

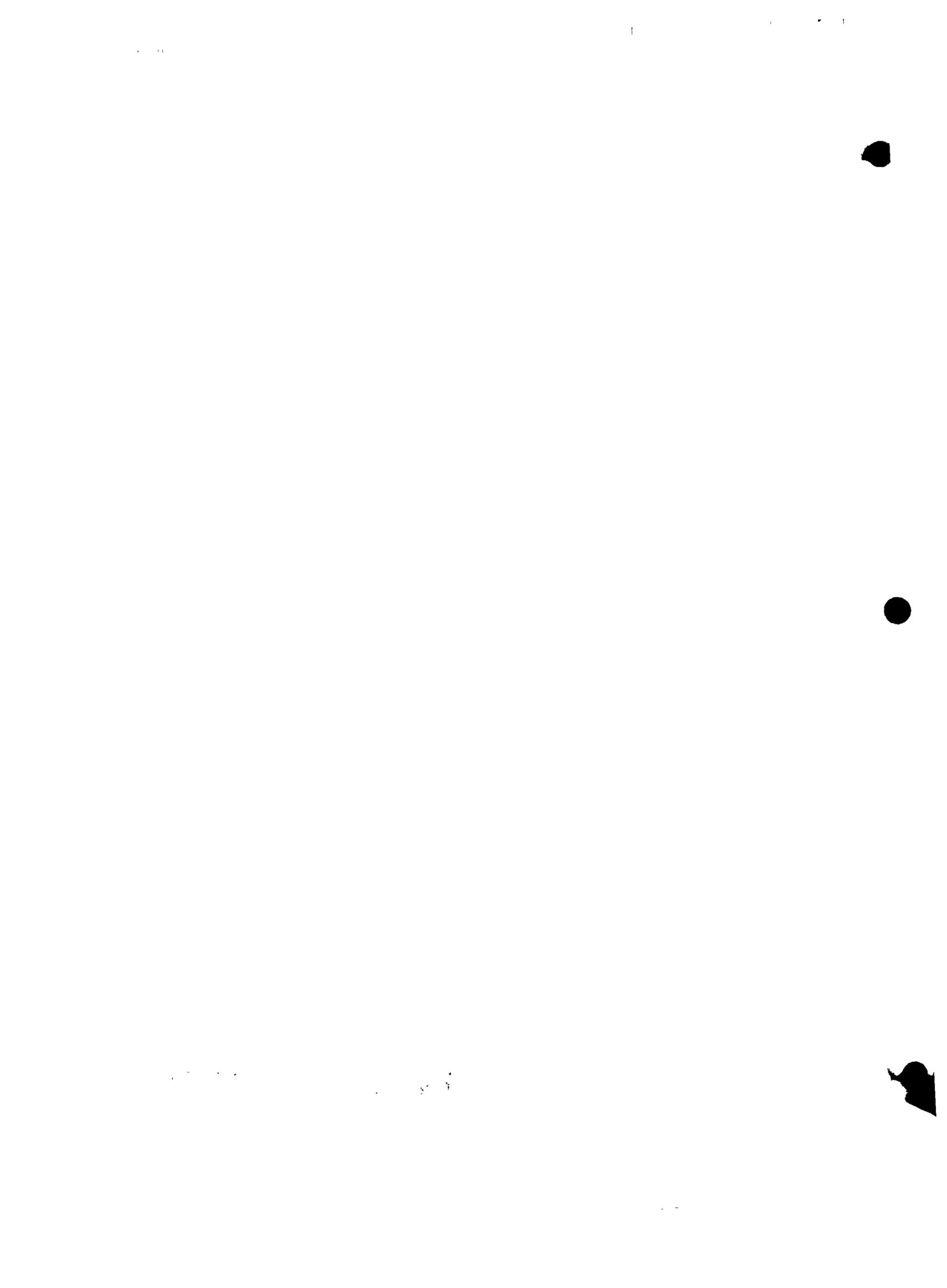


# Cost of Air and Water Pollution Control 1976-1985



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## Section Three

### THE ECONOMICS OF WATER POLLUTION CONTROL

#### Chapter 1 Summary

The economics of controlling water pollution encompasses both the expected benefits and the probable costs of control. The principal findings in the control cost area are summarized below, benefits of water pollution control are discussed in the next chapter of this section

#### 5. INDUSTRIAL CONTROL COSTS

##### Introduction

The extent of water pollution and the costs of treating it vary significantly among industries and among the firms within an industry; therefore, it is important to examine the structure, production methods, sources of pollution, effluent standards, and wastewater control technology for each industry. The following sections of this chapter briefly summarize the relevant characteristics of each industry and report the estimated annual abatement costs attributable to achieving full compliance with the 1977 (BPT) and 1983 (BAT) effluent standards.

##### MODELING AN INDUSTRY

The plants in an industry have various options by which to comply with the water pollution standards. In general they may

1. Fully treat their effluents.
2. Pretreat their effluents and discharge to a municipal system.
3. Change their manufacturing process.

**Table 10.**  
General Projections of the Reference Scenarios (S1),  
1975-1985

Statistics	Value In			Annual Percentage Change			
	1975	1985	1975-85	1975-77	1977-80	1980-83	1983-85
Population (Millions)	211.9	235.7	0.97	0.89	0.97	1.02	1.00
Labor Force (Millions)	93.8	107.7	1.40	1.71	1.62	1.25	0.96
Unemployment Rate (%)	8.4	4.4	-6.38	-8.07	-10.66	-3.04	-2.94
Disposable Income Per Capita (1975 \$)	1,551	5,753	4.94	5.16	7.96	3.29	2.74
Gross National Product (Trillion 1975 \$)	1.470	2.365	4.87	6.43	6.50	3.34	3.18
Personal Consumption Expenditure	933	1,563	5.30	4.87	7.55	4.36	3.79
Investment	.222	.380	5.59	13.69	6.43	1.85	2.31
Government Expenditures	.307	.414	3.05	2.99	3.74	2.68	2.64
Federal	.117	.136	1.61	.71	.70	2.58	2.43

**Table 24.**  
Pollution Control Costs as a Percentage  
of Almon Scenario GNP

	1975	1977	1980	1983	1985
<b>Air Stationary Source Costs</b>					
Capital Costs	0.60%	0.47%	0.30%	0.18%	0.11%
O&M Costs	0.42%	0.37%	0.43%	0.38%	0.34%
<b>Water Industrial Costs</b>					
Capital Costs	0.26%	0.36%	0.52%	0.48%	0.06%
O&M Costs	0.02%	0.02%	0.23%	0.27%	0.52%
<b>Water Municipal Costs</b>					
Capital Costs	0.36%	0.39%	0.36%	0.07%	0.02%
O&M Costs	0.03%	0.05%	0.12%	0.11%	0.11%

#### ECONOMIC FORECASTING IN THE SEAS SYSTEM

Economic forecasting within the SEAS system takes place in a context which meshes the features of a traditional input-output (I/O) model and econometric model-building. The basic structural economic component of SEAS, INFORUM<sup>1</sup>, is not a typical economic input-output model. It is, to a substantial degree, a combined econometric-I/O approach to economic forecasting.

$$\frac{i(1+i)^N}{(1+i)^N - 1}$$

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THE ECONOMICS OF AIR POLLUTION CONTROLSS

Chapter 1  
Summary\$R

The purpose of setting the ambient and emission standards associated with the Clean Air Act is to protect human health and reduce or prevent the other damages associated with polluted air. To accomplish these goals, the emissions released to the environment must be reduced far below their 1971 levels.

The estimated net emissions of the five criteria air pollutants in 1971, 1975, and 1985 are shown in Table 1. Also shown in the table are the control efficiencies by pollutant for the three years. Note that particulates were controlled to a large extent even in 1971; quite often these controls existed for economic reasons. That is, plants recovered economically-valuable metals and materials from the particulate wastes.

National Trend in Emission Levels  
 Table 1.  
 \$d

Sources and Pollutants	Net Emissions (Millions MT)				Control Efficiency (%)		
	1971	1975	1985	1985	1971	1975	1985
<b>All Sources</b>							
Particulates	41.7	27.3	8.8	59.0	77.0	94.7	
Sulfur Oxides	30.3	23.0	18.6	27.2	51.9	72.2	
Nitrogen Oxides	16.3	17.6	24.8	0	1.4	3.4	
Hydrocarbons	14.3	10.5	6.3	17.4	29.3	57.4	
Carbon Monoxide	72.4	57.17	29.1	9.8	16.8	41.6	
<b>Industrial &amp; Electric Generation</b>							
Particulates	40.9	26.6	7.8	59.5	77.4	95.3	
Sulfur Oxides	29.7	22.4	17.7	27.6	52.5	73.3	
Nitrogen Oxides	7.7	9.3	14.1	0.2	2.5	5.7	
Hydrocarbons	5.3	4.2	3.5	36.4	50.8	70.8	
Carbon Monoxide	11.6	9.0	10.1	40.3	56.1	65.9	

Emissions after control devices have been installed.  
 Percent of unabated emissions that are eliminated by the control devices.\$s

In order to bring about these reductions in air emissions, businesses and consumers must make expenditures to install pollution control devices, institute process changes switch fuels, and operate and maintain them. Governments must allocate expenditures to regulate and monitor pollution sources, control their own emissions, and perform research.

Table 2 shows the estimated total expenditures for air pollution control brought about by the Clean Air Act during the 1971-85 period:

Table 2.  
 Accumulated Estimated Air Pollution Expenditures,  
 1971-85

(In Billions of 1975 Dollars)

	1971-1985		1976-1985		Total Resource Costs
	Total Resource Costs	Investment	Investment	O&M	
Industries	110.1	49.8	24.8	53.7	78.5
Transportation	143.4	60.8	55.0	76.1	132.1
Government	7.6	2.7	2.7	4.9	7.6
Totals	261.1	113.3	82.5	134.7	218.2

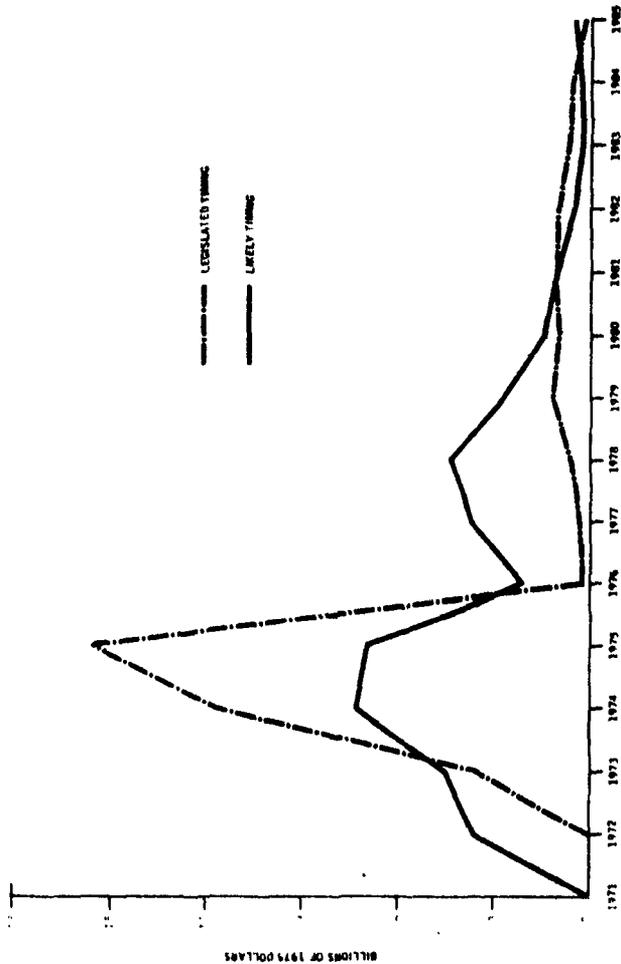
Note: Government costs for the period 1971-1975 were not estimated.

Mainly the costs for automobile emission controls that are paid for directly by the car owners.\$s

The pattern that expenditures will take during the 1971-85 period depends not only on regulations, but also on the pattern of compliance by businesses, automobile users, and local governments. If compliance with present Federal regulations is assumed, the time path of expenditures during the 1971-85 period is shown by the Legislated Timing line in Figure 1; note the peaking of investment expenditures in 1975.

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Figure 1.  
Air Pollution Abatement Investment Costs by Industrial  
Sources Other than Electric Utilities



Surveys by the Bureau of Economic Analysis in the Department of Commerce do not indicate such high past and planned investment on the part of businesses during the 1971-75 period. Therefore, some more extended pattern of expenditures will probably occur. The timing of air pollution expenditures made by EPA and CEQ in the 1975 report entitled The Economic Impact of Pollution Control: Macroeconomic and Industry Report's March 1975\_ prepared by Chase Econometric Associates, Inc., is assumed for this report. The dark lines on Figure 1 show the more realistic expenditure pattern.

#### SBGOVERNMENT EXPENDITURES\$R

The air pollution abatement expenditures made by governments at all levels are shown in Table 3. Special tabulations were made by the Office of Management and Budget to determine Federal expenditures by agency for grants, research, abatement control, manpower development, and control of pollution from Federal facilities. The future estimates for expenditures by state and local governments were divided into the functional areas of enforcement, engineering services, technical services, and management. In the aggregate, government expenditures are estimated to

Increase over time, but at a slower rate than Government spending for pollution control has grown in the past. Federal expenditures are expected to far exceed those of state and local governments.

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Table 3.  
Government Spending for Air Pollution Control,  
1976-85.

(In Billions of 1975 Dollars)

Year	Federal		State & Local		Total Capital	O&M	Total Yearly Costs
	Capital	O&M	Capital	O&M			
1976	0.32	0.32	0.06	0.06	0.38	0.38	0.76
1977	0.24	0.28	0.07	0.07	0.31	0.35	0.66
1978	0.24	0.30	0.06	0.08	0.30	0.38	0.68
1979	0.23	0.33	0.06	0.09	0.29	0.42	0.71
1980	0.22	0.36	0.06	0.09	0.28	0.45	0.73
1981	0.21	0.39	0.05	0.10	0.26	0.49	0.75
1982	0.20	0.42	0.05	0.11	0.25	0.53	0.78
1983	0.19	0.46	0.04	0.11	0.23	0.57	0.80
1984	0.17	0.49	0.05	0.12	0.22	0.61	0.83
1985	0.16	0.53	0.04	0.13	0.20	0.66	0.86
<b>Totals</b>	<b>2.18</b>	<b>3.88</b>	<b>0.54</b>	<b>0.97</b>	<b>2.72</b>	<b>4.85</b>	<b>7.57\$</b>

\$bTRANSPORTATION EXPENDITURES\$R

Two major types of transportation control costs were estimated:

- Costs needed to meet Federal emissions standards for autos, trucks, and aircraft.
- Costs that residents of certain cities must pay to finance programs that will reduce transportation-generated residuals to achieve Federal ambient standards.

In this report, the former costs are mobile source costs and the latter are Transportation Control Plan (TCP) costs. Table 4 shows these costs in summary fashion for the appropriate years. As is evident from the table, the TCP costs are very small in comparison with the total mobile source controls. The TCP's could not have their planned effect, however, if the pollution from autos is not controlled as required by the mobile source emission standards.

Table 4.  
Transportation Control Costs  
(In Billions of 1975 Dollars)

Year	Mobile Source Costs		TCP Costs	Total Yearly Costs
	Capital	O&M		
1968	0.07	0.44	-	0.51
1969	0.07	1.00	-	1.07
1970	0.43	1.35	-	1.78
1971	0.48	1.77	-	2.25
1972	0.50	2.25	-	2.75
1973	1.43	3.02	-	4.45
1974	1.01	4.23	-	5.24
1975	2.04	5.00	-	7.04
1976	2.58	4.76	0.34	7.68
1977	3.03	4.41	0.44	7.88
1978	5.68	4.69	0.32	10.69
1979	5.73	4.97	0.34	11.04
1980	6.29	5.61	0.35	12.25
1981	5.88	6.17	0.37	12.42
1982	6.00	6.71	0.40	13.11
1983	6.14	7.23	0.39	13.76
1984	6.22	7.81	0.40	14.43
1985	6.34	8.31	0.41	15.06
Totals	60.75	79.73	3.76	143.41\$R

\$B INDUSTRIAL EXPENDITURES\$R

Costs for industries to comply with Federal emission standards (for new plants or facilities in specially-designated industries) and State Implementation Plans (SIP) required to meet Federal ambient air standards were estimated for over 40 separate industries, such as Iron and Steel manufacture, Petroleum Refining, and Kraft Paper

production. Table 5 shows the estimated expenditures for aggregations of these industrial sectors.

\$dTable 5.  
Industrial Air Pollution Control Expenditures  
(In Millions of 1975 Dollars)

Industry	Accumulated Expenditures			1976-85		
	Investment	Annualized Capital	O&M	Investment	Annualized Capital	O&M
Coal Cleaning	28.14	34.22	15.99	13.81	30.52	14.16
Coal Gasification	120.36	68.23	53.07	120.36	68.23	53.07
Natural Gas Processing	149.07	171.53	279.67	51.09	141.87	243.45
Feed Mills	2,074.43	2,735.27	1,053.43	938.40	2,409.33	931.58
Kraft Pulp Mills	2,835.04	3,539.52	4,250.06	1,304.81	3,114.45	3,798.16
NSSC Mills	312.46	430.61	599.20	128.99	367.32	514.77
Printing	43.91	69.01	57.73	21.34	60.43	51.27
Mercury Cell	29.90	51.09	58.12	13.59	44.86	51.59
Chlor-Alkali						
Nitric Acid	80.99	121.27	181.78	37.76	107.00	163.61
Paint Manufacture	34.40	59.94	77.98	11.78	51.67	67.65
Phosphate	174.78	212.01	358.40	96.99	188.28	323.62
Fertilizer						
Nonfertilizer						
Phosphate	10.57	16.20	6.08	5.62	14.46	5.42
Sulfuric Acid	746.53	1,240.00	770.21	268.58	1,075.18	688.36
Petrochemicals	48.21	55.18	339.42	25.57	48.77	303.49
Petroleum	1,454.79	1,830.15	1,107.95	683.86	1,595.74	967.83
Ferroalloy	343.81	605.85	166.91	118.83	525.94	147.94
Iron & Steel	3,957.76	6,058.30	1,593.67	1,438.79	5,243.10	1,400.35
Iron Foundaries	511.86	874.57	1,828.25	186.74	755.71	1,605.03
Steel Foundaries	268.98	535.36	45.36	18.21	428.20	40.37
Primary Aluminum	2,242.47	3,415.08	4,449.90	801.16	2,976.59	3,821.20
Secondary Aluminum	39.37	54.70	58.57	14.15	47.67	52.53
Primary Copper	1,407.80	2,649.05	1,573.56	752.44	2,376.36	1,409.00
Secondary Brass & Bronze	25.96	34.70	54.56	11.65	30.94	48.28
Primary Lead	74.03	109.24	48.65	52.87	101.38	42.10
Secondary Lead	10.21	12.64	16.73	9.15	12.29	14.99
Primary Zinc	80.95	179.33	133.96	54.79	169.89	117.32
Secondary Zinc	2.90	3.72	7.77	1.57	3.28	6.83
Asbestos	24.76	41.37	33.52	10.17	35.95	31.69
Asphalt Concrete	664.87	1,184.10	2,029.92	161.35	1,013.29	1,772.37
Cement	936.39	1,299.15	1,356.08	322.07	1,130.86	1,198.95
Lime Manufacture	334.94	481.56	112.46	114.43	411.85	99.40
Clay Construction Products	80.83	148.85	194.58	17.51	126.91	157.61
Surface Coatings	516.04	874.39	3,241.10	217.27	745.97	2,902.83
Steam Electric Power Plants	10,358.68	11,384.25	15,246.03	7,905.74	10,730.14	13,807.75
Solid Waste Disposal	1,943.06	3,040.94	4,651.95	629.12	2,596.14	4,091.76
Sewage Sludge Incineration	187.74	225.68	153.16	111.01	201.08	141.61

Grain Milling	2,478.10	3,271.73	428.11	1,204.48	2,964.68	385.20
Dry Cleaning Commercial	204.05	347.74	0	79.13	304.38	0
Industrial Heating	14,963.96	19,285.46	13,708.64	6,864.75	16,970.28	12,201.89
<b>Totals</b>	<b>49,803.10</b>	<b>66,752.99</b>	<b>60,342.43</b>	<b>24,819.93</b>	<b>49,170.99</b>	<b>53,675.21</b>

## SeChapter 2

### Benefits of Controlling Air Pollution

Contemporary damage estimates are based on the interpretation of the results of numerous studies of varying scope, methodology, and data quality. The availability and reliability of information from these studies is indicated in Table 1. As indicated in the Table, dose-response data are most available for effects of sulfur oxides, oxidants, and particulates in the damage categories of human health and vegetation.

Table 1.  
 Information Availability and Reliability  
 on Air Pollution Effects

Air Pollution Damage Categories	NOx	Oxidants	SOx	CO	HC's	Particulates	Other
Human Health	SP	SF	IF	SF	SP	IG	IF
Animal Health	SF	SF	IF	SP	SP	IF	SP
Aesthetics	U	SP	IF	*	*	IF	U
Vegetation	IF	IG	IG	*	UP	SF	SF
Materials	SF	IP	IG	I	I	SG	SF

Availability Reliability

I-insufficient  
 S-scarce  
 U-unavailable  
 \* Negative effect expected

G-good  
 F-fair  
 P-poor

Substantial uncertainty remains regarding the effects of other air pollutants and the extent of the damages caused.

In combining estimates from different classes of damages, care must be taken to minimize duplicate counts. For example, studies of the differences in residential property values associated with differences in air pollution reflect primarily the aesthetic and soiling effects rather than health, materials, and vegetation effects. This approach is based on the argument that the aesthetic effects are experienced directly in everyday life, whereas health effects are mostly long-term, and are not distinguishable by the general population from other causes of illness. Although improved education may be altering people's awareness of pollution effects on health, it is not likely that this change has been reflected in past property values, on which these benefit estimates have been based.

## SBHEALTH DAMAGES

### Nature and Effects of Air Pollution Damage to Health

The major air pollutants that have been linked to health damages are suspended particulates, sulfur oxides, nitrogen oxides, oxidants, and carbon monoxide. The effects of these pollutants are increased morbidity (incidence and prevalence of disease) and mortality. The specific diseases that have been associated with air pollution are bronchitis, emphysema, asthma, respiratory infections, heart disease, cancer of the respiratory and digestive tracts, and chronic nephritis. The quantitative relationships between these diseases and air pollutants have been explored in a variety of studies; other studies have examined the link between air pollution and measures of illness or discomfort, such as absenteeism, emergency ward visits, and automobile accidents.

The most widely-cited studies of the health effects from air pollution were performed by Lave and Seskin (1970, 1973) and by EPA's Community Health and Environmental Surveillance System (CHESS). Lave and Seskin analyzed the relationship between mortality (in total and in 14 disease categories), a variety of socioeconomic variables, and several indices of suspended particulates and sulfates in the air. Their

findings indicate that at least 9 percent of the 1960 death rate was attributable to particulates and sulfates. The strongest effects were on bronchitis and lung cancer.

The CHES studies (1974) gathered data on a number of communities chosen to control socio-economic variables related to disease. A variety of indicators of illnesses were examined for their relationship to the pollution composite of sulfur dioxide, suspended sulfates, and total suspended particulates. The morbidity measures chosen as most significant were: asthma attacks, restricted activity days, and physician visits resulting from acute lower respiratory disease; prevalence of chronic bronchitis; and aggravation of cardiopulmonary symptoms in the elderly.

In a recent study, Sprey and Takacs (1974) indicated the likelihood that the health effects of air pollution may turn out to be greater than expected from previous studies. In this study, a greater range of specific pollutants and health effects was examined. Strong correlations were found between nitrogen dioxide and mortality from arteriosclerotic and hypertensive heart disease, cancer of the lung, larynx, and esophagus, and nephritis. In addition, sulfates were found to be associated with arteriosclerotic heart disease and cancer of the respiratory and gastrointestinal tracts.

These results suggest that the fraction of the death rate associated with air pollution may be as high as 15 percent.

#### Survey of Source Studies

The majority of health studies center around damages from particulates and sulfur oxides. Recently, oxidants and carbon monoxide have been receiving increasing attention, but the data base is still very small for most important effects. Very little work has been done on nitrogen dioxide because of the difficulties in isolating the pollutant in ambient situations and problems in defining valid measurement techniques. The more important studies are listed in Table 2.

SoTable 2.  
Summary of Health Effects Studies

Study	Publication Date	Location	Pollutants Measured	Effects
CHES	1974	5 Areas	Sulfur dioxide, sulfates	Increased incidence of chronic and acute respiratory disease
Lave and Seskin		117 SMSAs	Particulates, sulfates	Mortality
Buechley	1973	New York-N.J.	Sulfur dioxide	Mortality
Finkles et al.	1975	Based on various studies	Sulfates	Mortality and various morbidity measures
Bates	1973	Laboratory	Ozone	Changes in lung function
Gardner	1971	Laboratory	Ozone	Stability changes in alveolar macrophages
Hazucho	1973	Laboratory	Ozone	Chromosomal changes
Zelac et al.	1971	Laboratory	Ozone	Aggravation of asthma
Shoettlin & Landau	1961	Los Angeles	Oxidants	Changes in respiratory function and susceptibility
CARB	1975		Oxidants	Earlier onset of angina pain
Aronow and Isbell	1973	Laboratory	Carbon monoxide	Time discrimination deterioration
Horwath et al.	1971	Laboratory	Carbon monoxide	Mortality
Beard and Wertheim	1967	Laboratory	Carbon monoxide	Increased incidence of respiratory diseases
Hexter & Goldsmith	1971	Los Angeles	Carbon monoxide	
Shy et al.	1970	Chattanooga	Nitrogen dioxide	

A recent survey of health damage studies was accomplished by the National Academy of Sciences and the National Academy of Engineering (1974) in their report, Air Quality and Automobile Emission Control (1974), which concentrates largely on effects of carbon monoxide, with other pollutants treated in slightly less detail. Neuberger and Radford (1974) cite more than 100 references on both human and animal experiments for seven pollutants, including formaldehyde and benzo-pyrene, in the context of identifying threshold levels for health effects. Source descriptions of the older literature may be found in the NATO reports (1971, 1972, 1973), which detail both toxicological and epidemiological effects grouped by specific pollutants. Waddell (1974) has reviewed a number of primary source studies in the process of deriving one chapter to economic costs of diseases based on statistics from the U.S. Public Health Service, and various reports and studies. Selected source studies on health effects are summarized below as an indication of the large resource literature that exists.

The effects of sulfur oxides and particulates are often difficult to separate due to collinearity of their concentrations. The basic work on a national scale has been provided by the CHES program. Recently published results (EPA, May 1974) provide data from five study areas selected across the United States; they were: the Salt Lake Basin,

Rocky Mountains, Chicago-Northwest Indiana, New York, and Cincinnati. The basic study concentration was on acute and chronic respiratory disease including asthma aggravation, but some correlations with cardiopulmonary symptoms were found in New York.

The published CHES studies were carried out between 1967 and 1971. In some cases, data from as early as 1940 on population exposure of pollutant measurement were extrapolated. Current monitoring data were obtained from pollutant-specific air quality sensors placed in each community. Each study involved comparisons of several communities within a geographic area. The major conclusions support the correlation of suspended sulfate concentrations with both increased incidence of asthma and aggravation of cardiopulmonary disease.

A recent study by Finklea et al. (1975) has formulated "best judgment" dose-effect functions for suspended sulfates. Damage functions were derived from various studies on mortality, aggravation of heart and lung disease in the elderly, aggravation of asthma, excess acute lower respiratory disease in children, and excess chronic respiratory disease. All except mortality showed positive responses below 15 micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ) of sulfate concentration; the threshold for mortality effects

determined by the study is approximately 25 ug/m . The suspended sulfate concentrations are related to sulfur dioxide concentrations by a linear equation, such that in the case of morbidity, 320 ug/m of sulfur dioxide corresponds to a 25 ug/m sulfate level. Thus, effects are shown to occur here even below the primary 24-hour sulfur dioxide standard of 365 ug/m .

Another investigation of air pollution effects in a large number of areas has been performed by Lave and Seskin (1973). The relationship between mortality rates and pollutant concentrations was investigated for 117 standard metropolitan statistical areas. Correlations with various socioeconomic indices were investigated by multivariate regression analysis, and sulfate levels were isolated as having a significant association with mortality rates. It was determined that a 10 percent reduction in the level of suspended particulates and sulfates would reduce the mortality rate by 0.9 percent.

Buechley (1973) has investigated relationships between sulfur dioxide and mortality in the New York-New Jersey Metropolitan area. The study utilizes statistical techniques and regression analysis to investigate residual mortality after elimination of meteorological and other covariates. Records over the period from 1960 to 1964 were

correlated with 11 levels of sulfur dioxide concentration, indicating that a change in 24-hour levels between 140 and 500 ug/m corresponds to a change in residual mortality in excess of 3 percent.

Results of a study on outpatient medical costs in the Portland, Oregon, standard metropolitan statistical area (SMSA) have been presented by Jaksch and Stoevener (1974). The study utilized records and surveys developed by the Kaiser-Permanente Medical Care Program to investigate the impact of suspended particulate concentration from 60 to 80 ug/m would result in only a 3.5 cent increase in expense per medical visit for respiratory diseases. Recommendations for future study include the determination of impact of pollutants on the number of medical contacts.

The National Academy of Sciences report summarizes investigations of acute and chronic respiratory illness in high oxidant atmospheres, mostly in California, or in laboratory experiments. The report lists aggravation of asthma, decreased cardiopulmonary reserve, increases susceptibility to acute respiratory disease, decrease in pulmonary function, as well as changes in cell physiology, as being prime documented effects of oxidants. Toxicological studies with rabbits (Gardner, 1972) have shown that the stability of cells that prevent lung

Infection (alveolar macrophages) is reduced at concentrations of 196 ug/m (0.10 ppm) for 2.5 hours. Experiments with hamsters (Zelac et al., 1971) have shown mutagenic changes (chromosome breaks in white blood cells) when exposed to 392 ug/m (0.20 ppm) for 5 hours. Studies with humans (Bates et al., 1973, Hazucha et al., 1973) have shown significant changes in pulmonary function upon exposure to 1,470 ug/m (0.75 ppm) and 725 ug/m (0.37 ppm) for 2 hours. Asthma attack rate in asthmatics has been found to increase significantly at daily peak oxidant concentrations of 490 ug/m (0.25 ppm) (Shoettlin and Landau 1961). These studies and others are listed as being indicative, but incomplete, data base for photochemical oxidant effects on health. The need for further investigation in both the formulation of dose-response relationships and the validity of the present standards in the light of new evidence was strongly recommended by the panel.

Current studies in health damages are being pursued under the auspices of EPA's Office of Research and Development to estimate the health costs associated with air pollution. One of these studies recently completed by the California Air Resources Board (1975) has estimated "rough order" dose-effect functions compiled by an expert panel using a Delphi approach. The panel generally agreed that patients

suffering from viral or bacterial illness would have enhanced susceptibility to oxidant-induced abnormalities. It was deduced that 90 percent of the infected individuals would experience increased dyspnea at 1.560 ug/m (0.80 ppm) and increased cough at 1.176 ug/m (0.60 ppm). Ten percent of this population would be incapacitated by superimposed bacterial pneumonia (Influenza) or acute respiratory failure (viral bronchitis) following exposure to 1.176 ug/m (0.60 ppm) of oxidant.

Carbon monoxide is the principal pollutant reviewed in the National Academy of Sciences (NAS) report. Effects on symptoms of cardiovascular disease, behavioral vigilance effects, and effects during pregnancy are presented as the major categories. In an experiment in the Los Angeles area (Aronow and Isbell 1973), a reduction in the time before onset of pain from patients with angina pectoris was observed after breathing carbon monoxide at 56 ug/m (50 ppm) for 2 hours. In psychological experiments testing response to environmental stimuli, some indications show that reduction in vigilance and response can occur after exposures of 56 ug/m (50 ppm) for 1.5 hours (Beard and Wertheim 1967). The investigations into effects of carbon monoxide exposure on the developing fetus in women during pregnancy have been primarily carried out on animals, and the results are not clearly extrapolatable to humans.

Hexter and Goldsmith (1971) have carried out a regression analysis of daily mortality data in Los Angeles County for the period 1962-65; they considered temperature variations and other cyclic factors as covariates to carbon monoxide concentration. The study indicates a significant correlation of carbon monoxide with mortality, and concludes that the estimated contribution of carbon monoxide between concentrations of 23 ug/m (20.2 ppm) and 8 ug/m (7.3 ppm) is 11 deaths per day, other factors being equal.

Nitrogen dioxide has been primarily associated with chronic and acute respiratory disease. The NAS study cites the work of Shy et al. (1970) in Chattanooga which tied acute bronchitis rates in infants with differential nitrogen dioxide exposure. Relative incidence of bronchitis was observed to vary as much as 58 percent between low and high exposures. Questions about the validity of nitrogen dioxide measurement methods and the presence of an influenza epidemic have thrown some doubt on the validity of the conclusions; the NAS panel recommends further investigations in this area.

## \$BAESTHETIC DAMAGES

### Nature and Effects of Air Pollution Damage to Aesthetics

Air pollution reduces the pleasantness of peoples' daily experiences and it can also cause unpleasant experiences that lead to psychic damages. Opinion surveys have shown that the most noted aesthetic effects of air pollution are material soiling and deterioration, irritation of eyes, nose, and throat, malodors, and reduced visibility. These effects are primarily related to the aesthetic aspects of experience rather than to direct physical, health, or economic damages. There is an area of overlap, however, between aesthetic damages and materials damages because of the aesthetic losses from soiling and deterioration.

The primary pollutant responsible for soiling is particulates. Irritation of eyes, nose, and throat is caused primarily by photochemical oxidants. Hydrogen sulfide, produced by anaerobic decomposition of wastes, is a frequent cause of malodor. Reduced visibility is caused primarily by particulates and nitrogen dioxide.

**Survey of Source Studies**

A summary of the property value studies of primary interest in developing national estimates of the aesthetic benefits of air pollution control is shown in Table 3. These studies employed multiple regression techniques using a variety of pollution level measures, other variables influencing property values, and property values. All study results confirmed the hypothesis that pollution and property values are inversely related, and they found statistically significant coefficients expressing the relationships.

Table 3.  
Summary of Property Value Studies

St Investigator	Date	Location	Pollution Measure
Ridker-Manning	1967	St. Louis	Sulfation
Zerbe	1969	Toronto Hamilton	Sulfation Sulfation
Anderson-Crocker	1970	St. Louis	Sulfation and suspended particulate
		Kansas City	Sulfation and suspended particulate
		Washington, D.C.	Sulfation and suspended particulate
Crocker	1971	Chicago	Sulfur dioxide and suspended particulate
Peckham	1970	Philadelphia	Sulfation and suspended particulate
Spore	1972	Pittsburgh	Sulfation and dustfall
NAS and NAE	1974	Boston and Los Angeles	Nitrogen oxides and particulates
Nelson	1975	Washington, D.C.	Oxidants

A measure of SO<sub>3</sub> deposition, probably also indicative of particulate levels.\$R

The study of air quality and automobile emission control by the National Academies of Sciences and Engineering provides a more recent estimate of the air pollution damages related to automobiles. This study employed a general equilibrium model of the property market for business, residential, and agricultural land use. Using data on Los Angeles and

Boston, the study estimated the national damages from automobile emissions to be in the range of \$1.5 to \$5 billion, annually.

The bidding game study of pollution control benefits at the Four Corners power plant added a new dimension to the estimation of aesthetic benefits. A questionnaire was administered to local residents and tourists after showing them three sets of photographs, each set showing the aesthetic aspects of different levels of pollution. Bidding games, using realistic payment mechanisms, were designed to determine the maximum amounts that households would be willing to pay for improvements shown in the photographs. The payment mechanisms included sales taxes, electricity bills, monthly payments, user fees, and compensation for environmental damages.

## SO VEGETATION DAMAGES

### The Nature and Effects of Air Pollution Damage to Vegetation

Until recently, studies of the effects of air pollution on vegetation were limited primarily to leaf damage caused by acute exposures in areas adjoining urban centers. However, recent work has begun to change this picture, indicating that vegetation damage is likely to be far more extensive than had been expected.

Measurements of air pollution in rural areas in many states have shown the presence of hazardous concentrations of oxidants over large areas; this condition appears to be the result of the processes of transport and chemical reaction within plumes carried from urban areas. Fluorides, nitrogen dioxide, and sulfur dioxide, with its resultant acid rain, have also been found to have impacts on rural vegetation.

In addition, a number of experimental techniques have been developed to determine the impact of specific pollutants on plant growth. Studies using these techniques have shown that chronic exposure to ozone affects the yield of many crops to a far greater extent than that indicated by leaf damage from acute exposures. Experimental work still in the

exploratory stage suggests that oxidants, such as ozone, may destroy chlorophyll and cause reductions in plant growth, which are not manifested by visible injury. Conversely, it appears that acute exposure can cause leaf damage without having a substantial effect on long-term plant growth.

A series of Swedish studies have indicated that the potential effects of sulfur dioxide on vegetation extend far beyond the emission sources and the affected vegetation in the immediate area that is exposed to contact with sulfur dioxide laden air. It appears that sulfur dioxide that is not washed out of the air by rainfall can be transported for distances up to 600 miles and it is exposed to chemical reactions that produce sulfuric acid mist or acid rain. Although acid rain is known to affect vegetation directly, greater damage results in areas where the soils lack sufficient alkalinity to provide a buffer against the acid. The leaching of nutrients by such acids reduces plant growth.

**\$bSurvey of Source Studies\$R**

Damage studies have been performed on a wide variety of agronomic crops, citrus trees, lumber trees, and ornamentals. The largest segment of these studies relates to damage from oxidants and sulfur dioxide, although nitrogen oxides and fluorides have also been implicated; the more important studies are listed in Table 4.

Table 4.  
Summary of Vegetation Damage Studies

Study	Date	Location	Pollutants Measured	Effects
Benedict et al.	1973	Laboratory	Ozone	Increased damage index
Heck et al.	1966	Laboratory	Ozone	5% injury and threshold levels
Heck and Brandt	1974	Laboratory	Ozone	Reduction of photosynthesis
Botkin et al.	1971	Laboratory	Ozone	Induced needle blight
Costonis and Sinclair	1969	New York	Ozone	Yield reduction in citrus
Miller	1973	California	Ozone	Yield reduction in soybeans
Thompson et al.	1972	Riverside	Ozone	Foliar injury
Davis	1972	Herford, Arizona	Sulfur dioxide	Foliar injury and yield reduction in various species
Hill et al.	1974	Utah and New Mexico	Sulfur dioxide and nitrogen dioxide	
Temple	1972	Laboratory	Sulfur dioxide	
McCune	1969	Various studies	Fluorides	



Quantitative relationships between air pollution and vegetation damage have been developed in only a few studies. The NATO criteria documents (November 1971, February 1973, and 1974) for these pollutants contain overall reviews of the literature, as does the chapter by Heck and Brandt (1974) in Stern's air pollution volumes. Jacobson and Hill (1974) contains several hundred primary source references, although damage functions are not specifically addressed. The National Academy of Sciences (1974) publication is the most complete source on fluorides. A recent study for the Environmental Protection Agency (Benedict 1973) has attempted to circumvent physical damage functions by relating source emissions directly to economic losses; this method is suspect, especially for oxidants, as indicated by the recently-discovered, high rural oxidant levels shown in the 1973 EPA Trends Report.

Heck and co-workers (1966) have provided a number of studies quantifying ozone damages to various species. In an investigation of damages to one variety each of tobacco and pinto beans, dose-effect functions of a sigmoidal nature were derived. For pinto beans, the injury index for 1 hour of exposure to ozone rose from zero to 90 percent at 0.60 ppm concentration. Chronic effects of ozone are also documented by the data as changing by approximately 15 percent between exposure times of 1 hour and 4 hours. This

Percentage held true at both high ozone levels and levels near the primary standard of 0.08 ppm. The chronic effects on tobacco showed more than a 20 percent variation in injury between 1 hour and 4 hours of exposure. Heck developed a number of useful visual display techniques for damage functions, illustrating both synergistic effects of pollutants and acute versus chronic effects. He used three-dimensional graphs to simultaneously demonstrate variations in pollutant concentration, exposure time, and resulting damage.

Heck and Brandt (NATO 1974) have shown oxidant damage at the 5 percent level for over 100 plant species on a scatter diagram. Damage envelopes are drawn at the 5 percent and threshold levels for concentrations ranging from 0-2.160 ug/m (0-1.1 ppm) and with time exposures from zero to 8 hours. This effort is useful in providing ranges of damages for a large number of unrelated higher plant species.

A number of studies are available of damages to species of pine trees. Botkin, et al\_ (1971), Costonts and Sinclair, (1969), and Miller (1973) have investigated pine tree damages. The study by Miller is perhaps the most impressive due to the high damage and death rates found for Ponderosa Pine over a 2-year study period. All of the trees were found to be injured to some degree, and 8.1 percent died

during the study. Ambient oxidant readings in the area exceeded 196 ug/m (0.10 ppm) for more than an average of 8 hours per day.

Thompson and co-workers (1972) have performed several studies of oxidant effects on citrus tree yields; both ozone and peroxyacyl nitrates have been investigated. Thompson et al\_ (1972) quantified differences in leaf drop, fruit set and drops, and fruit weight per tree on navel oranges. Variance analysis was then performed on the data, and confidence levels given for each value. Addition of ambient ozone to carbon-filtered air was observed to reduce fruit yield by 35 percent.

Sulfur dioxide effects on soybeans have been investigated by Davis (1972). A 3-year study was conducted on 485 soybean plots. Sulfur dioxide fumigations were carried out at two growth stages the first 2 years and at seven stages during the last year. Good correlations were found between leaf area destroyed and reduction of yield. While sulfur oxide exposure is not directly related to yield loss, the study is important in indicating a possible general link between leaf loss and yield loss resulting from sulfur oxide exposures.

Hill et al\_ (1974) have carried out one of the most massive studies based on the number of species involved. About 80

native desert species in Utah and New Mexico were examined for sulfur and nitrogen dioxide effects under field conditions. Fumigation levels ranged from 1.430 ug/m (0.5ppm) to 25.600 ug/m (10 ppm) sulfur dioxide concentration; most species for which data was complete showed a marked injury increase at either 6 or 10 ppm concentration. While these are much higher than normal ambient levels, the study was intended to simulate effects in a power plant plume.

Four ornamental species, Chinese elm, Norway maple, ginkgo, and pin oak, were fumigated with sulfur dioxide in controlled environmental chambers by Temple (1972). Three dimensional dose-response curves similar to those of Heck were constructed for each species. Damages to foliage of up to 95 percent were found at concentrations of 11 ug/m (4 ppm) after 6 hours of exposure. This study fails to provide data near ambient urban levels of 365 ug/m (0.14 ppm) or less, but a small amount of damage was observed at 715 ug/m (0.25 ppm) over time periods of 30 days.

The effects of other pollutants are not well documented. McCune (1969) has done research on fluorides, but this pollutant is not widespread in ambient air. Particulates have been found to show slight effects due to limitation of photosynthesis. Nitrogen oxides and carbon monoxide have

shown no appreciable effects in the few studies that have been performed.

#### \$B MATERIALS DAMAGES

The Nature and Effects of Air Pollution Damage to Materials\$R

A wide variety of air pollutants cause damages to materials. Sulfur dioxide corrodes metals, particularly galvanized steel; it also attacks cotton textiles, finishes and coatings, paints, building stone, electrical and electronic equipment, paper, and leather. Ozone has been shown to shorten the life of rubber products, dyes, and paints. Nitrogen oxides also cause fading of dyes and paints. Particulates cause deterioration and soiling of stone, clay, and glass structures and products. These damaging effects are experienced by society in a number of ways. In many cases, avoidance costs are additional because research and development has been needed to develop new materials more resistant to attack by air pollution. These new materials are sometimes more expensive than those more susceptible to damage. Society also bears the costs of cleaning and repairs, including the replacement of failed or deteriorated



components and structures. In some cases, the failure of a material can cause damages.

#### \$bSurvey of Source Studies\$R

Best documentation for damage to materials covers the effects of sulfur dioxide, ozone, and nitrogen dioxide. Particulates have been shown to have effects on soiling of paints and building materials. Surveys of physical damage functions may be found in Yocom and McCaldin (1968) and the NATO criteria documents for particulates (1971), sulfur dioxide (1971), and photochemical oxidants (1974). Much of the recent work in both ambient air and controlled chamber studies has been pursued at EPA's National Environmental Research Center in Triangle Park, N.C. Economic estimates based on physical damage studies have been made by Salmon (1970), Gillette (1974), Haynie (1974), and Maddell (1974). The major damage studies are summarized in Table 5.

Table 5.  
Summary of Materials Damage Studies

St Study	Date	Pollutants Measured	Effects
Upham	1965	Sulfur dioxide	Metal corrosion
Haynie and	1970	Sulfur dioxide	Zinc corrosion due to sulfur dioxide and humidity
Beloin and Haynie	1973	Particulates	Soiling
Booz Allen and Hamilton	1970	Particulates	Soiling
Michelson and Tourin	1967	Particulates	Paint Soiling
Upham et_al_	1974	Nitrogen dioxide	Textile dye fading\$R

The most comprehensive survey of economic losses incurred from air pollution damage to materials is the work of Salmon (1970). Thirty-two categories of materials were the basis for calculating a total economic loss of \$3.8 billion due to air pollution. The pollutants, in decreasing order of economic importance, were found to be sulfur oxides, ozone, nitrogen oxides, carbon dioxide and particulates. Waddell has used parts of this study, combined with in-depth studies on specific categories, to arrive at an estimate for the cost of materials losses in 1970.

Haynie (1974) has assessed economic damages to metals, paints, elastomers, electrical contacts and electronic

components at \$2.7 billion per year. The percentages of total economic loss and available reference material are given for metals, paints, textiles, elastomers, and plastics. Each area is also rated as to whether there is strong or weak evidence of damage or only a suspected relationship. This approach clearly defines areas requiring further investigation.

Economic damage due to sulfur dioxide has been estimated by Gillette (1974), both on a national and regional basis; the estimate shows significant reductions in sulfur dioxide levels nationwide between 1968 and 1972. These calculations were carried out for various SMSAs using the air quality at the center of the city as representative of the entire SMSA. Reductions of damages due to sulfur dioxide were calculated to decrease from \$900 million to \$75 million over the 5-year period. This loss was determined to occur mostly from corrosion of painted or unpainted surfaces.

Physical damage studies pertaining to materials are not available on a comprehensive basis, but studies that have been done on specific materials are usually better quantified than studies on health or vegetation damage due to the lack of biological complications. The studies presented below are representative of the backup data which support the economic damage functions.

Metal corrosion is the most economically significant category. A number of studies have been completed on metal corrosion caused by sulfur dioxide. One of the most illustrative for widespread geographic interpretation was a study by Upham (1965) on metal corrosion in eight major cities. Values of corrosional weight loss between levels of 0.02 and 0.14 ppm annual sulfur dioxide concentration vary from 4 to 12 grams, respectively. Except for one city, the data very nearly fits a straight line dose-response function. Corrosion of zinc has been investigated by Haynie and Upham (1970); sulfur dioxide and relative humidity were determined to act synergistically in the corrosion process. Significant reductions in useful lifespan were predicted even at sulfur dioxide concentrations as low as 130 ug/m .

Good correlation of soiling of painted and unpainted surfaces with particulate concentration has been found by Beloin and Haynie (1973) for a variety of substances. Dose-effect functions were developed by regression analysis and particulates were found to account for up to 92 percent of the variability of reflectance for certain substances. Whether or not this physical change can be linked to changes in maintenance frequency is not yet clear. Studies by Booz Allen and Hamilton (1970) in the Philadelphia area demonstrated no correlation with particulate concentration between 50 and 150 ug/m . While a study by Michelson and

Tour'in (1967) showed more than four times as much repainting was done in areas with 250 ug/m concentration than in areas with 50 ug/m concentration. However, the transgeographic nature of the study leaves these results open to question.

Nitrogen dioxide has been only tentatively linked to significant materials damage. A recent study by Upham et al\_ (for EPA) has indicated that certain cellulosic fibers may be affected by nitrogen dioxide. Controlled test chambers were employed to investigate both nitrogen dioxide and relative humidity effects. Correlation of nitrogen dioxide concentration with dye fading was found, as well as evidence of a synergism with relative humidity. This correlation is supported somewhat by the cost study of Salvin, which linked sulfur and nitrogen oxides and acids to changes in textile fibers and dyes.

