard two times per month, we have also computed the average sulfur level taking this variance into account for one of the cases described in Table 8: RSD of 0.15, SO_2 standard of 4.46 lb SO_2 per million Btu, confidence level of 99.87 percent, and a normal probability distribution.

The mean, m, for this case when no exceedances are allowed was shown to be 3.07, using:

$$4.46 \text{ lb} - m = 3m \cdot 0.15,$$

where 0.15 is the RSD and the factor 3 is the normal variate (the number of standard deviations above the mean) corresponding to a 99.87 percent confidence level (a probability of .0013 that the 24-hour standard of 4.46 lb SO_2 per million Btu will never be exceeded).

To find the average SO_2 level when two exceedances per month are permitted, we first compute the single-day probability, P, of meeting the requirement that the probability of three or more violations occurring during a 30-day period is .0013 (corresponding to a 99.87 percent confidence level). To do so, we sum the probabilities of (1) no violations, (2) one violation, and (3) two violations:[69]

$$.0013 = 1 - \binom{30}{0} P^0 (1 - P)^{30} + \binom{30}{1} P^1 (1 - P)^{29} + \binom{30}{2} P^2 (1 - P)^{28},$$

or

$$.9987 = (1 - P)^{30} + 30^P (1 - P)^{29} + 435\, P^2 (1 - P)^{28}.$$

Through iteration, the value of P is found to be about 0.013. We now apply the normal variate corresponding to P = 0.013, which is 2.23 (for the same case, but with no exceptions, the normal variate is 3.0, corresponding simply to 0.0013 or a 99.87 percent confidence level). Therefore, for the Sammis limit of 4.46 lb SO_2

per million Btu (units 5-7) and an RSD of 0.15, allowing <u>two exceptions per month</u> implies:

$$4.46 \text{ lb} - m = 0.15m \cdot 2.23,$$

or

$$m = 3.34 \text{ lb } SO_2 \text{ per million Btu},$$

which can be compared with the lower allowable mean of 3.07 lb SO_2 per million Btu when no exceedances are permitted for the 24-hour standard of 4.46 lb SO_2 per million Btu, given the same confidence level (99.87 percent).

The result yielded by a similar computation for three exceptions per month was not very different: 3.36 instead of 3.34 lb SO_2 per million Btu.[70]

NOTES

1. William R. Forsyth, Manager of the Production Fuel Department of Ohio Edison Company, in affidavit in Case No. C-2-78-786, 12 March 1978.

2. Ibid.

3. ICF, Potential Impacts on the Ohio Coal Market: Ohio Utility Compliance with Applicable Air Emission Limitations, Section 125 Study, report submitted to U.S. Environmental Protection Agency, Office of Planning and Evaluation, December 1978.

4. Ohio Edison, 1978 Annual Report (Akron, Ohio).

5. Federal Register 41, no. 168 (27 August 1976).

6. Daniel Bodor, superintendent of the W.H. Sammis Station, in affidavit for Case No. C-2-8-786, 24 September 1978.

7. Ibid.

8. Jack Crittenden, Commonwealth Associated Inc. of Jackson, Michigan, in affidavit for Case No. C-2-78-786, 21 September 1978.

9. See n. 6.

10. See n. 6.

11. Henry Modetz, power generation specialist, EPA Region V, Air Enforcement Branch, Enforcement Division, speaking as affiant in Civil Action No. 02-78-786, 22 September 1978.

12. Personal communication with F. Richard Kurzynske, engineer, Environmental Protection Agency, Region V, Chicago, Illinois, 30 May 1979.

13. "Amended Motion for Preliminary Injunction," submitted by James E. Rattan, assistant United States attorney, to U.S. District Court, Columbus, Ohio, 15 June 1979.

14. Federal Register 41, no. 168 (27 August 1976): 36332-33.

15. Ibid.

16. Federal Register 43, no. 32 (15 February 1978): 6646.

17. Personal communication with Bertram Fry, legal counsel, Environmental Protection Agency, Region V, Chicago, Illinois, 19 March 1979.

18. See n. 6.

19. See n. 1.

20. Temple, Barker, & Sloane, Inc., Ohio Section 125 Study: Regional Economic Impact Analysis, report prepared for U.S. Environmental Protection Agency, EPA Contract No. 68-01-4905 (Wellesley Hills, Mass., 14 December 1978).