#### \$B#ORE ELUSIVE DAMAGES\$R

As pointed out on repeated occasions, the current state-of-the-art in benefit assessment does not permit full estimation of all the damages associated with air pollution. For example, in assessing the damages to human health, the

costs of lost leisure time and psychic costs are not adequately reflected in estimates of the economic cost of illness. In other cases, the effects themselves have not yet been adequately defined, as in the case with the risk of large-scale ecological disruptions. With some types of damage, both the effects and the damage values elude adequate definition. Additional damage categories that have been excluded from the discussion presented above include:

- Unquantified health effects
- Animal health
- Natural environment.

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## SeChapter 3

### The Costs of Controlling Air Pollution

#### \$b1. INTRODUCTION\$R

This 1975 estimation of the total incremental costs that will be required to meet the provisions set forth by the Clean Air Act is significantly different from the estimates presented in the 1974 Cost of Clean Air Report for the following reasons:

1. Costs for more industries have been included, providing a broader base than previous reports.
2. Compliance dates for some standards are different.
3. More detailed analysis has been performed on the Transportation Control Plans costs.

All major industrial pollutant sources which were included in the 1974 report are reevaluated in this report. In addition, costs have been estimated for the following industrial sources which have been added to make this report more comprehensive:

1. Clay construction products
2. Coal gasification plants
3. Paint manufacturers
4. Printing establishments
5. Surface coatings facilities
6. Petrochemical industry
7. Nonfertilizer phosphate reduction products
8. Building and industrial incinerators.

This report assumes that the compliance date for scrubber installations in the electric utility plants will be extended from July 1, 1975 to July 1, 1980. This assumption will postpone the investment cost by approximately 5 years, and it will also reduce the annual cost of operating pollution control equipment and the cash requirements of the electric utilities sector during the period 1975-80.

Air pollution control costs passed on to the purchasers of light-duty motor vehicles have been calculated based upon the prevailing policy on the level of emissions control. This policy has become less stringent than originally forecast, resulting in lower control costs as shown in the Mobile Sources discussion included in this Section. The reduction in new car sales during this 1975 model year, and future estimates of reduced car sales will result in lower

control costs than were previously estimated because control costs are calculated on the basis of new car sales.

Estimates of the costs associated with State Transportation Control Plans were made on a metropolitan-by-metropolitan basis and, consequently, exceed the \$2 billion estimate reported in the 1974 cost report.

**\$b2. SUMMARY OF FEDERAL, STATE, AND  
LOCAL GOVERNMENT EXPENDITURES, 1976-85\$R**

The Clean Air Amendments of 1970 (P.L. 91-604) imposes a somewhat different requirement on governmental agencies than on others affected by the legislation. Instead of abatement, the principle purpose of expenditures in the Government sector are research, monitoring, management, and enforcement. Research is mainly supported by Federal funds, while state and local funds, supplemented by Federal grants, will be used primarily to implement, operate, and maintain monitoring and enforcement programs.

For the period 1976-85, cumulative expenditures by Federal agencies are estimated to be about \$6.0 billion, of which

about \$510 million will be grants to state and local governments. In addition to these funds, state and local governments will spend about \$810 million and \$725 million, respectively. Thus, the grand total for all government agencies is projected to be about \$7.6 billion. The estimated yearly expenditures by each level of government are given in Table 2-1.

Government expenditures are further broken down by capital and operating and maintenance (O&M) costs; this forecast assumes roughly even distribution between capital and O&M costs in 1976 with a steady increase in the proportion of dollars going to O&M costs by 1985. The rationale for the breakdown between capital and O&M expenditures is that during implementation and early operation, heavy capital investments will be required whereas in later phases, capital investments will taper off and a larger percentage of funds will be directed to operation and maintenance of abatement activities. The annual and cumulative costs of capital investment and O&M are given in Table 2-2.

\$d  
 Table 2-1.  
 Total Estimated Air Pollution Control Expenditures for 1976-85 Federal,  
 State, and Local Funds

(In Millions of 1975 Dollars)

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
<b>Federal (In-house)</b>	587.9	466.7	485.4	504.8	525.0	546.0	567.8	590.5	614.1	638.7
Cumulative	587.9	1,054.6	1,540.0	2,044.8	2,569.8	3,115.8	3,683.6	4,274.1	4,888.2	5,526.9
<b>Federal Grants</b>	53.5	53.6	49.7	49.8	49.9	50.0	50.1	50.2	50.3	50.4
Cumulative	53.5	107.1	156.8	206.6	256.5	306.5	356.6	406.8	457.1	507.5
<b>State</b>	63.8	72.0	80.1	81.4	82.6	83.7	84.7	85.7	86.6	87.2
Cumulative	63.8	135.8	215.9	297.3	379.9	463.6	548.3	634.0	720.6	807.8
<b>Local</b>	57.6	64.8	71.9	73.0	74.0	74.9	75.7	76.7	77.6	78.6
Cumulative	57.6	122.4	194.3	267.3	341.3	416.2	491.9	568.6	646.2	724.8
<b>Total</b>	762.8	657.1	687.1	709.0	731.5	754.6	778.3	803.1	828.6	854.9
Cumulative	762.8	1,419.9	2,107.0	2,816.0	3,547.5	4,302.1	5,080.4	5,883.5	6,712.1	7,567.0

Source: Ref. 6 - Special computer printout, Loren Casement,  
 Office of Management and Budget, Environmental  
 Branch, Received December 17, 1974.

To State, Interstate, and Local Governments

Table 2-2.  
**Distribution of Air Pollution Control Governmental Funds  
 by Capital and Operating and  
 Maintenance (O&M) Costs, 1976-85**  
 (In Millions of 1975 Dollars)

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
<b>Federal (In- house)</b>										
Capital	293.9	219.3	213.6	207	199.5	191.1	181.7	171.2	159.7	146.9
Cumulative	293.9	513.2	726.8	933.8	1,133.3	1,324.4	1,506.1	1,677.3	1,837.0	1,983.9
O&M	294.0	247.4	271.8	297.8	325.5	354.9	386.1	419.3	454.4	491.8
Cumulative	294.0	541.4	813.2	1,111.0	1,436.5	1,791.4	2,177.5	2,596.8	3,051.2	3,543.0
<b>Federal grant</b>										
Capital	26.7	25.2	21.9	20.4	19.0	17.5	16.0	14.6	13.1	11.6
Cumulative	26.7	51.9	73.8	94.2	113.2	130.7	146.7	161.3	174.4	186.0
O&M	26.8	28.4	27.8	29.4	30.9	32.5	34.1	35.6	37.2	38.8
Cumulative	26.8	55.2	83.0	112.4	143.3	175.8	209.9	245.5	282.7	321.5
<b>State</b>										
Capital	31.9	33.8	35.2	33.4	31.4	29.3	27.1	24.9	22.5	20.1
Cumulative	31.9	65.7	100.9	134.3	165.7	195.0	222.1	247.0	269.5	289.6
O&M	31.9	38.2	44.9	48.0	51.2	54.4	57.6	60.8	64.1	67.1
Cumulative	31.9	70.1	115.0	163.0	214.2	268.6	326.2	387.0	451.1	518.2
<b>Local</b>										
Capital	28.8	30.5	31.6	29.9	28.1	26.2	24.2	22.2	20.2	18.1
Cumulative	28.8	59.3	90.9	120.8	148.9	175.1	199.3	221.5	241.7	259.8
O&M	28.8	34.3	40.3	43.1	45.9	48.7	51.5	54.5	57.4	60.5
Cumulative	28.8	63.1	103.4	146.5	192.4	241.1	292.6	347.1	404.5	465.0
<b>Total</b>										
Capital	381.3	308.8	302.3	290.7	278.0	264.1	249.0	232.9	215.5	196.7
Cumulative	381.3	690.1	992.4	1,283.1	1,561.1	1,825.2	2,074.2	2,307.1	2,522.6	2,719.3
O&M	381.5	348.3	384.8	418.3	453.5	490.5	529.3	570.2	613.1	658.2
Cumulative	381.5	729.8	1,114.6	1,532.9	1,986.4	2,475.9	3,005.2	3,576.4	4,189.5	4,847.7

Sources: Table 1; Ref. 5 - "The Economic Impact of Environmental Programs", Executive Office of the President, The Council on Environmental Quality, Washington, D. C., November 1974.\$s

**\$Federal Governments\$R**

Federal funds will comprise approximately 80 percent of the cumulative government expenditures resulting from the 1970 Clean Air Amendments. As stated earlier, about \$510 million will be used to support state, interstate, and local programs. The remaining \$5.5 billion will be used to support other Federal programs. About 50 percent of these funds will be used for research, development, and demonstration, which implies that they will be distributed to governmental and private research facilities throughout the United States. The remaining funds will be used for abatement and control, manpower development, and actions to control pollution from Federal facilities. Cumulative Federal in-house expenditures are estimated to be about \$2.0 billion and \$4.0 billion for capital and O&M costs, respectively.

**\$State and Local Governments\$R**

The viability of state and local programs for complying with the 1970 Amendments is highly dependent on Federal grant support as illustrated by the fact that in 1974, Federal funds made up 47 percent of the total spent by state agencies and 37 percent of funds spent by local agencies.

The percentage of Federal support is expected to diminish based on the assumptions that programs will continue to grow gradually after implementation and that the level of Federal support will remain essentially constant. In 1976, Federal support will account for 31 percent of the funding, diminishing to 23 percent in 1985. Cumulative expenditures will account for 25 percent of the total for 1976-85. It is noteworthy that in the initial stages of implementation, some states relied heavily on Federal funds whereas others have developed sophisticated programs from their own financial capabilities. The U.S. Environmental Protection Agency provides 97 percent of the Federal money required to support the state and local programs with the remaining 3 percent contributed by the Department of Transportation (DOT) and the Appalachian Regional Commission (ARC).

Estimated expenditures of Federal, state, and local funds by each state and the U.S. possessions are given in Table 2-3 for alternate years during the 1976-85 period.

Table 2-3.  
**SUMMARY OF TOTAL AIR POLLUTION CONTROL EXPENDITURES  
 BY STATE AND LOCAL GOVERNMENTS**  
 (In Thousands of Dollars)

1350  
 1351  
 1352  
 1353

State	1960			1961			1962			1963			1964			1965		
	Fed.	Sta.	Loc.	Fed.	Sta.	Loc.												
Alabama	126	57	13	131	898	1,217	915	918	1,449	925	898	1,479	945	699	1,500	944		
Alaska	158	132	1	158	326	182	316	182	123	342	182	123	357	182	128	363		
Arizona	115	152	256	997	1,172	236	1,220	268	597	1,253	275	597	1,276	279	1,276	279		
Arkansas	253	633	255	255	999	255	999	255	999	255	999	255	999	255	999	255		
California	1,312	2,138	1,239	3,157	8,227	22,629	31,414	34,407	9,106	23,414	34,407	9,106	23,414	34,407	9,106	23,414		
Colorado	154	254	315	824	1,264	1,616	1,616	1,616	1,616	1,616	1,616	1,616	1,616	1,616	1,616	1,616		
Connecticut	110	1,075	387	1,953	2,223	823	1,853	2,224	850	1,853	2,224	850	1,853	2,223	850	1,853		
Delaware	213	270	22	279	696	320	306	320	306	320	306	320	306	320	306	320		
District of Columbia	369	369	369	369	369	369	369	369	369	369	369	369	369	369	369	369		
Florida	559	559	559	559	559	559	559	559	559	559	559	559	559	559	559	559		
Georgia	137	253	183	183	183	183	183	183	183	183	183	183	183	183	183	183		
Idaho	155	452	161	161	480	161	480	161	480	161	480	161	480	161	480	161		
Illinois	1,134	4,338	6,271	1,200	5,725	5,966	7,037	3,000	5,009	7,037	3,000	5,009	7,037	3,000	5,009	7,037		
Indiana	123	533	533	1,206	1,206	553	520	1,206	553	520	1,206	553	520	1,206	553	520		
Iowa	679	136	121	991	316	316	316	316	316	316	316	316	316	316	316	316		
Kansas	790	175	72	685	257	116	685	257	116	685	257	116	685	257	116	685		
Kentucky	398	567	357	357	357	357	357	357	357	357	357	357	357	357	357	357		
Louisiana	272	323	337	337	337	337	337	337	337	337	337	337	337	337	337	337		
Maine	1,135	935	1,035	1,035	1,035	1,035	1,035	1,035	1,035	1,035	1,035	1,035	1,035	1,035	1,035	1,035		
Maryland	1,236	933	1,189	1,189	1,189	1,189	1,189	1,189	1,189	1,189	1,189	1,189	1,189	1,189	1,189	1,189		
Massachusetts	2,107	549	1,578	2,064	1,012	1,580	2,064	1,012	1,580	2,064	1,012	1,580	2,064	1,012	1,580	2,064		
Michigan	712	233	156	691	293	293	691	293	293	691	293	293	691	293	293	691		
Minnesota	414	936	302	302	1,241	302	1,241	302	1,241	302	1,241	302	1,241	302	1,241	302		
Mississippi	1,134	521	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062		
Missouri	338	211	96	299	299	299	299	299	299	299	299	299	299	299	299	299		
Montana	430	99	231	417	174	357	417	174	357	417	174	357	417	174	357	417		
Nebraska	193	182	182	275	31	275	31	275	31	275	31	275	31	275	31	275		
Nevada	137	193	229	182	182	182	182	182	182	182	182	182	182	182	182	182		
New Hampshire	2,137	1,177	1,177	1,177	1,177	1,177	1,177	1,177	1,177	1,177	1,177	1,177	1,177	1,177	1,177	1,177		
New Jersey	3,672	3,557	10,521	5,208	13,726	5,208	13,726	5,208	13,726	5,208	13,726	5,208	13,726	5,208	13,726	5,208		
New York	1,187	1,436	771	1,131	2,131	1,131	2,131	1,131	2,131	1,131	2,131	1,131	2,131	1,131	2,131	1,131		
North Carolina	74	101	72	136	72	136	72	136	72	136	72	136	72	136	72	136		
North Dakota	2,738	3,070	3,373	2,656	3,331	2,656	3,331	2,656	3,331	2,656	3,331	2,656	3,331	2,656	3,331	2,656		
Ohio	472	335	354	390	476	595	390	476	595	390	476	595	390	476	595	390		
Oklahoma	582	1,522	299	565	2,512	565	2,512	565	2,512	565	2,512	565	2,512	565	2,512	565		
Oregon	1,340	2,735	1,399	3,436	3,732	2,718	3,436	3,732	2,718	3,436	3,732	2,718	3,436	3,732	2,718	3,436		
Pennsylvania	545	1,337	255	432	1,895	356	432	1,895	356	432	1,895	356	432	1,895	356	432		
Rhode Island	32	123	31	123	31	123	31	123	31	123	31	123	31	123	31	123		
S. Carolina	332	1,492	769	906	1,315	778	906	1,315	778	906	1,315	778	906	1,315	778	906		
S. Dakota	2,356	9,312	2,353	2,865	11,574	2,865	11,574	2,865	11,574	2,865	11,574	2,865	11,574	2,865	11,574	2,865		
Texas	166	385	163	392	163	392	163	392	163	392	163	392	163	392	163	392		
Utah	189	236	183	236	183	236	183	236	183	236	183	236	183	236	183	236		
Vermont	1,114	2,577	945	1,178	2,411	945	1,178	2,411	945	1,178	2,411	945	1,178	2,411	945	1,178		
Washington	1,422	3,383	4,217	1,108	3,525	1,108	3,525	1,108	3,525	1,108	3,525	1,108	3,525	1,108	3,525	1,108		
West Virginia	995	62	316	84	316	379	316	379	316	379	316	379	316	379	316	379		
Wisconsin	193	136	102	102	267	102	267	102	267	102	267	102	267	102	267	102		
Wyoming	69	39	67	67	67	67	67	67	67	67	67	67	67	67	67	67		
Puerto Rico	368	121	357	357	357	357	357	357	357	357	357	357	357	357	357	357		
Virgin Islands	84	65	81	81	75	81	75	81	75	81	75	81	75	81	75	81		
<b>TOTAL (in Billions)</b>	<b>51.9</b>	<b>53.8</b>	<b>57.6</b>	<b>67.8</b>	<b>71.9</b>	<b>82.6</b>	<b>75.0</b>	<b>84.7</b>	<b>75.7</b>	<b>86.6</b>	<b>77.6</b>	<b>86.6</b>	<b>77.6</b>	<b>87.2</b>	<b>87.2</b>	<b>87.2</b>		

Sources: Ref. 1 - "Air Pollution Control Agency Program Grants", Frank Lane, EPA Office of Management and Budget, Washington, D.C., September, 1973.  
 Ref. 2 - Data from Donald R. Smith, Chief, Control Agency Station, EPA Research Triangle Park, North Carolina, November 15, 1974.  
 Ref. 3 - State Implementation Plans, Resources Data for Michigan, Ohio, Indiana, Texas, Connecticut, Massachusetts, Georgia, Florida, Nebraska, Montana, Oregon, New York, California, Pennsylvania, Wyoming, and Washington, D.C.  
 Ref. 4 - Special computer print out, Green Campaign, Office of Management and Budget, Environmental Branch, Received September 17, 1974.  
 Ref. 5 - "Air Pollution Control Agency Program Grants", Carl Close, U.S. EPA Resources Management, January 3, 1975.

As indicated by the level of funding shown in Table 2-3, several states have extensive programs underway. These states are principally those which are highly populated, industrialized, and consequently have the most severe air pollution problems. The funding summarized in Table 2-3 does not include DOT or ARC funds which constitute approximately 3 percent of the total.

The yearly growth of state and local programs is based on the estimated rate of 430 new sources which will come under the jurisdiction of these agencies. The yearly increase in costs for additional equipment and manpower translates into \$2 million for all states and possessions. The increase is apportioned to each state and local agency according to its ranking in the total program. State and local expenditures are further categorized into functional areas, namely enforcement services, engineering services, technical services, and management services in the State Implementation Plans (SIP's). These divisional annual expenditures and period cumulatives are shown in Table 2-4.

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Table 2-4.  
Total State and Local Air Pollution Control  
Expenditures (Including EPA Grants)  
by Functional Area

(In Millions of 1975 Dollars)

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
<b>\$t</b>										
Enforcement Services	55.5	56.5	59.9	60.6	61.4	61.9	62.5	63.0	63.6	64.1
Cumulative	55.5	112.1	172.0	232.6	294.0	355.9	418.4	481.4	545.0	609.1
Engineering Services	43.3	45.3	48.0	48.5	49.1	49.5	50.0	50.4	50.8	51.3
Cumulative	43.3	88.6	136.6	185.1	234.2	283.7	333.7	384.1	434.9	486.2
Technical Services	48.5	60.4	64.0	64.7	65.4	66.0	66.7	67.2	67.9	68.4
Cumulative	48.5	108.9	172.9	237.6	303.0	369.0	435.7	502.9	570.8	639.2
Management Services	26.0	26.4	27.9	28.3	28.5	28.9	29.0	29.4	29.7	29.9
Cumulative	26.0	52.4	80.3	108.6	137.1	166.0	195.0	224.4	254.1	284.0

Sources: Table 1; Ref. 4 - State Implementation Plans.  
Resources Data for Michigan, Ohio, Indiana,  
Texas, Connecticut, Massachusetts, Georgia,  
Florida, Nebraska, Montana, Oregon, New York,  
California, Pennsylvania, Wyoming, and  
Washington, D.C. \$sR

### \$b3. CONTROL OF EMISSIONS FROM STATIONARY SOURCES\$R

For the purposes of this report, stationary sources are considered to include industrial sources, utilities, and industrial/commercial heating and incineration which are treated as industries. Dry cleaning establishments, paint shops, and other small scale activities are also considered as industries.

Service stations are considered under the Mobile Source section because they are controlled for vapor emissions under Transportation Control Plans.

### \$bClassification of Industrial Sources\$R

In order to calculate air pollution control costs, industries are represented by "segments" and "model plants".

A "segment" is all or a portion of an industry that has: (1) the same production process, (2) the same air pollution control technology, and (3) the same pollution control standard. For example, the Kraft Paper Industry is dealt with for purposes of air pollution control costs in terms of 10 different segments. These segments are defined in Table

3-1.

Table 3-1.  
Kraft Paper Industry Segment Definitions

Process	Control Technology	Pollution Standard
1. Power Boiler	Electrostatic Precipitators	Federal Particulates
2. Boiler	Double Alkali Scrubber	Federal Sulfur Dioxide
3. Recovery Furnace	Electrostatic Precipitators	Washington/Oregon Particulates
4. Recovery Furnace	Venturi Scrubber	Washington/Oregon Particulates
5. Recovery Furnace	Recovery Furnace Replacement	Washington/Oregon Total Reduced Sulfur
6. Recovery Furnace	BLO	Washington/Oregon Total Reduced Sulfur
7. Smelting Tank	Orifice Scrubber	Washington/Oregon Particulates
8. Lime Kiln	Venturi Scrubber	Washington/Oregon Particulates
9. Stock Washer	Incinerate in Recovery Furnace	Washington/Oregon Total Reduced Sulfur
10. Evaporator	Incinerate in Lime Kiln	Washington/Oregon Total Reduced Sulfur

"Model plants" are the building blocks of a segment; that is, a segment capacity for production is comprised of a number of model plants that are classified as either "existing" or "new" (new facilities are those constructed after the date when the Clean Air Act affects that industry). For example, Segment 7 for Kraft Paper (Smelting Tanks) has three model plant sizes (454, 907, and 1,361 units of production per day). There are existing facilities in all three sizes, but during the 1975-85 period, new facilities are expected to be built in only the middle size class. Table 3-2 lists the industries for which air costs are calculated, the number of segments for those industries, and the Standard Industrial Classification (SIC) industry code as defined by the Office of Management and Budget (OMB).

Table 3-2.  
Segments for Industrial Cost Analysis

Name	Existing Segments	SIC (1972 Definition)
Steelmaking	22	331 (pt)
Steel Foundries		3324.5
Ferroalloy	5	3313
Steel-Coke	3	331 (pt)
Steel-Scintering	7	331 (pt)
Solid Waste Disposal	6	4953
Sludge Incineration	1	4953
NSSC	2	2611272
Primary Zinc	1	33331
Primary Lead	1	33321
Secondary Zinc	1	33414
Secondary Aluminum	1	33417.8
Industrial Heating	1	N/A
Commercial Heating	1	N/A
Crude Oil Storage	1	291X
Gasoline Storage	1	291X
Jet Fuel Storage	1	291X
Refining	1	291X
Petroleum Cost Cracking	2	291X
Petroleum Aluminum	3	33347
Natural Gas	2	1321
Coal Cleaning	1	1211 (pt), 12136
Iron Foundries	5	3321.2
Dry Cleaning	3	7215.6
Grain Handling	1	5153
Feed Mills	1	2047.8
Asphalt	2	29510
Cement	4	3241
Sulfuric Acid	2	28193
Nitric Acid	1	2873
Phosphate Fertilizer	4	2874
Kraft	10	2611231.35.39.43
Lime	3	3274
Primary Copper	3	33311
Secondary Lead	1	33412
Secondary Brass	2	3362
Asbestos	6	3292
Clay Construction Products	3	1452.3.4.5.6.7.8.9:
		3295
Coal Gasification	2	N/A
Petrochemicals	7	2869
Nonfertilizer Phosphate	3	2819
Mercury Cell Chlor Alkali	2	2812

Table 3.2. (Continued)  
 Segments for Industrial Cost Analysis

Commercial and Industrial	2	N/A
Building Incineration	4	3711.12.13.14.15; 3631.32.33.34.3479;
Surface Coatings		7531.35
Paint Manufacture	2	2851
Painting	1	2751.52.53.54; 2711.21.31\$R

The cost of controlling air pollution from industrial sources is estimated for model plants. All existing and new capacity is expressed in terms of the model plants. For example, the smallest model plant in Segment 7 for Kraft Paper has to spend \$54,000 for capital equipment to control particulates. In summary, this model plant is defined by:

- Industry - Kraft
- Production process - Smelt Tank
- Control technology - Orifice Scrubber
- Pollution standard - Washington-Oregon Particulates
- Model plant capacity - 454 Units
- Type of facility - Existing.

#### **\$Costs Related to Required Reduction in Air Emissions**

The control costs that industries incur are directly, but usually not linearly, related to the amount of reduction in the emissions required. Since the purpose of this section is to estimate the control costs resulting from provisions of the Clean Air Act, it is necessary to factor out the levels of control that existed in industries prior to the Clean Air Act. Controls could have existed prior to 1971 because it was economically worthwhile to recover byproducts

or because there were prior emission regulations (either self-imposed or government-generated).

#### REDUCTIONS IN EMISSIONS PRIOR TO THE CLEAN AIR ACT

**Byproduct Recovery.** In some industries, it is common to control particulate or sulfur oxides emissions in order to recover materials in these gases that have economic value. Where this was common practice prior to 1971, the associated control costs are not calculated in this report. Some byproduct recovery values are, however, calculated in this report. Such values are calculated when the controls were prompted by State Implementation Plans (SIP) that responded to requirements of the Clean Air Act. For example, petroleum storage tanks are controlled by SIP's to reduce the hydrocarbon emissions. In most cases, the value of the fuel recovered by the control devices placed on these storage tanks is greater than the cost of the control devices. Thus, the control saves industry money rather than causing a net cost to the industry.

**Average Industrial Controls Prior to the Clean Air Act.** An attempt has been made to estimate the average level of control in each industry prior to the date that each industry was impacted by the provisions of the Clean Air

Act. This date is usually 1971, but for some industries, it might be as late as 1972 or 1973. For new facilities in a specific industry built during the late 1970's and early 1980's, it is assumed that they will have installed pollution equipment equal to the average practice that existed prior to the Clean Air Act. Therefore, costs are estimated for the incremental amount of pollution equipment needed to meet the current emission standards.

#### REDUCTIONS IN AIR EMISSIONS REQUIRED BY THE CLEAN AIR ACT

The Clean Air Act affects pollution control through: (1) ambient standards for six pollutants [particulates, sulfur oxides (SO<sub>x</sub>), nitrogen oxides (NO<sub>x</sub>), hydrocarbons (HC), oxidants, and carbon monoxide (CO)], (2) New Source Performance Standards (NSPS) which are emission standards and (3) emission standards for three hazardous pollutants (mercury, asbestos, and beryllium).

Federal Ambient Standards and State Implementation Plans. In order to meet the ambient standards set by EPA, states must devise plans that take into account the unique characteristics of metropolitan and other local areas with regard to the size and mix of pollutant sources.

meteorology, terrain, etc. State Implementation Plans control pollution from industrial sources based upon local conditions. For example, Oregon and Washington place stringent controls on existing Kraft pulp mills, whereas many states have no existing Kraft pulp mills, and therefore no present controls. For some industries, such as Steelmaking, some states have more stringent emission controls than others. In fact, in this report, steel mills are classified into four categories based upon the stringency of various state air emission controls.

Effectively, the SIP's translate the Federal ambient air standards into a set of emission standards for particulates, sulfur oxide, nitrogen oxide, hydrocarbon, and carbon monoxide.

Some of these types of state differences in controlling existing facilities are taken into account in this report.

With regard to new plants, there is much less state differentiation because there is a set of Federal controls for new facilities called New Source Performance Standards.

New Source Performance Standards. New Source Performance Standards have been promulgated for only a portion of the industries that will eventually be covered; Table 3-3 shows the industries that are presently covered under NSPS and the

associated emission factors. The reference sources for the data in this table are references 1 through 7 which are contained in the References listing at the end of Table 3-3.

Table 3-3. New Source Performance Standards Regulations

Source	Pollutant	Emission Standard	Suitable Control Technology
1. Steam Electric Generators	Particulates	0.2 lb/10 Btu heat input (0.36 g/10 cal)	Electrostatic Precipitator Scrubber (lime slurry) or low-sulfur fuel switch Scrubber (lime slurry) or low-sulfur fuel switch Combustion Modifications Combustion Modifications Combustion Modifications
	SO <sub>2</sub> (liquid fossil fuel)	0.8 lb/10 Btu heat input (1.4 g/10 cal)	
	SO <sub>2</sub> (solid fossil fuel)	1.2 lb/10 Btu heat input (2.1 g/10 cal)	
	NO <sub>x</sub> (gaseous fuel)	0.2 lb/10 Btu heat input (0.36 g/10 cal)	
	NO <sub>x</sub> (liquid fuel)	0.3 lb/10 Btu heat input (0.54 g/10 cal)	
	NO <sub>x</sub> (solid fuel)	0.7 lb/10 Btu heat input (1.26 g/10 cal)	
2. Municipal Incinerators		0.10 grain/SCF dry flue gas (chngd to 12% CO <sub>2</sub> )	Electrostatic Precipitator or Venturi Scrubber
		1.9 lb/T (0.95 Kg/MT)	
3. Portland Cement Plants	Particulates (kilns)	0.30 lb/T of dry feed (0.15 Kg/MT)	Baghouse
	Particulates (clinker coolers)	0.10 lb/T of dry feed (0.05 Kg/MT)	Baghouse
4. Nitric Acid Plants	NO <sub>x</sub>	3.0 lb/T of acid, avg over 2 hrs. (1.5 Kg/MT)	Catalytic NO <sub>x</sub> Decomposition Systems
5. Sulfuric Acid Plants	SO <sub>2</sub>	4.0 lb/T of acid (100%) (2 Kg/MT)	Dual Absorption Plant or Sodium Sulfite/Bi-sulfite Scrubber
	Acid Mist	0.15 lb/T (0.075 Kg/MT)	
6. Asphalt Concrete Plants	Particulates	70 mg/Nm	Fabric Filter or Venturi Scrubber
	Particulates	50 mg/Nm	
7. Petroleum Refineries (FCC Catalyst Regeneration) (Process Gas Burning)	CO	0.050 volume %	Electrostatic Precipitator
	H <sub>2</sub> S	230 mg/Nm of fuel gas	
8. Hydrocarbon Vessels (Storage Tank)	Hydrocarbons	Require Floating Roof Tank	Floating Roof Tank
	Particulates	50 mg/Nm	Fabric Filter or Scrubber

Table 3-3. (Continued)  
New Source Performance Standards Regulations

10.	Brass and Bronze Ingot (Furnace)	Particulates	50 mg/Nm	Fabric Filter
11.	Iron and Steel (BOF)	Particulates	50 mg/hr	Open-Hood Scrubber or Electrostatic Precipitator or Closed-Hood Scrubber
12.	Sewage Sludge Incineration	Particulates	70 mg/Nm	Venturi Scrubber
13.	Ferroalloy (Electric Submerged ARC Furnace)	Particulates	0.99 lb/MW-hr (0.45 kg/MW-hr)	Baghouse
		CO	0.51 lb/MW-hr (0.23 kg/MW-hr)	Electrostatic Precipitators Scrubber Afterburner
			20% CO by volume	
14.	Iron and Steel (Electric Arc furnace)	Particulates	0.0052 gr/dry scf (12 mg/dry scm) 5% opacity (but there are many exceptions)	Direct shell evacuation (DSE) with either building evacuation or canopy hoods. Or, DSE with canopy hoods and natural ventilation through the open roof.
15.	Primary Potroom	Inorganic Fluorides Visible Emissions (particulates, fluorides)	2 lb/ton (1 kg/MT) of aluminum produced from both Potroom and Bake Plant	Wet gas scrubber in series with an electrostatic precipitator or fabric filters using alumina absorbant
	Anode Bake Plant	Inorganic Fluorides Visible Emissions (particulates, fluorides)		Wet scrubber in conjunction with a wet electrostatic precipitator or clean residual fluoride-bearing cryolite from anode remnants before recycling
Table 3-3. (Continued)				
New Source Performance Standards Regulations				
16.	Phosphate Fertilizer Plants	Inorganic Fluorides	0.020 lb/ton (10 g/MT) of equivalent P2O5 feed	Cross-flow spray packed scrubber
	Wet Process Phos-			

phoric Acid Plants	Inorganic Fluorides	0.010 lb/ton (5.0 g/MT) of eqvint P205 feed	Cross-flow spray packed scrubber
Super- phosphoric Acid Plants	Inorganic Fluorides	0.060 lb/ton (30 g/MT) of equivalent P205 feed	Cross-flow spray packed scrubber
Diammonium Phosphate Plants	Visible Emissions (particulates, fluorides)	20% opacity	
Triple Superphos- phate	Inorganic Fluorides	0.20 lb/ton (100 g/MT) of eqvint P205 feed	Cross-flow spray packed scrubber
Granular Triple Super- phosphate Storage	Visible Emissions Inorganic Fluorides	20% opacity 5.0x10 <sup>-10</sup> lb/hr/tn (0.25 g/hr/MT) of equivalent P205	Cross-flow spray packed scrubber
	Visible Emissions	20% opacity	
17. Coal Cleaning Facilities			
Wet Clean- ing Systems	Particulates	0.031 grain/dry scf (0.06 mg/dry SCM)	High efficiency, venturi type wet scrubbers
Dry Clean- ing Systems	Particulates	0.018 grain/dry scf (0.029 mg/dry SCM)	Fabric filters

Not to exceed the amount given.  
When producing silicon metal, ferrosilicon, calcium silicon, or silico-manganese zirconium.  
When producing high carbon ferrochrome, charge chrome, standard ferromanganese, silicon carbide, ferrochrome silicone, ferromanganese silicon, or silvery iron.\$R

\$a

## **SbReferencesR**

1. Background Information for Proposed New-Source Performance Standards: Steam Generators, Incinerators, Portland Cement Plants, Nitric Acid Plants, Sulfuric Acid Plants. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. APTD-0711. 50 p.. August 1971.
2. Background Information for Proposed New Source Performance Standards: Asphalt Concrete Plants, Petroleum Refineries, Storage Vessels, Secondary Lead Smelters and Refineries, Brass or Bronze Ingot Production Plants, Iron and Steel Plants, Sewage Treatment Plants. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. APTD-1352a. 61 p.. June 1973.
3. Background Information for Standards of Performance: Primary Aluminum Industry Volume 1: Proposed Standards. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. 450/2-74-020a. 99 p.. October 1974.
4. Background Information for Standards of Performance: Electric Arc Furnaces in the Steel Industry Volume 1: Proposed Standards. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. 450/2-74-017a. 155p.. October 1974.
5. Background Information for Standards of Performance: Electric Submerged Arc Furnaces for Production of Ferroalloys Volume 1: Proposed Standards. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. 450/2-74-018a. 147 p.. October 1974.
6. Background Information for Standards of Performance: Phosphate Fertilizer Industry Volume 1: Proposed Standards. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. 450/2-74-019a. 119 p.. October 1974.
7. Background Information for Standards of Performance: Coal Preparation Plants Volume 1: Proposed Standards. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. 450/2-74-021a. 40 p.. October 1974.

Hazardous Air Substances. The costs of control (as measured by either the cumulative investment over a 10-year period or the annual costs) are relatively small for those industries controlling hazardous substances in comparison to the control costs for other industries. The industries affected by hazardous substances regulations are:

- Chlor-Alkali and Primary Mercury for mercury emissions
- The Asbestos industry for asbestos emissions
- Primary Beryllium for beryllium emissions.

#### Methods for Controlling Air Emissions from Stationary

Sources. The most common pollutants that industrial sources have to control are particulates and sulfur oxides. Of the thirty-nine industries evaluated in this report, twenty-two must control for particulates and nine must control for sulfur oxides.

1. Particulate Control Devices. In simplest terms, particulates are controlled by using electrostatic precipitators (ESP), scrubbers, or filters. The scrubbers are usually a wet process that generates a water effluent problem in the water medium. ESP and filters are usually dry processes insofar as the extraction of particulates from

the air is concerned, but plants often choose to dispose of the extracted particulates via a water stream. When this is done, a water problem is also created. Several of these intermedia impacts are dealt with in this report.

Plants often put several control devices in series or use various types of control devices within the category of scrubber. For example, a segment of the Primary Aluminum industry employs a primary collector (hoods and ducts), a wet ESP, and spray tower (scrubber) in series. Different segments of the Kraft pulp mill industry employ cyclonic scrubbers, Venturi scrubbers, and orifice scrubbers. The individual industry descriptions will explain the control techniques assumed in each case. These examples are provided here to highlight the intermedia problem and to place the control devices into some common categories that are easy to understand.

Electrostatic precipitators are employed for particulates that can be ionized and separated from a gas stream by electrical means. Scrubbers usually employ water to "wash" particles out of a gas stream. Filters are used to remove particles that can be trapped as the gas stream moves through a fabric media. Filters are gaining in application because the new fiberglass filters can be employed at very high temperatures (up to 550 F).

There are a group of miscellaneous control devices that also can be used for particulate reductions. These include afterburners, hoods, and building evacuation (where the building is sealed tight and workspace emissions are collected at vented locations).

2. Sulfur Oxide Control Devices. The most common control devices for sulfur oxides are scrubbers, absorbers, and acid plants. The scrubbers are of the amine, lime, limestone, or lime/limestone type. Often an acid plant (a control technique that recovers sulfuric acid from the sulfur gas) such as a Claus plant is used in conjunction with a scrubber to obtain a valuable byproduct that can be sold. Claus recovery plants must themselves be controlled with a tail-gas treatment facility.

3. Nitrogen Oxide Control Devices. The only industry for which nitrogen oxide is explicitly controlled in this report is the Nitric Acid industry. Nitric acid plants reduce nitrogen oxide emissions by employing catalytic reduction devices. In this method of control, the gas is treated with a catalytic reduction technique that uses natural gas, ammonia, or hydrogen. Use of natural gas dominates because of its lower costs and proven ability. However, the increasing shortages of natural gas could alter its use in the future.

4. Hydrocarbon Control Devices. Petroleum, Dry Cleaning, Paint Manufacture, Surface Coatings, and Printing are industries that must control hydrocarbon emissions. Petroleum storage controls tend to be handled by installing floating roofs on the storage tanks; this is almost always a profitable byproduct recovery process. Dry cleaning emissions will be reduced by switching material reports. Printing emissions are reduced by using thermal incinerators.
5. Carbon Monoxide Control Devices. The only industry in this report that treats carbon monoxide emissions is the Petroleum Industry. Carbon monoxide is burned along with hydrocarbons to form less noxious gases. This burning takes place in waste-heat boilers, and the energy generated in this burning is often used to economic advantage by the industry. In some existing refineries, the additional steam generated by these boilers cannot be used, but new plants can be designed to take advantage of this means of reducing their total energy requirement.
6. Pretreatment Options. Quite often, it is very efficient to reduce the emissions from a plant by changing fuels or making some kind of process change. Two cases where this is often practiced are the Steam Electric Power Plants and Dry Cleaning. As the summaries for these two industries show,

assumptions are made about the amount of fuel switching and solvent fluid used, respectively.

Industrial Descriptions and Assumptions. The industry summaries and assumptions are presented in the sequence listed in Table 3-4, and they describe each source in terms of the industry characteristics, emissions, control technology, and costs of control.

Table 3-4.  
 Industrial Sector Coverage for Air Pollution  
 Control Analysis of Stationary Sources

Sequence	Industry	\$t	Summary Page No.
1	Coal Cleaning		
2	Coal Gasification		
3	Natural Gas Processing		
4	Feed Mills		
5	Kraft Pulp Mills		
6	NSSC Mills		
7	Printing		
8	Mercury Cell Chlor-Akali		
9	Nitric Acid		
10	Paint Manufacture		
11	Phosphate Fertilizer		
12	Monfertilizer Phosphate		
13	Sulfuric Acid		
14	Petrochemicals		
15	Petroleum		
16	Ferroalloy		
17	Iron and Steel		
18	Iron Foundries		
19	Steel Foundries		
20	Primary Aluminum		
21	Secondary Aluminum		
22	Primary Copper		
23	Secondary Brass and Bronze		
24	Primary Lead		
25	Secondary Lead		
26	Primary Zinc		
27	Secondary Zinc		
28	Asbestos		
29	Asphalt Concrete		
30	Cement		
31	Lime Manufacture		
32	Clay Construction Products		
33	Surface Coatings		
34	Steam Electric Power Plants		
35	Solid Waste Disposal		
36	Sewage Sludge Incineration		
37	Grain Milling		
38	Dry Cleaning		
39	Industrial and Commercial Heating	\$R	

Note: Summary Page Numbers will be included in printed document.

## SCOAL CLEANING INDUSTRY\$R

Production Characteristics and Capacities. In 1972, which is the last year that Bureau of Mines data was available, the total production of bituminous and lignite coal in the United States was about 540 million metric tons. The annual production rate has gone both up and down in recent years, but the net change from 1968 to 1972 was an increase of about 9 percent. The 1972 production came from 4,879 mines. About 51 percent of the production came from underground mines, 46 percent from strip mines, and 3 percent from auger mines. The trend over recent years has been toward fewer mines and toward a greater dependence on strip mining. The number of underground mines has been decreasing, largely because of the strict regulations of the 1969 Coal Mine Health and Safety Act.

In the mining of coal, various inert materials and other impurities, such as pyritic sulfur, are recovered along with the coal. If these materials are present in sufficient quantity, they must be removed by coal cleaning. This cleaning process increases the heating value of the coal and reduces the amount of pollutants emitted when the coal is burned.

In strip mining where the coal seams are uncovered, the amount of impurities in the coal is relatively low, and only about 32 percent of the coal mined in this manner requires cleaning. In underground mining, the cutting and loading methods used lead to somewhat greater amounts of impurities, and about 67 percent of the coal mined in this manner requires cleaning. Overall, about 49 percent of the coal mined in this country is mechanically cleaned. In 1972, about 355 million metric tons of raw coal were cleaned, yielding about 266 million metric tons of cleaned coal. The amount of coal cleaning showed a net decrease of about 20 percent from 1968 to 1972; this decrease resulted from the increased use of strip mining (which requires less cleaning), and the increased shipments to electric utilities, who usually do not require cleaning. However, the amount of coal cleaning increased by about 8 percent between 1971 and 1972.

Mechanical coal cleaning involves methods similar to those used in the ore-dressing industries. About 96 percent of coal cleaning is done by wet-processing methods, with pneumatic or air cleaning methods being used for the other 4 percent. The dust abatement regulations of the Occupational Health and Safety Act will eventually cause a phasing out of pneumatic cleaning over the next few years.

About 18 percent of the coal which is cleaned by wet-processing methods is thermally-dried before being loaded. Drying is done to avoid freezing problems, to facilitate handling, to improve quality, or to decrease transportation costs. In 1972, there were 112 thermal drying plants in this country which processed about 48 million metric tons of coal. This represents an increase of about 11 percent from the previous year. During the same year the total number of coal cleaning plants decreased from 411 to 408, but the number of coal cleaning plants with driers increased from 103 to 112. In such drying plants, a significant source of pollution is the particulate emissions from the driers. To meet the new regulations on particulate emissions, venturi scrubbers (or the equivalent) must be installed.

The present turmoil in the related areas of energy supply and environmental protection makes the prediction of future growth trends in the coal industry rather uncertain. The basic factor inhibiting the rapid growth of coal production is the high sulfur content of most readily-available Eastern coals. The Western portion of the nation has large reserves of low sulfur coal but the high cost of transporting this coal to the Midwestern and Eastern markets has, at least until recently, precluded large scale use of this source. The alternative to the use of low sulfur coal is fine gas desulfurization technology, and an intensive effort is

currently being directed in this area. If the regulations on sulfur dioxide emissions from electrical power plants are adhered to and flue gas desulfurization technology lags, a slowing in the growth rate of coal could result. On the other hand, restrictions on imports of petroleum could accelerate the demand for coal.

Based on this background, a growth rate of 4 percent per year has been used for the coal cleaning industry, as well as the growth rate for the thermal drying of coal.

**Emission Sources and Pollutants.** The emissions of primary concern from coal cleaning plants are the particulates resulting from drying operations. The available data indicate that in 1971, only 1 percent of the coal drying capacity was equipped with devices capable of removing at least 99 percent of the particulate matter in the effluent gas. Another 87 percent of the capacity was equipped with low-energy cyclones which remove only about 90 percent of the particulate matter. In order to meet the new regulations, these cyclones will have to be replaced with the high-energy venturi scrubbers.

The uncontrolled emission levels were calculated from the emission factors for coal driers. The emission factors given by the EPA are 5.9 kilograms of particulates per

metric ton of coal dried for fluidized bed driers and 2.3 kilogram per metric ton for flash driers. Since the Bureau of Mines data indicate that 64 percent of the coal driers are fluidized bed units and the rest are various designs which should have emissions similar to flash driers, a weighted average emission factor of 4.6 kilogram of particulates per metric ton of dried coal was calculated.

The emissions at the 1972 control level are based on 90 percent particulate removal for 87 percent of the throughput, and 99.5 percent particulate removal for 1 percent of the throughput. In the state-by-state breakdown, this value has little meaning for the states with a small number of plants because in these cases, the extent of control may vary considerably from the national average values used in the calculations.

The "allowable" emissions are the values that apply if all throughput existing before January 1, 1974, just meets the appropriate State Implementation Plan level, and all throughput added after that date just meets the Federal New Source standard. The calculation of the allowable emissions for the plants existing in 1972 is detailed in Table 3-1-1. These emissions were adjusted to 1974 by adding 4 percent per year, which is equivalent to assuming that the growth in throughput over these two years occurred through new plants

having the same size distribution as the existing plants. Again, this could be considerably in error for some states but should be quite good for the national total.

Table 3-1-1.  
Coal Cleaning Industry Allowable Particulate Emissions

State	No. of Plants	Average Drying Rate		Allowable Particulate Emission kg/hr/ plant	Total metric ton/yr
		1,000 metric ton/yr	kkg/hr		
Alabama	1	1,137	129.8	16.4	158
Colorado	1	294	33.6	13.4	130
Illinois	9	722	82.6	23.2	2,018
Indiana	1	1,213	138.5	23.2	224
Kentucky	15	256	29.1	18.2	2,628
North Dakota	2	74	8.6	8.7	168
Ohio	4	289	33.1	18.2	701
Pennsylvania	13	388	44.5	-	675
Utah	2	327	37.2	-	580
Virginia	10	408	46.8	21.0	2,028
West Virginia	54	448	51.3	21.0	10,951
Totals	112				20,261

0.2 grains/.03 cubic meter gas  
85% control  
Assumed, since no general regulation was included in SIP.\$R

Control Technology and Costs. In most cases, the technology used for removing this particulate matter will be venturi scrubbers. If other technology is used for some of the driers, its cost should be comparable to the cost of venturi

scrubbers. so that a cost analysis based on venturi scrubbers should be valid.

A report by the Industrial Gas Cleaning Institute (IGCI) gives some cost information on venturi scrubbers for coal driers. This information and some calculations based on it are summarized in Table 3-1-2. Annualized control costs and industry operating data are detailed in Table 3-1-3.

**Table 3-1-2**  
**Coal Cleaning Industry Unit Cost Data**  
 on Wet Scrubbers  
 (In 1973 Dollars)  
 \$t

	Typical Plant 1	Typical Plant 2
Coal Drying Capacity (MT/Hr)	227	680
Gas Flow Rate (m <sup>3</sup> /min)	5.378	16.134
Particulate Removal (%)	99.64	99.84

Operating Cost Components:	No. Units	Cost (1,000 \$/yr)			No. Units	Cost (1,000 \$/yr)		
		Low	Medium	High		Low	Medium	High
Operating labor	125 hr/yr	0.63	0.88	1.25	125 hr/yr	0.63	0.88	1.25
Maintenance materials	2.45x10 <sup>3</sup> kWh/yr	2.39	2.66	2.93	8.13x10 <sup>3</sup> kWh/yr	6.47	7.19	7.91
Power	64.0x10 <sup>3</sup> kWh/yr	12.26	26.93	49.00	193x10 <sup>3</sup> kWh/yr	40.65	89.50	162.7
Process water	1/yr	2.55	4.24	5.94	1/yr	7.64	12.73	17.83
<b>Total O&amp;M Costs</b>		17.83	34.71	59.12		55.39	110.30	189.69

**Basis:** Industrial Gas Cleaning Institute report on Contract No. 68-02-0301 for EPA, 9/30/72. Values for two units given were averaged.

At 190 F and 14.16 psia.  
 Escalated from 1971 to 1973 using CE Plant Cost Index (= 132.2 in 1971; 144.1 in June 1973). \$R\$

\$aTable 3-1-3.  
Coal Cleaning Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (MT/Hr)	5,691.0	7,200.0	7,771.0		
Annual Growth Rate Over the Period 1971-85 = 10.32%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes (MT/Hr)</b>	<b>pollutants Generated</b>	<b>Control Technology</b>		
Model 1	31.94	Particulates	Venturi Scrubber		
Model 2	54.51	Particulates	Venturi Scrubber		
Model 3	101.22	Particulates	Venturi Scrubber		
Model 1 (new plants)	31.94	Particulates	Venturi Scrubber		
Model 2	54.51	Particulates	Venturi Scrubber		
Model 3	101.22	Particulates	Venturi Scrubber		
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
1971 Controls:					
Particulates	56.40	70.21	73.34		
Legislated Controls:					
Particulates	24.73	1.68	1.75		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	4.76	0.40	0.22	28.14	13.81
Total Annual	2.52	5.74	4.82	50.21	44.68
Capital	1.68	3.26	3.31	34.22	30.52
O&M	0.84	1.48	1.51	15.99	14.16

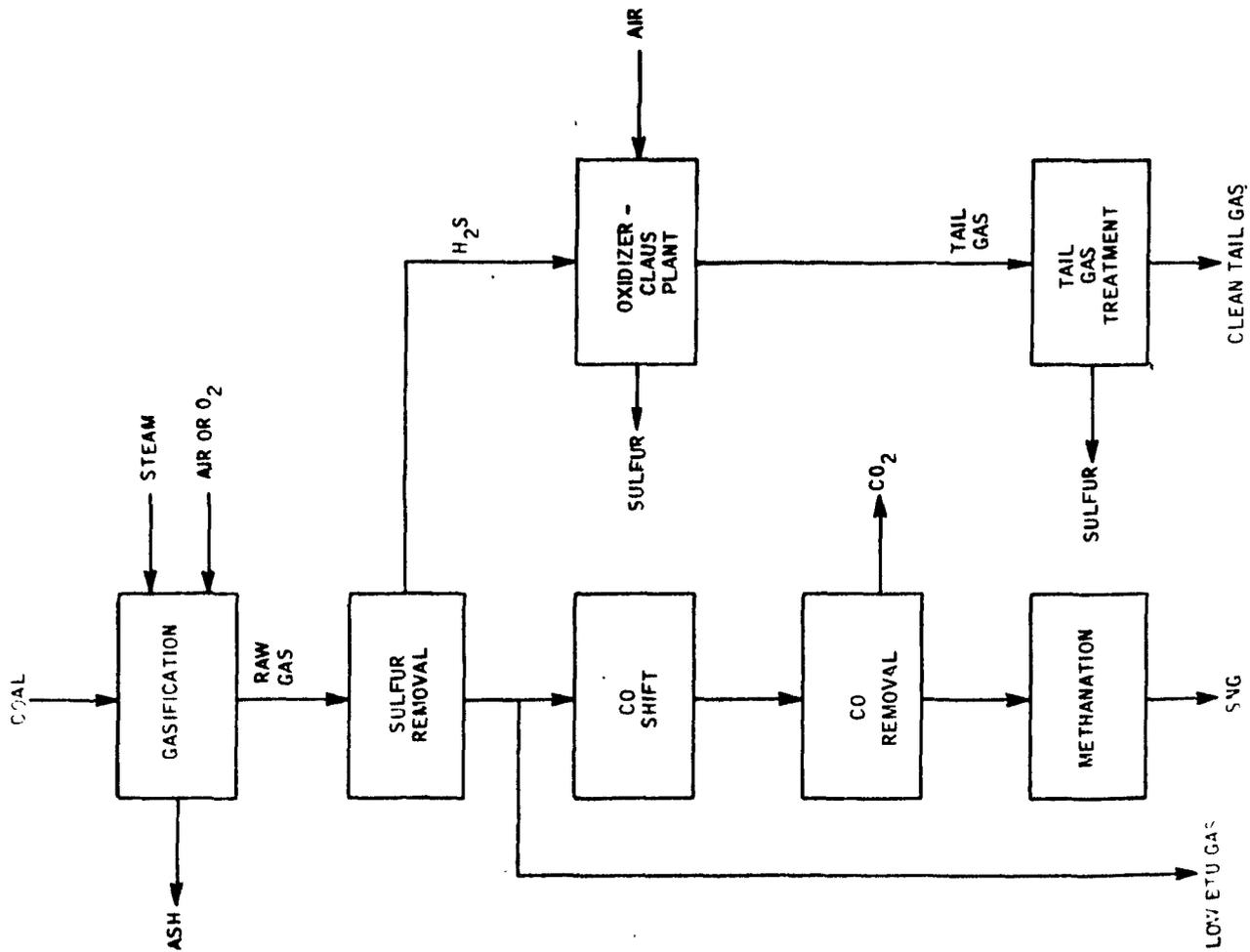
## SCOAL GASIFICATION INDUSTRY\$R

Production Characteristics and Capacities. One of the most pressing aspects of the current national energy problem is the present and projected shortage of natural gas. As a result of this shortage, a considerable number of projects are underway involving the manufacture of synthetic natural gas (SNG) from the heavier, more plentiful energy sources. Although SNG could be made from several energy sources, including coal, coke, and petroleum residuum, all of the present commercial plans are based on coal.

For some industrial applications, fuel gases that have a heating value which is considerably less than that of natural gas or SNG can be used. Whereas the primary constituent of natural gas is methane, the primary combustible components of the "low Btu" gases are hydrogen and carbon monoxide (see Figure 3-2-1). Coal gasification processes involve the reaction of coal with steam and oxygen to produce synthetic natural gas. Low Btu gases can be produced by substituting air for oxygen as a reactant.

Figure 3-2-1.  
Simplified Flow Diagram of Coal Gasification

2241  
2222



NOTE: H<sub>2</sub>S AND CO<sub>2</sub> ARE REMOVED TOGETHER AFTER THE CO SHIFT.

Production of both SNG and low Btu gas are expected to be rather extensive by 1985, even though commercial scale operations do not currently exist. However, projections of the amounts of synthetic fuel gases which will be produced at a given time in the future are subject to considerable uncertainty because of the general turmoil in the energy situation. Most plants that are expected to be in commercial operation by 1985 are already in the planning stages, and initial plants are expected to be in operation during the period 1977-78. Estimates of future production of synthetic fuel gases are provided below.

\$t

	(Million SCM/d)		
	1975	1980	1985
SNG	--	32.5	150
Low Btu	--	16.7	228

Report to Project Independence Blueprint, Task Force on Synthetic Fuels from Coal, September 13, 1974. Production figures derived by applying 90 percent utilization ratio to capacity estimates.

E. H. Hall, et al., EPA 600/2-74-001, February 1974.\$R

A total of 23 plants are expected to be producing SNG by 1985, representing a capacity of 167.2 million standard cubic meters per day (SCM/d); plant capacities will range from 2.4 to 9.12 million SCM/d. About 46 low Btu production plants are expected to be in operation by 1985, with the average plant size equivalent to approximately 5.47 million

SCM/d. Plant size distributions projected for 1985 are shown below.

Capacity Range 10 SCM/d	Number of Plants	Total Capacity of Plants in Capacity Range 10 SCM/d	Average Capacity 10 SCM/d
SNG			
< 7.6	2	5.06	2.5
7.6	19	144.4	7.6
> 7.6	2	17.9	8.94
Low Btu			
All sizes	46	252.3	5.44\$R

Emission Sources and Pollutants. Coal contains varying amounts of sulfur (from less than 1 to 7 percent). Essentially all sulfur contained in coal is converted into gaseous species (i.e. H<sub>2</sub>S) during the gasification process. These gases can be removed by a two-step process which involves (1) the concentration of H<sub>2</sub>S through an amine scrubbing process and (2) the conversion of the H<sub>2</sub>S to elemental sulfur via a Claus sulfur recovery plant. The Claus sulfur recovery process is currently widely practiced by petroleum refiners and natural gas processors. Approximately 95 percent of the sulfur in coal is removable by Claus plants. However, the remaining 5 percent escapes from the Claus unit (tail gas) in the form of various sulfur oxides (mostly sulfur dioxide) and must be controlled with

tail gas scrubbing to reduce sulfur dioxide emissions to acceptable levels.

The emissions of sulfur oxides from the Claus plants were calculated by assuming that all the sulfur in coal goes into the gas and 95 percent of this sulfur is recovered by the Claus plant. The sulfur dioxide emission levels for year 1985 are as follows:

Type of Gas	\$t (1,000 Metric Tons/Year)	
	Without Treatment	With Treatment
Synthetic natural gas	130.4	13.0
Low Btu gas	18.1	1.8
Totals	148.5	14.8SR

The corresponding emission factors without tail gas treatment, in metric tons of sulfur dioxide per billion standard cubic meters of gas, are 88.41 for synthetic natural gas and 6.60 for low-Btu gas. The installation of tail gas treatment facilities is assumed to reduce sulfur dioxide emissions by 90 percent.

**Control Technology and Costs.** It is assumed that the cost of bulk sulfur removal from a coal gasification plant is not a cost associated with the Clean Air Act of 1970 but is a

standard practice partially induced by the byproduct value of elemental sulfur. In other words, even before the Clean Air Act was passed, coal gasification would have had a Claus plant for bulk sulfur removal. The additional facility which is attributable to the Clean Air Act is the tail gas treatment plant. The situation here is analogous to that for natural gas plants which process gas containing significant amounts of H<sub>2</sub>S. Even before the Clean Air Act, these plants did not have tail gas treatment facilities nor do they have them now. The investment and operating costs for tail gas treatment plants were developed in conjunction with the Cost of Clean Air sections on petroleum refining and natural gas processing.

Since a Claus plant normally recovers about 95 percent of the sulfur fed to it and the tail gas treatment facility recovers about 90 percent, the combined recovery for both units operating together is about 99.5 percent. The credit for the additional sulfur recovered by the tail gas treatment plant is calculated by assuming a price of \$10-\$15 per ton of sulfur.

Investment and annual operating and maintenance costs for selected model-sized coal gasification plants, and total industry costs for controlling sulfur dioxide from plants

expected to come on stream between 1977 and 1985 are given  
in Table 3-2-1.

Table 3-2-1.  
Coal Gasification Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (MT/Day)	0	748.0	2,120.0		
Annual Growth Rate Over the Period 1978-85 = 114.6%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes (10 SCM/Day)</b>	<b>Pollutants Generated</b>	<b>Control Technology</b>		
SNG	70.210.247	Sulfur Oxides	Claus Plant: Tail Gas Treatment		
Low BTU Gas Plants	11.2	Sulfur Oxides	Claus Plant: Tail Gas Treatment		
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
1971 Controls:					
Sulfur Oxides	0	1.495	4.315		
Legislated Controls:					
Sulfur Oxides	0	1.555	4.467		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	-	14.86	11.16	120.36	120.36
Total Annual Capital	-	8.41	26.25	122.30	120.30
O&M	-	3.59	15.82	68.23	68.23
	-	4.82	10.43	53.07	53.07

## \$CNATURAL GAS INDUSTRY\$R

Introduction Characteristics and Capacities. The natural gas industry may be viewed as having two major sectors:

production and transmission/distribution. The production sector is dominated by large firms, but a large number of smaller firms do contribute a sizable share of the total output. The transportation/distribution sector is primarily organized as public utility companies which operate under Federal and/or state regulations. Although many gas utility companies are now integrating back into production, the basic structure of the industry remains as described here.

As of January 1, 1974, the 763 natural gas processing plants in the United States had a total capacity of 2.11 billion cubic meters per day. The actual production rate of these plants in 1973 was 1.57 billion cubic meters per day. For each of the last two years, the natural gas production rate has decreased slightly. The rate of change in production rate since 1967 has been at an increase of only about 4 percent per year. Most projections of natural gas supply assume little or no increase over the next several years. Hence, a constant production rate was used in this study.

The production of petroleum (crude oil) is almost always associated with the production of substantial quantities of

natural gas. The distinction between "oil wells" and "gas wells" is an arbitrary one based on the ratio of oil-to-gas produced. Natural gas is primarily methane, but the raw gas contains varying amounts of heavier hydrocarbons and other gases, such as carbon dioxide, nitrogen, helium, and hydrogen sulfide. In order to obtain a natural gas of pipeline quality, much of these undesired components must be removed. The heavier hydrocarbons, which can be conveniently condensed, are combined with the liquid (oil) production and sent to refineries for further processing; the remaining gas is normally purified at the well site.

**Emission Sources and Pollutants.** Hydrogen sulfide is the impurity of concern from an air pollution standpoint. Because of the corrosive, poisonous, and odorous nature of hydrogen sulfide, only very low concentrations of it are permitted in the natural gas product. Approximately 5 percent of the natural gas produced in the United States requires some form of treatment to remove hydrogen sulfide. The hydrogen sulfide content of natural raw gas varies from trace quantities to over 50 percent by volume.

Although removal of the hydrogen sulfide from natural gas is universally practiced, recovery of the corresponding sulfur in elemental form to avoid air pollution is not universally practiced. In many of the larger operations, Claus plants

have been installed for this purpose, but in many plants the hydrogen sulfide is merely incinerated and flared, resulting in emissions of sulfur oxides.

For the natural gas plants which have Claus plants, the source of the sulfur oxides emitted is the Claus plant tail gas. The amount of this emission corresponds to about 6 percent of the sulfur fed to the Claus plant, as estimated from the capacities of the Claus plants associated with natural gas plants. For the natural gas plants which do not have Claus plants, the sources of the sulfur oxides emitted are the flares in which the hydrogen sulfide removed from the gas is burned. The only available estimate of the emission from such plants which was made by EPA in 1972, was 852,000 metric tons of sulfur dioxide per year.

**Control Technology and Costs.** Because of the severe limitations on the hydrogen sulfide content of pipeline gas, all natural gas processing plants that handle the sour gas already have the amine scrubbing facilities or equivalent to remove it from the raw gas. The technology needed to prevent hydrogen sulfide from causing air pollution consists of:

- A Claus sulfur plant in which the hydrogen sulfide is converted to elemental sulfur.

- Treatment facilities to remove sulfur dioxide from the Claus plant tail gas.

The investment and operating costs for these processes were discussed in the section on refinery fuel gas burning; the credit for the byproduct sulfur obtained with these processes was also discussed in that section.

In 1973, there were 84 Claus plants in the natural gas processing industry. These plants had a total sulfur capacity of 6,249 metric tons per day, and an actual production rate of 2,443 metric tons per day. The gas throughput associated with this sulfur recovery was 36 million cubic meters per day, or only about 2 percent of the total natural gas production.

Annualized control costs and industry quality data are detailed in Table 3-3-1.

SdTable 3-3-1.  
Natural Gas Processing Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (1,000 MT/Yr)	2,467.0	2,793.0	3,031.0		
Annual Growth Rate Over the Period 1971-85 = 1.88%					

PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Day)	Pollutants Generated	Control Technology
Model 1	5.88	Sulfur Dioxide	Scrubber
Model 2	34.31	Sulfur Dioxide	Scrubber
Model 3	272.81	Sulfur Dioxide	Scrubber
Model 4	5.88	Sulfur Dioxide	Scrubber and Claus Unit
Model 5	34.31	Sulfur Dioxide	Scrubber and Claus Unit
Model 6	272.81	Sulfur Dioxide	Scrubber and Claus Unit

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Sulfur Oxides	1,348.37	1,468.41	1,536.00		

Legislated Controls:	Sulfur Oxides	1975	1980	1985	1971-85	1976-85
		553.58	9.83	10.46		

CONTROL COSTS (Million 1975 \$)	Investment	1975	1980	1985	1971-85	1976-85
		27.20	4.34	1.99	149.07	51.09
Total Annual Capital O&M		29.19	43.18	46.58	451.20	385.32
		12.88	18.39	19.60	171.53	141.87
		16.31	24.79	26.98	279.67	243.45

## SCFEED MILLS INDUSTRY\$R

Production Characteristics and Capacities. Feed manufacture is the process of converting the grain and other constituents into the form, size, and consistency desired in the finished feed. Feed milling involves the receiving, conditioning (drying, sizing, cleaning), blending, and pelleting of the grains, and their subsequent bagging or bulk loading.

As of July 1, 1974, the number of existing feed mills was estimated at 7,866 plants, with a total capacity of 148 million metric tons per year. For this report, these have been grouped into the size categories as shown in Table 3-4-1.

Table 3-4-1.  
Feed Mills Industry Production Capacities

Size Range (metric tons/day)	No. Mills	Capacity (million metric tons/year)	Total Capacity (%)	Mill Model Size
0-44	4,170	47	31.8	
45-90	2,790	70	47.3	
91-136	906	23	20.9	

Based on operating 40 hours per week and 50 weeks per year.\$R

Emission Sources and Pollutants. The primary emissions from feed manufacture are particulates, especially dust. The

factors affecting emissions include the type and amount of grain handled, the degree of drying, the amount of liquid blended into the feed, the type of handling (conveyor or pneumatic), and the degree of control. An indication of the relative ranking of emission sources in a typical feed mill are:

St Mill Operations	Particulates Generated(%)
Rail unloading	25
Collectors for product recovery dust control	21
Truck unloading	15
Truck loading (bulk loadout)	11
Bucket elevator leg vents	5
Bin vents	5
Scale vents	3
Grinding system (feeder, spills)	4
Incinerator (Waste paper)	2
Small boiler (oil)	1
Rail car loading (bulk loadout)	1
Miscellaneous (conveying spouts, pellet mills, feeder lines)	7
Total Feed Mill Dust Emission	100\$R

Unloading of bulk ingredients is generally acknowledged to be one of the most troublesome dust sources in feed mills. Centrifugal collectors used for product recovery and dust control represent the second largest emission source.

Factors affecting emission rates from the ingredient receiving area of a feed mill include the type of grain and other ingredients handled, the methods used to unload the ingredient, and the configuration of the receiving pits.

Control Technology and Costs. It is estimated that 88.1 percent of the volume handled in pellet-cooler operations and 56 percent of the volume handled in grinding operations have some type of emission control, largely the use of cyclones. In receiving, transfer, and storage operations, roughly one-third of the total volume is controlled by either cyclones or fabric filters, while shipping has only a few installations that have installed controls.

Table 3-4-2 shows the estimated sales, capacity, and emissions for the feed mills industry up to the year 1985. The table also shows the costs of controls on an annualized investment and cash requirements basis.

\$dTable 3-4-2.  
Feed Mills Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (Million MT/Yr)	117.97	150.56	192.16		
Annual Growth Rate Over the Period 1971-85 - 5%					
PROCESS CHARACTERISTICS					
	Model Plant Sizes (MT/Day)	Pollutants Generated	Control Technology		
Feed Mills	40.90, 140	Particulates	Fabric Filter		
EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	1,024.48	1,192.54	1,353.32		
Legislated Controls:					
Particulates	423.55	24.54	27.87		
CONTROL COSTS (Million 1975 \$)					
Investment	395.69	81.91	36.55	2,074.43	938.40
Total Annual Capital	204.07	341.61	381.55	3,788.70	3,340.91
OpM	149.36	247.38	272.73	2,735.27	2,409.33
	54.71	94.23	108.82	1,053.43	931.58\$

**SKRAFT PULP INDUSTRY\$R**

Production Characteristics and Capacities. The kraft pulp industry process mill size distributions are shown in Table 3-5-1. Control cost estimates are based on the "model plant" range size of 454, 907, and 1,361 ADMT/day.

Table 3-5-1  
Kraft Pulp Mill Size Distributions  
\$t

Range of Mill Capacities (ADMT/day)	Number of Mills	Total Cap. of Mills in Size Range (ADMT/day)	Average Mill Capacity (ADMT/day)	Model Mill Capacity (ADMT/day)
0-77	71	31,809	448.0	454
771-1088	29	24,675	850.9	907
1089-2359	25	33,736	1349.4	1361
Totals	125	90,220		

Sources: Publishing Co., Inc. "Lockwood's Directory of the Paper and Allied Trades", 97th Edition, New York, 1973; Paper Processing, August, 1974, p.36; Pulp and Paper. "Profiles of the North American Pulp and Paper Industry", June 30, 1974, p.27.\$R

Conventional kraft pulping processes are highly alkaline in nature and utilize sodium hydroxide and sodium sulfide as cooking chemicals. One modification used for the preparation of highly purified, or high-alpha cellulose, pulp utilizes an acid hydrolysis of the wood chips prior to the alkaline cook; this is the prehydrolysis kraft process. Kraft processes enjoy the advantages of being applicable for

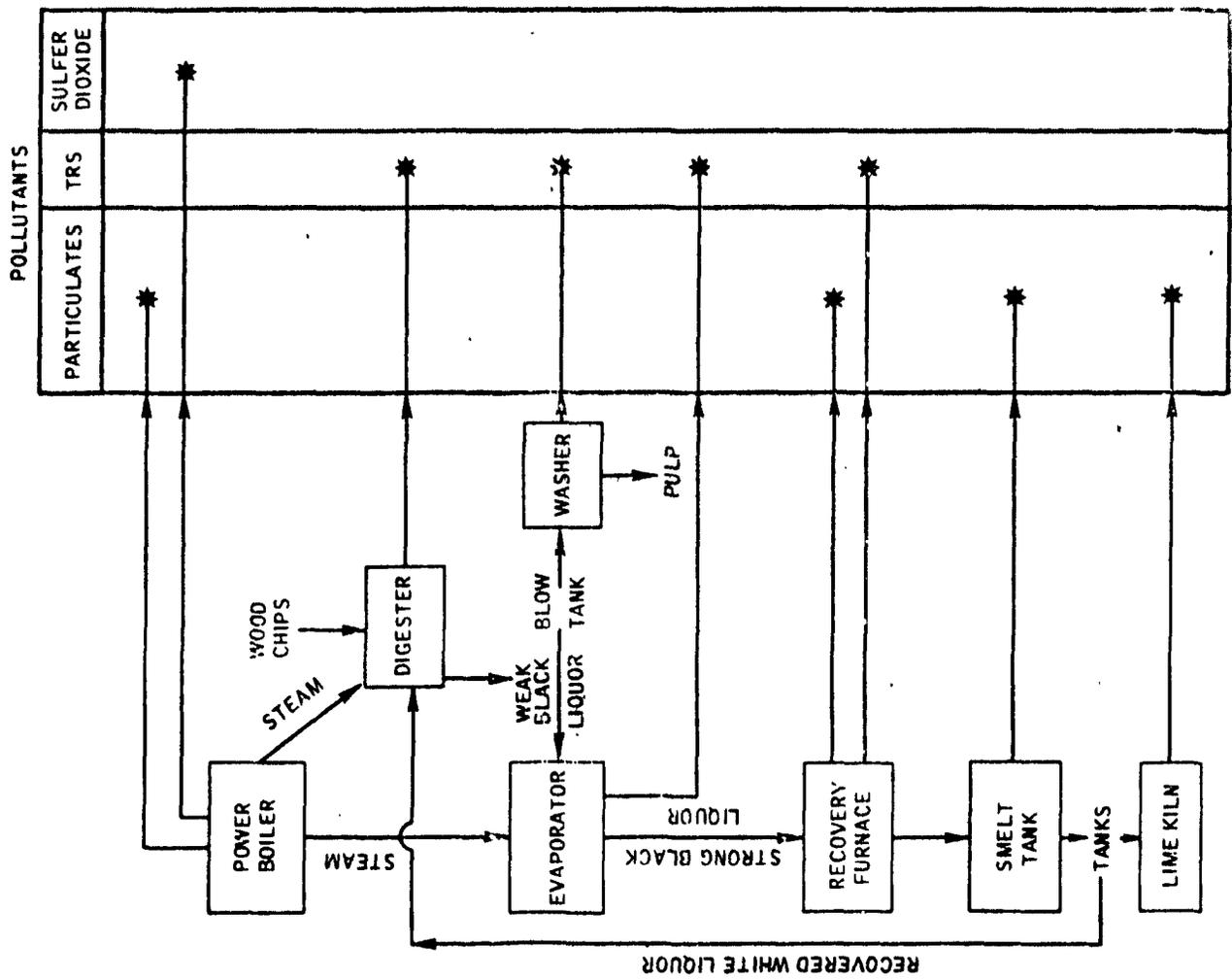
nearly all species of wood and of having an effective means of recovery of spent cooking chemicals for reuse in the process.

Kraft pulping, in simplified terms, consists of seven separate processes, as shown in Figure 3-5-1. The digesting liquor in this process flow is a solution of sodium hydroxide and sodium sulfide. The spent liquor (black liquor) is concentrated, then sodium sulfate is added to make up for chemical losses, and the liquor is burned in a recovery furnace, producing a smelt of sodium carbonate and sodium sulfide. The smelt is dissolved in water to form green liquor, to which is added quicklime to convert the sodium carbonate back to sodium hydroxide, thus reconstituting the cooking liquor. The spent lime cake (calcium carbonate) is recalcined in a rotary lime kiln to produce quicklime (calcium oxide) for recausticizing the green liquor.

Figure 3-5-1. Kraft Pulp Mill Production Processes

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Included in the uses of kraft pulp are the production of linerboard, solid-fiber board, high-strength bags, wrapping paper, high-grade white paper, and food-packaging materials.

**Emission Sources and Pollutants.** Main emission sources in the draft process are the recovery furnace, lime kiln, smelting dissolving tank, and the power boilers. The kraft pulping economics depend upon reclamation of chemicals from the recovery furnace and lime kiln. Hence, emissions from these processes are controlled to minimize losses of chemicals.

Particulates and gases are emitted from the various sources of kraft process. Numerous variables affect the quality and quantity of emission from each source of the kraft pulping process. There are several sources of emissions in the process and the applicable control technology and attainable efficiencies of the control methods depend on the quantity and quality of emissions. The gaseous emissions occur in varying mixtures, and are mainly hydrogen sulfide, methyl mercaptan, dimethyl sulfide, dimethyl disulfide, and some sulfur dioxide. The sulfur compounds are generally referred to as reduced sulfur compounds. These compounds are very odorous, being detectable at a concentration of a few parts per billion. The particulate emissions are largely sodium sulfate, calcium compounds, and fly ash.

The rates of uncontrolled and controlled emissions of particulate, total reduced sulfur (TRS), and sulfur dioxide from various sources of kraft pulping processing in 1974 were as shown in Table 3-5-2.

Table 3-5-2.  
Rates of Emissions from Kraft Process

Process	\$t		
	Particulates (kg/ADMT)	TRS (kg/ADMT)	Sulfur Dioxide (kg/ADMT)
Uncontrolled			
Digester	0.0	0.72	Trace
Washer	0.0	0.05	Trace
Multiple Effect Evaporator	0.0	0.18	Trace
Recovery Furnace	60.0	2.95	1.2
Smelt Tank	7.8	0.05	Trace
Lime Kiln	34.0	0.22	Trace
Power Boiler	35.3	0.0	19.7
Totals	137.1	4.17	20.95R
Controlled			
\$t			
Digester	0.0	Trace	Trace
Washer	0.0	Trace	Trace
Multiple Effect Evaporator	0.0	Trace	Trace
Recovery Furnace	2.00	0.25	1.2
Smelt Tank	0.25	Trace	Trace
Lime Kiln	0.50	Trace	Trace
Power Boiler	2.47	0.0	10.5
Totals	5.22	0.25	11.7

Fuel requirement = 3.09 x 10 Btu/ADMT. Coal provides 35%, oil 27%, gas 26%, and bark/wood 12% of the energy. Heating values = coal 13,000 Btu/lb, oil 150,000 Btu/ft<sup>3</sup>, and bark/wood 4,500 Btu/f. Sulfur content = coal 1.9% and oil 1.8%. Ash content = coal 8.1% and bark/wood 2.9%.

The process weight-emission limitation concept is considered unapplicable to chemical pulping because the nature and size range of particulates, as well as the characteristics of the processes, are vastly different. Provisions of the Washington and Oregon Regulations applicable to pulp mills are used in this report. The regulations include the following control provisions:

1. Total reduced sulfur (TRS) compounds from the recovery furnace: No more than 1 kg/ADMT (1972) reduced to no more than 0.25 kg/ADMT by 1975.
2. Noncondensable gases from the digesters and multiple effect evaporators: Collected and burned in the lime kiln or proven equivalent.
3. Particulates from the recovery furnace: No more than 2 kg/ADMT.
4. Particulates from the lime kiln: No more than 0.5 kg/ADMT.
5. Particulates from smelt tank: No more than 0.25 kg/ADMT.

6. Emissions from power boiler will meet the Federal emission standard.

Control Technology and Costs. The cost estimates for kraft pulping take into account the costs associated with each constituent process. The mill size categories, emissions, and control technologies that have been assumed for each process are shown in Table 3-5-3. This table also presents the total annual emissions and costs estimated for the kraft pulping industry in 1975, 1980, and 1985. The estimated costs of air pollution control are significantly higher than previous estimates because the costs to control TRS and sulfur dioxide were not estimated earlier.

The costs per pollutant controlled are estimated to be:

\$t	Millions	%
Particulates	\$620	30
Total Reduced Sulfur (TRS)	\$530	26
Sulfur Oxides	\$912	44
Totals	\$2062	100%

\$dTable 3-5-3.  
Kraft Pulp Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (1,000 ADMT/Yr)	80.332	110.051	129.306		
Annual Growth Rate Over the Period 1971-85 = 5.4%					
(These are sequential processes; that is, a unit of pulp must go through each of these processes to be manufactured.)					
PROCESS CHARACTERISTICS	Model Plant Sizes (ADMT/day)	Pollutant Generated	Control Technology		
Digester Stock Washer	454; 907; 1,361	TRS TRS	Incinerate in Lime Kiln Incinerate in Recovery Furnace		
Evaporator Recovery Furnace Sweil Tank Lime Kiln Power Boiler		TRS TRS, Particulates Particulates Particulates Particulates, Sulfur Dioxide	Incinerate in Lime Kiln ESP & Venturi Scrubber Onifice Scrubber Venturi Scrubber ESP & Double Alkali Scrubber		
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
<b>1971 Controls:</b>					
Particulates	518.53	715.19	842.62		
Sulfur Oxides	35.43	48.87	57.58		
<b>Legislated Controls:</b>					
Particulates	263.23	122.28	143.61		
Sulfur Oxides	35.80	48.95	57.49		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	421.29	87.50	45.70	2,835.04	1,304.81
Total Annual Capital O&M	394.62 187.64 206.98	716.58 327.57 389.01	819.20 360.44 453.76	7,789.58 3,539.52 4,250.06	6,912.61 3,114.45 3,798.16\$

**SEMINEUTRAL SULFITE SEMICHEMICAL PAPER INDUSTRY**

**Production Characteristics and Capacities.** The size distribution of neutral sulfite semichemical (NSSC) pulp mills is classified into three size ranges: 0-181, 182-363, and 364-635 air-dried metric tons (ADMT) of air-dried pulp per day. The number of plants in each size range and their capacities are:

\$t Capacity Range (ADMT/day)	No. Mills	Capacity (ADMT/day)	Average Mill Capacity (ADMT/day)	Model Mill Capacity (ADMT/day)
0 - 181	23	2,488	108	113
182 - 363	24	5,455	227	277
364 - 635	8	3,376	422	454
<b>Totals</b>	<b>55</b>	<b>11,319</b>		

**Sources:** Paper Processing, August 1974; p.36; Hendrickson, E.R., Roberson, J.E., and Koogler, J.E., "Control of Atmospheric Emissions in the Wood Pulping Industry", PB-190352, Environmental Engineering, Inc. and J.E. Sirrine Company, March 15, 1970.

Semichemical pulps are produced by digesting with reduced amounts of chemicals, followed by mechanical treatment to complete the fiber separation. The most prevalent semichemical pulping process is the neutral sulfite semichemical process. In this process, sodium sulfite in combination with sodium bicarbonate, or ammonium sulfite buffered with ammonium hydroxide, are used as cooking

chemicals. These cooks are slightly alkaline in contrast to the highly alkaline kraft, and highly or moderately acidic sulfite cooks. The semichemical pulping processes are used for production of high yield pulps ranging from 60 to 85 percent of dry wood weight charged to the digestion vessel, and can include kraft and sulfite processes suitably modified to reduce pulping action in order to produce higher-than-normal yield pulps.

Semichemical pulps are used in the preparation of corrugating medium, coarse wrapping paper, linerboard, hardboard, and roofing felt, as well as fine grades of paper and other products.

Emission Sources and Pollutants. Discussions and calculations of air emissions from the NSSC process are limited to particulate and sulfur dioxide. The used cooking liquors are discharged to sewers or in some cases they are evaporated and cross-recovered with an adjacent kraft mill or treated in a fluidized-bed system. In this study, the fluidized-bed combustion was assumed for the liquor treatment. The uncontrolled emissions from NSSC pulping would be as follows:

Process	Particulate (kg/ADMT)	Legislated 1971 Controls	Sulfur Dioxide (kg/ADMT)	Legislated Controls
Recovery Furnace	20.0	2.0	0.01	0.01
Power Boiler	35.3	2.47	19.7	10.5
<b>Totals</b>	<b>55.3</b>	<b>4.47</b>	<b>20.71</b>	<b>10.51</b>

Source: Atmospheric Emissions from the Pulp and Paper Manufacturing Industry - Report of NCASI - EPA Cooperative Study Project, Technical Bulletin No. 69, February 1974. \$R

Control Technology and Costs. This report assumed that particulate emissions from the recovery furnace and power boilers burning coal and bark/wood, and sulfur dioxide emission from power boilers burning high sulfur coal and oil were subject to control. To meet the particulate emissions standard from recovery furnaces, a control efficiency of at least 90 percent is required for the control system. A sodium-based, double alkali system was assumed for the control of sulfur dioxide from coal and oil burning power boilers.

Control methods for new plants were selected as follows:

\$tProcess	Pollutant	Control Methods
Recovery Furnace	Particulate	Electrostatic Precipitator
Power Boiler	Particulate Sulfur Dioxide	Electrostatic Precipitator Double alkali\$R

All new plants were assumed to be in the 364 to 635 ADMT/day capacity range.

Table 3-6-1 shows the estimated future sales, output, and capacity of NSSC pulp mills. The emissions statics are also shown, along with the three major cost categories, i.e. annualized, investment, and cash requirements.

The costs estimated in this report are nearly ten times those reported earlier since previous estimates did not include the cost of controlling sulfur oxides.

\$dTable 3-6-1.  
Neutral Sulfite Semichemical Paper Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (Million ADMT/Yr)	3.96	5.41	6.31		
Annual Growth Rate Over the Period 1971-85 = 5.2%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Size (ADMT/Day)</b>	<b>Pollutants Generated</b>	<b>Control Technology</b>		
Boiler	38, 80, 150	Particulates, Sulfur Dioxide	ESP, Double Alkali		
Recovery Furnaces	38, 80, 150	Particulates	ESP		
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
1971 Controls:					
Particulates	21.60	29.77	34.86		
Sulfur Oxides	2.12	2.93	3.43		
Legislated Controls:					
Particulates	9.17	0.98	1.14		
Sulfur Oxides	2.15	2.94	3.43		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	8.47	14.89	8.17	312.46	128.99
Total Annual	54.34	91.06	104.28	1,029.81	882.09
Capital	24.58	37.76	44.44	430.61	367.32
O&M	29.76	53.30	59.84	599.20	514.77\$s

## SCPRINTING INDUSTRY\$R

Production Characteristics and Capacities. Six major types of printing establishments were considered in this report: book printing and publishing; commercial printing by letterpress; commercial printing by lithography, and commercial printing by gravure. Newspapers were excluded because inks containing little, if any, volatile solvents are employed. Nearly 27,000 establishments comprise the six groups; 80 percent of these are small, employing fewer than 20 people.

Estimates of air pollution abatement costs were based on the application of controls (thermal incinerators) by the 50 largest establishments in each of the first five categories. Periodical and book plants accounted for about 70 percent of the annual volume of ink consumed, which amounted to about 18 million kilograms per year or 181.6 kilo-kilograms per plant annually.

Both commercial letterpress and lithography represent a large number of smaller establishments, about 13,000 and 8,000 facilities, respectively. While the 50 largest establishments in each of the categories comprise 40 percent and 25 percent of the annual volume of ink consumed, respectively, they tend to use web-processing techniques

exclusively, which are a primary contributor to hydrocarbon emissions. Virtually all volatile components (approximately 40 percent by weight) of the ink are driven off during the drying or curing stage of the web printing process.

All commercial gravure printers also use the web printing methods. There were 127 establishments in 1972 representing about 114 million kilograms of ink usage.

In summary, cost estimates were derived on the basis of applying controls to 327 establishments corresponding to an average plant size of 499 metric tons of ink consumed per year.

Emission Sources and Pollutants. Atmospheric hydrocarbon emissions associated with printing are attributable to the volatile organic components of the various types of inks employed. The volatile content ranges from about 40 percent (heat-set letterpress, lithographic, and screen process inks) to more than 60 percent for flexographic and gravure. The percentage of the volatile content released to the atmosphere can vary widely in the absence of controls. For purposes of this report, full volatilization is assumed without control. On this basis, an average-sized establishment that consumes approximately 499 metric tons of ink annually will generate about 204 metric tons of

hydrocarbon emissions per year. Total uncontrolled emissions for the plants considered would amount to approximately 67,000 metric tons annually.

Control Technology and Costs. Suitable controls (thermal incinerators) provide about 95 percent removal efficiency. Hence, total 1975 emissions, assuming full compliance, would be reduced to approximately 3,356 metric tons. Thermal incineration with heat exchange units could be employed to achieve desired levels of hydrocarbon emission control. Although carbon absorption techniques present advantages because of the possibility of solvent regeneration, they are difficult to apply to printing because inks often consist of a mixture of volatile solvents, making subsequent separation steps necessary.

Capital and annual operating and maintenance costs were estimated on the basis of applying a control unit designed to handle approximately 109 kilograms of hydrocarbon emissions per hour (or about 227 metric tons per year). Installation and equipment, including heat exchanger, are approximately \$70,000 for such a unit. Operating costs are about \$16,000 per year. Annualized control costs and industry operating statistics are detailed in Table 3-7-1.

Table 3-7-1.  
Printing Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (MT/Yr)	163.36	224.02	263.83		
Annual Growth Rate Over the Period 1971-85 = 5.28%					
PROCESS CHARACTERISTICS	Model Plant Sizes (Metric Tons)	Pollutants Generated	Control Technology		
Commercial Printing - Letterpress and Lithography	550	Hydrocarbons	Thermal Incinerators		
EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Hydrocarbons	99.36	137.23	161.91		
Legislated Controls:					
Hydrocarbons	100.13	137.07	8.07		
CONTROL COSTS (Million 1975 \$)					
Investment	5.18	2.72	0.79	43.91	21.34
Total Annual Capital O&M	6.61 3.67 2.94	12.22 6.37 5.34	13.45 7.15 6.30	126.74 69.01 5.73	111.70 60.43 51.275s

## SECHEM-ALKALI MERCURY CELLS INDUSTRY

Production Characteristics and Capacities. High-purity caustic soda and chlorine are coproducts in the electrolytic process which uses flowing mercury metals as a moving cathode. The caustic soda product finds major markets in those chemical manufacturing operations where high-purity and freedom from sodium chloride and metal impurities are in demand. Of the two basic processes, e.g., mercury cell and diaphragm cell for producing chlorine, only the one employing the mercury cell results in mercury emissions. Chlorine is produced almost entirely by the electrolysis of fused chlorides for aqueous solutions of alkali-metal chlorides. Chlorine is produced at the anode, while hydrogen and potassium hydroxide or sodium hydroxide derive from processes taking place at the cathode. Anode and cathode products must be separated, such as in a cell which employs liquid mercury metal as an intermediate cathode.

The use of the mercury cell in the United States has grown from 5 percent of the total installed chlorine capacity in 1946 toward a maximum of 28 percent of the installed chlorine capacity through 1968. Current capacity is estimated at 7,863 metric tons of chlorine per day at 31 plants. However, there are indications that the number of

operating plants in 1975 may be as few as 28. The size distribution of these plants is given below:

Number of Plants	Capacity Range (Chlorine Production) Metric Tons/Day
5	0 - 90.7
10	90.8 - 181
8	182 - 272
5	273 - 454
3	455 - 580
31	

31\$R

Emission Sources and Pollutants. The major sources of direct emissions of mercury to the atmosphere are the hydrogen by-product stream, end-box ventilation system, and cell-room ventilation air. The minimum known treatment of the byproduct hydrogen gas that leaves the decomposer consists of cooling the stream to 110 F followed by partial removal of the resulting mercury mist. For hydrogen saturated with mercury vapor at this temperature, the daily vapor loss is estimated to be 3.4 kg of mercury vapor per 100 metric tons of chlorine produced. The entrainment of condensed mercury in the hydrogen stream will result in additional emissions. The estimated uncontrolled emission of mercury vapor and mercury mist, after minimum treatment has occurred, is estimated to be up to 25 kg per 100 metric tons of chlorine produced.

Mercury vapor and mercury compounds are collected from the end-boxes, the mercury pumps, and the end-box ventilation system. Preliminary results of source testing by EPA indicate that the mercury emissions from an untreated or inadequately treated end-box ventilation system range from 1 to 8 kg per 100 metric tons of chlorine produced.

In addition to cooling the cell room, the cell-room ventilation system provides a means of reducing the cell-room mercury-vapor concentration to within the recommended Threshold Limit Value (TLV) for human exposure to mercury vapor. On the basis of data obtained from operating plants, it has been estimated that mercury emissions from the cell-room ventilation system vary from 0.2 to 2.5 kg per day per 100 metric tons of daily chlorine capacity, assuming a concentration equal to the TLV of 50 micrograms per cubic meter of ventilation air.

The Environmental Protection Agency has estimated that uncontrolled emissions from the production of chlorine in mercury cells averages approximately 20 kg of mercury per 100 metric tons of chlorine produced. On this basis, mercury emissions for 1975 are estimated to be 490 metric tons without further controls. With further controls emissions will be reduced to approximately 24 metric tons

Control Technology and Costs. Control technologies and cost estimates are based on the consideration that the maximum daily mercury emission from any single site shall not exceed 2,300 grams; this assumption is in compliance with the National Emissions Standards for Hazardous Air Pollutants promulgated by EPA. Control techniques applicable to the hydrogen gas stream include: cooling, condensation, and demisting; depleted brine scrubbing; hypochlorite scrubbing, adsorption on molecular sieve; and adsorption on treated activated carbon.

With appropriate modification, the control techniques applicable to the end-box ventilation stream include cooling, condensing, and demisting; depleted brine scrubbing; and hypochlorite scrubbing. It is judged that the molecular-sieve adsorption system will become applicable in the near future to the end-box ventilation-gas stream. This control technique will permit compliance with the hazardous emission standard.

Mercury vapor from the cell-room ventilation air can be minimized by strict adherence to recommended good housekeeping and operating procedures. No other control technique is commercially tested at this time. All mercury emissions could be eliminated by the conversion of mercury-cell plants to the use of diaphragm cells plus a special

caustic soda purification system. Such conversion is presently judged to be an unacceptable alternative due to the very high estimated cost. Control costs were estimated on a plant-by-plant basis. Investment per plant ranges from \$123,000 to just over \$1.3 million, depending on capacity and operating characteristics. Annual operating costs are approximately 20 percent of investment costs. Annualized control costs and industry statistics are detailed in Table 3-8-1.

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Table 3-8-1.  
Chlor-Alkali Mercury Cell Industry Data Summary

ACTIVITY LEVEL	1975	1980	1971-85	1976-85
Capacity (MT/Day)	6.419	7.781		
Annual Growth Rate Over the Period 1971-85 = 1.38%			7.319	
PROCESS CHARACTERISTICS				
	Model Plant Sizes (MT/Day)			
Mercury Cell Electrolysis 232	Pollutants Generated			
	Gases & Mists		Control Technology	
EMISSIONS (MT/Yr)	1975	1980	1971-85	1976-85
1971 Controls:			Scrubbing	
Mercury Gases & Mists	10.58	12.70		
Legislated Controls:				
Mercury Gases & Mists	5.21	1.82		
CONTROL COSTS (Million 1975 \$)				
Investment	4.91	0.41	20.90	13.59
Total Annual Capital	5.54	10.58	109.21	96.45
O&M	2.65	4.84	51.09	44.86
	2.89	5.74	58.12	51.59\$\$

## SCNITRIC ACID INDUSTRY\$R

Production Characteristics and Capacities. Nitric acid is used in the manufacture of ammonium nitrate and in numerous other chemical processes. Ammonium nitrate, which is used as both a fertilizer and in explosives, accounts for about 80 percent of the nitric acid consumption. Nitric acid is produced by oxidation of ammonia, followed by absorption of the reaction products in dilute acid solution. Most nitric acid plants in the United States are designed to manufacture acid with a concentration of 55 to 65 percent, which may subsequently be dehydrated to produce 99 percent acid.

At the beginning of 1974, 46 privately-owned companies operated 76 nitric acid plants in the contiguous 48 states, in addition to seven plants operated for the U.S. Government by five companies. These government-owned plants are included in cost estimates as part of the nitric acid industry by inflating the private costs by 10 percent. Nearly all nitric acid produced in the United States is for domestic consumption.

Emissions Sources and Pollutants. Nitrogen oxides, the primary pollutants of concern in the production of nitric acid, are emitted in the tail gas from the absorption tower. Numerous variations on the basic nitric acid production

process affect both the emissions and the difficulty of control. Two of the more important variables are the amount of excess oxygen present in the absorption tower and the pressure under which the absorption tower operates. Many plants practice partial pollution abatement (decolorization) in accordance with local regulatory agencies. Under this practice, the highly visible reddish-brown nitrogen dioxide is reduced to colorless nitric oxide. Although visible emissions are reduced, the practice does nothing to prevent emission of nitrogen oxides to the atmosphere.

Emissions from nitric acid plants consist of the oxides of nitrogen in concentrations of about 3,000 ppm nitrogen dioxide and nitric oxide, and minute amounts of nitric acid mist. Emissions from nitric acid plants are typically in the order of 22 kg nitrogen oxides per metric ton of 100 percent acid produced.

Control Technology and Costs. Catalytic reduction with natural gas is a feasible and proven control technology used in nitric acid plants both here and abroad. The absorber tail gas is mixed with 38 percent excess natural gas and passed over a platinum or palladium catalyst. Catalytic reduction with ammonia or hydrogen has the advantage of being selective in the sense that only the nitrogen oxides are reduced. In addition to higher costs, reduction with

ammonia requires close temperature control to prevent the reformation of nitrogen oxides at higher temperatures or the formation of explosive ammonium nitrate at lower temperatures.

Table 3-9-1 shows the estimated future sales, capacities, and outputs for the nitric acid industry. Also shown in the table are the reductions in nitrogen oxide emissions for the selected years, and the three major cost categories: annualized, investment, and cost requirements.

Table 3-9-1.  
Nitric Acid Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (1,000 MT/Day)	25.17	34.09	41.08*		
Annual Growth Rate Over the Period 1971-85 = 13.8%					
PROCESS CHARACTERISTICS	Model Plant Sizes (1,000 MT/Day)		Pollutants Generated	Control Technology	
Ammonia Oxidation	141.2:361.1:571.7: 940.0		Nitrogen Oxides	Catalytic Reduction	
EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Nitrogen Oxides	143.17	193.02	232.18		
Legislated Controls:					
Nitrogen Oxides	64.77	15.24	18.25		
CONTROL COSTS (Million 1975 \$)					
Investment	16.11	4.45	2.03	80.59	37.76
Total Annual	15.18	27.88	32.68	303	270.61
Capital	6.66	11.07	12.47	121.27	107.00
O&M	8.52	16.81	20.21	181.78	163.61\$

## SCPAINT MANUFACTURING INDUSTRY\$R

Production Characteristics and Capacities. The manufacturing of paints involves the mixing or dispersion of pigments in oil, resin, resin solution or latex at room temperature. Mixing is then followed by the addition of specified proportions of organic solvents or water to obtain the desired viscosity.

In 1972, there were 1,556 plants manufacturing paint products in the United States. Production is not divided evenly, with approximately 30 percent of the plants accounting for nearly 90 percent of production.

Production of paint by 1975 is estimated to be about 3,847 million liters. Since less than 500 plants produce about 3,411 million liters of paint per year, the average-sized plant would account for about 6.06 million liters per year or roughly 22,740 liters per day. The balance of the plants were omitted from control cost considerations because they collectively account for only about 379 million liters per year, or about 7 percent of the daily production of the average plant in the larger category.

Current trends in the industry should decrease the hydrocarbon emission levels associated with paint

manufacturing. These include the use of water-based paints and new application techniques such as powder coating. These developments will continue to have a negative impact on the demand for organic solvent-based paints; it is estimated that water-based paints currently represent about 25 percent of total production volume.

**Emission Sources and Pollutants.** Air pollutants from paint manufacturing are hydrocarbons originating from organic solvents and particulates from paint pigments. The emission factor for hydrocarbons is approximately 4.5 kilograms per metric ton of paint. About 908 grams of particulates are emitted per metric ton of pigment dispersed. Assuming that 75 percent of the projected 1975 volume of paint produced will be solvent-based, estimated hydrocarbon emissions will be about 19,047 metric tons.

**Control Technology and Costs.** Control of hydrocarbon emissions from paint production can be accomplished by these methods: flame combustion, thermal combustion, catalytic combustion, and absorption. Thermal combustion (with heat exchange) is considered the most feasible method of control; equipment incorporating heat exchange devices was chosen because of current anticipated future fuel shortages and assumed removal efficiencies of 95 percent. Catalytic combustion units, while highly promising from the standpoint

of lower fuel requirements (but higher initial investment costs), still present technical operating problems.