21. Federal Register 43, no. 25 (28 December 1978): 60652-61.

22. Energy Users Report, 15 March 1979, p. 14.

23. Environmental Reporter, 3 November 1978, p. 1247.

24. Richard A. Stuble et al., Deep-Core Investigation of Low-Sulfur Coal Possibilities in Southeastern Ohio, RI No. 81 (Columbus, Ohio: Ohio Division of Geological Survey, 1971).

25. Federal Energy Regulatory Commission, Annual Summary of Cost and Quality of Electric Utility Plant Fuels, 1977 (Washington, D.C., 1978).

26. U.S. Bureau of Mines, Reserve Base of U.S. Coals by Sulfur Content, Eastern States, IC 8680, PB-243 031 (Pittsburgh, Pa., May 1975).

27. U.S. Department of Energy, Coal – Bituminous and Lignite in 1976, DOE/EPA 0118/1(76) (Washington, D.C., 18 December 1978).

28. 1977 Keystone Coal Industry Manual (New York, New York: McGraw-Hill, 1977), p. 334.

29. Personal communications with (1) Weldon Fulgum, engineering manager, R & F Coal Company, Cadiz, Ohio, 30 June 1979, and (2) Natie Allen, Jr., chief of Fossil Fuels Planning Branch, Tennessee Valley Authority, Chattanooga, Tennessee, 12 June 1979.

30. Coal Week, 25 April 1977, p. 9.

31. See n. 1.

32. See n. 12.

33. Ibid.

34. The data are based on information supplied by coal brokers, mine representatives, and a consultant: Norman Kilpatrick, director of the Surface Mining Research Library, Charleston, West Virginia.

35. Coal Week, 8 January 1979. Pittsburgh is about 55 miles from Sammis.

36. *Ratio of the standard deviation to the mean.*

37. PEDCo, Inc., Preliminary Evaluations of Sulfur Variability in Low-Sulfur Coals from Selected Mines, EPA-450/3-77-044, prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina (Cincinnati, Ohio, November 1977).

38. Versar, Inc., SO_2 Emission Reduction Data from Commercial Physical Coal Cleaning Plants and Analysis of Product Sulfur Variability, Draft Final Task 600 report under EPA Contract No. 68-0202199, submitted to Fuel Process Branch, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (Springfield, Virginia, 18 October 1978).

39. Draft memorandum from Kenneth Schweers, ICF, to Robert Fuhrman, U.S. Environmental Protection Agency, 25 October 1978.

40. For units 1-4: 1.61 lb $SO_2/10^6$ Btu. For units 5-7: 4.46 lb $SO_2/10^6$ Btu.

41. Coal Outlook, 19 February 1979.

42. Personal communication with Jack Apel, vice president of Environmental Affairs, Columbus and Southern Ohio Electric Company, Columbus, Ohio, 19 March 1979.

43. Cavallero et al., Sulfur Reduction Potential of the Coals of the United States, Bureau of Mines RI 8118 (Pittsburgh, Pa.: U.S. Department of the Interior, Bureau of Mines, 1976).

44. For example, one can show that, for the fairly high moisture content of 30 percent,

$$(\text{lb } SO_2/10^6 \text{ Btu})_M \simeq (\text{lb } SO_2/10^6 \text{ Btu})_{MF} \cdot 1.034,$$

where M = with-moisture basis, and MF = moisture-free basis.

45. In fact, the percentage increase in heating value that can result from PCC spans a considerable range, depending upon the coal and the cleaning process used. A recent report for the Electric Power Research Institute showed a range of 1.3 to 26 percent; see M.K. Buder and K.L. Clifford et al., The Effects of Coal Cleaning on Power Generation (San Francisco, Calif.: Bechtel National, Inc., 1978).

46. See n. 42.

47. See n. 43.

48. Crushing to 3/8 inch; specific gravity of 1.4.

49. See n. 24.

50. Ibid.

51. See n. 38.

52. Sam Ruggeri, American Electric Power Company, in presentation to the "Front End Coal Cleaning Conference" sponsored by Pennsylvania Electric Company and New York State Electric and Gas, Pittsburgh, Pennsylvania, 8 November 1978.

53. Assuming coal-sulfur RSDs from 0.08 to 0.15, normal or lognormal probability distributions, two exceedances per month, and a confidence level of 99.87 percent.