Baghouses (fabric filters) are suitable for control of particulate emissions from pigments; particulate removal efficiencies of more than 95 percent are readily achieved.

Estimates for air pollution control for the total industry were based on assumed compliance by plants averaging about 7.58 million liters of paint production per year; fewer than 500 plants of this capacity were assumed to be in operation. Future cost predictions are complicated by the emergence of technological trends away from the use of solvent-based paints. Annualized control costs and production statistics are detailed in Table 3-10-1.

Table 3-10-1.  
Paint Manufacturing Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (Million Liters/Day)	2.21	2.36	2.48		
Annual Growth Rate Over the Period 1971-85 = 0.55%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes (Liters/Day)</b>	<b>Pollutants Controlled</b>	<b>Control Technology</b>		
Paint Production	22.740	Hydrocarbons	Thermal Incinerator		
Paint Production	22.740	Hydrocarbons	Scrubber		
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
<b>1971 Controls:</b>					
Hydrocarbons	908.48	1,104.06	1,150.33		
<b>Legislated Controls:</b>					
Hydrocarbons	926.62	1,111.83	1,148.72		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	6.81	1.35	0	34.40	11.78
Total Annual	8.30	12.31	12.73	107.92	119.32
Capital	3.68	5.33	5.60	59.94	51.67
O&M	4.62	6.98	7.13	77.98	67.65

## SCPHOSPHATE FERTILIZER INDUSTRY\$R

Production Characteristics and Capacities. The major end products of the phosphate fertilizer industry are ammonium phosphates, triple superphosphate, normal superphosphate, and granular mixed fertilizers. Phosphoric acid and superphosphoric acid are intermediate products.

All phosphate fertilizers are processed from ground phosphate rock treated with sulfuric acid to produce either normal superphosphate or wet-process phosphoric acid. A phosphoric acid intermediate may then be reacted with ammonia to produce diammonium phosphate and other ammonium phosphates, or reacted with ground phosphate rock to manufacture triple superphosphate. Superphosphoric acid, produced by dehydration of wet-process phosphoric acid, is used in preparing some mixed fertilizers. Granular mixed fertilizers are made from either normal superphosphate or triple superphosphate, with ammonia and potash. Bulk-blended mixed fertilizers are manufactured by physically mixing particles of other fertilizer components and liquid mixed fertilizers. Bulk blends and liquids are not major sources of air pollution and are not considered in estimating the industry abatement cost.

The phosphate fertilizer industry is characterized by a number of large, modern efficient plants located near the source of raw materials. In general, these plants manufacture the more concentrated forms of fertilizer, diammonium phosphate (DAP) and triple superphosphate (TSP). These industries are particularly concentrated in Florida.

Smaller plants, located near the retail markets, manufacture the less concentrated forms: granulated mixed fertilizer (NPK) and normal superphosphate (NSP). The smaller NSP, NPK, and bulk-blend plants are located in the farming states. At the beginning of 1973, there were 33 DAP plants, 13 TSP plants, 45 NSP plants, and 344 ammoniation-granulation (NPK) plants. In addition, about 5,000 bulk-blending plants were operating in 1973.

Due to the seasonal demand for fertilizer, many plants manufacturing NSP and NPK operate only a portion of the year. In contrast, those plants manufacturing DPA and TSP generally operate year-round.

Emission Sources and Pollutants. Emissions from phosphate fertilizer processing plants are mainly fluorides (in the form of hydrogen fluoride and silicon tetrafluoride) and particulates. Fluorides are generated in the processes of

acidulation of phosphate rock which contains calcium fluoride.

In the phosphate fertilizer industry, particulate emissions of significance originate from: phosphate rock grinding, calcination, drying, and transfer processes; triple superphosphate manufacture; ammonium phosphate production; normal superphosphate manufacture; and NPK bulk-blending and granulation plants.

In phosphate rock processing, particulate emissions are issued from the calcination, drying, grinding, and transfer processes. The emission factors for these processes are 7.5, 10, and 1 kg per metric ton of rock, respectively.

In granular triple superphosphate production, particulate emissions may originate from a number of points in the process. Most of the particulates are given off in the drying and product-classification processes. The off-gas from the reactor (in which phosphate rock is acidulated with phosphoric acid) and the blunger (in which the reactor effluent is mixed with recycled product fines to produce a paste) may account for a considerable percentage of the total particulates emitted.

Particulate emissions from diammonium phosphate manufacture originate mainly from the granulator and the dryer. It has been estimated that the total emissions amount to approximately 20 kg per metric ton of product from both sources.

Emissions from the manufacture of run-of-pile normal superphosphate originate from both the acidulation and "dennning" processes. Although the emission factors for particulates are not known, they are estimated to be in the order of 5 kg per metric ton.

The NPK or granulation plants manufacture a variety of products. Many different emission factors probably will apply for this class of fertilizer plant. In fixing the emission factors, these plants are assumed to employ an ammoniation-granulation process similar to that used in the DAP process, or approximately 20 kg of particulates per metric ton of product.

The emission factors for particulates are high in the triple superphosphate, diammonium phosphate, and NPK plants. The bulk of these emissions in all three processes originates from the granulation process. There is a strong economic incentive to reduce these emissions since they contain valuable products and in many cases are associated with

ammonia vapors (from the ammoniation process), whose recovery is an economic necessity.

**Control Technology and Costs.** Most of the phosphate rock of higher available phosphorus pentoxide content is ground and beneficiated to enhance its reactivity and to eliminate some of the impurities. The particulate emissions from the grinding and screening operations may be effectively controlled by employing baghouses in which the dust is deposited on mechanically-cleaned fabric filters. The dust-laden gas from the rock-drying (and perhaps defluorination) operations may first pass through a cyclone and then through a wet scrubber (such as a venturi). The efficiency of this combination should be better than 99 percent.

Particulate and fluoride emissions from phosphate fertilizer plants traditionally have been removed from waste gaseous streams by wet scrubbing. While efforts have been directed at removing fluorides, up to 99 percent of the particulates are simultaneously removed. Wet scrubbers of varying efficiencies have been used for this double purpose. The fluoride and particulate-laden scrubber water is usually disposed of in a gypsum pond.

For control of particulate emissions from granular TSP plants, various wet scrubbers will be provided for a number

of gaseous waste streams. The effluent from the reactor-granulator will be scrubbed in two stages. The first stage will be a cyclone and the second a cross-flow packed scrubber. The gases from the drier and cooler will be scrubbed in venturi-type packed scrubbers. Waste gases from storage of the granular product are usually scrubbed in a cyclone scrubber, although some plants use packed scrubbers. The scrubbing liquid used in all scrubbers will be recycled pond water except for the first-stage scrubbing of gases from the reactor granulator, where weak phosphoric acid will be used and recycled to the reactor.

In DAP plants, control of particulates will be achieved for gaseous streams originating from the reactor granulator, the drier, and the cooler, together with combined gaseous streams ventilating such solids-processing equipment as elevators, screens, and loading and unloading. Two-stage scrubbing will be employed for each of the streams listed. The first stage will consist of a cyclone scrubber; the scrubbing medium will be diluted (30 percent) phosphoric acid for purposes of recovering ammonia and the product. Most of the particulate matter will be removed in the first stage, and the balance will be removed in the second stage consisting of a cross-flow packed scrubber in which recycled pond water is used as the scrubbing medium.

It is assumed that only run-of-pile normal superphosphate is produced in MSP plants. A cyclone scrubber will be employed in removing particulates in gaseous streams originating from the reactor-pugmill, den. and curing operations.

An ammoniation-granulation process is assumed for NPK plants. Cyclones will be installed ahead of primary scrubbers. The primary scrubber (typically employing dilute phosphoric acid as a scrubbing medium) is considered an integral part of the process in which valuable reactants (ammonia) and the product are recovered.

Cross-flow scrubbers have been used in estimating costs of controlling emissions of both particulates and fluorides. Most of the control technologies described above have been applied for more than a decade. Wet scrubbers of varying efficiencies have been integral parts of many phosphate fertilizer processes. The collection of waste gaseous streams and the removal of fluorine compounds from these streams has long been practiced to protect the health and safety of process operating personnel. Collection of particulate materials from those waste gaseous streams is dictated by economic necessity because valuable products are involved.

Table 3-11-1 shows the estimated future sales and capacities for phosphate fertilizers. The table also shows the number of model plant sizes used to calculate costs for the four fertilizer types. The emissions are reduced dramatically below levels that would have been achieved for purely economic recovery purposes. The control costs are shown for investment and cash requirements, as well as for annualized expenditures over the next decade.

Table 3-11-1.  
Phosphate Fertilizer Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (1,000 MT/Yr)	35.83	45.69	56.23		
Annual Growth Rate Over the Period 1971-85 = 5.27%					
<b>PROCESS CHARACTERISTICS</b>	Model Plant Size		Pollutants Generated	Control Technology	
Type of Phosphate:					
NSP	62.7:99.0:132.0:165.0:	Particulates			Wet Scrubber
	198.0:231.5				
NPK	45	Particulates			Wet Scrubber
TSP	70:120:297.5:460:670:	Particulates			Wet Scrubber
	930				
DAP	54:155:248:378:513:	Particulates			Wet Scrubber
	700:900				
<b>EMISSIONS (1,000 MT/Yr)</b>	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	1,104.67	1,428.56	1,773.89		
Legislated Controls:					
Particulates	630.60	2.85	3.49		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	23.54	12.19	6.13	174.78	96.99
Total Annual Capital	25.57	51.75	65.25	570.41	511.90
O&M	10.23	19.06	22.98	212.01	188.28
	15.34	32.69	42.27	358.40	323.62

## NON-FERTILIZER PHOSPHORUS INDUSTRY

Production Characteristics and Capacities. In 1973, there were 21 plants engaged in the production of elemental phosphorus, defluorinated phosphates (DFP), and calcium phosphates (Dical). The combined capacity of these plants is approximately 4.808 metric tons per day or 1.6 million metric tons per year (P2O5 equivalent). Ten plants produce elemental phosphorus and account for over 60 percent of the total capacity involved in the production of non-fertilizer phosphates. A summary of model plant size distributions and capacities for the three products is provided in Table 3-12-1.

Table 3-12-1.  
Non-Fertilizer Phosphates Industry  
Plant Capacity Distribution

	Plant Capacity (P2O <sub>5</sub> , MT/day)	No. Plants	Total Capacity (P2O <sub>5</sub> , MT/day)	Percent Group	Industry
Phosphate reduction	54 217 649	3 4 3	162 867 1,948	5 29 66	3 18 41
		10	2,977	100	62
Defluorinated phosphate	31 93 125 386	1 1 1 1	31 93 125 386	5 15 20 60	nil 2 3 8
		4	635	100	14
Calcium phosphate	54 200 580	4 2 1	216 400 580	18 33 48	5 8 12
		7	1,196	100	25
Totals		21	4,808		100%

The production of industrial phosphorus and phosphate containing animal feeds begins with thermal and/or chemical processing of phosphate rock. Phosphates that are suitable as additives to feeds may result from the direct defluorination of phosphate rock, defluorination of phosphoric acid from wet process acid, or defluorination of furnace acid, e.g., acid made from elemental phosphorus produced by thermal reduction of phosphate rock. The production of feed-grade phosphates by conversion of

elemental phosphorus is expected to decline because of the energy requirements of the thermal reduction of phosphate rock. Decreased production by this process will be compensated for by increased production from wet process acids, so the overall production of feed-grade phosphates will increase at an annual rate of approximately 4 percent. Current production is estimated to be about 90 percent of capacity.

**Emission Sources and Pollutants.** Atmospheric emissions from the manufacture of defluorinated phosphates are primarily fluorides and particulates. Currently, only Florida has established controls for fluoride emissions; it is anticipated that Federal and state regulations for control of fluoride emissions will be promulgated shortly.

Gaseous fluorides are released during the thermal and/or chemical reduction of phosphate rock with the major point of emissions in feed preparation. Emission factors may be as high as 33 kilograms fluorine per metric ton of phosphorus processed.

A summary of estimated fluoride emissions from the production of defluorinated phosphates is presented below; control efficiencies of 95 percent are assumed.

	Present Controls (metric tons/yr)	Further Controls (metric tons/yr)
1975		
Phosphate reduction	430	25
Defluorinated phosphate	2,560	158
Calcium phosphate	40	2
1985		
Phosphate reduction	260	15
Defluorinated phosphate	3,910	242
Calcium phosphate	50	3R

Control Technology and Costs. Control of fluorides can be accomplished by the use of wet scrubbers. These devices, which could include liquid ejector venturi scrubbers, liquid impingement control systems, and spray towers, also serve to control particulate emissions to levels of 95 percent or more. Capital costs for pollution abatement for phosphate reduction range from about \$26,000 to \$131,000 depending on the plant capacity. Annual operating costs range from about \$1,800 to \$9,500.

For DFP and Dical plants, control costs are comparable for similar sized plants but almost four times as high as for phosphate reduction plants of similar size. Investment costs range from approximately \$55,000 to \$370,000 for 31 and 332 metric tons per day (P205 equivalent) plants. The lower control costs associated with animal feed production from furnace acid is due to the relatively lower percentage

of fluorides contained in the phosphoric acid obtained from thermal reduction of rock. Annualized control costs and industry operating statistics are detailed in Table 3-12-2.

Table 3-12-2.  
Non-Fertilizer Phosphorus Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (MT/Day)	4,712.0	6,987.0	8,681.0		
Annual Growth Rate Over the Period 1971-85 =	6.74%				
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes</b>	<b>Pollutants Generated</b>	<b>Control Technology</b>		
Defluorinated Phosphate	See Table 3-12-1.	Particulates	Wet Scrubber		
Phosphate Reduction		Particulates	Wet Scrubber		
Calcium Phosphate		Particulates	Wet Scrubber		
<b>EMISSIONS (MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
<b>1971 Controls:</b>					
Particulates	34.54	47.84	58.69		
<b>Legislated Controls:</b>					
Particulates	28.06	32.48	39.89		
<b>CONTROL COSTS (Million \$)</b>					
Investment	1.68	0.60	0.26	10.57	5.62
Total Annual Capital O&M	1.10 0.80 0.30	2.06 1.51 0.55	2.38 1.72 0.66	22.28 16.20 6.08	19.88 14.46 5.42

## **\$CSULFURIC ACID INDUSTRY\$R**

**Production Characteristics and Capacities.** About half of the sulfuric acid produced in the United States is used in the manufacture of phosphate fertilizers; the rest is used in myriad industrial applications ranging from steel pickling to detergent manufacturing.

Sulfuric acid is manufactured by chemical companies and by companies primarily engaged in smelting nonferrous metals; both sources compete for the same buyers. Nevertheless, the manufacturing of sulfuric acid by the smelter industry is primarily a byproduct resulting from the control efforts to reduce sulfur dioxide emissions to the atmosphere, and secondarily, as an attempt to generate additional revenue. For the purposes of this report, smelter acid is considered to be part of the smelter industry rather than the sulfuric acid industry.

The major products of the sulfuric acid industry are concentrated sulfuric acid (93 to 99 percent) and oleum. A few sulfuric acid plants associated with the fertilizer industry produce less-concentrated grades of acid. Essentially, all sulfuric acid in the United States is currently produced by the contact process, less than 0.4 percent is being produced by the older chamber process.

In sulfur-burning plants, sulfuric acid is produced by burning elemental sulfur with dry air in a furnace to produce sulfur dioxide. The latter is catalytically converted to sulfur trioxide. The hot converter effluent is cooled and introduced to an absorption tower where the sulfur trioxide is absorbed in a sulfuric acid solution to form more sulfuric acid by its reaction with water.

Some plants (including spent-acid plants and smelter-gas plants) operate on the same principle as sulfur-burning plants, except that the sulfur dioxide is obtained from the combustion of spent acid and hydrogen sulfide or from smelter off-gas. In these plants, the sulfur-bearing gas is dried with sulfuric acid and cleaned (subjected to particulate and mist removal process) before introduction to the acid plant.

Of the known 183 sulfuric acid plants operating in 1973, 167 were contact process plants and 16 were chamber process plants. Of the 25.5 million metric tons of new sulfuric acid produced, 25.3 million metric tons were made in contact process plants. This volume production included sulfuric acid produced by the sulfuric acid industry (as defined in this report) and by the smelter industry. In 1974, 58 companies operated sulfur-burning or wet-process contact acid plants in 134 locations, and 16 companies operated

smelter acid plants in 23 locations. In addition, five companies operated small chamber-acid plants in five locations.

**Emissions Sources and Pollutants.** Emissions from sulfuric acid plants consist of sulfur dioxide gases and sulfuric acid mist. These pollutants evolve from incomplete conversion of sulfur dioxide to sulfur trioxide in the converter, and from the formation of a stable mist consisting of minute particles of sulfuric acid that resist absorption in the acid absorber.

The controlled emission factors for existing facilities for FY 1976 are as specified by the SIP's; new source values were assumed to apply to both existing and new facilities in FY 1980.

In sulfuric acid plants using the two-stage or dual absorption control process, the gas from the first acid absorber is initially heated (sometimes removing the mist) and then sent through a single-stage converter where the sulfur dioxide is converted to sulfur trioxide. The gas from the converter is then sent to an absorber and a demister before release to the atmosphere.

Dual absorption has reliably met EPA standards of performance for new and modified sources in applications of two types of sulfuric acid plants (sulfur-burning and wet gas) of all sizes. In addition to controlling sulfur dioxide emissions, the dual absorption method offers the added advantage of not requiring new operational skills on the part of acid plant operators. This control technology has been used in computing the sulfur dioxide control costs for all new and existing sulfuric acid plants.

Table 3-13-1 shows that sales, production and capacity are estimated to remain at the 1975 level because of a rapid increase in sulfuric acid recovered in the control of sulfur oxides from smelters and utility plants. The control costs are also shown for total annualized expenditures, investment and cash requirements.

Table 3-13-1.  
Sulfuric Acid Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (1,000 MT/Day)	175.0	175.0	175.0		
Annual Growth Rate Over the Period 1971-85 = OX					
PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Day)	Pollutants Generated		Control Technology	
Sulfur Burning	297:665:1,814	Sulfur Oxide & Acid Mist	Sulfur Oxide & Acid Mist	Dual Absorption	Dual Absorption
Met Gas		Sulfur Oxide & Acid Mist		Dual Absorption	
EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Sulfur Oxides	711.36	982.04	1,180.74		
Other Gases & Mists	22.92	31.65	38.05		
Legislated Controls:					
Sulfur Oxides	334.24	101.97	121.56		
Other Gases & Mists	11.23	4.39	5.24		
CONTROL COSTS (Million 1975 \$)					
Investment	152.80	11.51	5.00	746.53	268.58
Total Annual Capital O&M	110.59 73.59 37.00	184.79 111.66 73.13	192.92 114.94 77.98	2,010.21 1,240.00 770.21	1,763.54 1,075.18 688.36

## SCPETROCHEMICALS INDUSTRY\$R

Production Characteristics and Capacities. In estimating air emission control costs associated with the petrochemical industry, the production of the following major large volume petrochemicals was considered:

- Formaldehyde
- Acrylonitrile
- Ethylene dichloride
- Ethylene oxide
- Phthalic anhydride.

A major air pollution problem in the petrochemical industry is the emission of hydrocarbons and carbon monoxide via off-gases produced in oxidation processes. The petrochemicals involved in this problem include not only oxygen-containing compounds, such as oxides, aldehydes, and anhydrides, but also compounds in which oxygen serves an intermediate role in the synthesis, such as acrylonitrile and ethylene dichloride. In a typical process of this type, the raw material, air (sometimes oxygen), and sometimes a third reactant are fed into a vapor-phase catalytic oxidation reactor. The reactor effluent gases go to an absorber in which the desired product is scrubbed out. The off-gas from this absorber, which is vented to the atmosphere, contains

mostly nitrogen and carbon dioxide, but smaller amounts of carbon monoxide and unconverted hydrocarbons are also present.

**Formaldehyde.** Formaldehyde is synthesized by oxidation of methanol with air and sold as an aqueous solution (37 percent by weight). Two different processes are used, one based on a metal oxide catalyst and one based on a silver catalyst; about 77 percent of the domestic formaldehyde production uses the silver process and the other 23 percent uses the metal oxide process.

Production in 1974, as estimated from data for the first 8 months of the year, was about 2.8 billion kilograms of 37 percent formaldehyde. The production is estimated to increase to about 6.2 billion kilograms per year by 1985. This growth is due primarily to increased demand for urea-formaldehyde and phenol-formaldehyde resins, which consume about half of all the formaldehyde produced.

**Acrylonitrile.** Ammoxidation of propylene, the most widely practiced method for producing acrylonitrile, consists of the catalytic oxidation of ammonia with air. Typically, the gaseous products from the oxidation chamber are passed to an absorber where the acrylonitrile is collected. The off-gas

from the absorber is normally vented to the atmosphere, a process which is largely uncontrolled at present.

Production in 1974, as estimated from data for the first 8 months of the year, was about 681 million kilograms. Production is estimated to increase to about 814 million kilograms per year by 1985. This growth is due primarily to increased demand for acrylic fibers, which consume about half of all the acrylonitrile produced, and for plastics, which consume another 15 percent of total production.

Ethylene Dichloride (EDC). Ethylene dichloride can be produced by two alternative processes, direct chlorination or oxychlorination. While half of the U.S. production of EDC is by direct chlorination, the process results in only 10 percent of the volume of atmospheric emissions that result from the oxychlorination process and, hence, only oxychlorination is considered here.

Production in 1974, as estimated from data for the first 8 months of the year, was about 3.5 billion kilograms. The total production of EDC in 1985 is projected to be about 4.1 billion kilograms. The use of the oxychlorination process should continue to account for about 48 percent of the total production, or about 2.8 billion kilograms in 1985.

Ethylene Oxide. In recent years, the dominant process for manufacturing ethylene oxide has become the direct oxidation of ethylene. There are four processes used for ethylene oxide manufacture by direct oxidation and all use a silver catalyst. Only two of the plants oxidize with dioxide, the others use air. The plants which oxidize with dioxide are similar except that usually only a primary reactor and absorber are used. Compared to the plants which use air, the plants which use dioxide produce much less absorber gas but much more carbon dioxide rich purge gas.

Production in 1974, as estimated from data for the first 8 months of the year, was about 1.8 billion kilograms. The total production of ethylene oxide in 1985 is projected to be about 3.4 billion kilograms.

Phthalic Anhydride. Phthalic anhydride is produced by the oxidation of either o-xylene or naphthalene; about 55 percent of the phthalic anhydride is produced from o-xylene. This process is expected to gain an increasing share of industrial production because o-xylene is less expensive than naphthalene.

A number of processes are available for producing phthalic anhydride. Most of the naphthalene-based processes use fluidized-bed reactors, whereas all xylene-based processes

use tubular fixed-bed reactors. Except for the reactors and the catalyst handling facilities required for the fluidized-bed units, the processes based on the two raw materials are quite similar. In both cases, the reactor effluent gases are used to generate steam in a waste heat boiler and then go to a separation system in which the phthalic anhydride is condensed out as solid crystals. The condenser effluent gases are ultimately vented to the atmosphere, although in most plants they are first water-scrubbed or incinerated.

Production in 1974, as estimated from data for the first 8 months of the year, was about 454 million kilograms. The production is estimated to increase to about 0.99 billion kilograms per year by 1985, which corresponds to a growth rate of about 7.1 percent per year.

**Emission Sources and Pollutants.** Atmospheric emissions arising from petrochemical production result from the venting of off-gases from the absorber. The chief air pollutants are hydrocarbons and carbon monoxide. Corresponding emission factors for these pollutants as a function of production volume are given in Table 3-14-1

Table 3-14-1.  
 Petrochemicals Industry  
 Calculated Emission Factors

(No Controls)

Petrochemical	Waste Gas Streams	Kilograms Emitted Per 10 Kilograms of Product		
		CO	Hydrocarbons	SOx (as SO2)
Formaldehyde (37%)	Absorber vent	3.33	5.28	-
Acrylonitrile	Absorber vent	74.19	83.52	-
Ethylene dichloride	Absorber vent	3.31	12.94	-
Ethylene oxide	Absorber vent + CO2 purge	0.	50.15	-
Phthalic anhydride	Absorber vent	73.76	19.50	2.2955

Control Technology and Costs. The control technology judged to be most feasible for control of hydrocarbon and carbon monoxide emissions from the manufacture of petrochemicals is thermal incineration (often referred to as afterburners). Thermal incinerators were considered in place of catalytic incinerators because of the latter's higher initial investment costs and requirement for catalyst replacement costs. The investment for thermal incinerators was based on a compilation of costs by the Midwest Research Institute (MRI), which considered the purchased cost of a thermal incinerator plus the heat exchanger in which the effluent gases heat up the influent gases. These costs were inflated to mid-1973 using the Chemical Engineering Plant Cost Index and were found to compare closely with investment data provided in a recent report by Houdry on acrylonitrile. Annual costs were calculated from utility (fuel and power) requirements, annual maintenance, and operating labor.

The distribution of plant size categories, number of plants, capacity and percent of industry capacity represented by model size, and the unit investment and annual operating and maintenance costs are given in Table 3-14-3 for each petrochemical production process covered. Annualized industry costs for air pollution abatement in the period 1976-85 are also provided in Table 3-14-2.

Table 3-14-2.  
Petrochemicals Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (Million Kg/Yr)					
Formaldehyde	3,587.025	5,320.108	6,173.511		
Phthalic Anhydride	623	924	1,072		
Acrylonitrile	549	814	945		
Ethylene Oxide	1,973	2,927	3,396		
Ethylene Dichloride	2,360	3,500	4,061		
Annual Growth Rate Over the Period 1971-85 = 6.92%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes (1/2 MT/Yr)</b>	<b>Pollutants Generated</b>		<b>Control Technology</b>	
Formaldehyde-Silver Process	34.2;89.2;149.6; 492.2	Hydrocarbon: Carbon Monoxide		Afterburners	
Formaldehyde-Metal Oxide Process	43.5;90.0;123.8	Hydrocarbon: Carbon Monoxide		Afterburners	
Phthalic Anhydride	38.6;87.9;128.8	Hydrocarbon: Carbon Monoxide		Afterburners	
Acrylonitrile	178;270	Hydrocarbon: Carbon Monoxide		Afterburners	
Ethylene Oxide - O2	210.3	Hydrocarbon Monoxide		Afterburners	
Ethylene Oxide - Air	71.2;303.8;733.3	Hydrocarbon Monoxide		Afterburners	
Ethylene Dichloride	177.5;425;695	Hydrocarbon: Carbon Monoxide		Afterburners	
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
<b>1971 Controls:</b>					
Hydrocarbons	410.83	621.17	713.65		
Carbon Monoxide	171.28	273.58	316.90		
<b>Legislated Controls:</b>					
Hydrocarbons	181.34	32.64	37.24		
Carbon Monoxide	75.69	14.90	17.12		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	3.88	2.04	0.85	48.21	25.57
Total Annual Capital O&M	19.13	37.19	42.57	394.60	352.26
	2.68	5.26	5.85	55.18	48.77
	16.45	31.93	36.72	339.42	303.49

## SCPETROLEUM INDUSTRY\$R

Production Characteristics and Capacities. The petroleum industry can be divided into the following four operating areas:

Exploration and production, which includes the search for new oil supplies, the drilling of oil fields, removal of oil from the ground, and pretreatment at the well site.

Refining, which includes the operations necessary to convert the crude oil into salable products such as gasoline, jet fuel, kerosene, distillate and residual fuel oils, lubricants, asphalt, speciality products, and chemical raw materials such as ethylene and benzene.

Transportation, which involves the movement of crude oil to the refinery and refined products to market areas.

Marketing, which involves the distribution and sale of the finished products.

Integration and diversification prevail within the industry. Most of the firms involved in refining are also involved in production and/or marketing. All the large and medium sized firms are involved in the manufacture of petrochemicals.

Some firms are involved in the production aspects of energy sources other than crude oil, i.e., coal or Canadian tar sands.

As of January 1, 1974, the 247 refineries in the United States had a total crude oil capacity of 14.2 million barrels per day. A distribution of these refineries by size and percent of total capacity is as follows:

St Capacity Range (1,000 bbl No. Cal day)	Total Capacity (1,000 bbl Cal day)	Total Industry Capacity(%)	Average Capacity (1,000 bbl Cal day)
Up to 5	46	1.01	3
5 to 10	30	1.66	8
10 to 15	21	1.92	13
15 to 25	21	3.07	21
25 to 50	45	11.57	37
50 to 75	23	10.15	63
75 to 100	20	12.88	92
100 to 200	26	25.72	141
Over 200	15	32.02	303
Totals	247	14.216	100.005R

During the period from 1970 to 1974, total crude processing capacity increased by 2.1 million barrels per day, despite a drop in the number of refineries from 262 to 247, indicating a gradual trend toward larger plants. Although there are about 130 firms which operate refineries, over 80 percent of the total capacity is controlled by 17 major firms; each firm controls crude processing capacity in excess of 200,000

barrels per day. A breakdown of capacity and number of plants operated by these firms is as follows:

Company	No. Refineries	Crude Capacity (1000 bbl/cal day)	Crude Capacity (%)
Exxon	5	1,252	8.8
Shell	6	1,109	7.8
Texaco	12	1,083	7.6
Amoco	10	1,065	7.5
Standard (CA)	12	984	6.9
Mobil	8	932	6.6
Gulf	8	861	6.1
ARCO	6	790	5.6
Union Oil	4	487	3.4
Sun Oil	5	484	3.4
Phillips	6	404	2.8
Sohio/BP	4	384	2.7
Ashland	7	358	2.5
Continental	7	349	2.5
Marathon	3	314	2.2
Cities	1	268	1.9
Amer. Petrofina	4	200	1.4
<b>Subtotal</b>	<b>110</b>	<b>11,324</b>	<b>79.7</b>
<b>Remaining Firms</b>	<b>137</b>	<b>2,892</b>	<b>20.3</b>
	<b>247</b>	<b>14,216</b>	<b>100.0%</b>

The intensity of the energy shortage last year resulted in the largest absolute capacity increase since 1967, and the largest percentage increase in at least a decade. The increase was 6.2 percent, compared with 2.3 - 4.3 percent for the preceding 3 years.

Very few new refineries have been built in the last 5 years; the growth has occurred primarily through the expansion of existing facilities. This is in part due to difficulty in securing approval for new sites. A survey of refinery construction plans in August of 1973 showed "definite" projects" for 1974-77 totaling 1.13 million barrels per day (all expansions) and projects "under study" totaling about 0.9 million barrels per day (mostly new refineries). Present expectations are that refinery capacity will grow at a rate of about 4.2 percent per year, which will result in a capacity of nearly 19 million barrels per day by 1980.

Turning now to the aspects of the petroleum industry which are of particular importance in air pollution abatement, the capacity of fluid bed catalytic cracking is expected to grow at the same rate as total refinery capacity, i.e., 4.2 percent per year. This will increase the capacity from the present 4.2 million barrels per day of fresh feed to about 5.5 million barrels per day by mid-1980.

It is estimated that the 247 domestic refineries produce about 70 million cubic meters per day of refinery gases. The present Claus plant capacity for recovering sulfur from these gases is about 8,300 metric tons per day. The expected increase in the sulfur content of the crude oil processed in this country plus the growth in refining

capacity will cause an increase of about 67 percent in the quantity of sulfur going into fuel gases by 1980. This increase plus the greater sulfur recovery required will increase the total sulfur recovery from fuel gases to about 20,000 metric tons per day by mid-1980.

Hydrocarbon storage capacity at refineries is expected to increase at a rate of about 1 percent per year. This will result in 1980 storage capacities of about 429 million barrels of crude oil, 374 million barrels of gasoline, and 9.9 million barrels of naphtha-type jet fuel.

Emission Sources and Pollutants. The three major sources of air pollution in the petroleum industry covered in this report are regeneration of catalysts, used in catalytic cracking, burning of fuel gases from various refinery process operations in order to recover the fuel values, and handling and storage of volatile petroleum products and crude oils. A consolidated view of the type and extent of the emissions from refining and related operations, is presented below.

Catalytic Cracking. Catalyst regeneration during the operation of catalytic cracking units has been identified as a major source of carbon monoxide, unburned hydrocarbons, and, in the case of the fluid bed units which dominate this

process, particulate emissions. The coke deposited on the catalyst during the cracking operation must be continually removed to permit the catalyst to maintain high activity. In a fluid bed catalytic cracker, the catalyst bed is continuously circulated between the reactor, where the coke is deposited on the catalyst, and the regenerator, where it is burned off with air. The amount of coke deposited on the catalyst per unit of feedstock is a function of the feedstock and operating conditions.

**Fuel Gas Burning.** Currently, amine scrubbing units are widely used to remove hydrogen sulfide from the fuel gas generated within refineries. The hydrogen sulfide is thermally stripped from the scrubbing liquor and then is either sent to a sulfur recovery plant (usually a Claus plant) or is burned to sulfur dioxide, which is emitted to the atmosphere through a flare. In 1973, about 70 percent of the sulfur which went into fuel gas was recovered as elemental sulfur, the other 30 percent was emitted as sulfur dioxide.

**Petroleum Storage.** The most significant contribution to total hydrocarbon losses in the petroleum industry is associated with the necessary use of vast storage facilities. The National Petroleum Council has shown that the entire industry maintains a total storage capacity of at

least two barrels for each barrel of actual inventory. This is the minimum amount necessary to insure continuous refinery operations and to provide for seasonal variations in product demands. The magnitude of hydrocarbon emissions from storage tanks depends on many factors including the physical properties of the material being stored, climatic and meteorological conditions, and the size, color, and condition of the tank.

**Control Technology and Costs.** Control technology and costs for the three major emission sources in the petroleum industry are outlined in the following paragraphs.

**Catalytic Cracking.** The removal of particulate matter (catalyst fines) from the regenerator gas can be accomplished with high-efficiency electrostatic precipitators. Although some reduction in carbon monoxide and unburned hydrocarbons can be achieved by increasing the regeneration temperature, essentially complete removal of these species will require carbon monoxide boilers. The additional combustion which occurs in the carbon monoxide boiler generates substantial quantities of heat, which the boiler recovers as steam; the value of this steam helps offset the cost of the equipment. Equipment for controlling emission of particulate matter, carbon monoxide, and

hydrocarbons is commercially available and is already in use in some catalytic cracking units.

In 1971, about 29 percent of the fluid catalytic cracking capacity was equipped with electrostatic precipitators and about 69 percent was equipped with carbon monoxide boilers. These boilers are often economically justified by the steam which they generate, especially for large catalytic cracking units. Increasing energy costs are making carbon monoxide boilers more attractive for this reason. In some existing refineries, the additional steam generated by the addition of a carbon monoxide boiler cannot be used, but new refineries can be designed to take advantage of this means of reducing their total energy requirement.

The catalyst fines collected by the electrostatic precipitator must be disposed of as solid waste. Using the average particulate emission factor for fluid cat crackers (110 kg/1000 bbl fresh feed), a precipitator efficiency of 93 percent, and an operating factor of 0.913 (8,000 hr/yr), the disposal cost is:

$$\begin{array}{r} \text{Disposal cost, } \$/\text{yr} = \\ (\$/\text{ton unit disp. cost}) (\text{bbl}/\text{d feed}) \\ (242) (0.93) (0.913) (365) \\ (1000) (2000) \end{array}$$

or Disposal cost,  $\$/\text{yr} = (Kp)$  (bbl/d fresh feed).

where the constant  $Kp$  is as follows:

\$t	Low	Medium	High
Unit disposal cost (\$/ton)	1.0	3.0	5.0
Constant Kp	0.038	0.114	0.190\$R

Annualized control costs and control data are detailed in Table 3-15-1.

Fuel Gas Burning. The control technology involves installing additional amine scrubbing facilities where required, installing Claus plants on the 30 percent of capacity now without them, and installing tail-gas treatment facilities on all the Claus plants. The tail-gas treatment facilities increase the overall sulfur recovery from about 95 to 99.8 percent.

The amine solution used in the scrubbing operation cannot be regenerated and reused indefinitely. Complex sulfur salts are formed which must be purged from the system, and fresh solution must be added to replace the amine thus lost. Two methods are used commercially: one involves continuously withdrawing a purge stream, and the other involves using the solution for a period of time and then completely replacing it. For the purpose of analyzing costs, it is immaterial which method is used. All that is needed is an equivalent daily purge rate. The following relationship was used for this:

lb/day amine purge = (1.74)(LT/D sulfur recovery).

The cost of disposing of this material is then:

Disposal cost, \$/yr =  $(1.74) (0.956) (365)$   
(\$/ton unit disp. cost) (LT/D sulfur rec.) 2000

or Disposal cost, \$/yr = (KA) (LT/D sulfur recovery)

where the constant KA is as follows:

\$t

	Low	Medium	High
Unit disposal cost (\$/ton)	1.0	3.0	5.0
Constant KA	0.30	0.91	1.52\$R

This cost is a very small portion of the total process operating cost.

The credit for the sulfur recovered in these processes is an important economic consideration and is also difficult to define. In the coming years, the reduction of allowable sulfur emissions from refineries, power plants, etc., plus the increasing sulfur content of the crude oil processed will combine to cause a very large increase in the production of sulfur. This will certainly depress the price of sulfur, but the extent of depression is open to considerable speculation. The three price levels used in this study are: \$5, \$10, and \$15 per metric ton. The sulfur credit is:

Sulfur credit. \$/yr = (0.956)(365)(sulfur price, \$/LT) (\$  
prod. rate, LT/CD)

or Sulfur credit. \$/yr = Ks (S product rate, LT/CD)

where the constant Ks is as follows:

\$t	Process Cost Level	Low	Medium	High
Sulfur price, \$/LT		15	10	5
\$/YR-LT/CD		5.234	3.489	1.745\$R

Since this is a process credit, the highest byproduct sulfur price is used with the lowest process cost level.

Annualized control costs and control data are detailed in

Table 3-15-1.

Hydrocarbon Storage. The new Federal standards require that all hydrocarbons having a vapor pressure at storage conditions between 78 and 570 millimeters of mercury must be stored in tanks equipped with a floating-roof or the equivalent. This requires that for hydrocarbons in this vapor pressure range all existing fixed-roof tanks must be converted to floating-roof and all new tanks must be floating-roof tanks. For hydrocarbons having a vapor pressure greater than 570 millimeters of mercury, it is already standard industry practice to use some type of vapor recovery system.

To minimize evaporative losses, it has been standard practice in the petroleum industry to use floating-roof

tanks, vapor recovery systems, pressure storage, refrigeration, or combinations of these methods for hydrocarbons with high vapor pressures. Floating-roof tanks are the preferred method for products with vapor pressures of 1.5 to 11 psia. The principal products in this volatility range are crude oil, jet fuel (naphtha type), and gasoline. Products with vapor pressures less than 1.5 psia can be stored in conventional fixed-roof tanks without appreciable emission loss. The more elaborate control methods are used for products with vapor pressures greater than 11 psia.

The EPA new source pollution regulations require that all petroleum products having vapor pressures of 1.5 to 11 psia be stored in floating roof tanks or their equivalent. There is also a requirement for products with vapor pressure greater than 11 psia, but this will cause no additional expense since the control methods are presently used for these products. Thus, this report is concerned only with the storage of crude oil, jet fuel, and gasoline.

The typical industry practice (1968) involved a distribution of 75 percent floating-roof and 25 percent fixed-roof tanks; this distribution is felt to be applicable for crude oil and jet fuel. For gasoline, the economics of evaporation control have led to a distribution more like 90 percent

floating-roof and 10 percent fixed-roof. Thus, the cost of meeting the new regulations is the difference between the cost of using 100 percent floating-roof tanks for these products and the cost of using the above distributions.

The tank costs were based on quotations obtained in October of 1974 from representative vendors. These quotations were for a typical midwestern location. The following items were added to the basic tank cost:

\$t	Item	Tank Cost (%)
	Excavation and dike	25
	Foundation	6
	Electrical grounding	3
	Piping, etc.	10
	Painting	3
	Total	47\$R

These percentages were taken from a report by the MSA Research Corporation; no land cost was included. Quotations were obtained for both fixed-roof and floating-roof tanks. The difference between these two is then the differential cost applicable to new tanks. Since the desired time basis for this study is mid-1973, these costs were adjusted back to that time using the Nelson refinery cost index. Quotations were also obtained for converting existing fixed-roof tanks to floating-roof by retrofitting an internal floating cover. This is the conversion method which will

evidently be used, since it costs only about half as much as removing the fixed roof and replacing it with a floating roof. The annual operating costs for the tanks, including maintenance, property taxes, and insurance, were taken as 3.5 percent of the investment. Annualized control costs and control data are detailed in Table 3-15-1.

Table 3-15-1.  
Petroleum Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity					
Storage - Million Bbl/Day	74.198	957.797	1,287.517		
Catalytic Cracking 10 Bbl/Day)	399.587	1,735.848	2,333.411		
Refining - MT/Yr Revised	3.913	4.653	6.524		
Annual Growth Rate Over the Period 1971-85 = 4.34%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes (Million Bbl/Day)</b>	<b>Pollutants Generated</b>	<b>Control Technology</b>		
Gasoline Storage	56	Hydrocarbons	Flating Roof		
Crude Oil Storage	80	Hydrocarbons	Floating Roof		
Jet Fuel Storage	56	Hydrocarbons	Floating Roof		
Catalytic Cracking	1.6, 9.6, 30	Particulates, Carbon Monoxide	ESP		
Refining (1,000 Bbl/Day)	5, 10, 31, 67, 93, 211	Hydrocarbons Sulfur Oxides Hydrocarbons Carbon Monoxide	Tail Gas Treatment		
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
<b>1971 Controls:</b>					
Particulates	98.32	124.78	147.38		
Sulfur Oxides	2,542.34	3,226.72	3,811.17		
Hydrocarbons	933.45	1,178.14	1,424.74		
Carbon Monoxide	2,702.98	3,430.61	4,051.98		
<b>Legislated Controls:</b>					
Particulates	42.66	18.32	2.14		
Sulfur Oxides	1,329.51	477.43	556.86		
Hydrocarbons	578.10	355.72	414.49		
Carbon Monoxide	1,217.92	144.58	51.89		

Table 3-15-1. (Continued)  
 Petroleum Industry Data Summary

CONTROL COSTS (Million 1975 \$)

Catalytic Cracking:

Investment	57.97	15.83	11.04	583.94	295.09
Total Annual Capital O&M	49.74 40.61 9.31	85.22 69.90 15.32	94.46 76.90 17.56	948.20 775.98 172.22	1,228.84 677.03 151.81

Fuel Gas Burning:

Investment	50.78	15.12	8.25	515.59	228.58
Total Annual Capital O&M	90.61 37.73 52.88	145.18 62.11 83.07	157.19 67.79 89.40	1,630.73 655.00 935.73	1,417.99 601.97 816.02

Storage:

Investment	47.40	15.81	10.25	355.26	180.19
Total Annual Capital O&M	18.57 18.57 0	32.10 32.10 0	37.75 37.75 0	359.17 359.17 0	316.74 316.74 0

## SCFERROALLOY INDUSTRY\$R

Production Characteristics and Capacities. In 1972, there were 26 companies operating an estimated 44 ferroalloy plants. The industry is composed of steel companies, chemical and mineral companies having access to particular alloying elements, and specialist producers of ferroalloys. Five companies use the metallothermic process to make specialty ferroalloys containing molybdenum, tungsten, vanadium, columbium or titanium. Six companies are involved in making ferrophosphorus. The remaining companies use the submerged-arc electric furnace to produce about one-half of the ferromanganese and virtually all of the silicon- and chromium-containing ferroalloys used in steelmaking.

Alloying elements required for making different steels are often added in the form of ferroalloys which contain iron and at least one other element. The ferroalloys are named according to the major alloying element: ferromanganese contains manganese as the additive; ferrochromesilicon contains both chromium and silicon. Another group of additives in which the iron content is very small (such as silicomanganese and silicon-chrome-manganese) are also considered as ferroalloys.

Ferrous alloys are made by three methods with submerged-arc electric furnaces producing most of the output. Three types of furnaces are adapted to the three production methods. open furnaces, semicovered furnaces, and sealed furnaces. Metalthermic reduction furnace production has been included with electric furnace production in the absence of sufficient information on number, location, emissions, and air-pollution-control methods. Two domestic producers use blast furnaces for making ferromanganese and occasionally ferrosilicon.

Emission Sources and Pollutants. Particulate emissions are generated during the handling of the ores, fluxes, and reductants used in the production of ferrous alloys. Particulate and gaseous emissions are continuously evolved during smelting operations. Fuming occurs when the ferroalloy is poured, the amount varying with the particular ferroalloy. Submerged-arc electric furnaces of the open or open-hood type are required because of the formation of crusts with certain ferroalloys; these crusts must be broken mechanically. With semicovered or low-hood type submerged-arc furnaces, the charge is fed to the furnace through openings around the electrodes. In open-hood furnaces, the collection hood is raised sufficiently to provide room for charging between the hood and the charging floor; in semicovered furnaces, the hood is lower and water-cooled.

Open and semicovered furnaces produce greater emissions than sealed furnaces, which are used to prevent the escape of emissions and to minimize the influx of air.

Metallic silicon and aluminum are very strong deoxidizers which are used under high-temperature conditions to reduce the mineral oxides of molybdenum, titanium, zirconium, and similar metals in metalothermic reduction furnaces.

In blast furnace smelting operations, particulates and gaseous emissions are carried out of the furnace in the same off-gas stream.

Control Technology and Costs. Baghouses, electrostatic precipitators (ESP), and high-energy scrubbers are all used to control emissions from submerged-arc electric furnaces. Fumes evolving from the casting of ferromanganese in blast furnace operations must also be controlled by baghouses.

A total of 155 ferroalloy furnaces were used in developing the model furnaces used to produce cost estimates; however, only 56 furnaces could be identified as to specific ferroalloy produced and the furnace electric power rating. The distribution for these 56 furnaces was assumed to represent the size distribution for all the existing

furnaces. Emissions from ferroalloy furnaces are related to the furnace electric power input.

A relationship between furnace power input and production was used to estimate furnace capacity. Capacities of open-hood and low-hood electric furnaces were related to the capacities of baghouse, scrubber, and electrostatic precipitator control devices required to satisfy the requirements.

To estimate these air pollution control expenditures, the existing ferroalloy industry was divided into three segments. These segments are shown in Table 3-16-1 under the Process Characteristics heading. Annualized production and cost control data is presented in Table 3-16-1.

Table 3-16-1.  
Ferroalloy Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (1,000 MT/Yr-KVA)	3,270.0	4,569.0	4,826.0		
Annual Growth Rate Over the Period 1971-85 = 4.77%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes (1,000 MT/Yr)</b>	<b>Pollutants Generated</b>	<b>Control Technology</b>		
Open and Low Hoods	14.5:37:41	Particulates	Baghouse		
Open and Low Hoods	33	Particulates	Scrubber		
Low Hoods	32	Particulates	ESP		
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
1971 Controls:					
Particulates	162.01	226.45	255.97		
Legislated Controls:					
Particulates	74.77	8.39	9.00		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	73.06	0.94	0.09	343.81	118.83
Total Annual Capital O&M	45.34	70.69	71.17	772.76	673.88
	36.61	55.14	55.95	605.85	525.94
	8.73	15.55	15.22	166.91	147.94

## IRON AND STEEL INDUSTRIES

Production Characteristics and Capacities. The iron and steel industry production operation includes the following major sequential processes: recycling (sintering), coke production, and steelmaking. There are three types of steelmaking: open-hearth (OH), basic-oxygen furnace (BOF), and electric-arc furnace (EAF).

Sintering is the process by which iron-ore fines and reclaimed iron dusts, sludges, and scale generated in various iron and steelmaking processes are agglomerated and prepared for charging in blast furnaces. Coking is the process used to convert suitable grades of coal to metallurgical coke for charging in the blast furnace. Blast-furnace operation is a smelting process by which iron ore is reduced to pig iron; open-hearth, basic oxygen, and electric-arc furnaces are used to make steel.

Sintering Plants. There are 15 companies operating 43 recycling or sintering plants ranging in size from about 180,000 metric tons per year to 4.3 million metric tons per year. Total annual capacity is estimated to be about 56 million metric tons. Sintering plants have been grouped into 14 categories based on size and applicable pollution control regulation. Sintering consists of agglomerating ore

finer and reclaimed iron-containing dusts, sludge, and scale generated in various iron and steelmaking processes. Sinter is made by mixing these fines with limestone and coke (or anthracite coal), charging the mixture onto a continuous traveling grate, and igniting the mixture. Air is blown through the mixture to support combustion. The sintering is completed by the time the end of the grate is reached. The sinter clinker is cooled, crushed, and screened to size for charging to the blast furnace.

**Coke Plants.** There are about 60 coke plants operating in the United States, ranging in size from about 220,000 metric tons to 6.4 million metric tons of coal throughput per year. The vast bulk of the coke production is owned by iron and steel companies (or affiliates). About 10 percent of the coke is produced in merchant plants for sale in the open market to foundries, other industrial users, or for internal consumption for other than steel-producing purposes.

Coking coals are received at a coal preparation facility where they are finely pulverized and mixed in the required proportions to meet specifications for the blast furnace or for other end uses. The prepared coal mixture is delivered to storage bunkers above the coke oven batteries. Measured quantities of the mixture are withdrawn from the bunkers and carried to individual ovens for charging. The coal is

heated in the absence of air for a period of 14 to 18 hours at temperatures of from 900 to 1100 C to convert the coal to coke having the desired properties. During the coking cycle, volatile constituents and noncondensable gases are distilled and transferred via collecting mains to the byproducts plant for the recovery of the gas and various chemicals. When the coking cycle is completed, the doors on the ends of the oven are removed and a ram pushes the incandescent coke from the oven into a quench car. The hot coke is transported to a quench tower where it is cooled under a direct water spray. The coke is then crushed and screened for use in the blast furnace or for other purposes. The fines from the crushing operation are used as a fuel in sintering operations, or are sold commercially.

Open-Hearth Steelmaking. This method is the oldest of the three steelmaking processes presently being used to produce raw steel. Open-hearth steel production has declined from a peak of 89 million metric tons in 1964 to about 36 million metric tons in 1973. In 1973, there were an estimated 18 operating open-hearth shops in the integrated iron and steel industry. It is doubtful that any new plants will be constructed. Furnace capacities range from 50 to 300 net metric tons of steel. For this report, the open-hearth plants have been grouped into five model sizes as follows:

\$t	Average Size (1,000 metric tons/year)	No. Plants	Capacity (million metric tons/year)	Total Capacity (%)
	283.4	2	0.57	2.0
	982.6	3	2.95	10.4
	1360.5	6	8.16	28.9
	1814.0	4	7.26	25.7
	3099.0	3	9.30	32.9
Totals		18	28.24	100.0\$R

The open-hearth furnace is a shallow-hearth furnace that can be alternately fired from either end. The process consists of charging scrap, fluxes, and molten pig iron into the furnace where the required melting and refining operations are performed to produce the desired analysis of steel. Firing of an open hearth can be done with a variety of fuels, depending on availability, cost, and sulfur content in the fuel.

Basic-Oxygen Furnace Steelmaking. BOF was first used to produce steel in the United States in 1955. By 1965, economic replacement of the open-hearth furnace by the BOF had been well established. BOF steelmaking expanded rapidly to about 76 million metric tons in 1973. Recently, a newer process called Q-BOF has been used for commercial production of steel. This new process has been included with the BOF process for the purposes of this report. In 1973, there were 19 companies operating 38 BOF plants, ranging in size from 450,000 metric tons to 4.3 million metric tons of

annual capacity. For the purposes of this report, these plants have been grouped into four model sizes as follows:

\$t	Average Size (net metric tons/year)	No. Plants	Capacity (million metric tons/year)	Total Capacity (%)
	68-127	10	11.2	14.7
	136-172	5	8.1	10.7
	181-240	20	46.0	60.7
	263-295	3	10.5	13.9
		38	75.8	100.0\$R

In BOF steelmaking, the pear-shaped, open-top vessel is positioned at a 45-degree angle and charged with the required amount of steel scrap, molten pig iron, and other materials. The vessel is vertically positioned and high-purity oxygen is blown into the molten bath through a water-cooled oxygen lance positioned above the bath. Products of the oxygen reaction with the carbon, the silicon, and the manganese in the charge pass off as carbon monoxide and carbon dioxide gases, and manganese and silicon oxides in the slag. When the required content of carbon, silicon, and manganese is obtained in the melt, oxygen blowing is stopped, and ferroalloys are added as needed to attain the desired final chemical composition of the steel. The molten steel is then poured into a ladle for transfer to subsequent operations.

Electric-Arc Furnace Steelmaking. This process has long been the established unit for the production of alloy and stainless steels. More recently, it has been widely used in mini-steel plants to make plain carbon steels for local markets. In 1972, electric-arc furnace production amounted to 1.5 million metric tons of stainless steel. In 1973 there were almost 100 companies operating electric-arc furnace plants ranging in size from 9 thousand metric tons to 1.2 million metric tons annual capacity. The total electric-arc furnace production in 1973 was about 25 million metric tons. For the purposes of this report, electric-arc furnaces have been grouped into six model sizes as follows:

Average Size (1,000 metric tons/year)	No. Plants	Capacity (million metric tons/year)	Total Capacity (%)
45-77	11	1.0	4.0
82-127	26	2.5	10.1
136-204	21	3.4	13.4
218-340	11	3.1	12.3
363-544	21	9.1	36.1
907-1197	6	6.1	24.2
Totals	96	25.2	100.1%R

The electric-arc furnace is a short, cylindrical-shaped furnace having a rather shallow hearth. Three carbon electrodes project through the fixed or moveable roof into the furnace. Charge materials consist of prepared scrap, although one or two electric furnace shops make use of

molten pig iron as part of the charge. After charging, the melting operation is started by turning on the electric power to the electrodes which are in contact with the scrap. Electrical resistance of the scrap produces heating and eventual melting of the scrap. Additional scrap is added, and refining is accomplished by blowing high-purity oxygen into the molten scrap to remove carbon and silicon. Ferroalloys are added as needed to attain the desired final chemical composition of the steel. Power is shut off and the molten metal is tapped into a ladle.

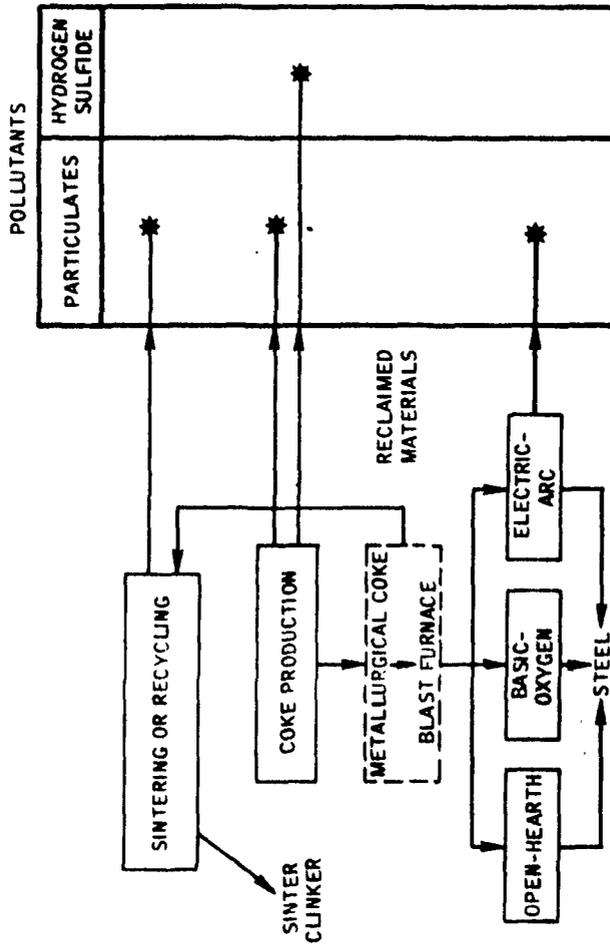
**Emission Sources and Pollutants.** The processes employed in producing steel are shown in Figure 3-17-1. Five of these processes are important generators of air emissions, and therefore they must be controlled to meet State Implementation Plans and Federal New Source Performance Standards.

**Sintering Plants.** The emissions associated with sinter plant operations are particulates that (1) become entrained in the combustion air as it is drawn through the sinter mixture into the windbox, (2) are generated during the cooling operation, and (3) are generated during the crushing and screening operations. Sulfur contained in the fuel is not considered to be a major problem, although any sulfur

present in the sinter mix or in combustion fuel will be  
emitted as sulfur oxides.

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Figure 3-17-1.  
Iron and Steel Production Processes



Coke Plants. Emissions from the production of coke occur as particulates, hydrogen sulfide, sulfur oxides, carbon monoxide, hydrocarbons, and nitrogen oxides. Particulate emissions occur from the following sources: coal receiving and stockpiling, coal grinding and handling, charging of coke ovens, pushing the coke from the ovens, and coke quenching. Gaseous emissions occur during the following operations: charging the coke ovens, the coking cycle, and subsequent combustion of coke-oven gases.

Open-Hearth Furnace Steelmaking. Particulates are the primary emissions from open-hearth-furnace operations. Emissions of iron oxide occur during the time the scrap is melted and large quantities of iron, silicon, and manganese oxides are formed and carried into the exhaust system of the furnace where high-purity oxygen is blown into the steel bath to remove the carbon. Gaseous emissions are largely carbon dioxide, but sulfur oxides may result through use of sulfur-containing fuels. If the scrap used in the charge contains combustibles, greater volumes of gaseous contaminants will be produced.

Basic-Oxygen Furnace Steelmaking. Particulates and carbon monoxide are major emissions in BOF steelmaking. Particulate emissions occur at the hot-metal transfer stations, the flux and alloy material-handling and transfer

points, and the BOF vessel. Carbon monoxide and carbon dioxide are emitted at the BOF vessel.

Electric-Arc Furnace Steelmaking. Particulates are the primary emissions released by electric-arc furnace steelmaking. Charging, scrap melting, oxygen blowing, and tapping are major sources of particulate emissions. Blowing the molten steel with high-purity oxygen produces the highest emission rates. Emissions from the scrap charge and other operations are similar to those from other steelmaking processes and constitute the largest portion of the total emissions.

Control Technology and Costs. The following paragraphs contain a brief analysis of pollution control methods used in each process of the iron and steel industry.

Sintering Plants. Electrostatic precipitators, high-energy scrubbers, and baghouses are used to control the particulates originating from the sinter strand. Dry cyclones and baghouses are used to control particulates from other emission sources. Developments in blast-furnace technology which require additions of limestone and dolomite to the sinter mix make continued use of electrostatic precipitators problematical because of the difference in electrical properties between limestone dusts and iron-

containing dusts. Installation of high-energy wet scrubbers may be required as replacements for some existing electrostatic precipitator installations.

**Coke Plants.** The technology for controlling emissions from coke ovens is still in the developmental stage: definitive control measures have not been established. Scrubbers are being used as the principal control technique for particulates in the control systems now under development. In addition to air-pollution-control devices, improved coke oven design and improved operating practices (such as sequence charging) are factors offering significant means of control.

**Open-Hearth-Furnace Steelmaking.** Electrostatic precipitators and high-energy scrubbers are used in controlling emissions from open-hearth furnaces.

**Basic-Oxygen Furnace Steelmaking.** Electrostatic precipitators and high-energy scrubbers are the principal control systems applied to the BOF. Baghouses have been suggested for use in the United States and have been tried in Europe. Baghouses are used for collecting particulates at the hot-metal stations, and the flux and ferroalloy handling locations.

Table 3-17-1 shows the estimated growth of the steel industry in terms of sales, production, and capacity. It is estimated that the open-hearth process of making steel will decline in importance as the basic oxygen and electric-arc processes increase in importance.

\$dTable 3-17-1.  
Iron and Steel Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (1,000 MT/Yr) Processes	100.361	135.996	138.614		
Coke & Sintering	271.325	354.689	352.900		
Annual Growth Rate Over the Period 1971-85 = 11.10% Processes 10.18% Coke & Sintering					

PROCESS CHARACTERISTICS	Segment	Model Plant Sizes (1,000 MT/Yr)	Control Technology	Standard
1. Sintering (alternatives)	1	508;1,100;2,700;	ESP	
		5,250		Pennsylvania
	2	500	Flooded Disc Scrubber	Pennsylvania
	3	575	ESP	Illinois
	4	500	Flooded Disc Scrubber	Illinois
	5	422;1,100;2,375;	ESP	Federal
		3,600;5,200		
2. Coking (sequential)	6	550	Flooded Disc Scrubber	Federal
	7	1,300	Baghouses	Federal
	1		CO gas desulfurization	H2S Federal
	2		Charging Car Collector	Federal
	3		Collection Hood	Federal
	1	2,000;3,375	ESP	Pennsylvania
	2	125;150	ESP	California
3. Open Hearth	3	1,250	ESP	Illinois
	4	500;750;1,500;	ESP	Federal
		2,000;3,500		
	5	1,250;2,500	Scrubber	Federal
	1	1,125;2,333	ESP	Pennsylvania
	2	875;2,325	Scrubber	Pennsylvania
	3	1,440	ESP	California
4. Basic Oxygen	4	965	ESP	Illinois
	5	1,633;1,500;2,265;	ESP	Federal
		3,500		
	6	3,000;2,575;4,050	Scrubber	Federal
	1	64;120;185;272;	Baghouse	Pennsylvania
		400,800		
	2	200;350;488	Building Evacuation	Pennsylvania
3	1,000	Scrubber	Pennsylvania	
5. Electric Arc				
\$dTable 3-17-1. (Continued)				
Iron and Steel Industry Data Summary				
PROCESS CHARACTERISTICS	Segment	Model Plant Sizes (1,000 MT/Yr)	Control Technology	Standard
	10	300;477;1,200	Scrubbers	Federal

	11	450	1975	1980	1985	1971-85	1976-85
4	80:102:160						
5	108:575						
6	187:350:600:725						
7	1,000						
8	69:108:175:338.463						
	750:1,177						
9	100:350						

ESP  
 Baghouse  
 Building Evacuation  
 Baghouse  
 Scrubber  
 Baghouse  
 Building Evacuation  
 Federal  
 California  
 California  
 Illinois  
 Illinois  
 Federal

EMISSIONS (1,000 MT/Yr)

Particulates

1971 Controls:	633.58	840.86	889.34		
Open Hearth	156.64	136.07	56.38		
BOF	444.62	653.58	764.04		
Electric-Arc	32.32	51.21	68.92		
Legislated Controls:	296.67	34.59	34.94		
Open Hearth	71.86	5.38	2.12		
BOF	209.95	27.10	30.12		
Electric Arc	14.86	2.11	2.70		

CONTROL COSTS (Million 1975 \$)

Investment	782.77	61.37	14.15	3,957.76	1,438.79
Total Annual	452.24	685.01	726.72	7,651.97	6,643.43
Capital	367.70	540.43	573.81	6,058.30	5,243.10
O&M	84.54	144.58	152.91	1,593.67	1,400.33

## SCIRON FOUNDRIES

Production Characteristics and Capacities. Iron foundries may be found in almost all urban areas. The economies of scale for the industry do not prohibit the continued existence of relatively small foundries. Because many of the foundries are operated in conjunction with steel making facilities, iron foundries tend to be concentrated in the major steel producing states: Pennsylvania, Ohio, Michigan, Illinois, and Alabama.

Iron foundries range from primitive, unmechanized hand operations to modern, highly-mechanized operations. Captive plants (owned or controlled by other businesses) are more likely to be mechanized and better equipped with emission-control equipment than are noncaptive plants.

In 1973, about 6 percent of the 1,432 plants were classified as large (over 500 employees), 29 percent as medium (100 to 500 employees), and 65 percent as small (less than 100 employees).

The major markets for iron castings include motor vehicles, farm machinery, and industries that build equipment for the construction, mining, oil, metalworking, and railroad industries. Captive plants have the capability of

economical production of large lots of closely related castings. Most of the largest plants are captive and do not generally produce for the highly competitive open market.

Castings for machine parts, automotive parts, and soil pipe are produced from both pig iron and scrap. Cupola, electric-arc, electric-induction, and reverberatory furnaces are used. In 1973, 79 percent of the production was by cupolas, 12 percent by electric-arc furnaces, and the remainder by induction and reverberatory furnaces. The latter two types emit relatively small quantities of pollutants and require little or no emissions-control equipment.

The cupola furnace is a vertical, cylindrical furnace in which the heat for melting the iron is provided by injecting air to burn coke which is in direct contact with the charge. An electric-arc furnace is an enclosed, cup-shaped refractory shell that contains the charge. Three graphite or carbon electrodes extend downward from the roof. An electric arc between the electrodes and the charge generates the required heat. The cupola melts the charge continuously, while the arc furnace operates in a batch mode.

Emission Sources and Pollutants. Emissions from cupolas are carbon monoxide, particulates, and oil vapors.

Particulate emissions arise from dirt on the metal charge and from fines in the coke and limestone charge.

Hydrocarbon emissions arise primarily from partial combustion and distillation of oil from greasy scrap charged to the furnace, but their control is not costed in this report because the emissions are small. Arc furnaces produce the same kind of emissions to a lesser degree because of the absence of coke and limestone in the charge.

The particulate emission factor for uncontrolled cupola operation is taken to be 8.5 kg per metric ton. The best available estimate of the particulate emission factor for uncontrolled arc furnaces is taken to be 5 kg per metric ton.

An uncontrolled cupola generates approximately 150 kg carbon monoxide per metric ton of charge. Half of this carbon monoxide burns in the stack. On this basis, the estimated emission factor for carbon monoxide discharged from an uncontrolled cupola is approximately 75 kg per metric ton of charge. Uncontrolled arc furnaces produce negligible quantities of carbon monoxide.

Control Technology and Costs. In industrial practice,

large cupolas use high-energy scrubbers to control the emission of particulates to acceptable levels. Medium sized cupolas can use either a high-energy scrubber or a baghouse. For small cupolas and arc furnaces, baghouses are preferred.

High-energy scrubbers usually are operated at a particulate collection efficiency of 95 percent. This efficiency can be increased to 99 percent by increasing the pressure drop. Fabric filters (baghouses) have an efficiency of 98 percent. Electrostatic precipitators also have a high efficiency rate of 96 percent.

Afterburners are used to control carbon monoxide emissions from cupolas. The efficiency of afterburners to control carbon monoxide emission is generally taken to be 94 percent.

Table 3-18-1 presents annualized production and cost control data for the industry; iron castings are made using either the cupola or electric-arc process. To estimate the costs of controlling air pollution from this industry, the five processes were listed individually for cost-comparison evaluation.

Table 3-18-1.  
Iron Foundries Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (Million MT/Yr)	35.28	46.48	48.16		
Annual Growth Rate Over the Period 1971-85 = 3.4%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes (MT/Yr)</b>	<b>Pollutants Generated</b>	<b>Control Technology</b>		
Process 1 - Cupola	87,000;13,060;2,180	Carbon Monoxide	Afterburners		
Process 2 - Cupola	87,000	Particulates	Scrubber		
Process 3 - Cupola	13,060;2,180	Particulates	Baghouse		
Process 4 - Arc Furnace	13,060;2,180	Carbon Monoxide	Afterburners		
Process 5 - Arc Furnace	13,060;2,180	Particulates	Baghouse		
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
1971 Controls:					
Particulates	90.93	119.48	129.80		
Carbon Monoxide	1,171.81	1,539.83	1,672.83		
Legislated Controls:					
Particulates	48.47	21.46	2.62		
Carbon Monoxide	644.18	418.68	101.15		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	90.07	13.89	2.54	511.86	186.74
Total Annual Capital O&M	154.80	250.15	249.62	2,702.82	2,360.74
	52.91	79.81	89.30	874.57	755.71
	101.89	170.34	166.32	1,828.25	1,605.03

## SCSTEEL FOUNDRIES INDUSTRY\$R

Production Characteristics and Capacities. Two types of steel are produced from steel foundries: carbon steel castings and alloy-stainless steel castings. The plants that produce these castings are assumed to be controlled at a very high level by state emission standards (those for Pennsylvania are assumed) or by less strict Federal standards. The 1971 capacity of steel foundries is allocated among the types of steel and level of control as shown below:

\$t	Production Capacity(%)	Standard of Control(%)	
		Penns.	Federal
Carbon	90.44	38.40	52.04
Alloy-Stainless	9.56	3.07	6.49
Totals	100.00	41.47	58.53\$R

The electric-arc furnace is the established equipment for the melting of steels that are subsequently poured into molds to make castings. Castings may be in a semi-finished form that requires considerable machining before it can be used in other components, or it may be a high quality product that requires a minimum of additional work before subsequent use. Production of steel castings closely parallels the production of steel.

As a means of minimizing the factors influencing the capacity of the various foundries, a parameter termed "plant furnace holding capacity" was considered as an indicator of plant capacity. As an example: assuming a foundry and one furnace that held 1 metric ton of steel, two furnaces that held 5 metric tons each, and a third furnace that held 10 metric tons; the foundry's plant furnace holding capacity would be =  $(1 \times 1) + (2 \times 5) + (1 \times 10) = 21$  net metric tons. A relationship was then established between the "plant furnace holding capacity" and the estimated production capacity for steel castings. This was done for foundries producing essentially plain-carbon steel castings, others producing essentially alloy and stainless steel castings, and a third group producing large, plain-carbon or low-alloy steel castings. In determining control costs, the foundries producing large castings were grouped with the foundries producing carbon-steel castings on a one-shift basis.

Emission Sources and Pollutants. Particulates comprise almost 100 percent of the emissions occurring during the production of steel for castings. Minor amounts of carbon monoxide, nitrogen oxides, and hydrocarbons may be emitted. Most of the particulate emissions, which occur during the charging operation, are carried upward by the thermal gas currents created by the hot furnace; these emissions are

Generated during the charging operation and are the most difficult to control.

Control Technology and Costs. The allowable emissions of particulates per unit of process weight per hour under State Implementation Plans and Federal New Source Performance Standards for steel foundries were used as guidelines in establishing the level of control required for electric-arc furnace steel foundries, and the subsequent costs.

Baghouses are the only reported means for the control of emissions from steel foundry electric-arc furnaces. One of the probable reasons for not using scrubbers or electrostatic precipitators is the lack of space for installing the required water treatment facilities in the case of scrubbers, and a reluctance on the part of the smaller foundry operators to get involved with electrostatic precipitators

The inventory of electric-arc furnace steel foundries used in the report is based on information in two foundry directories and information in the published literature. A few steel foundries still use open hearth furnaces but these are rapidly being phased out of use.

Development of control costs for steel foundries is complicated by several factors: foundries do not operate the same number of hours during the year, different furnaces sizes are used in a single plant, some foundries specialize in plain-carbon steel castings, and some foundries produce only those castings that can be produced in large production runs, while a small number produce large, complicated castings on a one-or two-shift basis.

The cost calculations also take into account the fact that some plants work one 8-hour shift while others work two or three shifts. For example, the 38.4 percent of steel foundry capacity that produces carbon steel castings and is controlled by Pennsylvania particulate standards is actually 11.6 percent, 21.3 percent and 5.5 percent of the steel foundry capacity on one, two, and three shifts, respectively.

Table 3-19-1 shows the annualized summary information for steel foundries.

Table 3-19-1.  
Steel Foundries Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (Million MT/Yr)	1,686.6	2,331.5	2,292.9		
Annual Growth Rate Over the Period 1971-85 = 4.85%					
PROCESS CHARACTERISTICS					
	Model Plant Sizes (1,000 MT/Yr)		Pollutants Generated		Control Technology
Carbon/Alloy	5.583		Particulates		Baghouse
EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	27.39	36.62	37.68		
Legislated Controls:					
Particulates	15.57	8.94	0.82		
CONTROL COSTS (Million 1975 \$)					
Investment	3.42	2.08	0	268.98	18.21
Total Annual Capital	43.32	47.38	47.99	580.72	468.57
O&M	40.81	43.11	43.77	535.36	428.20
	2.51	4.27	4.22	45.36	40.3755

\$CPPRIMARY ALUMINUM INDUSTRY\$R

Production Characteristics and Capacities. The domestic primary aluminum industry is presently comprised of 12 companies operating 31 reduction facilities in 16 states. Three companies, Alcoa, Reynolds, and Kaiser, operate about two-thirds of the total capacity. Plants tend to be located in areas where cheap electrical power is available. The plant-size distribution for the industry is as follows:

\$t	Size Range (1,000 Metric Tons/Year)	No. Plants	Capacity(%)
	0-90.7	6	8.8
	90.8-136	11	28.1
	136.1-190	8	30.8
	191-254	6	32.3
		31	100.0\$R

Aluminum is one of the most abundant of the elements and when measured either in quantity or value, its use exceeds that of any other primary metal except steel. It is used to some extent in virtually all segments of the economy, but its principal uses have been in transportation, building and construction, electrical industry, containers and packaging, consumer durables, and machinery and equipment. Growth rate of aluminum industry in the United States has averaged 7 percent in recent years.

Bauxite ore (typically containing 50-55 percent alumina) is the principal source of aluminum. Alumina is extracted from bauxite by any one of a number of variations of the Bayer process. In turn, alumina is dissolved in molten cryolite and reduced to aluminum by electrolysis in the universally-used Hall-Heroult aluminum reduction cells, which are connected in series to form a potline.

The aluminum reduction plant may be classified according to the type of anodes used in the cells: there are two major types based on how they are replaced. Prebaked anodes are replaced intermittently, and Soderberg anodes are replaced continuously. In the Soderberg continuous system, an anode paste is continuously supplied to a rectangular metal shell suspended above the cell. As the anode shell descends, it is baked by the heat of the cell. The two types of Soderberg anodes use different support methods: a Vertical Stud System supported on vertical current-carrying pins (studs), and a Horizontal Stud System supported by pins which are inclined slightly from the horizontal.

Emission Sources and Pollutants. All three alternative processes currently used to produce aluminum release particulates which must be controlled. The prebaked anode process is easiest to control which explains its increased use in the future.

Of the three anode systems in use, prebaked, horizontal Soderberg, and vertical Soderberg, the vertical Soderberg system emits the lowest quantity of particulates, and the prebaked and horizontal Soderberg systems are higher in pollutant emissions. On the other hand, the prebaked system is easiest to control, the vertical Soderberg somewhat more difficult, and the horizontal Soderberg the most difficult to control.

Based upon reports from the aluminum industry, it is assumed that both gaseous and solid fluoride emissions are reasonably well-controlled at present. Hydrocarbon emissions from the Soderberg anode systems are ignited by a burner; the combustion gases are removed from the vicinity of the cells through a duct system.

**Control Technology and Costs.** At present, most smelters exert a good measure of control on particulate emissions, usually by means of electrostatic precipitators. The addition of an acid plant to handle gases from the roaster and the converter requires almost complete removal of particulates from these streams prior to processing in the acid plant. In addition, a wet scrubber should be preceded by an electrostatic precipitator to prevent scrubber plugging and to permit most of the furnace dust to be

returned to the smelting process or to dust byproduct recovery.

Table 3-20-1 shows the estimated growth of primary aluminum in terms of sales and capacity. Note that the prebaked anode process is the dominant one in existence now, and that all new plants are assumed to employ this process.

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Table 3-20-1.  
Primary Aluminum Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (1,000 MT/Yr)	4.070	5.473	5.069		
Annual Growth Rate Over the Period 1971-85 = 2.6%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes (1,000 MT/Yr)</b>	<b>Pollutants Generated</b>	<b>Control Technology</b>		
Prebaked Anode	144	Particulates	Hoods and Ducting; Scrubber		
Horizontal Soderberg	137	Particulates	Hoods and Ducting; Wet ESP; Scrubber		
Vertical Soderberg	32	Particulates	Hoods and Ducting; Wet ESP		
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
Particulates:					
1971 Controls:	49.22	65.49	63.90		
Prebaked Anode	33.41	50.61	53.76		
Horizontal Soderberg	12.67	11.97	8.17		
Vertical Soderberg	3.14	2.91	1.97		
Legislated Controls:	31.09	21.06	4.92		
Prebaked Anode	21.11	16.29	4.14		
Horizontal Soderberg	7.67	3.34	0.55		
Vertical Soderberg	2.31	1.43	0.23		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	477.79	6.71	0.04	2,242.47	801.16
Total Annual Capital O&M	488.22	723.86	648.44	7,864.98	6,797.79
	202.91	313.92	315.69	3,415.08	2,976.59
	285.31	409.94	332.75	4,449.90	3,821.20

## SECONDARY ALUMINUM INDUSTRY

Production Characteristics and Capacities. Aluminum has become one of the most important metals in industry, only iron surpasses it in tonnages used. Major uses of the metal are in the construction industry, aircraft, motor vehicles, electrical equipment and supplies, beverage cans, and fabricated metal products which include a wide variety of home consumer products. The automotive industry is a large user of secondary aluminum ingot.

Secondary aluminum ingot is produced to specification. Melting to specification is achieved mainly by segregating the incoming scrap into alloy types. The magnesium content can be removed with a chlorine gas treatment in a reverberatory furnace.

For the purpose of this report, the secondary aluminum industry is defined as that industry which produces secondary aluminum ingot to chemical specifications from aluminum scrap and sweated pig. The industry is viewed as consisting of secondary aluminum smelters excluding primary aluminum companies, the activities of non-integrated fabricators, or scrap dealers.

The secondary aluminum industry, as defined above, consists of an estimated 54 firms operating 58 plants. Although most sources list the industry as having more plants, their data usually include sweaters, scrap dealers, and non-integrated fabricators. Of the total estimated industry capacity of approximately 1 million metric tons per year, the top four firms account for about 50 percent of the total capacity.

The growth in estimated production of secondary aluminum ingot has increased at the average rate of 5.3 percent annually during the period 1963-71; it is estimated that future growth in production and capacity will continue at this average rate.

Emission Sources and Pollutants. The most serious emission sources during secondary aluminum smelting are: the drying of oil borings and turnings, the sweating furnace, and the reverberatory furnace. Emissions from the drying process are vaporized oils, paints, vinyls, etc; the sweating furnace produces vaporized fluxes, fluorides, etc; and the reverberatory furnace emissions are similar to the other two plus hydrogen chloride, aluminum chloride, and magnesium chloride from the chlorine gas treatment used to remove magnesium. As of 1970, an estimated 25 percent of chlorination station emissions were controlled, and it is estimated that by 1980, 80 percent will be controlled.

The several processes that cause emissions during the operation of a reverberatory furnace must be understood to calculate control costs properly; they are:

- Emissions at the forewell. Secondary smelters charge scrap directly into the forewell of the reverberatory furnace, and any oil, paint, vinyl, grease, etc., on the scrap vaporizes. The emissions from the charging process vary greatly with the material charged. Quantitative data on forewell emissions or the need for control are not available and costs or possible costs cannot be estimated.
- Emissions from the bath. During the time the aluminum bath is molten, it is covered with a flux to protect it from oxidation.
- Emissions caused by chlorination. The magnesium content of aluminum can be reduced by chlorination, but chlorination produces chloride emissions. Particulate emissions from the chlorination process are 500 kilograms per metric ton of chlorine used. Maximum magnesium removal requires about 18 kilograms of chlorine per metric ton of aluminum which has an emission rate of 9 kilograms of particulates per metric ton of aluminum. Magnesium removal is practiced by

plants representing 92 percent of the estimated industry capacity. A small portion of these plants use aluminum fluoride fluxing for magnesium removal rather than chlorine. This report assumes that control costs for these few plants are similar to those that use chlorination. Wet scrubbing is the usual means of controlling chlorination station emissions. Recent innovations on a dry control process are being tested.

Control Technology and Cost. Dryer emissions are known to exist and in many cases are treated with afterburners. However, there is insufficient data relating to the drying operations to permit evaluations of possible costs that might be expended to meet air-quality specifications

Sweating furnace emissions, fluoride from fluxes, organic materials, oils, etc., can be controlled by using afterburners, followed by a wet scrubber or baghouse for which control costs have been reported. However, no data is available on the number, capacity, or location of sweating furnaces. Thus, realistic estimate of control costs cannot be made. Industry costs and operating data are included in

Table 3-21-1.

Table 3-21-1.  
Secondary Aluminum Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (1,000 MT/Yr)	952.88	1,523.17	1,777.34		
Annual Growth Rate Over the Period 1971-85 = 11.9%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes (MT/Yr)</b>	<b>Pollutants Generated</b>	<b>Control Technology</b>		
Model 1	5,261:17,120:	Particulates	Wet Scrubber		
Model 2	43,536	Particulates	Wet Scrubber		
Model 3		Particulates	Wet Scrubber		
Model 4		Particulates	Wet Scrubber		
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
1971 Controls:					
Particulates	8.67	13.88	17.20		
Legislated Controls:					
Particulates	6.08	6.04	4.93		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	8.94	1.40	0.52	39.37	14.15
Total Annual Capital O&M	6.27	10.33	11.88	113.47	100.20
	3.36	4.88	5.63	54.70	47.67
	2.91	5.45	6.25	58.57	52.53

## \$PRIMARY COPPER INDUSTRY\$R

Production Characteristics and Capacities. Copper is one of the most important of the nonferrous metals, surpassed only by iron in one tonnage produced in the United States. Its extensive use depends chiefly upon its electrical and heat conductivity, corrosion resistance, ductility, and the toughness of its alloys. Mechanical properties (and sometimes special properties) are enhanced by alloying with zinc to form brass, with tin to form bronze, with aluminum or silicon to form the higher strength bronzes, with beryllium to form high strength-high conductivity bronzes, with nickel to form corrosion resistant alloys, and with lead to form bearing metals.

Principal users of copper include the electrical, electronic, and allied industries for manufacturing power transmission lines, other electrical conductors, and machinery. The automobile industry (radiators, wiring, and bearings) and building-construction industry (tubing, plumbing) are the second- and third-largest consumers of copper in the United States.

Copper ore is either surface or underground mined, concentrated by ore-beneficiation techniques, then sent to the smelter. Processing of copper concentrates at a smelter

Involves the following operations. Roasting is normally used to dry the finely ground concentrates and to remove some sulfur, arsenic, antimony and selenium impurities. Roasting is frequently bypassed in modern smelters because better concentration methods remove free pyrite and permit the substitution of simple dryers for roasters at some smelters. The roasted concentrate is treated in a reverberatory furnace to produce an intermediate material called matte, which nominally contains copper, iron, and sulfur. The matte is converted to impure blister copper by blowing with air of an air-oxygen mixture in a vessel called a converter to remove the sulfur and the iron. Removal of the impurities from blister copper is sometimes limited to fire refining, in which the impurities are removed in a furnace by volatilization and oxidation. More often, it entails a two-step procedure: fire refining to produce electrodes for further refining by electrolytic methods.

The principle sectors of the primary copper industry (mining, smelting, refining, fabricating and marketing) are dominated in varying degrees by three large, vertically-integrated companies. In the smelting sector, four companies account for about 85 percent of the smelting capacity. The smelting sector comprises 8 companies operating 15 active smelters with a total annual smelter

charge capacity of about 8.0 million metric tons, equivalent to about 1.8 million metric tons of copper metal.

Seven of the active smelters are in southern Arizona, with one each in Texas, New Mexico, Utah, Nevada, Montana, Washington, Michigan and Tennessee.

In early 1973, one company operated only a smelter, while eight operated both smelters and refineries. The plant size distribution for 15 active smelter operations, based on equivalent roaster charge, is shown in the tabulation below:

Capacity Range (1,000 metric tons/year)	No. Plants	Total Capacity(%)
0-181	1	1.0
182-363	4	14.7
364-544	4	23.1
545-816	3	27.7
817-907	3	33.5SR

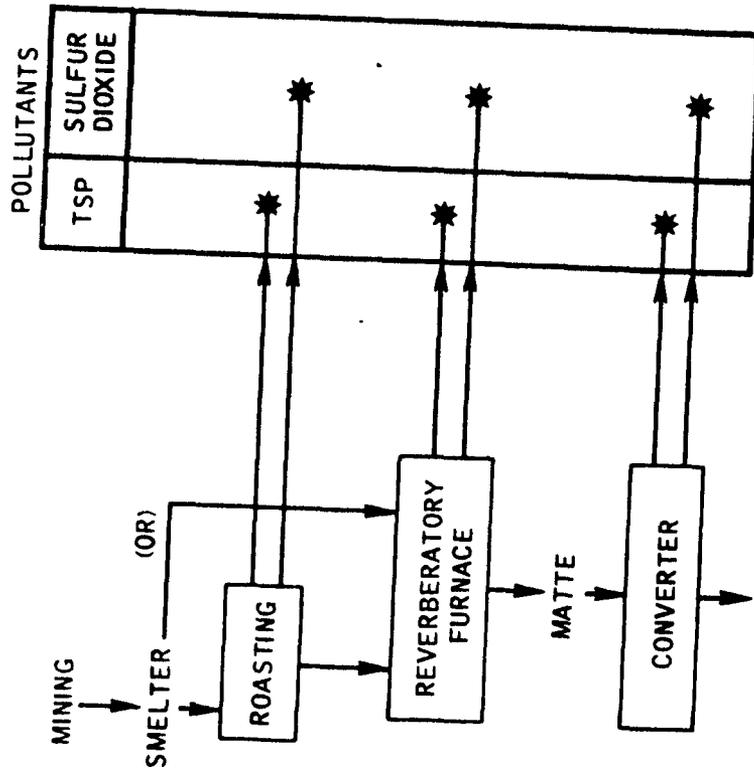
Emission Sources and Pollutants. Emissions from copper smelters are primarily particulates and sulfur oxides from the roaster, reverberatory, and converter furnaces. The density and continuity of emissions vary with the furnace type. Particulates can contain considerable byproduct credits, particularly noble metals and selenium. Accordingly, part of the traditional production process is to recycle particulates up to the limit of economic

viability, between 90 to 99.5 percent control, leaving the rest to be discharged as uncontrolled emission.

The three processes that produce significant sulfur dioxide and particulate emissions in the production of primary copper are shown in Figure 3-22-1. The roasting process may be bypassed by modern smelters that have better concentration methods to remove free pyrite. Half of the plants operating in 1971 were able to bypass the roaster process.

Figure 3-22-1.  
Primary Copper Production Processes

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Sulfur dioxide is emitted from all three smelter operations; however, the concentration of sulfur dioxide in the gases varies considerably among the three. Sulfur dioxide concentrations for fluid-solid roasters, reverberatory, and converter furnaces are 6-10 percent, 0.50-2 percent, and 2-5 percent by volume, respectively.

Control Technology and Costs. In 1971, approximately 95 percent of the particulate emissions were being controlled from copper smelters because of the economic advantage of recovering precious metals. Further removal of particulates is required to allow the sulfur dioxide control devices to operate effectively. Thus, the cost of controlling air emissions from copper smelters to meet Federal legislation requirements could be attributed to the control of sulfur dioxide.

The various techniques being used and proposed to control sulfur oxides emission in the gaseous effluents from copper smelters have been described in detail in public literature. It is assumed that most smelters will manufacture sulfuric acid by the contact process from the sulfur dioxide in the roaster and the converter gases. Two major conditions must be met: (1) the concentration of sulfur dioxide in the gas stream should be at least 4 percent by volume, and (2) the gas must be practically free of particulate matter to avoid

poisoning the catalyst in the acid plant. Eleven smelters already have acid plants. The one plant in Michigan does not require an acid plant because of the low sulfur content of the ore, and therefore it is not costed out in this report.

Several methods have been proposed and have been considered here for the purpose of removing the sulfur dioxide from the reverberatory gas stream. These include:

- Absorption of sulfur dioxide in dimethylaniline, followed by desorption and recovery.
- Cominco absorption process in which sulfur dioxide is absorbed into an ammonium sulfite solution, which yields concentrated sulfur dioxide and an ammonium sulfate by-product.
- Wet lime scrubbing, whereby the reverberatory furnace gases are scrubbed in a slurry of lime and water.
- Wet limestone scrubbing, essentially similar to wet lime scrubbing except a slurry of limestone is used as the scrubbing medium.

Annualized control costs and industry operating statistics are detailed in Table 3-22-1.

\$d  
Table 3-22-1.  
Primary Copper Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (Million MT/Yr)	9.40	13.24	15.67
Annual Growth Rate Over the Period 1971-85 = 5.4%			
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes (MT/Yr)</b>	<b>Pollutants Generated</b>	<b>Control Technology</b>
Roaster	704,000	SO2 & TSP	Acid Plant
Reverberatory Furnace or Converter	400,000; 501,400	SO2 & TSP SO2 & TSP	Limestone Scrubber Acid Plant
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1971-85</b> <b>1976-85</b>
<b>1971 Controls:</b>			
Sulfur Dioxide	2,032.58	2,966.87	3,011.89
Particulates	56.73	82.81	84.06
<b>Legislated Controls:</b>			
Sulfur Dioxide	1,084.92	516.43	106.42
Particulates	25.91	4.12	2.95
<b>CONTROL COSTS (Million 1975 \$)</b>			
Investment	329.71	16.11	0
Total Annual Capital O&M	213.12 139.21 73.91	413.66 257.09 156.57	417.08 261.66 155.42
			1,407.80
			752.44
			3,785.36
			2,376.36
			1,409.00

## SCSECONDARY BRASS AND BRONZE INDUSTRY\$R

Production Characteristics and Capacities. The secondary brass and bronze industry may be divided into two segments: ingot manufacturers and brass mills. Both segments of the industry charge scrap into a furnace where it is melted and alloyed to meet design specifications for chemical composition. Ingot manufacturers use either a stationary reverberatory furnace or a rotary furnace for most of their production. The capacity range is from 4.5 to 90 metric tons for reverberatory furnaces, and from 2 to 27 metric tons for rotary furnaces. Small quantities of special alloys are processed in crucible or electric induction furnaces. A few cupolas exist in which highly oxidized metal, such as skimmings and slag, is reduced by heating the charge in contact with coke. Ingot manufacturing invariably requires injection of air to refine the scrap. Brass mills use scrap that does not require such extensive refining; the channel induction furnace is the most common type used in these mills.

This industry could be represented by three model furnace sizes: 68 metric tons per day, 32 metric tons per day, and 10 metric tons per day. From the survey, 15 plants had 47 furnaces; the size distribution of the furnaces was: 11 percent-large, 23 percent-medium, and 66 percent-small.

With 3.13 furnaces per plant and 39 plants in existence in 1973, the number of furnaces in existence in 1972 was calculated to be 122. Of the 122 furnaces, 13 were large, 29 were medium, and 80 were small.

The large furnaces produced 50 percent of the total annual ingots, while the medium furnaces produced 30 percent, and the small furnaces produced 20 percent. Thus, the annual operating hours for a large furnace was 3,880, 2,240 hours for a medium furnace, and 1,580 hours for a small furnace to produce an annual charge of 287 thousand metric tons in 1973; the 287 thousand annual metric tons of charge was based on a yield of 89 percent for the 255 thousand tons of ingot that was reported in 1973.

No growth is expected in the manufacture of ingots; in 1980, ingot production is expected to be at the level of 272 thousand metric tons. Adequate capacity currently exists in terms of additional available operating hours to be able to meet the slight production increase from 1973.

The capacity of channel induction furnaces ranges from 0.5 to 5 metric tons, with smaller furnaces being the most common. It was estimated that there were 35 plants in existence in 1973 with an average of 3.7 furnaces per plant, on a total of 130 furnaces. The annual brass metric tonnage

produced in 1973 was 702 thousand. Based on an 89 percent yield, a total of 785 thousand metric tons of hot metal was poured; the amount of annual metric tons of hot metal per furnace is 6,090. Based on operating 242 days per year, the capacity of each furnace is 25 metric tons per day; each furnace can produce 12 heats per day. At a projected growth rate of about 4.5 percent per year, the production of brass mill products in 1980 will be 844 thousand metric tons. This will require 156 model furnaces having a capacity of 25 metric tons per day.

Emission Sources and Pollutants. Metallurgical fumes containing chiefly zinc oxide and lead oxide are the major emissions from the reverberatory and rotary furnaces that are used by ingot manufacturers and from the induction furnaces that are used by the brass mills. Fly ash, carbon, and mechanically-produced dust are often present in the exhaust gases, particularly from the furnaces used by the ingot manufacturers. Zinc oxide and lead oxide condense to form a very fine fume which is quite difficult to collect. The emission factors for particulates are 35 kg per metric ton of metal charged for a reverberatory furnace, 30 kg per metric ton for a rotary furnace, 3.2 kg per metric ton for an electric induction furnace, 6 kg per metric ton for a crucible furnace, and 36.75 kg per metric ton for a cupola furnace.

Control Technology and Costs. Ingot manufacturers use fabric-filter baghouses, high-energy wet scrubbers, and electrostatic precipitators because of their high efficiency in collecting the fine zinc oxide fumes: 67 percent use a baghouse, 28 percent use a scrubber, and 5 percent use an electrostatic precipitator. The survey mentioned earlier showed that about 85 percent of the industry used a fabric filter baghouse to control particulates that amounted to 68, 45, and 18 metric tons per day per respective model furnace plant capacities.

The collected dust had a value of 10 cents per kilogram. The following credits were based on the dust collected when all of the furnaces were under control at an average collector efficiency of 97.5 percent in 1973, and in 1980 when there will be a slight increase in annual production and all the furnaces will be in compliance.

\$t	1973 Credit		1980 Credit	
	Furnace Size (metric tons/hour)	Avg. Per Furnace	Total	Per Furnace Total
	68	\$2,938	\$38,186	\$2,968
	32	352	10,203	356
	10	30	2,465	32
Totals			\$50,854	\$51,360\$R

Fabric filter baghouses are used on the brass induction furnaces to collect the particulates. Investment and annual

costs were obtained from three plants that use furnaces with capacities ranging from 22 to 32 metric tons per day. Because their costs did not correlate with furnace capacity and were quite similar, the average value for the three plants was used for the model furnace of 25 metric tons per day. The collected dust is being stored for byproduct recovery because there is a market for the dust from the brass mills.

Annualized control costs and industry operating statistics are detailed in Table 3-23-1.

\$d  
 Table 3-23-1.  
 Secondary Brass and Bronze Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (Million MT/Yr)	0.907	1.373	1.412		
Annual Growth Rate Over the Period 1971-85 *	4.8%				
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes (MT/Yr)</b>	<b>Pollutants Generated</b>	<b>Control Technology</b>		
Model 1	716	Particulates	Fabric Filter		
Model 2	2,966	Particulates	Fabric Filter		
Model 3	6,105	Particulates	Fabric Filter		
Model 4	11,020	Particulates	Fabric Filter		
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
1971 Controls:					
Particulates	5.21	7.94	8.58		
Legislated Controls:					
Particulates	2.53	0.55	0.58		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	5.83	0.31	0.04	25.96	11.65
Total Annual Capital	4.80	8.53	8.40	89.26	79.22
O&M	1.88	3.34	3.42	34.70	30.94
	2.92	5.19	4.98	54.56	48.28

## SECPRIARY LEAD INDUSTRY\$R

Production Characteristics and Capacities. Lead production in the United States involves three major steps: mining, crushing, and grinding of sulfide ores, and beneficiation to produce lead concentrates; smelting of the concentrates by pyrometallurgical methods to produce impure lead bullion; and refining the bullion to separate other metal values and impurities.

The U.S. primary lead industry has some 80 small mining companies in 14 states who mine and mill their own concentrates; some of the smaller mines utilize custom mills. Smelting and refining of lead in the United States is done by four companies (Asarco, St. Joe, Amax, and Bunker Hill) that operate six smelters and five refineries. St. Joe is the only company not involved in custom smelting (outright purchase of concentrates) or toll smelting (smelting of concentrates for a fee).

Lead consumption in 1973 was 1.40 million metric tons, up 3-3/4 percent from the previous year. Battery components and metal products accounted for most of this growth. Gasoline additives, pigments, and cable coverings are subjected to downward consumption pressures. The growth rate in demand

during the 1970's is expected to be between 1 and 3 percent per year.

U.S. 1973 primary lead mine production was 561,000 metric tons, secondary lead production amounted to 593,000 metric tons, and imports of refined lead were 221,000 metric tons. Domestic mining capacity is expected to increase, reducing import levels.

Emission Sources and Pollutants. Emissions from lead smelters are primarily particulates and sulfur dioxide from two sources: sintering machines and blast furnaces. Most of the sulfur dioxide is removed in the sintering machine; the density of emissions varies with the source.

Flue-gas particulates include the following metals: as high as 30 percent lead, and traces of zinc, antimony, cadmium, and copper. In Western smelters, often significant byproduct credits of noble metals are also emitted; in one case, over 30 ounces of silver per ton and 0.14 ounce of gold was recovered. Thus, there is an economic reason to recover particulates in addition to fume control. The emissions from the slag furnaces used in the Western smelters to recover zinc also include particulates containing zinc oxide and zinc dust.

Control Technology. Sulfur oxides and particulates in sintering machine off-gases are being controlled by the use of sulfuric acid plants in three of the six U.S. smelters. In these smelters, particulate control is required for effective operation of the acid-plant system. In the three U.S. smelters without acid plants, most of the particulates in the processing off-gases are removed from the cooled off-gases in a baghouse prior to the stack; sulfur oxide in the off-gases is not controlled. (One of these smelters has an acid plant which is used only on the off-gases from a copper converter in an adjoining plant.)