54. In 1976 the median capacity factor of all U.S. plants with capacity ratings exceeding 500 MW was 59 percent.

55. Assuming 5 percent retention of sulfur in the boiler ash.

56. Again, assuming 5 percent retention in the boiler ash.

57. Peter J. Phillips, "How Blending Improves Coals' Quality," Coal Mining and Processing, October 1977.

58. Acurex Corporation, JACA Corporation, and Professional Management, Inc., Engineering Study for Ohio Coal Burning Power Plants, Final Report 78-311, prepared for U.S. Environmental Protection Agency, Division of Stationary Source Enforcement (Mountain View, Calif.; Fort Washington, Pa.; and Cincinnati, Ohio; March 1979).

59. PEDCo Environmental, Inc., Cost Benefits Associated with the Use of Physically Cleaned Coal. Draft report under EPA Contract No 68-02-2603, submitted to James Kilgroe, U.S. Environmental Protection Agency, Industrial Engineering Research Laboratory, Research Triangle Park, North Carolina (Dallas, Texas, 25 May 1979).

60. See n. 4.

61. Peter J. Phillips and Randy M. Cole, "Economic Penalties Attributable to Ash Content of Steam Coals," paper presented at the AIME Coal Utilization Symposium, New Orleans, Louisiana, 18 February 1979.

62. Personal communication with Richard A. Chapman, Teknekron Research, Inc., regarding his ongoing research for "Evaluation and Assessment Methodology for Collecting Fly Ash from the Combustion of Low-Sulfur Coal," EPA Contract No. 68-02-2652.

63. The prices shown in Figure 9 are multiplied by a levelization factor of 1.81 (see Table 16); the SO_2 values in Figure 9 are multiplied by 0.95 to allow for 5 percent sulfur reduction during combustion.

64. Weldon Fulgum. See n. 29.

65. For a more detailed discussion, see Teknekron, Inc., An Evaluation of Institutional, Economic and Social, Regulatory and Legislative Barriers to Investment in Physical Coal Cleaning as a Sulfur Dioxide Emissions Control Strategy, prepared for U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina (Berkeley, California, 15 December 1977).

66. PEDCo, Inc., Preliminary Evaluations of Sulfur Variability in Low-Sulfur Coals from Selected Mines, EPA-450/3-77-044, prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina (Cincinnati, Ohio, November 1977).

67. See n. 38.

68. The Versar report cautions that values of both the product-coal RSDs and the reduction in RSD resulting from cleaning "are valid only for analysis of individual preparation plants and should not be aggregated on a seam or regional basis."

69. The factors $\binom{30}{k}$ are "binomial coefficients," the number of ways that 30 objects and k objects can be arranged. These factors are equal to $30!/k!\,(30-k)!$; values can be found in standard statistical tables.

70. The method used here was adapted from an internal Environmental Protection Agency working memorandum from John W. Melone, Statistical Evaluation Staff, to Paul Stolpman, Office of Policy Analysis, 17 October 1978.

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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16. ABSTRACT The report discusses the background and issues related to the control of air pollutants emitted by a large coal-burning plant in eastern Ohio. The plant not only has had a history of severely exceeding Ohio's State Implementation Plan (SIP) particulate emission limit, but also its SO2 emissions have exceeded the limit of Ohio's forthcoming SIP. An important issue is the extent to which compliance with the SIP will promote the plant's switching from Ohio coals to Southern Appalachian coals (which produce fewer particulate and SO2 emissions) and the consequent disruption to Ohio's coal mining industry. Addressing this issue, the report examines the plant's historical coal usage, the production and characteristics of Ohio and Southern Appalachian coals, the relevance of coal-sulfur variability, and the feasibility and implications of producing and burning cleaned Ohio coals as a strategy for complying with Ohio's SIP. The report discusses factors that will affect the relative economics of burning cleaned Ohio coals at the plant. The report indicates that, by burning cleaned Ohio coals, the plant's largest and newest units (constituting 60% of the plant's total capacity) can increase their consumption of Ohio coal by 50-100%, depending on the characteristics of the coals and the cleaning processes used.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Dust	Pollution Control	13B	11G
Coal	Aerosols	Stationary Sources	21D	07D
Combustion	Coal Mining	Particulate	21B	
Emission	Industrial Processes	Coal Cleaning	14B	13H
Coal Preparation			08I	
Sulfur Oxides			07B	

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