Each of the six U.S. plants was examined in terms of equipment required to bring the plant within Federal control standards. Acid plants were assumed for those plants which do not now control sulfur oxide emissions. Methods of metallurgical operation at all six plants are similar, the differences stem from the type of ore handled by the three Missouri smelters and by the three Western smelters. In the West, lead ore concentrates are leaner with much higher amounts of gold, silver, zinc, cadmium, copper, antimony, and arsenic present. Except for a slagfuming furnace operation in the Western smelters to remove the higher amounts of zinc in the concentrates, there are no major differences in the basic smelter operations. There is a difference in degree in the refining operations, but off-

gases are not a problem in the refineries. Refining involves kettle operations at low temperatures just above the melting point of lead; no fumes are produced.

To determine control costs, the following sequences were assumed. The feed has a sulfur content of 15 percent, of which 85 percent is removed as sulfur dioxide in the sinter step. Particulate emissions are 54.5 kg/ton of feed in the sinterer, and 13.6 kg/ton of feed in the blast furnace.

Sulfur dioxide from the sinter step is available for conversion into acid. The acid plant is assumed to convert 90 percent of the sulfur dioxide it receives, emitting the rest. With an acid plant on the sinter, the additional gas cleaning scrubber is assumed to remove 90 percent of particulates.

The costs for the use of sulfuric acid plant to control sulfur dioxide were calculated as \$19.4 million for a plant producing 1,000 tons of acid daily, and an operating cost of \$1.85 million per year. A power law was used to describe the economies of scale for larger plants. The results of these calculations are presented in Table 3-24-1 along with anticipated emission levels.

Table 3-24-1.  
Primary Lead Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (1,000 MT/Yr)	292.0	444.5	485.6		
Annual Growth Rate Over the Period 1971-85 = 2.73%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes (MT/Yr)</b>	<b>Pollutants Generated</b>	<b>Control Technology</b>		
Blast Furnaces	107,026; 130,608	Particulates	Baghouse		
Blast Furnaces, Sintering		SO <sub>2</sub>	Acid Plant		
<b>EMISSIONS (MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
1971 Controls:					
Particulates (Lead)	331	503	552		
Sulfur Oxides	102,685	156,062	171,338		
Legislated Controls:					
Particulates (Lead)	244	272	294		
Sulfur Oxides	60,266	44,597	48,087		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	5.83	1.08	0.62	74.03	52.87
Total Annual Capital O&M	5.70	16.24	16.80	157.89	143.48
	3.44	11.66	12.05	109.24	101.38
	2.26	4.58	4.75	48.65	42.10\$

## SECSECONDARY LEAD INDUSTRY\$R

Production Characteristics and Capacities. The secondary lead industry is defined as the industry that recovers lead or lead alloys by smelting and/or refining lead scrap; this does not include the activities of scrap dealers who may sweat lead. A total of 22 companies in the secondary lead industry operate 45 plants. The two leading producers are estimated to account for about 64 percent of lead production.

Approximately 526,000 metric tons of secondary lead were recovered from scrap in 1970. In 1971, production rose to 528,000 metric tons. By 1973, the production of secondary lead rose to approximately 577,000 metric tons. Future growth in the secondary lead industry is projected at 3.2 percent per year. Plant capacities listed in Table 3-25-1 were estimated on a 1970 production basis. Industry capacity is estimated to be about 752,000 metric tons (assuming a production rate at 70 percent of capacity).

The assumption of an average emission factor for cupolas and reverberatory furnaces allows the breakdown of the secondary lead industry on the basis of capacity alone. Available capacity data indicate three model plant sizes. The

estimated industry capacity and model plant data are given in the following tabulation:

St	Capacity Range (metric tons/day)		No. Plants	Total Capacity (metric tons/day)	Model Plant Capacity (metric tons/day)
	83-181	27-82			
Plant Model I	83-181	23	2,482	109	
Plant Model II	27-82	6	327	54	
Plant Model III	12-26	16	253	15.8	
Totals	12-181	45	3,062\$R		

Emission Sources and Pollutants. Emission of particulates occurs from lead-processing furnaces. Generally, about 67 percent or more of the output of the secondary lead industry is processed in blast furnaces or cupolas that are used to reduce lead oxide in the form of battery plates or dross, to lead. If oxide reduction is not needed, then lead scrap can be processed in reverberatory furnaces. Kettle or pot furnaces may be used to produce small batches of alloys for holding or refining lead. These lead processing furnaces represent obvious particulate emission sources; the primary emissions being lead oxide. Another particulate emission source is the slag tap and feeding ports on the cupolas and reverberatory furnaces. Although lead is occasionally sweated in a reverberatory furnace, reclamation of secondary lead by this means is a very small portion of the total lead production. Emissions from slag operations are not known.

The industry estimate of 90 percent net control in 1970 indicates that nearly all plants had emission controls of some sort. A control increase to 98 percent estimated by 1980 is based on implementation of the proposed new source performance standards.

Control Technology and Costs. Either a baghouse or a wet scrubber can be utilized to achieve emission control. The baghouse is chosen for this cost analysis because it is generally cheaper; it is assumed baghouse life averages 15 years.

Annual costs include capital charges, operating and maintenance, and credits for byproduct recovery value. Since the lead oxide collected in the control equipment is recycled into the smelting furnace, it has value as a byproduct; therefore, the recovery of this lead oxide lowers estimated operating and maintenance costs.

The calculated costs for Model I, II, and III plants presented in this model plant cost tabulation included in Table 3-25-1 were based on the following key points:

- Model I plants are assumed to require two separate baghouse installations, while Model II and Model III were assumed to need only one baghouse for control.

• Baghouse airflow needs were estimated at 11.2 cubic meters per ton of daily capacity.

• The value of lead oxide recovered from baghouse operations was estimated to be 5 cents per kilogram, plus 50 percent. It was further assumed that only the lead oxide recovered by going from 90 percent net control in 1970 to an estimated 98 percent net control in 1980 should be credited against control costs. This amounts to 6.17 kilograms per ton of lead processed. In addition, production at full capacity was assumed.

Table 3-25-1.  
Secondary Lead Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (MT/Day)	2,623.2	3,985.7	4,339.1		
Annual Growth Rate Over the Period 1971-85 = 2.70%					
PROCESS CHARACTERISTICS					
	Model Plant Sizes (MT/Day)		Pollutants Generated		Control Technology
Secondary Lead	17.4,60.120		Particulates		Fabric Filter
EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	3.73	5.68	6.23		
Legislated Controls:					
Particulates	2.04	1.23	1.33		
CONTROL COSTS (Million 1975 \$)					
Investment	0.31	0.37	0.21	10.21	9.15
Total Annual Capital Outlay	0.93	3.03	3.48	29.37	27.28
	0.17	1.44	1.75	12.64	12.29
	0.76	1.59	1.73	16.73	14.99

## PRIMARY ZINC INDUSTRY

Production Characteristics and Capacities. Zinc ranks after aluminum, copper, and lead in tonnage of nonferrous metals produced in the United States. Major uses in 1973 were zinc-base alloys, particularly die-cast alloys used in automotive and electrical equipment (41 percent), galvanized steel used in construction and electrical transmission equipment (36 percent), brass and bronze used for plumbing, heating, and industrial equipment (14 percent), zinc chemicals, particularly zinc oxide, used in the rubber, paint, and ceramic industries (4 percent), and rolled zinc used in dry cells and lithographic plates (2 percent).

The principal ore minerals are sulfides, which may be predominantly zinc ores or lead-zinc ores. Also, some zinc is obtained from lead-base and copper-base ores. Zinc sulfide concentrates produced from these ores are converted to the oxide state (calcine) by roasting, and then reduced to metallic zinc by either electrolytic deposition or by distillation in retorts or furnaces. In plants using distillation methods, the calcine is given an additional sintering step to provide a more compact feed as well as to remove impurities. Some zinc producing companies also produce zinc oxide. In pyrolytic plants, both zinc metal and zinc oxide are produced from zinc vapor; in the first

case, the vapor is condensed to zinc metal; in the second, it is oxidized in a chamber.

Over three-quarters of the domestic mine production comes from these six states, listed in order of greatest output: Tennessee, Colorado, Missouri, New York, Idaho, and New Jersey. Numerous small companies participate in only the mining and beneficiation sector of the zinc industry; these companies sell their concentrates to custom smelters.

In 1973, six companies (St. Joe, Asarco, Amax, Bunker Hill, New Jersey Zinc, and National Zinc) operated the eight primary zinc plants shown in Table 3-26-1, all of which operate as custom smelters to some extent. Information on the locations, acid plant installations, annual capacities, and types of roasting processes used is also included. As indicated in the table, the three remaining horizontal-retort plants totaling 161,000 metric tons of capacity are in various stages of being phased out of operation. New electrolytic capacity totaling 354,000 metric tons of zinc will replace these horizontal retort plants; plant size distribution of the three new U.S. electrolytic plants is tabulated below:

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Capacity Feed (metric tons/yr)	Capacity. Slab Zinc (metric tons/yr)	% of U.S. Capacity After Closing Horizontal Retort Plants
296.000	163.000	29
264.000	145.000	26
82.000	45.000	85R

The main product of zinc reduction plants is slab zinc. One concentrate capacity in 1973 was 1.337.000 metric tons per year, equivalent to 763.000 metric tons slab zinc.

Approximately 24 percent of this capacity utilizes

horizontal retort plants; all of which will be phased out by July 1975.

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Table 3-26-1.  
Primary Zinc Plant Operations During 1973\$

In 1973, the three types of pyrothermic plants (electrothermic, vertical retort, and horizontal retort) accounted for almost two-thirds of the primary zinc capacity. This will change in the near future because three new electrolytic plants are in the early stages of construction; they are: the Asarco plant at Stephensport, Kentucky with a planned capacity of 163,000 metric tons of zinc annually, the New Jersey Zinc Company plant at Clarksville, Tennessee with a planned 145,000 metric tons capacity, and the New National Zinc plant at Blackwell, Oklahoma with a planned capacity of 45,000 metric tons.

Emission Sources and Pollutants. Emissions from zinc reduction plants are primarily particulates and sulfur dioxide from the roasters in the electrolytic plants, and from the roasters and traveling-grate sintering machines in the pyrothermic plants. In the electrolytic plants, the calcine from the roaster is substantially sulfur-free so that there is a heavy concentration of sulfur dioxide in the off-gases. In the case of the pyrothermic plants, roaster off-gases are also heavy, but there are only light concentrations of sulfur dioxide in the sintering machine off-gases. Particulates are relatively heavy in both streams.

Control Technology and Costs. Sulfur oxide and particulates in roaster off-gases are now being controlled by the use of sulfuric acid plants in six of the present eight plants. In these cases, particulate control necessary for the effective operation of the acid plant system is achieved with associated gas cleaning equipment. With the closing of the three horizontal retort plants by July 1, 1975, all the roasters in the primary zinc plants will be controlled with acid plants. In the two remaining pyrothermic plants, the sintering machine particulates are controlled in one case by settling flues, electrostatic precipitators, and a baghouse, in the other, by a venturi scrubber.

In general, the control scheme for the primary zinc industry is to use acid plants on the roaster off-gases where most of the sulfur dioxide is given off. All other operations, with the exception of three plants using a horizontal retort, have particulate control devices. In the case of these plants with horizontal retorts, conversion to vertical retort equipment is the practical control scheme; however, costs for this conversion were not obtained, as this involves a major plant renovation.

With the closing of the three horizontal retort plants, the only new control equipment required for the industry will be

the acid plants and associated gas cleaning equipment necessary to control sulfur dioxide and particulates in the three new electrolytic plants under construction; these controls come under New Source Performance Standards.

Annualized control costs are detailed in Table 3-26-2.

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Table 3-26-2.  
Primary Zinc Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (1,000 MT/Yr)	967.82	1,287.25	1,431.0		
Annual Growth Rate Over the Period 1971-85 = 4.73%					
<b>PROCESS CHARACTERISTICS</b>	Model Plant Sizes (1,000 MT/Yr)		Pollutants Generated		
Roaster and Sinter; Electrolytic	42-226 45-163			Control Technology	
			Particulates (Zinc) Sulfur Dioxide	Acid Plant	
<b>EMISSIONS (1,000 MT/Yr)</b>	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates (Zinc)	29.69	42.14	46.18		
Sulfur Oxides	212.98	302.32	331.27		
Legislated Controls:					
Particulates (Zinc)	13.80	4.00	3.97		
Sulfur Oxides	108.74	41.27	35.90		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	8.58	1.57	0.81	80.95	54.79
Total Annual Capital O&M	11.85 4.77 7.08	30.14 17.66 12.48	38.29 24.59 13.70	313.19 179.33 133.86	287.21 169.89 117.32\$

## SCSECONDARY ZINC INDUSTRY\$R

Production Characteristics and Capacities. Zinc ranks after aluminum, copper, and lead in tonnage of nonferrous metals produced in the United States. Major uses in 1973 were zinc-base alloys, particularly die-cast alloys used in automotive and electrical equipment (41 percent), galvanized steel used in construction and electrical transmission equipment (36 percent), brass and bronze used for plumbing, heating, and industrial equipment (14 percent), zinc chemicals, particularly zinc oxide, used in the rubber, paint, and ceramic industries (4 percent), and rolled zinc used in dry cells and lithographic plates (2 percent).

Secondary zinc comes from two major sources: the zinc-base alloys and the copper-base alloys. Most of the secondary zinc that is recovered comes from reconstituted copper-base alloys; slab zinc is next, then chemical products, and zinc dust. For purposes in this report, the 14 operating plants that comprise the secondary zinc industry uses sweating and/or distilling operations to produce zinc slab, dust, and oxide solely from scrap; it does not include the activities of:

- Primary zinc producers that may manufacture zinc from scrap and ore

- Secondary brass and bronze plants that recover zinc in copper alloys
- Chemical manufacturers that produce zinc compounds by chemical treatment of zinc scrap
- Scrap dealers that may sweat zinc.

The total secondary industry zinc slab capacity stood at 18,100 metric tons at the end of 1972. Redistilled secondary zinc slab production in 1971 was 73,400 metric tons, of that total 11,200 metric tons were produced by the secondary zinc industry and the remainder was produced by the primary zinc industry. Other zinc materials produced by the secondary zinc companies included zinc dust and zinc oxide. In 1971, slightly over 24,500 metric tons of zinc in the form of zinc oxide was produced from zinc scrap. It is assumed that nearly all of this oxide is produced by the secondary zinc companies and that this production is indicative of a secondary capacity of 31,700 metric tons per year of contained zinc. Statistics are not available for total secondary zinc dust and zinc oxide capacity; estimates were derived from the available data. To further complicate capacity estimation, some production set-ups permit production of either oxide or slab.

The production of zinc dust from zinc-base scrap in 1970 totaled 26.300 metric tons. It is assumed that much of this production came from the secondary industry and that secondary capacity is 31,700 metric tons per year. On the above basis, the total secondary zinc industry has a capacity for producing refined zinc products containing 81,500 metric tons of zinc per year.

Growth in refined secondary zinc capacity is expected to be essentially nil. Production in the three segments of the industry as reviewed above stood at 63,100 metric tons in 1962, and 62,100 metric tons in 1971. Peak production occurred in 1968 and totaled 70,100 metric tons.

No data is available for sweating capacity: which can be performed in various types of furnaces. It is assumed that much of the feed material for production of refined secondary zinc is sweated; sweating capacity is therefore placed at 63,500 metric tons per year.

Emission Sources and Pollutants. There are at least four operations which generate emissions in the secondary zinc industry: materials handling, mechanical pretreatment, sweating, and distilling. This report is concerned with control costs for emissions from the sweating and distilling operations, as insufficient data is available for

calculating the possible costs of controlling emissions from the other sources.

In the sweating operation, various types of zinc containing scrap are treated in either kettle or reverberatory furnaces. The emissions vary with the feed material used and the feed material varies from time-to-time and from plant-to-plant. Emissions may vary from almost 0 to 15 kg of particulates per metric ton of zinc reclaimed. For purposes in this report, it is assumed that the maximum emission rate applies.

In the case of the various types of zinc distilling furnaces, the accepted emission rate is 23 kilograms per metric ton of zinc processed. Some distillation units produce zinc oxide, and normally utilize a baghouse for collection of the product. This report assumes that these baghouses are sufficient to meet national process weight standards. However, for the purpose of calculating control costs, it was assumed that essentially all of the estimated zinc oxide capacity could be switched to slab zinc or dust production, and emission controls would be required.

Controlled and uncontrolled emissions from secondary zinc sweating operations cannot be estimated with an acceptable

degree of probable accuracy because reliable data are not available.

The estimated emissions from secondary zinc distillation based on available production estimates and an average emission factor of 23 kg per metric ton are tabulated below. It is estimated that 57 percent of the emissions were controlled in 1971 and that 90 percent will be controlled in 1980.

Fiscal Year	Mode	Particulates (kg/metric tons)
1971	Without further control	617
1975	With further control	219
1980	With further control	108 <sup>R</sup>

Control Technology and Costs. The major emission of concern is particulates, consisting mainly of zinc oxide. Baghouses have been shown to be effective in controlling both distillation and sweating-furnace emissions except when the charge contains organic materials such as oils.

A complete accounting of secondary zinc plants by type of furnaces used and the product or products produced is not available. Based on the limited information, it is assumed that the industry's 14 plants can be represented by two models: two Model 1 plants, each consisting of 7.260 metric

tons per year sweating capacity and 10,900 metric tons per year distilling capacity; and twelve Model II plants, each consisting of 4,080 metric tons per year of sweating capacity and 4,990 metric tons per year of distilling capacity.

Estimated annualized control costs for the secondary zinc industry are detailed in Table 3-27-1.

Table 3-27-1.  
Secondary Zinc Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (1,000 MT/Yr)	79.71	109.71	117.12		
Annual Growth Rate Over the Period 1971-85 = 4.75%					
PROCESS CHARACTERISTICS					
	Model Plant Sizes		Pollutants Generated		
	(MT/Yr)		Particulates	Control Technology	
Sweating and Distilling	12,800; 5,500		Particulates	Fabric Filter	
EMISSIONS (MT/Yr)					
	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	332.0	471.0	516.0		
Legislated Controls:					
Particulates	290.0	342.0	121.0		
CONTROL COSTS (Million 1975 \$)					
Investment	0.21	0.05	0.02	2.90	1.57
Total Annual Capital O&M	0.61 0.18 0.43	1.07 0.36 0.71	1.13 0.38 0.75	11.49 3.72 7.77	10.11 3.28 6.83

## ASBESTOS INDUSTRY

Production Characteristics and Capabilities. The asbestos industry consists of the following major activities: mining of ore, milling of ore, and the manufacture of asbestos products, all of which are used in thousands of products and applications. Over 40 percent of annual consumption, which was estimated to be nearly 750,000 metric tons in 1972, is used for construction materials, primarily cement products; other important users include floor tiles, paper, asphalt felts, friction products, and packing and gaskets. Domestic consumption has been growing at an annual rate of about 5 percent.

Asbestos is normally handled by air conveyance during processing. The air conveying system must be tightly controlled because of the adverse health effects of airborne fibers, which are kept airborne for significant distances as a result of their fine structure and low density. The finishing processes that involve breaking, grinding or polishing, which are required in making asbestos products, account for most of the air emissions.

A total of nine milling plants were in operation during 1970. Over 98 percent of milling capacity (about 149,000 metric tons) was represented by five large, vertically-

integrated firms. Imports represented nearly 85 percent of the asbestos used in various manufacturing processes during 1973. Capacity in 1975 is expected to be about 161,000 metric tons consisting of plants ranging from 200 to almost 65,000 metric tons per year.

Manufacturing plants can be grouped into facilities producing the following types of general product categories: construction materials, floor tiles, felts and papers, friction products, textiles, and miscellaneous; Table 3-28-1 provides a summary of the model plant capacities, number of plants represented by that capacity, and the total 1975 estimated capacity for each process.

Table 3-28-1.  
Asbestos Industry Size Distributions  
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Process	No. Plants	Average Capacity (1,000 MT/yr)	Total Capacity of Group (1,000 MT/yr)	Percent
<b>Milling</b>				
Maryland	1	0.2	0.2	n11
Arizona	3	0.78	2.4	0.2
California	4	23.6	94.4	9.2
Vermont	1	64.7	63.8	6.2
<b>Subtotals</b>	<b>9</b>		<b>160.8</b>	<b>15.6</b>
<b>Manufacturing</b>				
<b>Construction</b>				
Products	90	3.96	355.2	34.5
Floor tiles	12	7.6	88.8	8.6
Felts and papers	33	3.67	121.3	11.8
Friction products	32	2.54	80.8	7.9
Textiles	12	0.67	8.2	0.8
Miscellaneous	927	0.23	213.3	20.7
<b>Subtotals</b>	<b>1,106</b>		<b>867.6</b>	<b>84.4</b>
<b>Totals</b>	<b>1,115</b>		<b>1,028.4</b>	<b>100.0</b>

Source: Estimated from U.S. Bureau of Mines 1972 Minerals Yearbook and Commodity Data Summaries, 1974, Appendix I to the Mining and Minerals Policy Document.\$R

Emission Sources and Pollutants. Principal emission sources of asbestos are from the air conveying systems used in the processing and finishing stages required in making asbestos products. Asbestos emissions can be divided into two categories: either asbestos remains essentially a free fiber throughout the process and in the final product or the

asbestos is wetted or bound into a matrix at an early stage of processing.

Production of asbestos textiles is the major manufacturing process in the first category. In this process, the long asbestos fibers are fluffed and then blended with a cellulosic fiber. The subsequent processing, which involves carding, lapping, roving, spinning, and weaving or braiding, is performed on equipment similar to the standard textile machining processes requiring frequent access when operating.

Virtually all other processes fall in the second category. Significant emissions may occur in finishing operations for cement pipe and building products, felts and papers, and friction products. Asbestos emissions from floor-tile manufacture are essentially nil after the fibers are mixed with the hot vinyl or asphalt. In friction products, the processes of molding and curing are usually pollution free, while the finishing processes involving shaping, cutting, and sawing may give rise to some emissions. In sprayed insulation, asbestos emissions occur from handling the dry asbestos and cement mixture, the escape of non-wetted fiber, overspray and splash, and the disposal of wastes.

Emission factors for the various activities are summarized in Table 3-28-2: total uncontrolled emissions (assuming 1968 control levels) and controlled (99 percent) emissions are also provided.

Table 3-28-2.  
Asbestos Industry Pollutant Emissions (1975 Estimates)

	Emission Factor (kg/MT)	Pre-1970 Control (%)	Emissions Without Controls (MT)	Emissions with Further Control (MT)
Milling	160	80	5,146	40
Construction	2	75	177	7
Floor tile	2	75	44	2
Felts and papers	2	75	61	2
Friction products	60	95	242	48
Textiles	20	95	8	2
Miscellaneous	10	90	213	36
Totals			5,891	137

Source: "Asbestos - Section III", National Inventory of Sources and Emissions: Cadmium, Nickel, and Asbestos, W. E. Davis and Associates for U. S. Department of Health, Education, and Welfare, 1970.

Assumes pre-1970 control levels.\$R

Control Technology and Costs. The only acceptable control technique for asbestos milling and manufacturing is the fabric filter. Efficiencies of 95 percent or higher are relatively easily obtained. For the various manufacturing processes, unit investment costs for fabric filters range

from \$5,000 to \$60,000, depending on the plant capacity. For example, a plant with a capacity of 2,500 metric tons per year manufacturing friction products will require an approximate investment of \$21,000 to achieve 99 percent control efficiency with a fabric filter. Annualized control costs and industry statistics are detailed in Table 3-28-3.

Table 3-28-3.  
Asbestos Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (1,000 MT/Yr)	924.28	1,227.84	1,274.57		
Annual Growth Rate Over the Period 1971-85 = 3.75%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes (MT/Yr)</b>				
Textile	608				
Miscellaneous	189				
Felt Friction	2,721				
Tiles	6,893				
Construction	3,592				
Milling	29,024				
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
1971 Controls:					
Particulates	53.09	71.41	79.42		
Legislated Controls:					
Particulates	25.05	2.98	1.59		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	0.30	0.69	0.06	769.93	3.41
Total Annual Capital O&M	127.19 124.75 2.44	129.32 125.19 4.13	129.67 125.30 4.37	1,672.38 1,623.44 48.94	1,290.33 1,251.07 39.26\$\$
				<b>Pollutants Generated</b>	<b>Control Technology</b>
				Particulates	Baghouse
				Particulates	Baghouse
				Particulates	Baghouse
				Particulate	Baghouse
				Particulates	Baghouse
				Particulates	Baghouse

## ASPHALT CONCRETE PROCESSING INDUSTRY

Production Characteristics and Capacities. The asphalt concrete processing industry manufactures asphalt concrete, which includes a mixture of aggregates and an asphalt cement binder. Aggregates usually consist of different combinations of crushed stone, crushed slag, sand, and gravel. Asphalt concrete plant processing equipment includes raw-material apportioning equipment, raw-material conveyors, a rotary dryer, hot-aggregate elevators, mixing equipment, asphalt-binder storage, heating and transfer equipment, and mineral-filler storage and transfer equipment.

There are approximately 1,320 companies employing approximately 300,000 to operate 4,800 asphalt concrete plants in the United States. Plant size distribution is listed below; 60 percent of the capacity is located in plants having an average size of 182 metric tons per hour. Based on a 1972 survey conducted by the National Asphalt Pavement Association (NAPA) covering 1,081 plants, 76 percent were stationary plants and 24 percent were portable. Continuous mixers comprised 24 percent of the portable plants, compared with only 2 percent for stationary plants.

St	Size Range (metric tons/hr)	Average Size (metric tons/hr)	No. Plants	Capacity(%)
	82-100	91	694	6.6
	101-263	182	3,122	59.5
	264-282	273	520	14.9
	283-499	391	464	19.0
Totals			4,800	100.0\$R

Asphalt concrete production is essentially a batch-type operation; continuous-mix represents only 10 percent of the industry. The current production of the industry, 444 million metric tons of asphalt paving material per year with a gross value of \$3,250 million, is not expected to grow for several years. The energy crisis has reduced state gasoline tax receipts, and consequently this has reduced construction of new roads, possibly even the repair of existing roads. Because of batch-type operations and seasonal nature of production, the average plant operates only 1,500 hours per year at 50 percent of plant capacity. Current industry capacity has been estimated by NAPA at 1.0 to 1.3 billion metric tons.

Emission Sources and Pollutants. The predominant emissions are dust particulates from the aggregates used in making asphalt concrete. The largest sources of particulate emissions are the rotary dryer and screening, weighing, and mixing equipment. Additional sources that may be significant particulate emitters, if they are not properly

controlled, are the mineral-filler loading, transfer, and storage equipment, and the loading, transfer, and storage equipment that handles the dust collected by the emission control system. Generally, the uncontrolled emissions from asphalt batching plants amount to 23 kg of dust per metric ton of product.

**Control Technology and Costs.** Practically all plants use primary dust collection equipment, such as cyclones or settling chambers. These chambers are often used as classifiers with the collected aggregate being returned to the hot-aggregate elevator to combine with the dryer aggregate load.

The gases from the primary collector must be further cleaned before venting to the atmosphere. The most common secondary collector is expected to be the baghouse, although venturi scrubbers are used in some plants. The baghouse allows dry collection of dust which can be returned to the process or hauled away to a landfill, although land-use legislation makes this operation more and more difficult. The venturi scrubber makes dust hauling expensive due to the wetting of the dust. Also, the use of large settling ponds and the possible need for water treatment discourage the use of venturi scrubbers.

Annualized control costs and industry capacities are  
detailed in Table 3-29-1.

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Table 3-29-1.  
Asphalt Concrete Processing Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (MT/Hr)	931.80	1,078.30	1,102.90		
Annual Growth Rate Over the Period 1971-85 = 2.20%					
PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Hr)	Pollutants Generated	Control Technology		
Type 1	100,200,300,400	Particulates	Wet Scrubbers		
Type 2			Fabric Filter		
EMISSIONS (1,000 MT/Yr)	1975	1980	1971-85	1976-85	
1971 Controls:					
Particulates	3,186.32	3,710.72	3,836.16		
Legislated Controls:					
Particulates	1,366.59	114.04	46.80		
CONTROL COSTS (Million 1975 \$)					
Investment	200.59	23.45	1.14	664.87	161.35
Total Annual Capital O&M	201.22 81.95 119.27	288.59 103.78 184.81	300.24 108.21 192.03	3,214.02 1,184.10 2,029.92	2,785.66 1,013.29 1,772.37\$

## CEMENT INDUSTRY\$R

Production Characteristics and Capacities. Portland cement, which accounts for approximately 96 percent of cement production in the United States, is processed from a blend of various calcareous, argillaceous, and siliceous materials including limestone, shell, chalk, clay, and shale. As the binder in concrete, portland cement is the most widely-used construction material in the United States. The four major steps in producing portland cement are: quarrying and crushing; blending, grinding, and drying; heating the materials in a rotary kiln to liberate carbon dioxide, causing incipient fusion; and fine-grinding of the resultant clinker, with the addition of 4 to 6 percent gypsum. Finished cement is shipped either in bulk or in bags. All portland cement is produced by either a wet or dry grinding process, the distinguishing characteristic being whether the raw materials are introduced into the kiln as a wet slurry or as a dry mixture.

In 1971, 170 plants producing portland cement clinker plus five plants operating grinding mills to produce finished cement were controlled by 51 companies located in 41 States and Puerto Rico. Fifty percent of this cement industry capacity is owned by multiplant companies, and the eight leading companies account for about 47 percent of the total.

Overcapacity has resulted in low profit margins, inhibiting modernization and construction of new plants during the past several years, and more stringent air-pollution regulations have increased both capital and operating costs. Recent trends are toward increased operations through installation of larger kilns to replace older marginal kilns, permitting more economic and efficient pollution control. Cement manufacturing plant capacity and size distribution are shown below.

Size Range (metric tons/day)	No.		Total Annual Capacity (million metric tons)	Total Capacity(%)
	Plants	Kilns		
Less than 513	6	10	0.8	1.0
514-1025	49	98	12.3	15.8
1026-1538	65	170	27.0	34.6
1539-2051	28	95	16.5	21.1
2052-2564	11	37	8.7	11.2
2565 and up	11	56	12.6	16.3
<b>Totals</b>	<b>170</b>	<b>466</b>	<b>77.9</b>	<b>100.0</b>

Based on 334-day operation.\$R

Estimated 1971 capacity of 77 million metric tons is expected to increase to about 104 million metric tons in FY 1980 based on a 4.3 percent average annual growth. Size distribution is expected to shift upwards as new plants are constructed and existing plants modified or closed, so the total number of plants is expected to remain about the same. It is also assumed that there will be no major shift in

production capacity percentages between dry and wet grinding processes, with the latter presently estimated at 59 percent. Production is typically 75 percent of capacity.

**Emission Sources and Pollutants.** Primary emission sources are the dry-process blending and grinding, kiln operation, clinker cooler, and finish grinding. Other sources include the feed and materials-handling systems. The primary air pollutant is dust particulates. Estimated dust-emission factor for an uncontrolled dry-process kiln is 180 kg per metric ton of cement, compared with 130 kg per metric ton for the wet-process plant, giving an average emission factor of 151 kg per metric ton of product. The corresponding emission factors for the blending, grinding, and drying processes are 48 and 16 kg per metric ton, respectively, for an average of 29 kg per metric ton.

**Control Technology and Costs.** Emissions from the blending, grinding, and drying processes are generally controlled with fabric filters. Where ambient gas temperatures are encountered during grinding, conveying, and packaging processes, fabric filters are used almost exclusively. The greatest problems are encountered with high-temperature gas streams which contain appreciable moisture.

Both fabric filters and electrostatic precipitators are used in controlling dust emissions from the kilns. The condensation problems from the high-moisture content in the wet-process plant may be overcome by insulating the ductwork and preheating the systems on start-up. Current state regulations, typified by the proposed Federal process weight rate curve, may be met with either fabric filters or electrostatic precipitators; however, new source performance standards will require the filters. At least one plant has a wet scrubber, but its costs were estimated on the basis of an electrostatic precipitator with little error in total estimated costs.

The total cost of control for portland cement plants was found by estimating the costs for control devices for grinding, mixing and drying (drying not included in the wet processes) and kilns, which are the major sources of pollutant. Kilns may have either baghouses for dry-process kilns or electrostatic precipitators for wet-process kilns; baghouses were assumed to have been used in both cases for the combined grinding, mixing, and drying processes. Other sources, including clinker coolers, packaging, and crushing, are not costed due to prevailing industry control prior to the Clean Air Act and/or minimal costs.

The capital cost of baghouses is assumed to be proportional to the 0.91 power of capacity, while the capital cost of electrostatic precipitators is proportional to the 0.67 power of capacity; in each case, the operating cost is linearly proportional to the capacity. The cost of baghouses for the grinding, mixing, and drying operations was scaled in the same manner. However, the required size was scaled by 0.78 (dry) and 0.26 (wet) to account for the smaller airflow rates of these processes, and the absence of control required for the wet-process raw material grinding mills.

Annualized control costs are detailed in Table 3-30-1.

Table 3-30-1.  
Cement Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (1,000 MT/Yr)	117.400	152.350	159.530		
Annual Growth Rate Over Period 1971-85 = 4.29%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes (MT/Day)</b>	<b>Pollutants Generated</b>	<b>Control Technology</b>		
Dry Process Kilns	116.7:254.6:437.5; 612.5:770.0:933.3	Particulates	Fabric Filter		
Wet Process Kilns	130:254.5:433.3:606.7; 817.1:924.4	Particulates	ESP		
Dry Gravel Mix	116.7:254.6:437.5; 612.5:770.0:933.3	Particulates	Fabric Filter		
Wet Gravel Mix	130:254.5:433.3:606.7; 817.1:924.4	Particulates	Fabric Filter		
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
1971 Controls:					
Particulates	5,235.45	7,012.04	7,897.26		
Legislated Controls:					
Particulates	2,370.96	22.96	24.83		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	247.45	20.17	9.31	936.39	322.07
Total Annual Capital O&M	153.45 80.77 72.68	243.20 119.24 123.96	255.99 123.11 132.88	2,655.23 1,299.15 1,356.08	2,329.81 1,130.86 1,198.95

## \$CLIME INDUSTRY\$R

Production Characteristics and Capacities. There are currently 186 lime producing plants in the United States. These plants can be divided into four size ranges, based upon output capacity of metric tons per year; the number of plants in each size range and their estimated capacities are shown in Table 3-31-1.

The U.S. lime industry can be conventionally divided into two product sectors. Approximately 35 percent of the output is consumed by the producers, while the remaining 65 percent is sold in the open market. Plants are located in 41 states and Puerto Rico, with over 22 percent of U.S. capacity in Ohio and the other major capacities located in Pennsylvania, Texas, and Michigan; plant size distribution is shown in Table 3-31-1. Recent trends are toward closing of small, old plants and replacing old kilns with larger units.

Table 3-31-1.  
Lime Industry Capacity Distributions

Size Range (1,000 metric tons/year)	No. Plants	Estimated 1972 Capacity, (million metric tons/year)	Total Capacity(%)
0-22.7	68	0.6	3.2
22.7-90.9	61	3.0	16.2
90.9-364	52	10.5	56.8
More than 364	5	4.4	23.8
	186	18.5	100.0SR

In 1972, producers at 186 plants sold or used 18.5 million metric tons. Growth in the demand for lime has been projected at 4 percent per year, which would indicate a demand of 25 million metric tons in fiscal year 1980. Should the use of lime in processes for the removal of sulfur oxides from combustion gases become standard practice, the demand for lime will be increased substantially. The number of plants, meanwhile, has declined from 195 in 1970 to 186 in 1972. Further consolidation may be expected to economically justify the increased cost of emissions controls. The 1974 estimated capacity for producing lime was 20 million metric tons. Current production is believed to be close to existing plant capacity.

Lime is formed by expelling carbon dioxide from limestone or dolomitic limestone by high temperatures. This calcination process forms quicklime. Hydrated lime is made by the

addition of water to the quicklime. The calcination of dolomite results in dead-burned (refractory) dolomite. Major uses of lime are for basic oxygen steel furnaces, alkalies, water purification, other chemical processes, and refractory dolomite.

About 73 percent of lime is produced in two basic types of rotary kilns: the long rotary kiln, and the short rotary kiln with external preheater. Vertical kilns are used to supply 27 percent of lime. Almost all new lime production is accomplished using the rotary process.

Emission Sources and Pollutants. Atmospheric emissions from lime manufacture are primarily particulates released when crushing the limestone to kiln size, calcining the limestone in a rotary or vertical kiln, and crushing the lime to size; also, fly ash is released if coal is used in calcination. Other emissions, such as sulfur oxides, may be generated by fuel combustion.

Uncontrolled emissions from rotary kilns are about 100 kg per metric ton of lime processed, compared with 4 kg per metric ton from vertical kilns. However, economics favor use of the rotary kiln, and virtually all new and expanded production is expected to be accomplished by this method.

Control Technology and Costs. Gases leaving a rotary kiln are usually passed through a dust-settling chamber where the coarser material settles out. In many installations, a first-stage, primary dry cyclone collector is used. The removal efficiency at this stage can vary from 25 to 85 percent by weight of the dust being discharged from the kiln.

The selection of a second stage to meet the high efficiency level of 0.03 grains per actual cubic foot may be either a high-energy wet scrubber, fabric filter, or electrostatic precipitator. The higher capital cost of the electrostatic precipitator may be more than offset in specific installations by lower operating and maintenance costs.

It is believed that vertical kilns can be effectively controlled to allowable emission limits with baghouses, scrubbers, or cyclone/scrubber combinations. In the latter cases, efficiencies of 99 percent have been reported.

The U.S. lime industry, with an estimated capacity for producing 20 million metric tons per year and an annual growth of 4 percent, is estimated to spend accumulated annualized expenditures of \$216 million for air pollution control in the 1971-80 period. All of these expenditures will be needed to control particulate emissions.

Estimated total annual emissions of particulates in fiscal year 1971 was 1.8 million metric tons. With further control, annual emissions in fiscal year 1980 will be 30,000 metric tons. The estimated total investment between these two years will be \$183.7 million, and expected cash requirements will be \$150 million.

Capital costs for fabric filters in existing plants were assumed to be twice their cost in new plants. Capital costs for wet scrubbers and electrostatic precipitators in existing plants were assumed to be 50 percent greater than in new plants. Annualized production and cost control data is presented in Table 3-31-2.

\$dTable 3-31-2.  
Lime Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (Million MT/Yr)	20.55	26.94	29.29		
Annual Growth Rate Over the Period 1971-85 = 4.55%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Size (1,000 MT/Yr)</b>	<b>Pollutants Generated</b>		<b>Control Technology</b>	
Type 1	10:54:232:686	Particulates		Fabric Filter	
Type 2	10:54:232:686	Particulates		Scrubber	
Type 3	10:54:232:686	Particulates		ESP	
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
<b>1971 Controls:</b>					
Particulates	1,059.34	1,413.85	1,561.67		
<b>Legislated Controls:</b>					
Particulates	459.69	27.85	30.16		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	55.92	2.97	1.33	334.94	114.43
Total Annual Capital O&M	35.03 28.99 6.04	53.62 43.19 10.43	54.80 44.03 10.77	594.02 481.56 112.46	511.25 411.85 99.40\$

## STRUCTURAL CLAY PRODUCTS INDUSTRY

Production Characteristics and Capacities. There are currently 466 plants in the United States manufacturing structural clay products, including common brick, fireclay or refractory brick, and sewer pipe. The latter category represents approximately 90 percent of the total production of structural clay materials, with common brick being by far the largest category, or approximately 75 percent of total production. Value of shipments in 1972 were \$404 million, \$143 million and \$13 million for common brick, clay sewer pipe, and fireclay brick, respectively. Plants are located in 45 states with North Carolina, South Carolina, Ohio, Pennsylvania, and Texas accounting for about 45 percent of production capacity.

For purposes of estimating air abatement costs, the industry was divided into those plants using either continuous tunnel kilns or periodic kilns; an average plant capacity was selected for each process, as shown below.

\$t

	Av. Cap. (1,000 Mt/Yr)	No. Plants	Est. 1974 Cap. (million Mt/Yr)	Total Cap. (%)
Periodic kilns	21	336	6.9	35
Continuous tunnel kilns	100	130	12.9	65
Totals		466	19.8	100\$R

Miscellaneous clays and shales are used to manufacture common brick, sewer pipe, and refractory brick. Typically, the plants are located in the proximity of the clay mines. The clays are crushed and ground at the plant, after which they are screened and mixed with water for the forming operation. Common brick, sewer pipe and some refractory brick are formed by extrusion; most refractory brick is formed by die pressing.

The formed materials are fire-treated by either continuous tunnel or intermittent periodic kiln processes. In the continuous tunnel kiln, the charge is first preheated by airflow escaping from the bake oven, passed through the oven at temperatures of approximately 1,900 F. and then passed through a cooling stage. In contrast, the periodic kiln heats the charge at ambient temperature to a peak temperature, after which the fuel is shut off, allowing the charge to cool to ambient temperature again; this cycle requires about 2 weeks, during which fuel is burned about 50

percent of the time. The remainder of the period is used for cooling and physical discharging of the product, steps which emit little if any air pollutants.

A process frequently practiced by manufacturers of common brick is flashing. This process involves firing the brick in a reducing atmosphere to achieve architecturally-desirable surface colorations. The process is noted because when it is used in conjunction with periodic kilns, carbon monoxide and/or hydrocarbon emissions usually result.

**Emission Sources and Pollutants.** Atmospheric emissions from the manufacture of clay construction products are primarily sulfur dioxides released during the firing process, and originating from the sulfur contained in the clay. Uncontrolled sulfur dioxide emissions are estimated to be about 0.37 metric ton per 100 metric tons of clay processed. The flashing process associated with the manufacture of certain types of brick can also result in hydrocarbon and carbon monoxide emissions. Approximately 0.42 metric ton of hydrocarbons and/or carbon monoxide are estimated to be released per 100 metric tons of brick flashed.

Table 3-32-1 summarizes estimated uncontrolled and controlled emissions from the production of clay construction materials.

Control Technology and Costs. It is anticipated that wet scrubbers will be used to control sulfur dioxide emissions from the production of clay construction materials.

Presently, only a few plants were found to be exercising this or any other control option. Control of hydrocarbon and carbon monoxide emissions can be accomplished by the use of afterburners. The requirement for afterburners will depend on the duration of the flashing treatment at different plants. Likewise, it is probable that certain plants will have minimal requirement for scrubbers because of the negligible sulfur content of some clays. About 10 percent of existing plants producing common brick, sewer pipe, and refractory brick were assumed to be either equipped with adequate controls or using new clay materials sufficiently low in sulfur content to avoid the need for wet scrubbers.

The 1974 industry capacity accounting for brick, sewer pipe, and refractory brick was estimated to be approximately 20 million metric tons. Annual costs and industry operating statistics are detailed in Table 3-32-1.

Table 3-32.1.  
Structural Clay Products Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (Thousand MT/Day)	135.19	155.73	155.88		
Annual Growth Rate Over the Period 1971-85 = 2.50%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes (MT/Day)</b>	<b>Pollutants Controlled</b>	<b>Control Technology</b>		
Tunnel Kiln	300	Sulfur Oxides	Wet Scrubber		
Periodic Kiln	200	Sulfur Oxides, Hydrocarbons	Wet Scrubber		
Periodic Kiln	200	Sulfur Oxides, Hydrocarbons	Thermal Incinerator		
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
1971 Controls:					
Hydrocarbons	18.55	14.49	9.14		
Sulfur Oxides	80.02	102.59	105.13		
Legislated Controls:					
Hydrocarbons	8.81	0.37	0.23		
Sulfur Oxides	48.59	22.99	22.97		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	23.73	0.11	0.50	0.83	17.51
Total Annual Capital O&M	16.41 10.30 16.11	29.55 13.07 16.48	25.18 13.15 12.03	343.43 148.85 194.58	284.52 126.91 157.61\$

## SCSURFACE COATINGS INDUSTRY\$R

Production Characteristics and Capacities. Air emission abatement costs associated with the use of organic-based surface coatings in four industries were considered: automotive, furniture, major appliances, and metal or coil coatings. These industries are considered together because of the general similarities between the coating processes employed, the nature of the resulting emissions, and the abatement technologies deemed applicable.

In 1971, approximately 606 million liters of coatings, i.e., paint, shellac, lacquer, and primers, were consumed by these industries. Since over 75 percent of the coatings used contained about 50 percent organic solvents, significant hydrocarbon emissions resulted during the application and curing stages of the process. Future estimates of the volume of hydrocarbon emissions attributable to surface coating processes must be considered in light of the following factors:

- Increased use of non-hydrocarbon solvent materials, i.e., water-thinnable solutions.

- Application techniques involving solvent-free systems, i.e., powder coatings applied by electrostatic spraying.

Where applicable, these process alternatives would provide as much as a 90 percent reduction in hydrocarbon emissions. Faced with the alternative of conventional emission control techniques (i.e., incineration) industries are expected to adopt the newer coating formulations and application techniques at an accelerated pace. By 1985, as much as 50 percent of the coating processes may employ non-hydrocarbon-based materials.

The coating process consists basically of two steps: application and curing. Both stages produce hydrocarbon emissions through evaporation. The coating is generally applied by a spray gun in a paint spray booth, and the surface is then cured or dried in a drying oven where the solvent is evaporated. A summary of industry production is presented in Table 3-33-1.

Table 3-33-1.  
Surface Coatings Industry  
Distribution (1971)

	No. of Plants	Coating Consumption (million liters)	Percent of Coating Consumption
Automobile	100	246	41
Furniture	7,000	189.5	31
Metal Coil Coating	56	95	16
Major Appliance	144	76	12
Totals		606.5	100

10 percent of furniture manufacturers account for 65 percent of sales (\$).\$R

Automotive Finishing. In 1971, there were 100 motor vehicle (auto, truck, and bus) assembly plants located in 28 states throughout the United States. Included in this group are: motor vehicles and car bodies, truck and bus bodies, motor vehicle parts and accessories, truck trailers, and travel trailers and campers. Approximately 246 million liters of coatings were consumed in finishing operations, which is about 41 percent of the total volume of coatings used by the four industries under consideration. The volume of coatings consumed by automotive plants has been increasing at an annual rate of about 9 percent.

Furniture Finishing. About 7,000 establishments are engaged in manufacturing the following types of furniture in the United States:

- Wood Household Furniture
- Wood Furniture - Upholstered
- Metal Household Furniture
- Wood Cabinetry
- Household Furniture - Unclassified
- Wood Office Furniture
- Metal Office Furniture
- Public Building Furniture
- Furniture and Fixtures - Unclassified.

Approximately 10 percent of the establishments account for 65 percent of industry sales, with the 10 largest producers representing nearly 20 percent of industry sales. Furniture is manufactured in all but seven states, and North Carolina, the principal producer, accounts for 22 percent of the total shipment value.

About 190 million liters of organic solvent-based coatings were consumed by the industry in 1971. Between 1967 and 1972, paint consumption has grown about 5 percent annually. Unlike the metal surfaces coatings, the use of water-based paints and finishes for wood furniture is limited in practice because of the tendency for the occurrence of surface distortions in the wood. Virtually all coatings used, therefore, are hydrocarbon-based and range from 30 to 70 percent by weight in organic content.

Coil Coating. The coil coating process consists primarily of the pretreatment of sheet metal in the strip or coil form, followed by the application of an organic coating and subsequent curing (or baking) to obtain the desired surface characteristics. It is estimated that 56 plants in the United States are engaged in this coating process. Almost 60 percent of the plants are located in Pennsylvania, Ohio, and Illinois, presumably near sources of steel production. In 1971, approximately 95 million liters of coatings were consumed by coil coating processes, representing an annual increase of 14 percent since 1964 when about 38 million liters were consumed. Annual growth will probably continue to be high because of the heavy use of precoated metals.

Major Appliances. In 1971, there were 144 plants in the United States engaged in the production of major appliances including: cooking equipment, refrigerators and freezers, and laundry equipment; about 76 million liters of coatings were consumed in this production effort. Growth in industry consumption of coatings averaged 4 percent annually between 1964 and 1971.

Emissions and Sources of Pollutants. While paint spray booths are a source of hydrocarbon emission, the volume of solvent released to the air through evaporation is dependent on the degree of overspray, which can vary anywhere from 10

to 90 percent. Aerosols resulting from overspray are usually removed by filters or water scrubbers, but these devices have little impact on removal of emissions due to solvent evaporation. The major source of emissions attributable to coating processes are the drying ovens.

Based on 1971 paint usage, estimated hydrocarbon emissions in the absence of controls for the four industries considered were approximately 435,360 metric tons per year. A breakdown of estimated emissions per industry category for 1971 and 1975 is provided in Table 3-33-2. Allowing for some replacement of hydrocarbon-based coatings with alternative formulations and application techniques, 1975 hydrocarbon emissions may be nearer 498,850 to 544,200 metric tons. Assuming full compliance to emission regulations, and control efficiencies of about 95 percent, the volume of emissions in 1975 would be about 27,210 metric tons per year.

Table 3-33-2.  
Surface Coatings Industry  
Summary of Emissions (No Controls)

Industry Category	1971 Paint Consumption (million liters)	1971 Emissions (thousand metric tons)	1975 Emissions (thousand metric tons)
Auto	246	177	240
Furniture	190	136	159
Metal Coil Coating	95	68	107
Major Appliance	76	54	63
Totals	607	435	569

Note: Assumes annual growths in paint-use of 8 percent, 4 percent, 12 percent, and 4 percent for auto, furniture, metal coil coatings, and major appliances, respectively.\$R

Control Technology and Costs. Incineration of the solvent vapors in the exhaust gases from the spray booths and the drying ovens is presently the most practicable technique for limiting hydrocarbon emissions from surface coating operations. Control costs are primarily a function of the exhaust gas volume.

Incineration essentially involves oxidation of hydrocarbons in the exhaust gases to form carbon dioxide and water. Several alternative techniques are available, including flame combustion, thermal combustion, and catalytic combustion. Presently, technical considerations favor the use of thermal incinerators. However, as continuing fuel

shortages prevail and prices rise, catalytic units will probably become more economical in the future. To offset the impact of current fuel shortages, thermal incinerators with heat exchange units were considered to be most applicable for all but the furniture category where little curing is employed. The heat exchanger extracts waste heat from the hot exhaust gases, enabling reuse and operating economy.

A summary of estimated investment and annual operating costs per model plant are provided in Table 3-33-3.

Table 3-33-3.  
Surface Coating Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (Million Liters/Day)	1.59	2.82	2.64		
Annual Growth Rate Over the Period 1971-85 = 5.1%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes (Liters/Day)</b>	<b>Pollutants Generated</b>		<b>Control Technology</b>	
Application and Curing	2.274:9.854; 175.477	Hydrocarbons		Vapor Incineration	
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
<b>Hydrocarbons</b>					
<b>1971 Controls:</b>					
Auto	147.19	212.09	246.04		
Major Appliance	49.53	82.93	103.78		
Furniture	148.09	243.73	273.00		
Metal Coil	60.09	81.34	90.83		
<b>Legislated Controls:</b>					
Auto	133.59	180.67	9.35		
Major Appliance	43.97	66.51	3.86		
Furniture	67.71	23.42	26.30		
Metal Coil	58.67	68.96	3.42		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	11.03	8.22	4.70	516.04	217.27
Total Annual Capital O&M	194.26	387.41	426.17	4,115.49	3,648.80
	48.62	79.12	83.98	874.39	745.97
	145.64	308.29	342.19	3,241.10	2,902.83

## STEAM ELECTRIC POWER PLANTS

Operating Characteristics. Among the largest stationary sources of air pollution are the coal, oil, and natural gas burners. Of the three fuels, coal is the most polluting and natural gas is the cleanest and most convenient to use. The principal uses for these fuels include furnace operation in steam electric power plants, steam generation and heating in the industrial sector, and space heating in the commercial and residential sectors. In 1972, more than 82 percent of the steam coal (in contrast to coking coal) produced was used for power generation. About 63 percent of all residual fuel oil consumed and 18 percent of natural gas produced were used for the same purpose. It is apparent from these estimates that utility power burners are the major sources of emission for the pollutants of concern, because they burn the most polluting fuels in the largest quantities.

Emission Sources and Pollutants. A choice must be made among the available fuels that will provide sufficient environmental protection from their combustion products by meeting ambient-air-quality standards while at the same time generating adequate quantities of heat and power as economically as possible. In the near future, energy resources that will be consumed in large amounts are the nuclear fuels with their radioactive-waste-disposal

requirements, and the fossil fuels with their residue disposal and gaseous emission-control requirements. Among the fossil fuels, natural gas is the cleanest, but it is in short supply. To demonstrate the cleanliness of gas relative to coal and oil, the emissions resulting from the use of each fuel in a typical 1,000 megawatt power plant are given below.

Fuel	Emissions (kilograms per hour)		
	Particulates	SO <sub>2</sub>	NO <sub>x</sub>
Coal	69,000	41,000	13,000
Oil	600	12,500	8,600
Gas	170	7	6.80C\$R

Obviously, natural gas is the preferred fuel from an emissions standpoint. Indeed, gas-fired power plants provided 29 percent of electricity produced in 1971, and gas provided about one-third of all the heating energy derived from fossil fuels. However, the production of gas during the near term is expected to remain fairly constant, and the growing fossil fuel demand will be supplied by coal and oil.

Despite current shortages in the United States, petroleum is still an abundant fuel internationally. For mobile sources, its derivatives, gasoline and diesel oil, are not expected to be supplanted in the near future. For utility power burners, despite the potential switch from oil to coal in

many power plants, distillate and residual fuel oil will continue to supply a significant fraction of the energy required in 1980. Fuel oils for utility burners contain sulfur (typical sulfur contents average about 0.7 percent for United States crude oils and about 2.2 percent for imported crude oils), much of which is removed from the final product. The ash from crude oil combustion is low, about 0.5 percent.

The supply of crude oil and its derivatives in the United States is becoming increasingly critical as a result of limited reserves of domestic sources and increasing international demand for this versatile fuel. Furthermore, oil is in greater demand for producing electrical power in areas where foreign oil was, and probably will continue to be, more accessible.

The most abundant fossil fuel in this country is coal. In 1971, about 327 million tons of coal were burned to produce about half of the electrical power. In 1970, 100.5 million tons were used for heating, 98 million tons were used to produce coke for use in industrial processes, and 73 million tons were exported. The resources of coal are widespread throughout the United States, but coal has not been used in proportion to its availability in comparison with the other fuels.

Coal typically has an ash content of 9 percent. Of which (under uncontrolled conditions) about 85 percent would be emitted from a dry-bottom boiler, and 65 percent from a wet-bottom boiler. The resulting emissions would be orders of magnitude higher than those from the other fossil fuels. Particulate controls of varying efficiencies are found on all but the smallest coal burners.

Sulfur dioxide emissions from coal burning are even more serious and more difficult to control. In 1970, the sulfur content of coal burned by utilities, industry, and in heating units for household and commercial use averaged 2.5 percent; this sulfur appears as sulfur dioxide and some sulfur trioxide. To reduce the sulfur oxides, a coal and low-sulfur content could be chosen. However, much of the Eastern low-sulfur coal is reserved for use as coke by the metals industries. In only 6 percent of current production is the sulfur content low enough to meet New Source Performance Standards. The major Western low-sulfur coals are uneconomical to ship to power plants east of Chicago. Western coals will be used extensively in the Central Region.

In spite of these problems, use of coal to supply most electric power in the near future seems unavoidable. Therefore, more stringent sulfur dioxide emission controls

will be needed. In addition to switching to low-sulfur coal, other strategies are possible, such as removal of sulfur from flue gases, and removal of sulfur from high sulfur fuels before burning.

The uncontrolled and controlled emissions from utility fossil-fuel burners may be estimated from known (measured) emission factors, for the first case, and from the capability of the various control techniques in the second.

**Control Technologies and Costs.** The following paragraphs analyze the different technologies presently employed to control sulfur oxides, nitrogen oxides, particulates, and the related costs.

**Sulfur Oxides.** The state-of-the-art of flue gas desulfurization (FGD) is such that the so-called throwaway scrubbing systems (lime and limestone) will predominate through 1980. By 1980, roughly 45 percent of all controlled capacity will be using limestone scrubbing, while 30 percent will use lime scrubbing. The balance (about 25 percent) will be divided equally between lime/limestone and "other" control methods, including the use of regenerative systems. On this basis, the capital and operating costs used for FGD through 1980 will be the weighted average of lime and

limestone costs. The capital, operating, and annual costs of FGD systems are as follows:

\$t	New Plants	Existing Plants
Investment (\$/kw)	51	72
O&M (mills/kw hr)	1.2	2.0
Annual (mills/kw hr)	3.0	4.0\$R

For these plants, it was assumed that the cumulative generating capacity controlled by this technique in 1971, 1972, 1975, and 1980 will be 0, 1,000, 7,000, and 33,000 megawatts, respectively. Investment costs for each period were simply computed by multiplying the dollars per kilowatt by the net generating capacity for which FGD systems were installed in that period.

Operating and maintenance costs (and in general time-dependent costs) for a given period were computed using an operating rate of 55 percent and the cost in mills per kilowatt hour. The time, in years, that a certain annual increment controlled generating capacity contributes to the time period under consideration as well as the magnitude of the increment will determine its contribution to the total cost in that period. The sum of the products of incremental megawatt capacity and number of years contributed was used to compute the O&M as well as annual and depreciation (10-year) costs.

The same procedure was used to compute the costs of FGD for existing plants. An operating rate of 70 percent was assumed for these plants.

It is projected that a significant number of Central and Eastern utilities, usually burning high-sulfur coal, will switch to burning Western and much less significantly, Eastern low-sulfur coal. It is estimated that cumulative generating capacities of 880 trillion, 1,540 trillion and 1,650 trillion Btu's per year will switch from high-to low-sulfur coal in 1975, 1977, and 1980, respectively. Western low-sulfur coal will be transported over long distances, and this will double or triple the cost of the coal. Some modifications in converting the power plant to low-sulfur coal are necessary; these changes are related to such items as increased capacity of coal pulverization equipment necessary to handle the higher tonnages and derating of the power plant owing to the high moisture content of Western low-sulfur coals.

In the period 1975-80, two other sulfur oxide methods of abatement will be employed in coal burners. These will involve the increased use of physically-cleaned coal and the blending of low-sulfur coal with high-sulfur coal. In some instances, low-sulfur coal will be burned exclusively during episodes of adverse meteorological conditions.

The approach used here was to use FEA's base case scenario for the total utilization of oil and gas. Thus, the projected energy scenario outlined in Table 3-34-1, with a modification to represent the expected switch of some existing oil burning plants back to coal:

Table 3-34-1.  
Energy Consumption by Oil and Gas Burners  
(In Trillion Btu/Year)

Fuel	1975		1980	
	Baseline	Baseline CAA	Baseline CAA	Baseline CAA
Distillate Oil (0.3%S)	140	240	482	389
Fuel Oil (1%S)	1,100	1,942	2,471	3,137
Fuel Oil (1-2%S)	390	682	412	1,098
Fuel Oil (2+%S)	450	785	285	1,304
Natural Gas	4,000	3,274	3,274	2,948
Coal Switch	0	113	113	985
				985\$R

The differential fuel costs resulting from the utilization of Western and Eastern low-sulfur coal are given below.

Fuel	\$/Million Btu	
	Western, Chicago	Eastern, Cleveland
Cost of high sulfur coal	47	37
Cost of low-sulfur coal as burned	60	73
Cost of boiler modifications (as explained above)	3	3
Differential fuel cost due to CAA	16	39\$R

It is not known at this time what percentage of the low-sulfur coal usage will be Western and what the price will be to burn it. However, most of the coal usage will be Western, and the price of 16 cents per trillion Btu will be used as explained above. The unit costs of physically cleaning and blending coal (transportation and storage mainly) are \$4.5 and \$0.25 per ton, respectively.

Fuel oil burning utilities will in some cases be required to switch to low-sulfur fuel oil. The costs of the various grades with respect to sulfur content are given below.

St	% Sulfur	per Million Btu
Distillate	0.3	90
Fuel Oil	1.0	82
Fuel Oil	1-2	71
Fuel Oil	2	65\$R

For the conversion of Eastern utilities to low-sulfur coal, only quantities involved between 1975 and 1980 were considered. Taking 1975 as the baseline year (zero conversion) and in the absence of information on how much Western (or Eastern) low-sulfur coal was burned in the East, the post-1975 conversion data will be used. The levels are 40 million and 77 million tons per year in the periods 1976-77 and 1978-80, respectively. In the period 1975 to 1980, this will amount to a total of 272 million tons. The cost

at 16 cents per million Btu will come to a total of \$800 million in the period under consideration.

Physical coal cleaning and blending in the period 1975 to 1980 will involve 65 and 182.5 million tons in the respective categories. The respective costs will be \$292 million and \$46 million.

In oil-burning utilities, the differential fuel costs resulting from switching to low-sulfur fuel oils and distillates has been estimated by integrating the differentials between the baseline case and that projected by the CAA for the years 1970, 1975, and 1980.

Nitrogen Oxides. These pollutants will be controlled by applying staged combustion and off-stoichiometric firing. The unit costs for a 500 megawatt plant burning coal, oil, and gas were used in assessing the total cost of control. It was assumed that emissions of nitrogen oxides will be abated by the above technique starting in July 1975. While it is recognized that this may not necessarily take place, the costs obtained by this assumption will represent an upper limit for the period 1975-80. Variances and exemptions issued in Air Quality Control Regions (AQCR) where the ambient levels of this pollutant are not critical will of course lower the overall costs of control.

The above-mentioned control technique applies only to dry bottom boilers; wet bottom boilers are not amenable to this abatement technique. Consequently, if total control is desired, massive conversion of the estimated 17 percent of the coal steam-electric generating capacity with wet bottom boilers will have to be converted to the dry bottom type.

Berkau's unit cost data were used, wherein a 500 megawatt model plant was assumed; the investment costs were as follows:

\$t	Fuel	\$ per kw	
		New	Existing*
	Oil/Gas	0.56	0.75
	Coal	2.75	3.04

\*Costs for new plants multiplied by a retrofit difficulty factor of 1.35. Operation and maintenance and total annual costs were assumed to be 2 and 18 percent of investment per year; depreciation was assumed to be 14 percent per year.\$R

It appears that only AQCR's 24 and 67, whose boundaries encompass the cities of Los Angeles and Chicago, respectively, will restrict nitrogen oxide emissions from utility burners. In Los Angeles, the 1975 total oil and gas fired capacity to be controlled amounts to 11,770 megawatts of coal, oil, and gas burning facilities. An additional 2,000 megawatts of coal burning capacity is estimated to be

on-stream by 1978. Estimates of control costs in these two AQCR's were made and added to the national estimates.

Control of Particulates in Coal Burners. It is estimated that about 75 percent of all coal-burning power plants existing in 1970 had particulate removal equipment of about 90 percent efficiency. However, it should be noted at this point that it is difficult to substantiate this because of a lack of data. Stringent local (city and state) regulations initiated the expansion of serious efforts to control particulates in the late 1960's and early 1970's. The assumption has been made that a gradual upgrading of particulate control devices to 99.9 percent efficiency or better will take place.

All generating capacity in operation before 1975 is considered to be controlled by electrostatic precipitators, and existing capacity for which FGD systems will be installed before and after 1975 will not require additional particulate control capability. New generating capacity coming into operation after 1975 and for which FGD will be applied will require a particulate control level up to 95 percent using electrostatic precipitators; this is roughly half the investment required for control up to 99.5 percent. Generating capacity existing in 1971 together with that coming on line between 1971 and 1975 (after FGD capacity is

subtracted) will have capacity efficiency upgraded to 99.9 percent by electrostatic precipitators. Increments to the 1975 capacity (after taking out all FGD) will be controlled to 99.9 percent efficiency by electrostatic precipitators and wet venturi scrubbing; the breakdown will be 90 and 10 percent, respectively. The breakdown in capacity to be controlled as explained above is shown in Table 3-34-2.

Table 3-34-2.  
Control of Particulates 1971 to 1980  
(Trillion Btu Coal Burning Capacity)

Year	FGD		Remaining Capacity	
	Existing	FGD New	99.9 Percent ESP	99.9 Percent Venturi Scrubbing
1971	0	0	7.800	0
1972	48.2	0	8.350	0
1973	79.5	0	9.000	0
1974	154	0	9.700	0
1975	337	0	10.500	0
1976	761	221	10.680	20
1977	1,340	552	10.760	10
1978	1,410	748	11.460	100
1979	1,490	1,060	12.080	100
1980	1,590	1,410	12.670	100

No particulate controls necessary. Variances granted up to time of installation of FGD.

Control to 95 percent before FGD system.

Calculated by difference assuming an operating rate of 55 and 70 percent of existing and new plants with FGD installed. A heat rate of 0.01 trillion Btu per kw hr was also assumed.

1971 capacity will require only half the investment in upgrading from 95 to 99.9 percent.

Unit Costs of Particulate Control. The following costs were used for 99.5 percent particulate control units:

\$t	ESP	Venturi Scrubbing
Investment (\$ per kw)	20.0	30.0
O&M (\$ per kw-yr)	0.35	2.6
Annual (\$ per kw-yr)	1.9*	8.7**

\* 20-year life.

\*\*10-year life.\$R

Capacity existing in 1971 will be gradually (1971 to 1975) upgraded from 90 to 99.9 percent. This implies that half the investment will be required and time-dependent charges (O&M and annual) will carry for only 2 years instead of 4 years. The annualized control costs and control technology data are detailed in Table 3-34-3.

\$dTable 3-34-3.  
Steam-Electric Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (Mega Megawatts)	1.40	1.77	1.97		
Annual Growth Rate Over the Period 1971-85 = 11.89%					

PROCESS CHARACTERISTICS	Pollutants Generated	Control Technology
Coal	Particulates Nitrogen Oxides Sulfur Oxides Hydrocarbons Carbon Monoxide Other Gases & Mists	Venturi Scrubbers; ESP Burner Modification Flue Gas Desulfurization None Applicable None Applicable None Applicable None Applicable
Oil	Particulates Nitrogen Oxides Hydrocarbons Carbon Monoxide Sulfur Oxide	Burner Modification None Applicable None Applicable None Applicable None Applicable

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:	29,446.74	38,565.97	41,544.68		
Particulates	4,542.52	6,144.04	6,673.94		
Nitrogen Oxides	6,024.67	7,963.90	8,905.93		
Sulfur Oxides	18,551.79	24,018.66	25,474.75		
Hydrocarbons	79.46	110.52	126.62		
Carbon Monoxide	248.08	328.15	363.11		
Other Gases & Mists	0.22	0.30	0.33		
Legislated Controls:	19,819.85	16,415.40	19,147.81		
Particulates	2,105.92	512.54	579.81		
Nitrogen Oxides	6,139.21	8,344.38	9,980.99		
Sulfur Oxides	11,235.01	7,079.59	8,019.48		
Hydrocarbons	82.28	120.18	144.26		
Carbon Monoxide	257.20	358.39	423.92		
Other Gases & Mists	0.23	0.32	0.35		

CONTROL COSTS (Million 1975 \$)	1975	1980	1985	1971-85	1976-85
Investment	960.38	645.89	187.68	10,358.68	7,905.74
Total Annual	977.00	2,691.36	2,702.66	26,630.28	24,537.89
Capital	322.50	1,121.02	1,361.90	11,384.25	10,730.14
O&M	654.50	1,570.34	1,340.76	15,246.03	13,807.75

**\$C SOLID WASTE DISPOSAL \$R**

Solid waste disposal contributes to air pollution from incineration and open burning methods. Air pollutants emitted to the atmosphere from such practices include particulates, carbon monoxide, sulfur oxides, nitrogen oxides, fluorocarbons, hydrochloric acid, and odors. The levels of pollutants emitted are primarily dependent on the input or the material being burned; incinerator levels are also dependent on the specific incinerator design and upon the specific methods of operation. Particulate emissions are the highest concentrations, making them the specific pollutant subject to controls. There are no current Federal regulations for odors, hydrochloric acid, and fluorocarbons.

The solid waste disposal methods that are discussed in the following paragraphs were in use in 1971 in the proportions shown below:

\$t Disposal Method	Solid Waste Disposed (%)
Municipal Incinerators	5.3
On-Site Incinerators (Commercial and Industrial)	8.3
Open Burning and Open Dumps	22.2
Other Methods	64.2
Total Disposed Wastes	100.0 \$R

## MUNICIPAL INCINERATORS

Operating Characteristics and Capacities. Basically, there are two types of municipal incinerators: the refractory-lined furnace type, the most common in this country, and the water-wall or waste-heat recovery type, more common in Europe. The water-wall units offer the advantage of steam generation, and as a consequence of heat recovered during steam generation, flue-gas temperatures are lower than the refractory-lined units. Incinerators with lower gas temperatures have smaller volumes of flue gases to control, and thus require smaller, less-costly air-pollution control equipment. In addition, with the low temperatures from heat recovery, incinerators can utilize control equipment that could not survive the higher temperature flue gases from the refractory-lined furnaces.

Emission Sources and Pollutants. Municipal incinerators contribute to air pollution by releasing a variety of pollutants to the atmosphere that include particulates, hydrocarbons, sulfur oxides, fluorocarbons, nitrogen oxides and carbon monoxides. The levels of these pollutant emissions are directly related to the design and operation of the incinerator, but more importantly to the input charge. Of these pollutants, only the particulates are

considered to be emitted in concentrations that are high enough to warrant controls.

Control Technology and Costs. Both high-efficiency wet scrubbers and electrostatic precipitators are capable of collection efficiencies to meet emission regulations of 91 grams per 45.4 kilograms of refuse charged. Annualized control costs and industry statistics are detailed in Table 3-35-1.

#### ON-SITE INCINERATORS (COMMERCIAL AND INDUSTRIAL)

Operating Characteristics and Capabilities. In 1972, there were approximately 100,000 on-site incinerators in use in this country. These intermediate-sized units are usually associated with office buildings, large retail stores and apartment buildings. Of the over 23 million metric tons of solid waste incinerated annually in the United States, more than one-third is processed by on-site units that typically process about 90 tons annually, or approximately 104 kilograms per hour. States bordering the Great Lakes (Minnesota, Ohio, Illinois, Wisconsin, Michigan, Indiana, New York, and Pennsylvania) account for about 60 percent of the total number of on-site units in the United States.

There are two types of commercial building and industrial incinerators: single-chamber and multiple-chamber. Single-chamber incinerators are similar to residential or domestic units and consist of a refractory-lined chamber with a grate on which the refuse is burned. Combustion products are formed by contact between under-fire air and waste on the grate. Additional air (over-fire air) is admitted above the burning waste to promote complete combustion. Multiple-chamber incinerators employ a second chamber to which combustion gases from the primary chamber are directed for further oxidation of combustible gases. Auxiliary burners are sometimes employed in the second chamber to increase the combustion temperature.

It is estimated that the use of apartment incinerators, which account for about 6 percent of installations for refuse disposal, will become virtually extinct during the 1976-85 period. The number of industrial and commercial units should remain stable during that decade because new installations will primarily be replacements of older units.

Approximately 88 percent of all on-site incinerators are the multiple-chamber type; emissions from multiple-chamber incinerators are generally lower than the single-chamber incinerators. The design capacity of the incinerator in this report is from 23 kilograms per hour to 1,816 kilograms

per hour, and the average incinerator operates between 3-5 hours a day.

**Emission Sources and Pollutants.** While on-site units emit various products of combustion, only particulates (fly ash) are released in sufficient quantities to warrant installation of controls. Approximate emission factors for single-chamber and multiple-chamber incinerators of intermediate size are respectively 7.5 and 3.5 kilograms per metric ton of refuse charged. Estimated uncontrolled particulate emissions in 1975 are projected to be approximately 25 thousand metric tons.

**Control Technology and Costs.** Operating conditions (e.g., air supply to the combustion chamber), refuse composition, and basic incinerator design have a pronounced effect on the volume and composition of air emissions. Afterburners and wet scrubbers can be installed to control particulate emissions and some other combustion products. However, with the shortage of natural gas and the expense of fuel oil, the use of afterburners as retrofit controls on building incinerators will probably be curtailed. Furthermore, the newer multiple-chamber units already employ auxiliary firing techniques which in effect fulfill the function of an afterburner.

Wet scrubbers will achieve an approximate 80 percent reduction in particulates emissions. This level of control is sufficient to meet Federal particulate emission guidelines of 2 kilograms per metric ton of refuse charged.

Unit investment cost for a wet scrubber required to control an intermediate size incinerator (approximately 81 metric tons per year) is estimated to be \$4,400. Annual operating and maintenance costs will be about \$670 per installation. Annualized control costs and performance statistics are detailed in Table 3-35-1.

#### \$OPEN BURNING AND OPEN DUMPS\$R

Emission Sources and Pollutants. Open burning refers to the indiscriminate and unconfined burning of wastes, such as leaves, landscape refuse, and other rubbish. Open dump burning refers to unconfined burning of refuse at municipal dumps. Emissions from open dumps reflects the composition of the refuse as well as the volume of such items as paper, plastics, garbage, etc. The primary emissions from open burning are particulates, smoke, and products of combustion. Only particulates emissions are considered to be in concentrations high enough to warrant control.

Control Technology and Costs. There is no control technology that can be applied to open burning, and the only suitable alternatives for emissions control are the use of municipal incinerators for disposal and the use of sanitary landfills. It was assumed that all on-site open burning and the resultant wastes would be diverted to sanitary landfills. Annualized costs and process characteristics are detailed in Table 3-35-1.

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Table 3-35-1.  
Solid Waste Disposal Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (1,000 MT/Day)	866.75	992.70	1,074.46		
Annual Growth Rate Over the Period 1971-85 - .05%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes (MT/Day)</b>	<b>Pollutants Controlled</b>	<b>Control Technology</b>		
Municipal Incinerators	300	Particulates	ESP and Wet Scrubber		
Open Burning	100,300,500,700,900,1500	Particulates	Landfill (Close or Remote)		
On-Site Incineration	100,300,500,700,900,1500	Particulates	Landfill (Close) or Wet Scrubber		
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
1971 Controls:					
Particulates	148.78	183.52	183.44		
Legislated Controls:					
Particulates	88.43	58.05	57.51		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	133.34	44.59	2.12	1,943.06	629.12
Municipal Incinerators	0	4.23	0	161.98	93.39
Open Burning	57.65	29.64	2.12	1,287.35	232.04
On-Site Incineration	75.69	10.72	0	493.73	303.69
Total Annual	446.11	718.24	730.90	7,692.89	6,687.90
Capital	189.02	273.56	278.43	3,040.94	2,596.14
Municipal Incinerators	9.36	21.70	22.10	223.39	197.97
Open Burning	123.95	147.28	151.20	1,755.94	1,429.08
On-Site Incineration	55.71	104.58	105.13	1,061.61	969.09
O&M	257.09	444.68	452.47	4,651.95	4,091.76
Municipal Incinerators	24.88	41.24	41.18	457.58	396.87
Open Burning	171.26	301.48	317.54	3,121.01	2,759.23
On-Site Incineration	60.95	101.96	93.75	1,073.36	935.66

**SEWAGE SLUDGE INCINERATION INDUSTRY\$R**

Operating Characteristics and Capacities. Incineration is one of several methods currently practiced for the disposal of sludges accumulated by the municipal sewage treatment plants. There are four types of sewage sludge incinerators:

- Multiple-hearth
- Fluidized bed
- Flash drying
- Cyclonic-type.

The majority of existing installations are the multiple-hearth type. The capacity distribution of sewage sludge incinerators in 1968 is shown below:

Number of Installations	Capacity Range, Metric		Capacity Metric		Average Cap. Metric	
	TPD (dry solids)	(dry solids)	TPD (dry solids)	Capacity(%)	TPD(dry solids)	TPD(dry solids)
51	0.27 - 9.1	270	27.13		5.3	
103	9.2 - 45.3	2,132	54.79		20.7	
27	45.4 - 90.7	1,705	14.36		63.4	
7	90.8 - 272.0	1,214	3.72		173.4	
188		5,865	100.00			

TPD is the abbreviation for tons per day.\$R

Based upon municipal sewage treatment plant construction projections in Section Three, it is estimated that 70 new sludge incinerators will be constructed annually in the United States during the next few years. The growth reflects more widespread use of incineration as an alternative to other disposal methods, such as landfills, barging to sea, and fertilizer application. Accordingly, growth between 1971 and 1985 was estimated to be as listed below.

Year	Number of Installations	Total Capacity, Metric TPD (dry solids)
1971	314	8,864
1975	538	15,164
1980	888	25,004
1985	1,238	34,840\$R

Emission Sources and Pollutants. Particulate emissions from uncontrolled sewage-sludge incinerators range from 32 grains per DSCM (dry standard cubic meter) for multiple-hearth type, and 282 gr per DSCM for fluidized-bed type incinerators. Particulate emissions from existing facilities controlled by wet scrubbers range from 0.35 to 2.12 gr per DSCM, with an average value of 1.45 gr per DSCM. New source performance standards proposed by EPA limit the particulate emissions at no more than 1.09 gr per DSCM.

Control Technology and Costs. All sewage sludge incinerators in the United States are equipped with wet scrubbers that have varying collection efficiency. The scrubbers range from low-energy types, with pressure drops in the range of 2.5 to 6 inches of water, to high-energy scrubbers with a pressure drop of 18 inches of water. The Federal Guidelines for Incinerators set the limit at 2 kg particulate per metric ton (dry solids) or 27.5 gr per DSCM for sewage sludge incinerators. Therefore, the well-controlled installations are in compliance with the Federal Guidelines.

Control estimates of particulate emissions from sewage sludge incinerators were based on the following assumptions:

1. Incinerator operating schedules are 3,640 hours per year for installations with capacities in the range of 0.3 to 45 metric tons per day, and 8,736 hours per year for installations with capacities in the range of 45.1 to 272 metric tons per day.
2. The majority of the existing installations are controlling particulate emissions to about 90 percent, or 1.5 kg per metric ton.

3. To meet State Implementation Plans, existing facilities will be upgraded by 1975 to control particulate emissions to no more than 2 kg per metric ton. New facilities will be controlled to an emission level of no more than 0.8 kg per metric ton.

Table 3-36-1 details the investment, annual costs, and total cash requirements for the industry along with operating statistics.

\$dTable 3-36-1.  
Sewage Sludge Incineration Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (MT/Day)	14,260	25,293	33,899		
Annual Growth Rate Over the Period 1971-85 = 19.27%					
PROCESS CHARACTERISTICS					
	Model Plant Sizes (MT/Day)		Pollutants Controlled		
Incineration	5.28;21;63;178	Particulates	Wet Scrubbers	Control Technology	
EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	38.58	68.94	92.36		
Legislated Controls:					
Particulates	19.58	11.27	10.78		
CONTROL COSTS (Million 1975 \$)					
Investment	13.39	6.29	5.93	187.74	111.01
Total Annual	15.74	35.83	43.95	378.84	342.69
Capital	10.09	21.38	24.68	225.68	201.08
O&M	5.65	14.45	19.27	153.16	141.61

These costs are not included in the municipal water pollution control cost estimates in Section Three.

## SEGRAIN HANDLING INDUSTRY\$R

Production Characteristics and Capacities. Traditionally, grain handling is considered in terms of series of grain storage facilities starting from the delivery by the farmer and ending with the ultimate user. These grain storage facilities or grain elevators, provide storage space and serve as collection, transfer, drying, and cleaning points. There are two main classifications of grain elevators-- country and terminal elevators. Country elevators receive grains from nearby farms by truck for storage or shipment to terminal elevators or processors. Terminal elevators (this category is subdivided into inland and port terminals), are generally larger than country elevators and are located at significant transportation or trade centers. Inland terminals receive, store, handle, and load these grains in rail cars or barges for shipment to processors or port locations. Port terminals receive grain and load ships for export to foreign countries. It has been noted that particulate emission is a function of both the amount of grain handled and the operations involved in handling. The cost of equipment for emission control is a function of the size of the facility and operations involved. Consequently, model sizes for the types of operations and size of country elevators, inland terminals and port terminals have been selected, ranging from 0 to 70 thousand kiloliters (dry

measure). 70 to 700 thousand kiloliters, and 0.7 to 7 million kiloliters. It should be noted that very few country elevators fall within the second range, while some inland terminal elevators may fall within the first capacity range.

Using data for the number and storage capacities of the country and terminal elevators by states as of September 30, 1972, size ranges and number of facilities per size range are estimated in Table 3-37-1.

Table 3-37-1.  
Grain Handling Industry  
Facilities Production Capacities

Ranges (thousand kl/yr)	Total Volume Handled (million kl/yr)	Total Volume (%)	No. of Facilities	Average Volume (thousand kl/yr)	Model Facility Size
0-70	217	55.5	7,147	30.4	1
70-700	70.9	18.1	413	171.6	6
700-7,000	103	26.4	64	1,615	50
Totals	390.9	100.0	7,624	\$R	

Emission Sources and Pollutants. Grain handling includes a variety of operations which emit differing amounts of air pollutants, primarily particulates. The particulates consist of attrition of the grain kernels and dirt. Hence, the amount of the dust (particulates) emitted during the various grain handling operations depends on the type of

grain being handled, the quality or grade of the grain, the moisture content of the grain, the speed of the belt conveyors used to transport the grain, and the extent and the efficiency of dust-collecting system being used, such as hoods and sheds.

**Control Technology and Costs.** Systems used to control particulate emissions from grain handling operations consist of either extensive hooding and aspiration systems leading to a dust collector or methods for eliminating emissions at the source. Techniques which eliminate the sources of dust emissions or which retain it in the process are enclosed conveyors, covers on bins, tanks and hoppers, and maintenance of the system's internal pressure below the external pressure so that airflow is directed in rather than out of the openings.

Control methods are also available to capture and collect the dust entrained or suspended in the air. The dust collection systems generally used are cyclones and fabric filters.

In order to meet the emission standards, it is assumed that (except for grain drying) fabric filters will be installed in all existing plants that do not have them or as replacements for cyclones and other control devices.

Table 3-37-2 shows the future estimated sales of grains and the volume of grain handled by the two types of elevators. The table also shows the tremendously reduced amount of particulate emissions that are being forecast once the controls are installed.

Table 3-37-2.  
Grain Handling Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (10 Liters/Yr)	391.6	453.84	515.50		
Annual Growth Rate Over the Period 1971-85 = 2.9%					
PROCESS CHARACTERISTICS					
Grain Elevator	Model Facility Size (10 Liters/Yr)		Pollutants Generated	Control Technology	
	35:210:1.750		Particulates	Baghouse	
EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	1,024.48	1,192.54	1,353.32		
Legislated Controls:					
Particulates	423.55	24.54	27.87		
CONTROL COSTS (Million 1975 \$)					
Investment	701.44	83.77	44.15	2,478.10	1,204.48
Total Annual Capital	187.48	331.99	68.23	3,699.84	3,349.88
O&M	167.45	291.77	325.81	3,271.73	2,964.68
	20.03	40.22	42.81	428.11	385.2055

## SDRY CLEANING INDUSTRY\$R

Production Characteristics and Capacities. There are basically two types of dry cleaning installations: those using synthetic solvents, such as perchloroethylene, and those using petroleum solvents, such as Stoddard. The trend in dry cleaning operations today is toward smaller-packaged installations located in shopping centers and suburban districts. These installations use synthetic solvents while the older, larger commercial plants still use the petroleum solvents. It is estimated that approximately 55 percent of dry-cleaning is accomplished by synthetic solvents, with the remaining 45 percent accomplished by petroleum solvents. Now that the small, older petroleum solvent plant is being replaced by synthetic plants, it is estimated that 80 percent of the dry-cleaning in 1980 will be accomplished using synthetic solvents. The larger, commercial plants using petroleum solvents will comprise only 20 percent of the market.

Emissions Sources and Pollutants. Older synthetic solvent plants, which are using separate vessels for cleaning and drying, emit about 105 kg of hydrocarbons per metric ton of textiles. The modern synthetic solvent plants combine the cleaning and drying operation utilizing one vessel, a tumbler that is equipped with a condenser for vapor solvent

recovery. Emissions from the single-vessel unit average about 47 kg per metric ton of textiles. Plants utilizing activated-carbon absorption systems for further vapor recovery can reduce the emissions to 38 kg per metric ton for the older plants, and about 25 kg per metric ton for the modern plants. These emissions can be reduced further (by 30 to 50 percent) by well-maintained equipment and good operating procedures by personnel.

Emissions from petroleum-solvent plants can be as high as 154 kg of solvent per metric ton of textiles. Although there are adsorption units commercially available for petroleum-solvent machines, none have been installed to date. However, it is estimated that these adsorption units are capable of recovering as much as 95 percent of the evaporated petroleum solvents.

**Control Technology and Costs.** The dry cleaning industry contributes to air pollution by the release of organic-solvent vapors to the atmosphere. The amount of solvent emitted to the atmosphere from any one dry cleaning plant is dependent upon the equipment design solvent used, the length of certain operations in the cleaning process, the precautions used by the operating personnel, and the quantity of clothes cleaned. The most important of these items are the precautions used and the weight of the clothes

cleaned. Because of the higher capital investment required for emission controls on petroleum-solvent plants, it is believed that all new plants will use synthetic solvents, and that 50 percent of the petroleum-naptha solvent plants will shut down or convert to synthetic solvent operations by 1980. Furthermore, increasing solvent costs will provide an incentive for better evaporative emission control.

Annualized control costs and industry operating statistics are detailed in Table 3-38-1.

\$dTable 3-38-1.  
Dry Cleaning Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (Million MT/Yr)	1.29	1.74	2.05		
Annual Growth Rate Over the Period 1971-85 = 4.7%					
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Size (MT/Yr)</b>	<b>Pollutants Generated</b>	<b>Control Technology</b>		
Synthetic Solvents	57	Hydrocarbons	Carbon Absorber		
Petroleum Solvents	106	Hydrocarbons	Carbon Absorber		
Switch from Petroleum to Synthetic	106	Hydrocarbons	Process Switch		
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
1971 Controls:					
Hydrocarbons	161.47	187.13	184.49		
Legislated Controls:					
Hydrocarbons	96.09	74.61	92.33		
<b>CONTROL COSTS (Million 1975 \$)</b>					
Investment	49.34	6.59	1.93	204.05	79.13
Total Annual Capital O&M	20.33	31.02	33.21	347.74	304.38
	20.33	31.02	33.21	347.74	304.38
	0	0	0	0	0
					0
					0

## SCINDUSTRIAL AND COMMERCIAL HEATING\$R

Operating Characteristics and Capacities. The majority of commercial and industrial heating is accomplished by hot water and steam boilers. Although hot air furnaces are utilized for space heating, these units are fired on gas or distillate oil and they generally do not contribute significantly regional air pollution.

Commercial equipment normally is defined as having a capacity in the range of 0.05 to 2.11 million kg cal per hour. Industrial equipment normally is defined as equipment having a capacity in the range 2.11 to 169 million kg cal per hour. These ranges are loosely defined and in practice they often overlap; the equipment size distribution by location and fuel type is not available.

The estimated 1974 installed capacity of commercial and industrial boilers is 10 x 10<sup>6</sup> kg cal per year based upon a 1967 inventory and assumed growth rates of 4.5 percent per year for commercial units and 4 percent per year for industrial units. The future growth rate for commercial and industrial boiler capacity is estimated to be 3 percent per year. The current estimated capacity for coal-fired boilers is 820 million kg per hour, with an estimated growth rate of 7 percent per year. This substantial increase in growth

rate of coal-fired boilers has been assumed because of the current shortage of natural gas and oil.

Emission Sources and Pollutants. Pollutants emitted by fossil-fuel combustion are a function of fuel composition, efficiency of combustion, and the specific combustion equipment being used. Particulate levels are related to the ash content of the fuel, and sulfur oxides levels are related to the sulfur content of the fuel. Emissions of nitrogen oxides result not only from the high-temperature reaction of atmospheric nitrogen and oxygen in the combustion zone, but also from partial combustion of the nitrogenous compounds contained in the fuel; thus, levels are dependent both on combustion equipment design and upon fuel nitrogen. Carbon monoxide, hydrocarbon, and particulate levels are dependent on the efficiency of combustion as it is affected by combustion equipment design and operation. Accordingly, natural gas and distillate oil are considered clean fuels because of their low ash and sulfur contents, and also because they are relatively easy to burn. In contrast, coal (and some residual oils) contain significant amounts of sulfur and ash, require more sophisticated combustion equipment, and are more difficult to burn than the clean fuels.

The estimated uncontrolled emission factors and average emission factors, as required by the State Implementation Plans (SIP) for commercial and industrial boilers, are listed below and they are based on the following assumptions and conditions:

- The sulfur contents of coal, residual oil, and distillate oil are assumed to be 3. 2, and 0.2 percent by weight, respectively.
- The ash content of coal is assumed to be 12 percent by weight.
- The difference in particulate emissions factors between commercial and industrial coal-burning installations probably is related to differences in equipment design.

In the following tabulation of emissions factors, the factors within parenthesis indicate those required or allowed by SIP where applicable:

Emission Factors (kg per million kg cal)		
	Particulates	Sulfur Oxides
Commercial		
Coal	1.8 (1.08)	8.6 (5.8)
Residual Oil	0.29 (1.08)	4.0 (2.0)
Distillate Oil	0.18 (1.08)	0.36 (0.43)
Gas	0.032 (1.08)	0.0011
Industrial		
Coal	11.7 (0.63)	8.6 (5.7)
Residual Oil	0.29 (0.63)	4.0 (2.0)
Distillate Oil	0.18 (0.63)	0.36 (0.43)
Gas	0.031 (0.63)	0.0011 --\$R

Control Technology and Costs. It is apparent that equipment fired with gas and distillate oil essentially meets all of the air pollution regulations. The most cost-effective control technology has been switching from coal and high-sulfur residual oil to the less-polluting fuels. The current shortages and projected price rises for natural gas and distillate oils, and the proposed ban on switching to these fuels will require implementation of other control technologies in many cases.

Estimates of control costs are based on the assumption that for commercial boilers, fuel switching from coal and high-sulfur residual oil to low-sulfur residual oil is attainable, and that for industrial boilers, fuel switching from high-sulfur residual oil to low-sulfur residual oil is attainable. Alternative control technologies for coal-fired industrial boilers include dual alkaline scrubbers for sulfur oxides and particulates control. For the coal-fired boilers, flue gas treatment appears plausible for the larger units, while fuel switching appears realistic for the smaller ones. However, because no boiler size distribution was available at this time, all industrial coal-fired boilers were assumed to be using flue gas treatment as a control technology; this assumption will overstate the control costs.

Because of the present instability and future uncertainty of fuel prices, no attempt was made to account for the cost differential among fuels. On a Btu or heating value basis, there could be little difference in costs. Although it appears that the cost of coal and high-sulfur residual oil would be lower than the cost of the clean fuels prior to firing in a boiler, the higher costs of handling the coal and high-sulfur residual oil, as well as the higher equipment maintenance costs, are judged to offset any price differential. The net effect of these considerations would

produce virtually equivalent fuel costs on a consistent basis.

The estimated control costs for the model heating plants are given in Table 3-39-1. Investments and annualized costs are considerably lower for commercial than industrial installations because of the relative ease of fuel switching compared to the use of sophisticated flue-gas cleanup systems.

Table 3-39-1.  
Industrial & Commercial Heating Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (MT/Hr)					
Industrial	283.675	388.909	455.937		
Commercial	113.059	161.580	172.775		
Annual Growth Rate Over the Period 1971-85 =	4.66% Industrial				
	3.08% Commercial				
<b>PROCESS CHARACTERISTICS</b>	<b>Model Plant Sizes</b>	<b>Pollutants Generated</b>			<b>Control Technology</b>
Industrial	N/A	Particulates		ESP & FGD	
Commercial		Sulfur Oxides		Fuel Switching	
		Nitrogen Oxides			
		Hydrocarbons			
		Carbon Monoxide			
<b>EMISSIONS (1,000 MT/Yr)</b>	<b>1975</b>	<b>1980</b>	<b>1985</b>	<b>1971-85</b>	<b>1976-85</b>
<b>1971 Controls:</b>					
<b>Combustion of Coal:</b>					
Particulates	2,192.12	3,020.69	3,753.83		
Sulfur Oxides	3,644.91	4,977.24	5,898.31		
Nitrogen Oxides	709.71	979.03	1,158.08		
Hydrocarbons	44.54	59.10	71.09		
Carbon Monoxide	113.78	151.46	180.32		
<b>Combustion of Oil:</b>					
Particulates	302.47	398.56	460.10		
Sulfur Oxides	3,767.63	4,975.44	5,808.50		
Nitrogen Oxides	835.15	1,097.84	1,276.14		
Hydrocarbons	42.01	55.17	64.76		
Carbon Monoxide	56.07	73.74	85.75		
<b>Combustion of Natural Gas:</b>					
Particulates	78.02	117.77	129.89		
Sulfur Oxides	3.39	4.06	4.47		
Nitrogen Oxides	858.69	1,011.36	1,099.42		
Hydrocarbons	21.78	27.33	31.06		
Carbon Monoxide	94.68	114.27	126.45		
<b>Combustion of Distilled Oil:</b>					
Particulates	58.50	83.50	102.70		
Sulfur Oxides	117.00	167.01	205.41		
Nitrogen Oxides	239.84	342.37	421.09		
Hydrocarbons	12.28	17.54	21.57		
Carbon Monoxide	16.38	23.38	28.76		

Table 3-39-1. (Continued)  
Industrial & Commercial Heating Industry Data Summary  
EMISSIONS (1,000 MT/Yr) \$t

	1975	1980	1985	1971-85	1976-85
<b>Legislated Controls:</b>					
<b>Combustion of Coal:</b>					
Particulates	1,020.85	242.39	288.06		
Sulfur Oxides	2,837.62	1,755.62	1,972.63		
Nitrogen Oxides	736.38	1,015.52	1,186.65		
Hydrocarbons	45.72	61.37	72.29		
Carbon Monoxide	116.38	154.91	182.97		
<b>Combustion of Oil:</b>					
Particulates	314.11	409.79	477.92		
Sulfur Oxides	3,938.61	5,184.42	6,068.11		
Nitrogen Oxides	804.40	911.87	1,055.23		
Hydrocarbons	43.48	56.50	64.99		
Carbon Monoxide	58.03	75.38	86.78		
<b>Combustion of Natural Gas:</b>					
Particulates	101.21	121.06	132.55		
Sulfur Oxides	3.51	4.18	4.57		
Nitrogen Oxides	893.65	1,043.56	1,125.72		
Hydrocarbons	22.44	27.87	31.47		
Carbon Monoxide	98.16	117.37	128.92		
<b>Combustion of Distilled Oil:</b>					
Particulates	58.91	83.24	102.20		
Sulfur Oxides	117.82	166.48	204.40		
Nitrogen Oxides	241.54	341.28	419.02		
Hydrocarbons	12.37	17.48	21.46		
Carbon Monoxide	16.50	23.31	28.62		
<b>CONTROL COSTS (Million 1975 \$)</b>					
<b>Investment</b>					
Industrial	1,759.41	147.81	117.02	11,217.76	5,138.00
Commercial	722.99	343.85	77.26	3,746.20	1,726.75
<b>Total Annual Capital</b>					
Industrial	1,714.68	2,974.62	3,317.37	32,994.20	29,172.17
Commercial	1,036.53	1,788.65	1,914.87	19,285.46	16,970.28
<b>O&amp;M</b>					
Industrial	799.33	1,412.87	1,474.84	15,143.51	13,339.78
Commercial	237.20	375.78	440.03	4,141.95	3,630.50
Industrial	678.15	1,185.97	1,402.50	13,708.74	12,201.89
Commercial	270.01	521.93	596.62	6,153.96	5,556.99
Commercial	408.14	664.04	805.78	7,554.78	6,644.90

## Chapter 4

### Transportation Control Costs

#### §B1. MOBILE SOURCES EMISSION CONTROLS

##### Introduction

Mobile sources are recognized as significant contributors to national air-quality problems. In areas subject to photochemical smog formation, over half the reactants can generally be attributed to motor-vehicle emissions. Similarly, motor-vehicle emissions frequently cause large concentrations of carbon monoxide in high-traffic-density urban areas during traffic peaks. In cities with large and busy commercial airports, aircraft operations are often the source of high levels of carbon monoxide, hydrocarbons, nitrogen oxides, and particulates in the vicinity of the runways and terminals.

Passenger cars and light-duty trucks have been highly significant and visible pollutant sources because of the large numbers in service. Consequently, they have been under Federal controls since the 1968 models. Federal controls on heavy-duty motor vehicles have been in effect

since 1970, and controls on aircraft emissions went into effect in 1974.

Other mobile sources, such as railroad locomotives, marine engines, and farm, construction, and garden equipment, have been under study by EPA, but to date, no regulations for these sources have been promulgated or proposed. Advanced notice for motorcycle emissions control has been given, but regulations have not been issued yet.

This section describes briefly the applicable standards and technology employed for mobile-source emission controls, and presents estimates for the equipment, operating, and maintenance costs of these controls. Cost estimates are expressed in December 1974 dollars. Rather than inflating every cost in this section to a 1975 dollar value, the costs in the final tables may be inflated by a factor of 1.087 to get costs in 1975 dollars. Data are given for the 1968-85 time interval. However, emphasis is given in this report to the 1975-85 interval since the 1974 Cost of Clean Air Report covered the 1968-74 period in detail. Selected information and data from last year's report will be included in brief summary form in this report.

In the Summary (Section One) of this report, an estimated \$126.8 billion was listed as the total national investment

cost through 1985 necessary for all mobile sources to satisfy requirements associated with the Clean Air Act. The annual cost for mobile sources was estimated to be \$13.5 billion by 1985. The following display shows the contribution to these totals by mobile source type and by cost category:

\$d	Estimated 1968-80 Investment Cost	Estimated 1960 Annual Cost	Estimated 1968-85 Investment Cost	Estimated 1965 Annual Cost
<b>Mobile Source</b>				
<b>Light-Duty Passenger Cars</b>				
Equipment	24.27	5.45	50.66	5.47
Maintenance	8.74	0.61	11.19	0.41
Fuel Costs	21.34	2.27	39.12	4.10
<b>Light-Duty Trucks</b>				
Equipment	1.85	0.29	3.34	.31
Maintenance	0.23	0	0.08	(.05)
Fuel Costs	4.16	0.98	11.26	1.74
Aircraft	0.09	0.002	0.098	0.002
Heavy-Duty Vehicles	4.59	0.95	10.99	1.50
<b>Totals</b>	<b>65.27</b>	<b>9.93</b>	<b>126.74</b>	<b>13.48</b>

(Billions of 1974 Dollars)

\$s

### \$bReview of Recent Factors Affecting Mobile Sources\$R

A number of events of the past year had significant effect on potential effect on the cost of mobile-source emission controls. These included the oil crisis of early 1974, the recession of late 1974, the high altitude certification regulation, and the suspension of the 1977 light-duty emission standards. A number of other events will or may have future effect on mobile-source emission control costs, including the proposed motorcycle emission standards, the proposed selective enforcement audit, the setting aside of EPA's lead phase-down regulations by an Appeals Court, the identification of a potential problem from sulfuric acid emissions with catalysts, and the debate over the degree of nitrogen oxide control actually needed for clean air.

The oil crisis of late 1973 and early 1974 resulted in a trend toward smaller cars and increased gasoline prices. It also resulted in increased emphasis on fuel economy, which has affected the selection of present and future emission control approaches.

The recession of late 1974 resulted in a drastic reduction in new-car sales for the last half of 1974, which is continuing into 1975. A year ago, new-car sales for 1974 were predicted to be 10.7 million. As of October 1974, the

1974 new-car sales projection was 9.4 million. Final unofficial sales figures for 1974 indicate a total sales of 8.7 million new cars. Currently, 1975 sales are also predicted to be off by a significant percentage from the year-ago predictions.

The Energy Supply and Environmental Coordination Act of 1974, passed by Congress on June 22, 1974, included a provision which delayed the scheduled 1976 and 1977 emission standards. With less stringent emission standards for these 2 years, the cost and fuel consumption penalties will be less than estimated in last year's Cost of Clean Air Report.

The high altitude certification regulation, promulgated on October 18, 1974, to take effect in the 1977 model year, is estimated to affect less than 2-1/2 percent of total car sales. No firm estimates have been made of the potential cost impact of this regulation. For this report, it is assumed that only minor adjustments or recalibration of ignition timing, carburetion, and engine gas recirculation (EGR) will be required, and, further, it is assumed that the cost penalty will be small, therefore, no costs for this regulation are included in this report.

On December 23, 1974, the U.S. Circuit Court of Appeals in Washington, D.C. set aside the EPA lead phase-down

regulation which was to go into effect on January 1, 1975. The basis for the court's ruling was that there is no conclusive scientific proof that the lead emitted from gasoline-fueled vehicles is posing health hazards to a substantial portion of the general population. EPA sought a rehearing of the case (which was granted) before the entire court rather than the three-judge court which heard the case earlier, claiming that the judges misinterpreted the Clean Air Act and the evidence presented. The full court heard oral arguments from EPA and plaintiffs on May 30, 1975; a decision on the rehearing is expected by August 1975.

If the original court order is sustained, even up to the Supreme Court if EPA chooses to take it there, then costs given in this report relating to the lead phase-down regulation will be significantly altered or completely eliminated. Since it is not possible to determine at this time what the final outcome will be, the estimated energy impact of lead removal (refer to Table 1-6) and the estimated "fuel price penalties" due to lead phase-down (refer to Table 1-8) are based on the original EPA regulations.

The promulgation of motorcycle emission standards and the selective enforcement audit, when and if they occur, will no doubt have some cost penalty. No estimates have yet been

made for these potential cost penalties, but it is believed that they will be nominal.

The debate over the need for such stringent nitrogen oxide controls which are scheduled for 1978 model-year cars, is based partly on ambient-level considerations and partly on cost-effectiveness. Ambient-level nitrogen oxide data, upon which the standards were originally based, were found to be in error. A reassessment of the ambient-level nitrogen oxide requirements for clean air is still in progress. The oil crisis has shifted emphasis somewhat away from clean air requirements to economic stability requirements. Thus, even if the 1978 nitrogen oxide emission standard can be justified on the basis of clean air needs, a compromise standard may be sought if the technology necessary to achieve this emission standard is very expensive or fuel wasteful or both. It is premature to make any cost estimates relating to relaxation of the 1978 nitrogen oxide standard.

As provided for in the Clean Air Act and Amendments, the auto companies filed requests for suspension of the 1977 emission standards early in January of this year. Hearings were held by the Environmental Protection Agency in late January and early February on the suspension requests, and the decision of the Administrator was published on March 5,

1975 . . . In summary, the decision was made to grant the request for suspension of the 1977 hydrocarbon and carbon monoxide emission standards, and to establish interim standards for the 1977 model year at the level of the current 1975-76 hydrocarbon and carbon monoxide standards. The 1977 legislated nitrogen oxide standard of 2.0 grams per mile (g./mile) was retained.

The Administrator's decision also included a recommendation that consideration be given to extending the interim 1977 emission standards through the 1979 model year, establishing more stringent emission standards of 0.9 g./mile for hydrocarbons and 9.0 g./mile for carbon monoxides for the 1980 and 1981 model years (retaining the 2.0 g./mile 1977 nitrogen oxides standards), and then going to the original statutory standards of 0.41 g./mile for hydrocarbons and 3.4 g./mile for carbon monoxide for 1982 and beyond. The decision implied that the more stringent nitrogen oxides standard of 0.4 g./mile was not now indicated as necessary, but an ongoing review of oxides of nitrogen ambient level needs might eventually show a need for lower motor vehicle emission levels of nitrogen oxides. And finally, the decision included a statement of intention to establish a motor vehicle emission standard for sulfuric acid to be applicable starting with 1979 model year vehicles.

The primary reason given by the Administrator for suspending the 1977 emission standards was the sulfuric acid emissions problem. Catalysts are being used on 1975 model year passenger cars to reduce emissions of hydrocarbon and carbon monoxide by oxidation to carbon dioxide and water vapor. Unfortunately, the same catalyst promotes oxidation of another exhaust-gas component, sulfur dioxide (SO<sub>2</sub>). The sulfur trioxide (SO<sub>3</sub>) formed combines readily with the water vapor always present in the exhaust to yield sulfuric acid aerosol (droplets). This phenomenon was noted at least 2 years ago, but the extent of conversion of SO<sub>2</sub> to H<sub>2</sub>SO<sub>4</sub> with the catalysts, and of the resultant sulfuric acid emissions was not very well known until more recently. Even now, the relationship of sulfuric acid tailpipe emissions to vehicle operating patterns, catalyst design, engine tuning and design, car mileage, etc., are not as fully characterized as is needed to define the extent of the problem.

Most researchers will agree that catalyst-created sulfuric acid emissions represent a potential problem. EPA is taking the position that, although catalysts are serving a useful purpose in controlling hydrocarbon and carbon monoxide emissions to the present low levels while not sacrificing fuel economy (in fact improved fuel economy resulted), their continued use in subsequent model years may not be needed under less stringent standards. It is hoped (by EPA) that

postponing the imposition of the statutory 1977 emission standards for several years will permit the auto industry to develop improved catalysts emitting less sulfuric acid, or to develop alternatives to meet the interim and the eventual statutory standards. The likelihood of a sulfuric acid emission standard in a few years should further encourage the improvement of catalysts or seeking alternatives.

#### Light-Duty Vehicle Controls

#### EMISSION STANDARDS

Since 1968, the Federal Government has regulated the output of air pollutants from the exhaust of new light-duty motor vehicles. Emission standards are expressed in terms of maximum levels of gaseous emissions per mile permitted from the vehicle while operating on a prescribed duty cycle. Sampling procedures and test equipment are also prescribed by the regulations. While the standards apply only to new vehicles, the certification procedure requires that test cars meet emission standards after being driven over a prescribed durability schedule for 50,000 miles.

Both emission levels and test procedures have been revised periodically in several steps of increasing stringency.

Changes in the Federal Test Procedure were implemented for the 1972 and 1975 model years. Changes in emission levels were prescribed by the Environmental Protection Agency (or its predecessors) for 1970, and 1973 (nitrogen oxides), and were based largely on evolving technology for emission control. In effect, the 1973-74 Federal Standards required a reduction in hydrocarbon and carbon monoxide exhaust emissions of about 66 percent and a reduction in nitrogen oxides of 44 percent from uncontrolled (pre-1968) levels.

The 1970 Amendments to the Clean Air Act called for the Administrator to prescribe 1975 Federal emission standards affecting a 90 percent reduction in the hydrocarbon and carbon monoxide emissions from 1970 levels, and to prescribe the 1976 Federal standards effecting a 90 percent reduction in nitrogen oxide emissions from 1971 levels. The 1970 Amendments further gave the Administrator the authority to grant a 1-year suspension of the 1975 and 1976 standards under specified conditions if it could be established that effective control technology was not available for compliance.

On April 11, 1973, the Administrator announced his decision to suspend the 1975 statutory Federal Motor Vehicle Emissions Standards covering carbon monoxide and hydrocarbon for a period of one year. After extensive hearings in March

1973, the Administrator found that, although the necessary technology existed to meet the 1975 standards based on the use of catalytic converters, there was a high degree of uncertainty concerning the industry's ability to certify and produce catalyst-equipped cars in 1975 in large enough numbers to meet production requirements for their full model line. In addition, in-use reliability of the catalysts had not been established. Because of this, it was found that the risk of introducing catalysts on all vehicles in 1975 outweighed the risk to human health if the standards were delayed. The suspension was applied in two parts:

- National 1975 interim standards were established which are more strict than standards now in force, but which should not necessarily require catalysts on the majority of vehicles sold.
- More stringent standards were established for vehicles sold only in California, which would require catalysts on cars sold in that state. The California waiver provision in the Clean Air Act was utilized to establish the California hydrocarbon and nitrogen oxide standards, while a more stringent standard was prescribed for carbon monoxide.

The 1975 statutory standards as originally established were to be applicable to all cars sold in the United States.

Similarly, the Administrator's decision to suspend the 1976 Clean Air Act Standards was announced on July 31, 1973. This decision was based on the belief that technological success in meeting the 1976 statutory standards could not be predicted reasonably. In applying this suspension, the Administrator established an interim nitrogen oxide Federal standard of 2.0 g./mile, which is attainable with existing advanced emission-control technology.

On June 22, 1974, the Energy Supply and Environmental Coordination Act of 1974 was passed which, among other things, delayed the 1975 Interim Standards for hydrocarbon and carbon monoxide until the 1977 model year with a mandated 2.0 g./mile nitrogen oxide standard and delayed the 1977 statutory standards for hydrocarbon, carbon monoxide, and nitrogen oxide until the 1978 model year.

In October 1974, a regulation was promulgated requiring light-duty gasoline and diesel-fueled passenger cars and trucks sold in high-altitude areas of the country (over 4,000 feet) to meet the applicable emissions standards when tested at 5,200 feet. Generally, vehicle emissions increase with higher altitude. Thus, a vehicle meeting emissions

standards at sea level may exceed those standards when operated above 4,000 feet. This new Certification for High Altitudes regulation is scheduled to go into effect with the 1977 model year. It is estimated that only 2-1/2 percent of all cars sold in a given year will be affected by this regulation, and it is believed that meeting this regulation will require minor adjustment or recalibration of ignition timing, carburetion, and EGR with only a small cost penalty.

Table 1-1 summarizes the Federal exhaust-emission standards for light-duty passenger cars and trucks in the period 1968-76.

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Table 1-1.  
Federal Exhaust Emission Standards and Control  
Levels for Light-Duty Vehicles

Under 6,000-lb Gross Vehicle Weight

Type of Vehicle	Pre-1968			1970			1973/1974			1975/1976			1977			1978/1985		
	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
Light-duty gasoline passenger car	8.7	87	4.0	4.1	34	--	3.0	28	3.1	1.5	15	3.1	1.5	15	2.0	0.41	3.4	0.4
Light-duty diesel passenger car	--	--	--	--	--	--	--	--	--	1.5	15	3.1	1.5	15	2.0	0.41	3.4	0.4
Light-duty gasoline truck	--	--	--	--	--	--	3.0	28	3.1	2.0	20	3.1	2.0	20	3.1	2.0	20	3.1
Light-duty diesel truck	--	--	--	--	--	--	--	--	--	2.0	20	3.1	2.0	20	3.1	2.0	20	3.1

Emissions expressed in grams per mile

Emission levels as measured on the 1975 FTP.  
Estimated levels before controls.

Original Interim 1977 Standards suspended for 1 year by EPA Administrator on March 5, 1975. \$R5s

## 5-PASSENGER CARS

Control Devices, 1968-1974 Model Years. From 1968 to 1974, compliance with Federal emission standards was achieved by utilizing various combinations of the following:

- Purging of crankcase fumes through the engine
- Recalibration and tighter precision of carburetor fuel metering
- Engine intake air preheat and temperature control
- Spark retard at idle and low speeds
- Reduced compression ratios and elimination of combustion chamber pockets
- Air injection into the exhaust manifold
- Changes in valve timing and recirculation of exhaust gases
- Capture of fuel evaporative emissions in charcoal canisters or in the crankcase.

Table 1-2 summarizes the EPA and NAS estimates for incremental cost increases per car due to emission control requirements for the period 1968 to 1974. These data, taken from the 1974 Cost of Clean Air Report, are expressed in current dollars.

Estimates of the aggregate initial-equipment or engine modification costs per car for emission control through 1974 (expressed in December 1974 dollars) are \$100 (EPA) and \$84 (NAS). Industry estimates for that same period are \$50-\$120 in December 1974 dollars.

Table 1-2.  
Estimated Passenger Car Emission-  
Control Equipment Cost, 1968-74

Model Year	Item	List Price	
		EPA	NAS
1968-69	Positive crankcase ventilation (PCV) valve	\$ 0.40	\$ 2.85
	Inlet air temperature control	5.00	3.80
	Cumulative cost through 1969	\$ 5.40	\$ 6.65
1970-72	Fuel evaporation control system	13.50	14.30
	Idle control solenoid	11.10	4.75
	Carburetor changes	3.00	0.95
	Hardened valves and seats (for unleaded gasoline)	2.00	1.90
	Transmission control system	--	3.80
1973-74	Ignition timing	--	0.95
	Choke heat bypass	--	4.18
	Compression ratio changes	--	1.90
	Cumulative costs through 1972	\$35.00	\$39.38
	Exhaust gas recirculation (EGR), 11-14 percent	26.00	9.50
	Speed-controlled spark timing	26.00	0.95
	Precision cams, bores, pistons	--	3.80
	Transmission changes	--	0.95
	Cumulative costs through 1974	\$87.00	\$54.53

List price includes both dealer and manufacturers  
profits, expressed in current dollars.  
From Reference 10.  
From Reference 14.\$R

Control Devices, 1975-1976 Model Years. When the 1975 Statutory Standards were suspended for 1 year and replaced with less stringent interim standards, it became apparent that two types of emission-control systems could be used for the 1975 model year. These were: (1) oxidation catalyst-equipped systems, and (2) advanced engine modifications systems. The oxidation catalyst systems have been preferred by the industry, and it is estimated that 85 percent of the 1975 model year sales will include catalysts. Other changes and additions for some 1975 model-year cars included:

- Quick-heat manifold
- High-energy ignition
- Advanced carburetors
- Air injection.

The 1976 emission standards called for the same hydrocarbon, carbon monoxide, and nitrogen oxide levels as the 1975 interim standards; it is believed that only minor changes in emission control systems will be made from 1975 models. Proportional exhaust gas recirculation may be introduced in some models, and fewer catalysts may be used (estimated at 80 percent of sales). Design refinements and

production cost reductions are expected to offset any new equipment costs, resulting in no increases in emission-control equipment costs between 1975 and 1976 model years.

Estimates of the initial equipment or engine modification costs per car for emission control for the 1975 and 1976 model years are \$200 (EPA), \$159 (NAS), and \$100-\$450 (Industry).

Control Devices, 1977 Model Year. With the suspension of 1977 emission standards on March 5, 1975, and the setting of interim standards for hydrocarbon and carbon monoxide at the 1975-76 levels, and nitrogen oxide at a level of 2.0 g./mile (which is 35 percent lower than the 1975-76 level), the automobile companies should be able to meet the 1977 standards with only minor modifications to engines and control devices. These modifications could take the form of increased use of secondary air for catalyst operation, improved exhaust gas recirculation, ignition timing modification, or modified catalysts with decreased use of secondary air. EPA has estimated the incremental cost to meet 1977 emission standards will be \$20.

Control Devices, 1978 Model Year. With the implementation of the 1978 Federal emission standards calling for considerably lower hydrocarbon, carbon monoxide, and

nitrogen oxide levels than the 1977 values, additional control technology will be required. The capability of many different systems to achieve the 1978 emission standards has been investigated; some of these systems involve the use of alternative (noninternal-combustion Otto cycle) engines (e.g., Rankine cycle, Brayton cycle, Diesel, Stirling). Such systems are not considered candidates because insufficient lead time remains to mass produce a significant number of passenger cars powered by alternative engines for the 1978 model year, and furthermore, no vehicle powered by an alternative engine has yet demonstrated the capability to meet all of the requirements of the Clean Air Act.

Several systems that are applicable to modified conventional internal-combustion engines have demonstrated the capability to meet the emission levels required for 1978 at low mileage. These include:

- Dual catalysts (nitrogen oxide reduction with advanced oxidation catalyst)
- Three-way catalysts
- Stratified charge engine with oxidation catalyst
- Thermal reactors plus nitrogen oxide reducing catalyst.

At this time, the dual and three-way catalyst systems have received the most attention and are considered the most advanced of the above options. Use of nitrogen oxide-reduction catalysts in dual catalyst systems will require recalibration of the carburetion and different plumbing of the air-injection system. Additional changes that might be used for the 1978 model year include addition of fuel evaporation techniques and use of proportional exhaust-gas recirculation. Estimates of the cumulative initial-equipment or engine modification costs per car for emission control for the 1978 to 1980 model years are \$470 (EPA), \$304 (NAS), and \$315-\$950 (Industry).

Summary of Estimated Emission Control Equipment Costs.  
Table 1-3 summarizes the various estimates for incremental cost increases per car due to emission control requirements for the period 1968 to 1985; data in this table were obtained primarily from Reference 11.

Table 1-3.  
Estimated Passenger Car Emission-Control  
Equipment Costs, 1968-1980 Model Years

Model Year	List Price EPA	(December 1974 Dollars) NAS	Industry
Cumulative costs through 1974	100	84	50-120
1975/76 incremental costs	100	75	50-330
1977 incremental costs	20	--	--
1978 incremental costs	250	145	215-500
Cumulative costs through 1985	470	304	315-950

List price includes dealer and factory profits.  
From data submitted by the domestic manufacturers.  
Data obtained primarily from Reference 11.  
Restated from Table 1-2 in 1974 dollars.\$R

Estimated Maintenance Costs Due to Emission Controls. The additional per vehicle maintenance costs attributable to emission-control devices has been estimated by EPA to be \$16 per year from model years 1968 through 1974. For the 1975, 1976, and 1977 model years, there are certain benefits in reduced maintenance cost derived from the use of high-energy ignition systems, long-life exhaust systems, and unleaded fuel. For the 1975-77 model years, the annual maintenance cost benefits are estimated to be \$23 per catalyst-equipped car over 1974 cars; thus, the net maintenance cost over the pre-controlled cars is a \$7 benefit.

Additional maintenance costs are anticipated for the 1978 through 1980 model year period because of the greater complexity expected in the emission control systems required to meet the lower hydrocarbon and carbon monoxide standards. This increase over 1975 cars is estimated to be \$8 per car, resulting in a net annual-maintenance cost benefit of \$1 per car, or about the same as pre-controlled cars.

Annual maintenance cost penalties for the various model years are shown in Table 1-4. The estimated costs for 1975 through 1977 are based on assuming that 85 percent of vehicles sold in the United States in 1975 will be catalyst-equipped, 80 percent in 1976, and 75 percent in 1977.

Table 1-4.  
 Estimated Incremental Maintenance Costs  
 for Passenger Car Emission Control Systems,  
 1968-1980 Model Years

Model Year	Annual Incremental Maintenance Cost Increase (Decrease) per Vehicle	Net Costs
1968-74	\$16	\$16
1975-77	(23)	(7)
1978-80	(8)	(1)

Additional cost over normal maintenance due to emission control. 1968-74, current dollars; 1975-80, December 1974 dollars.

Assuming oxidation catalysts used all three model years, and based on 1977 interim standards (1.5 HC, 15 CO, 2.0 NOx). One catalyst change in 10 years assumed at 50,000 miles.

Assuming dual catalysts (oxidation plus reduction) continue to be used, and based on statutory HC, CO, and NOx levels (0.41, 3.4, and 0.4). One catalyst change in 10 years assumed.\$R

**\$CFUEL-CONSUMPTION PENALTIES\$R**

The average fuel economy of motor vehicles decreased gradually from the 1968 through the 1974 model cars. This change can be attributed to variations in vehicle weight, engine size, optional equipment, and the effects of emission-control equipment. In particular, the specific emission-control measures that adversely affect fuel consumption are retarded ignition timing, reduced compression ratio, and exhaust-gas recirculation.

Fuel economy penalties for the 1968 to 1973 model years were obtained from an EPA study of passenger car fuel economy involving tests of nearly 4,000 vehicles ranging from 1957 production models to 1975 prototypes. The fuel economy loss for 1973 model cars over pre-1968 cars was estimated to be 10.1 percent. A fuel economy penalty of 12.3 percent over the pre-1968 baseline was estimated for the 1974 year from 1974 certification data and 1974 sales data for the first 6 months. A shift toward lighter cars was observed in the first 6 months sales, but the trend was reversed for the remainder of the year.

Early 1975 prototype systems had shown, in general, continuing fuel-consumption penalties. However, various industry sources as well as the EPA have indicated now that catalytic systems on most 1975 vehicles resulted in fuel economy superior to 1973 and 1974 model-year cars. The EPA-measured fuel economy data for 1975 certification vehicles, when weighted for the estimated vehicle sales, resulted in a slight fuel economy benefit over pre-1968 baseline data of approximately 1.0 percent.

An additional fuel economy improvement is anticipated for the 1976 model year, resulting in an estimated fuel economy gain of about 4.0 percent over pre-1968 cars. No change in fuel economy is anticipated for the 1977 model year.

For the 1978 model year, it is believed that meeting the more stringent hydrocarbon, carbon monoxide, and nitrogen oxide standards will result in a fuel economy loss over 1976 cars, for a fuel economy penalty of about 5.0 percent over pre-1968 cars. However, these estimates are very uncertain at this time because of the inability of the auto companies to develop an emission control system which is able to meet the statutory emission standards in conjunction with good fuel economy.

No additional fuel economy gains or penalties are estimated for model years 1979 through 1985. These estimates of future fuel economy are only the change in economy due to emission controls. In separate efforts to improve fuel economy, the auto companies are reducing the size and weight of its existing model line, improving engine efficiency, changing axle ratios, and introducing new lighter, smaller models. These projects will raise the average fuel economy of all affected models, regardless of the potential effect of pollution controls. The effect of emission controls on passenger-car fuel economy for the period 1968 to 1985 is summarized in Table 1-5. Fuel economy data were obtained from References 18-20.

Table 1-5.  
Effect of Emission Control on  
Passenger Car Fuel Economy

Model Year	Best Estimate Incremental Fuel Economy Loss (Gain) (%)	Fuel Economy Penalty (Gain) Over Baseline (%)
1957-67 (Uncontrolled)	--	--
1968	4.1	4.1
1969	1.8	5.9
1970	(2.3)	3.6
1971	2.3	5.9
1972	1.4	7.3
1973	2.8	10.1
1974	2.2	12.3
1975	(13.5)	(1.2)
1976	(3.0)	(4.2)
1977	0.0	(4.2)
1978	9.0	4.8
1979	0.0	4.8
1980-85	0.0	4.8

Data from EPA.  
Baseline fuel economy of 1967 model year car = 13.5  
mpg.\$R

\$CLIGHT-DUTY TRUCKS\$R

For this report, it is assumed that emission control equipment costs for light-duty trucks are the same as for passenger cars for 1973 and 1974 (i.e., \$87 per car in current dollars). Less stringent standards were set for light duty trucks beginning with the 1975 model year; consequently, it is assumed that emission control costs for model years 1975-85 will be only moderately higher than for

the 1973-74 model years (\$150 per car in December 1974 dollars).

Annual maintenance costs for 1973 and 1974 model year light-duty trucks are estimated to be \$16 per vehicle. For the 1975 to 1985 model year period, it is estimated that there will be a maintenance cost benefit of \$5 per vehicle due to the use of catalysts, low-maintenance emission-control components, and unleaded fuel in a significant portion of light-duty trucks sold in that period.

Fuel economy of light-duty trucks is expected to be the same as for light-duty passenger cars for 1973 and 1974. A fuel economy gain of 6 percent is estimated for the 1975 model year, and no change for the 1976 to 1985 period.

#### \$CFUEL COST INCREASES\$R

Two EPA regulations affecting fuel costs are discussed below. One pertains to requiring gasoline marketers to make available 91 research octane number lead-free gasoline by July 1, 1974, for use in oxidation catalyst-equipped vehicles. The other EPA regulation required that the lead content of leaded gasoline be reduced to an average of 0.5 grams per gallon (g./gal.) by January 1, 1979. This latter

regulation, aimed at reducing lead in the atmosphere for health purposes, was recently set aside by the courts. A rehearing was requested by EPA and held on May 30, 1975. At this moment, it is not possible to predict whether the lead phase-down regulations will be reinstated by the court, reintroduced by EPA as is, modified, or dropped altogether. Thus, for the purposes of this report, it is assumed that lead phase-down will take place as called for by EPA.

On January 10, 1973, EPA promulgated regulations requiring that by July 1, 1974, gasoline marketers make 91 research octane number (RON) lead-free gasoline generally available for use in vehicles equipped with lead-sensitive control systems. At the same time, EPA repropoed low-lead regulations, requiring that the lead content of leaded gasolines be reduced to an average of 1.25 g./gal. by January 1, 1978, for the purpose of protecting the public health. On November 28, 1973, EPA announced that revised lead regulations had been promulgated which provided for a phased reduction in the average lead content of all grades of gasoline produced by any refinery over a 4-year period. Refineries were to be restricted to 1.7 g./gal. beginning January 1, 1975, with annual reductions to 0.5 g./gal. by January 1, 1979.

The promulgated schedule stretches the lead removal over a relatively long period of time and the allowable lead content of leaded gasoline in the national pool is not significantly lowered until 1977-78. Two of the most important reasons for the lengthy promulgated schedule are to ensure an adequate margin of industry construction capability and to minimize refinery raw material penalties.

For the next several years, the lead content of leaded gasoline will remain relatively high according to the regulation. Our latest national projections on the allowable lead content of leaded gasolines are summarized in the following display, which shows the lead phase-down schedule as planned and our best estimates of the lead-free need. From these, we have calculated the allowable lead in leaded gasoline.

Anticipated Effect of Lead Phase-Down Schedule

Calendar Year	Promulgated Lead Phase-Down (grams/gallon)	Portion of Pool Lead-Free (%)	Allowable Lead in Leaded Gasoline (grams/gallon)
1974	---	7	2.0 to 2.2
1975	1.7	15	2.0
1976	1.4	30	2.0
1977	1.0	44	1.78
1978	0.8	51	1.63
1979	0.5	63	1.27
1980	0.5	72	1.11SR

The energy impact resulting from the EPA lead-free and low-lead regulations for the period 1975 to 1980 is presented in Table 1-6 in terms of a crude oil penalty. The data in Table 1-6 are obtained from an EPA analysis of lead phase-down regulations in response to a FEO review dated April 9, 1974. References 23 and 24 also provided input to fuel and lead phase-down cost estimates. The cost penalties per gallon of fuel due to the lead regulations are estimated to be 1.09 cents for 1975 and 1976, 1.3 cents for 1977 through 1979, and 1.5 cents for 1980.

\$d  
 Table 1-6.  
 Energy Impact of EPA's Lead Regulations

Calendar Year	Refinery Energy Requirements	Energy Impact (Thousands of Barrels Per Day)			Net Energy Penalty
		Gasoline Lead-Free	Production Penalty Lead Phase-Down	Lead Additive Production (Savings)	
1974	13,104	0	0	0	0
1975	13,890	6	0	(2)	4
1976	14,646	7	0	(4)	3
1977	15,246	13	27	(6)	34
1978	15,917	12	34	(8)	38
1979	16,823	34	75	(10)	99
1980	17,806	69	44	(11)	102\$

**\$AGGREGATE NATIONAL COSTS FOR LIGHT-DUTY VEHICLE EMISSION  
CONTROLS\$**

Costs to the nation for light-duty vehicle emission control will be comprised of the aggregate of equipment, maintenance, and fuel-consumption cost increments attributable to the control devices. Since the various costs attributable to emission controls are different for each model year, total costs to the nation have been estimated separately for each model year using vehicle-population data for previous years and projections for future years.

Vehicle Population Estimates. Registration data are available at this time for vehicle model years up to 1973 for each calendar year through 1973. Estimates of vehicle populations for future years are based on the U.S. passenger-vehicle sales projections shown in Table 1-7. These projections reflect the major downturn in new-car sales which began late in 1973. Using these projections and typical scrappage-rate histories for previous model years, the vehicle population trends shown in Figure 1-1 are estimated. As shown, uncontrolled passenger vehicles will constitute only about 5 percent of the population by 1980, and 29 percent of the vehicles will have been manufactured

under controls imposed by the Clean Air Act Amendments of 1970.

Table 1-7.  
Historical and Projected Sales  
Of Passenger Vehicles

Model Year	Sales (Millions of Vehicles)
1968	9.40
1969	9.53
1970	8.46
1971	9.96
1972	10.61
1973	11.46
1974	8.7
1975	8.2
1976	10.3
1977	11.2
1978	10.4
1979	10.4
1980	11.6
1981	11.26
1982	11.51
1983	11.78
1984	11.94
1985	12.16

1968 to 1973 sales data based on data from Automotive News 1974 Almanac Issue, April 24, 1974.

1974 sales, Automotive News, March, 3, 1975.

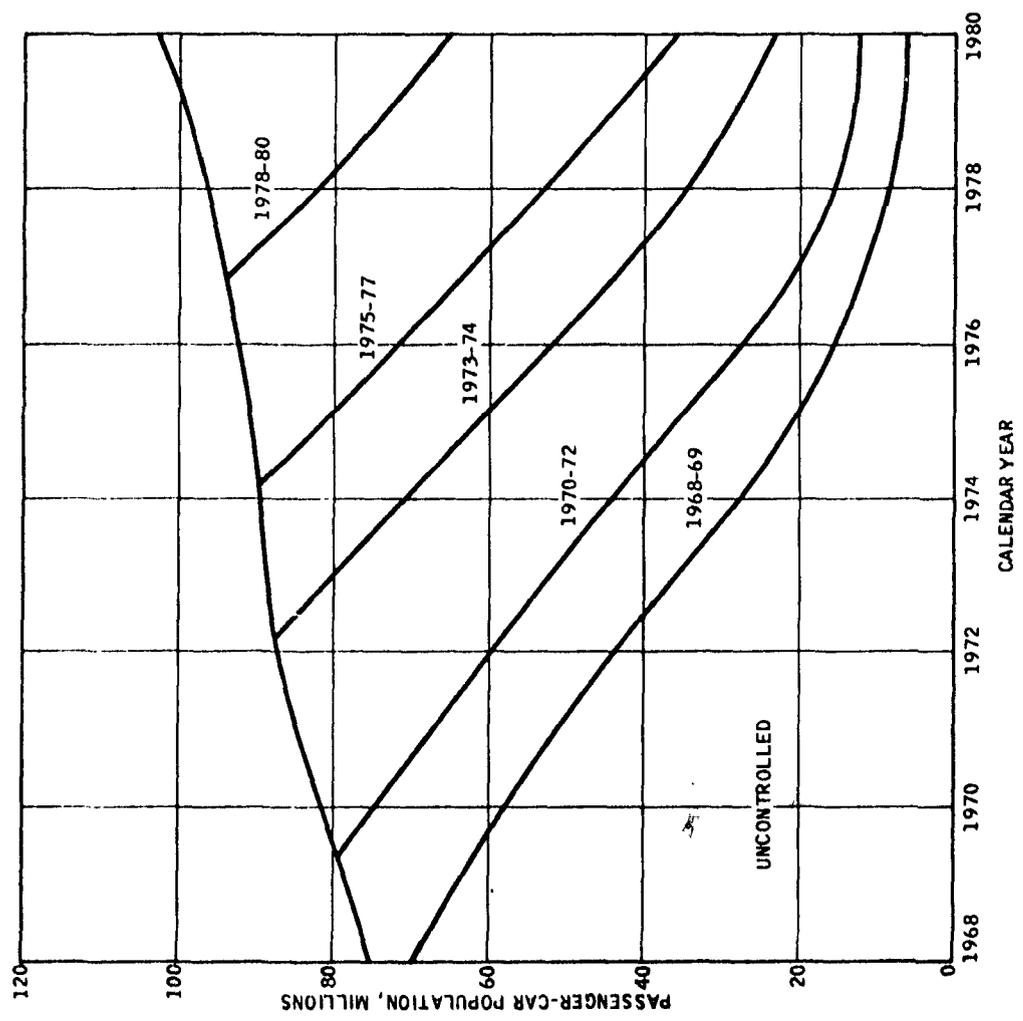
Predicted 1975 sales, Automotive News, May 19, 1975 (assuming imports = 21 percent of total sales).

1976-80 predicted sales from Chase Econometric Associates, March 10, 1975.

Estimates sales of automobiles that are consistent with the BLS projection of GNP during the 1980-85 period. Projection of consumer purchases of automobiles from the SEAS system as of July 7, 1975.\$R

Figure 1-1.  
 Estimated Passenger-Car Population

9110  
 9111  
 9112



In estimating light-duty truck population, it is assumed that survival factors for presently registered light trucks will be slightly higher than those for passenger cars, and that new registrations of light trucks will follow the same pattern as passenger cars for the interval 1974-85.

Estimated Total Costs, 1968-1985. A breakdown of annual national cost estimates for passenger car emission control is presented in Table 1-8. Equipment costs for each calendar year are taken as the equipment cost attributable to the new model-year vehicles. Maintenance and equipment costs for each calendar year are attributable to all controlled vehicles over 1-year old in the vehicle population for that year. Costs attributable to fuel price penalties are applied to all gasoline consumed by passenger vehicles for the affected years. Similarly, a breakdown of annual national cost estimates for light-duty truck emission control is presented in Table 1-9.

\$d  
 Table 1-8  
 Estimated National Costs Attributable  
 to Light-Duty Passenger Car Emission  
 Controls, 1968-1985

Annual Incremental Expenditures (Billions of Dollars)						
Calendar Year	Equipment	Maintenance	Fuel Consumption Penalty	Fuel Price Penalty	Annual Total	Cumulative Total
1968	0.05	0.15	0.15	--	0.35	0.35
1969	0.05	0.30	0.41	--	0.76	1.11
1970	0.30	0.43	0.55	--	1.28	2.38
1971	0.35	0.59	0.73	--	1.67	4.06
1972	0.37	0.75	0.96	--	2.08	6.14
1973	1.00	0.94	1.36	--	3.30	9.44
1974	0.76	1.07	2.37	--	4.20	13.64
1975	1.64	0.99	2.29	0.60	5.52	19.16
1976	2.06	0.86	1.93	0.63	5.48	24.64
1977	2.46	0.71	1.38	0.77	5.32	29.96
1978	4.89	0.69	1.29	0.93	7.80	37.76
1979	4.89	0.65	1.51	0.81	7.86	45.62
1980	5.45	0.61	1.72	0.95	8.73	54.35
1981	5.07	0.57	1.95	1.04	8.63	62.98
1982	5.18	0.53	2.15	1.13	8.99	71.97
1983	5.30	0.49	2.33	1.22	9.34	81.31
1984	5.37	0.45	2.55	1.31	9.68	90.99
1985	5.47	0.41	2.70	1.40	9.98	100.97
1968-85	50.66	11.19	28.33	10.79	100.97	

Current dollars used for 1968-74; December 1974 dollars used for 1975-85.

Fuel prices assumed: 1968, 49.7 cents/gal.; 1969, 47.2 cents/gal.; 1970, 44.3 cents/gal.; 1971, 43.4 cents/gal.; 1972, 41.5 cents/gal.; 1973, 41.6 cents/gal.; 1974-75 55 cents/gal.; 1976, 61 cents/gal.; 1977, 63 cents/gal.; 1978, 65 cents/gal.; 1979, 67 cents/gal.; 1980, 69 cents/gal. (plus 2 cents/gal. for catalyst cars).

Based on fuel cost increase due to lead regulations of 1.09 cents/gal. for 1975-76, 1.3 cents/gal. for 1977-79, and 1.5 cents/gal. for 1980.

\$s

\$d  
 Table 1-9.  
 Estimated National Costs Attributable  
 to Light-Duty Truck Emission Controls, 1973-1985

Calendar Year	Annual Incremental Expenditures (Billions of Dollars)					Annual Total	Cumulative Total
	Equipment	Maintenance	Fuel Consumption Penalty	Fuel Price Penalty			
1973	0.17	0.03	0.07	--		0.27	0.27
1974	0.13	0.05	0.21	--		0.39	0.66
1975	0.20	0.05	0.28	0.05		0.58	1.24
1976	0.26	0.04	0.38	0.07		0.75	1.99
1977	0.28	0.03	0.42	0.11		0.90	2.89
1978	0.26	0.02	0.57	0.14		0.99	3.88
1979	0.26	0.01	0.66	0.16		1.09	4.97
1980	0.29	0	0.76	0.22		1.27	6.24
1981	0.29	(0.01)	0.87	0.25		1.40	7.64
1982	0.29	(0.02)	0.98	0.28		1.53	9.17
1983	0.30	(0.03)	1.10	0.31		1.68	10.85
1984	0.30	(0.04)	1.22	0.35		1.83	12.68
1985	0.31	(0.05)	1.35	0.39		2.00	14.68
1973-85	3.34	0.08	8.43	2.33		14.68	

Trucks less than 6,000 pounds gross vehicle weight.

Current dollars used 1973-74; December 1974 dollars used 1975-85.

Fuel prices assumed: 1973, 41.6 cents/gal.; 1974-75, 55 cents/gal.; 1976, 61 cents/gal.; 1977, 63 cents/gal.; 1978, 65 cents/gal.; 1979, 67 cents/gal.; 1980, 69 cents/gal.

Based on fuel cost increase due to lead regulations of 1.09 cents/gal. for 1975-76  
 1.3 cents/gal. for 1977-79, and 1.5 cents/gal. for 1980.

\$s

By combining figures in Tables 1-8 and 1-9, cumulative costs are estimated to be \$14.3 billion as of 1974. Total annual costs to the nation will continue to increase as the result of both increasingly stringent control and an increasing population of controlled vehicles. Annual costs for 1975, 1980 and 1985 are estimated to be \$6.1, \$10.0, and \$12.0 billion dollars, respectively. Cumulative national costs are presently estimated to reach about \$20.4 billion by 1975, \$60.6 billion by 1980, and \$115.7 billion by 1985.

#### **\$Heavy-Duty Vehicle Controls**

#### **\$EMISSION STANDARDS**

Separate emission-control regulations have been in effect since 1970 for new heavy-duty gasoline and diesel truck engines manufactured for use in over-the-highway trucks and buses of over 6,000 pounds gross vehicle weight. Trucks under 6,000 pounds gross vehicle weight are considered light-duty vehicles and have been dealt with in the previous paragraphs of this section. Heavy-duty truck engine certification procedures are performed on the engine itself and do not pertain to the vehicle as in the case of light-duty truck and passenger car regulations.

Federal regulations for emissions from heavy-duty gasoline engines are shown in Table 1-10. For 1970 through 1973, regulations covered hydrocarbon and carbon monoxide emissions measured in terms of average concentrations in the engine exhaust over a nine-mode, constant-speed, variable-load dynamometer cycle. In 1974, new standards went into effect which are based on the same test procedure, but in which emissions are reported in terms of grams per horsepower-hour (g./hp-hr). The sum of hydrocarbon and nitrogen oxide emissions is limited to 16 g./hp-hr, while the standard for carbon monoxide is 40 g./hp-hr for 1974 and later model-year heavy-duty gasoline engines.

Heavy-duty diesel truck engine Federal standards are also shown in Table 1-10. Through 1970-73, standards covered smoke emissions only. In 1974, the standards were revised to include hydrocarbon, nitrogen oxide, and carbon monoxide emissions as well as more stringent smoke emissions. The permissible gaseous-emission levels are the same as for heavy-duty gasoline engines for 1974, but the test procedure is different. For diesels, emissions are averaged over a 13-mode, variable-speed, variable-load dynamometer cycle.

Table 1-10.  
Federal Standards for Heavy-Duty  
Gasoline and Diesel-Engine Emissions

Pollutant	Emission Standards	
	1970-73	1974
Gasoline Engines		
Hydrocarbons (HC)	275 ppm	16 g./hp-hr
Oxides of nitrogen(NOx)	--	--
Carbon monoxide (CO)	1.5 %	40 g./hp-hr
Diesel Engines		
Smoke:		
Opacity in accelerating mode	40%	20%
Opacity in lugging mode	20%	15%
Peak opacity in either mode	--	50%
HC + NOx	--	16 g./hp-hr
CO	--	40 g./hp-hr

For use in vehicles of more than 6,000 pounds gross vehicle weight.

#### HEAVY-DUTY GASOLINE ENGINE CONTROLS

The emission control technology used for heavy-duty gasoline engines through 1973 is similar to that employed for light-duty trucks and passenger cars through the 1972 model year. In fact, many heavy-duty gasoline engines are derivatives of passenger car engines. For 1974, the nitrogen oxide control standards were generally attainable without the use of EGR, although some EGR engines were certified in the previous

year to meet California standards for 1973 which were at the same level as Federal standards for 1974.

No detailed equipment cost estimates have been made by EPA for heavy-duty gasoline truck engine emission controls. In the absence of such estimates, it is assumed for purposes of this report that the per-vehicle emission control equipment cost increment of 1970-73 engines is equivalent to that for 1970 model-year passenger car engines minus the cost of fuel evaporation controls, equalling \$24 per vehicle. It is further assumed that the 1974 and following year control equipment costs will be equivalent to that for a 1973 passenger car engine less the cost of EGR and evaporative controls, or \$50.00 per vehicle.

Incremental annual maintenance costs for heavy-duty gasoline truck engine controls for all years are assumed to be the same as passenger car costs for model years 1968 through 1974, or \$16 per vehicle. Fuel consumption penalties are estimated to be 3 percent for the 1970-1973 period, and 5 percent for 1974 and beyond. A baseline fuel economy of 8.5 mpg is assumed. Estimates of total per-vehicle costs attributable to emission controls for this class of trucks are summarized in Table 1-11.

\$d  
Table 1-11.  
Estimated National Costs Attributable  
to Gasoline-Fueled Heavy-Duty Truck  
Emission Controls, 1970-1985

Calendar Year	Annual Incremental Expenditures (Billions of Dollars)					Annual Total	Cumulative Total
	Equipment	Maintenance	Fuel Consumption Penalty	Fuel Price Penalty			
1970	0.02	0.01	0.01	--	0.04	0.04	0.04
1971	0.02	0.02	0.03	--	0.07	0.07	0.11
1972	0.02	0.03	0.04	--	0.09	0.09	0.20
1973	0.02	0.05	0.07	--	0.14	0.14	0.34
1974	0.04	0.06	0.13	--	0.23	0.23	0.57
1975	0.04	0.08	0.17	0.09	0.38	0.38	0.95
1976	0.05	0.10	0.25	0.11	0.51	0.51	1.46
1977	0.05	0.11	0.31	0.16	0.63	0.63	2.09
1978	0.05	0.13	0.37	0.18	0.73	0.73	2.82
1979	0.05	0.14	0.44	0.19	0.82	0.82	3.64
1980	0.05	0.16	0.50	0.24	0.95	0.95	4.59
1981	0.05	0.18	0.55	0.28	1.06	1.06	5.65
1982	0.05	0.20	0.60	0.32	1.17	1.17	6.82
1983	0.05	0.22	0.65	0.36	1.28	1.28	8.10
1984	0.05	0.24	0.70	0.40	1.39	1.39	9.49
1985	0.05	0.26	0.75	0.44	1.50	1.50	10.99
1970-85	0.66	1.99	5.57	2.77	10.99	10.99	

Trucks over 6,000 pounds gross vehicle weight.

Current dollars used 1970-74; December 1974 dollars used 1975-1985.

Fuel prices assumed: 1970, 44.3 cents/gal.; 1971, 43.4 cents/gal.; 1972, 41.5 cents/gal.; 1973, 41.6 cents/gal.; 1974-75, 55 cents/gal.; 1976, 61 cents/gal.; 1977, 63 cents/gal.; 1978, 65 cents/gal.; 1979, 67 cents/gal.; 1980, 69 cents/gal.  
Based on fuel cost increase due to lead regulations of 1.09 cents/gal. for 1975-76, 1.3 cents/gal. for 1977-79, 1.5 cents/gal. for 1980.

\$s

It is estimated that the population of 1970-73 trucks of this class will peak at about 4.5 million in 1973, and that the total controlled population will have reached approximately 9.0 million in 1980. Total estimated annual costs for heavy-duty gasoline truck Federal emission controls are presented in Table 1-12. The cumulative total for the 1970-80 interval, is \$4.6 billion, and for the 1970-85 interval it is \$11.0 billion.

Table 1-12.  
Estimated Per-Vehicle Cost Penalties for Heavy-Duty Gasoline Engine Emission Control

Incremental Cost Item	Model Years	
	1970-73	1974-85
	(1974 Dollars)	
Emission-control equipment cost	\$24	\$50
Annual maintenance	16	16
Fuel consumption penalty	3%	5%

Based on 8.5 mpg for pre-1970 trucks.\$R

#### SCHEAVY-DUTY DIESEL ENGINE CONTROLS\$R

Both smoke and gaseous emission standards, including those for 1974, have been attained largely through fuel-injection system modifications. Nitrogen oxide and smoke are the more difficult emissions to control; even uncontrolled diesels

are usually well within carbon monoxide standards. Equipment cost penalties are considered nominal. Further, it is estimated that no fuel consumption penalties have been incurred. Accordingly, no national cost penalty is attributed to diesel-truck engine emission controls.

#### **Aircraft Emission Controls**

Aircraft emissions have been identified as significant contributors to the regional burden of pollution in comparison to other sources which will have to be controlled to meet National Ambient Air Quality Standards.

Airports are concentrated sources of pollutant emissions which will in many cases reduce local air quality to unsatisfactory levels even though emissions from automobiles and stationary sources are within acceptable levels within the general area. That is, unless aircraft emissions are reduced, airports will still remain intense area emitters of pollutants, even after emissions from other area sources have been greatly reduced.

The Clean Air Act directs the Administrator of the EPA to establish standards applicable to emissions of any air pollutant from any class or classes of aircraft or aircraft

engines which in his judgment cause or contribute to air pollution which endangers the public health or welfare." In July 1973, Federal emission standards and test procedures were established for various classes of new and in-use aircraft engines. These regulations are based on the need to control emissions occurring under 3,000 feet to protect ambient air quality in urban areas. However, the standards are not quantitatively derived from the air quality considerations in affected areas but, instead, reflect EPA's judgment as to the emission levels that will be practicable with present and projected technology. The requisite technology is assumed to include advanced combustion-system concepts for turbine engines and improved fuel systems for piston engines. The standards cover (a) fuel venting regulations beginning January 1, 1974, (b) smoke emission regulations taking effect in 1974, 1976, and 1978 for various engine classes, and (c) gaseous emission (carbon monoxide, hydrocarbon, and nitrogen oxide) standards for 1979 and 1981. Gaseous emissions regulations are based on a simulated landing-and-take off operating cycle which includes: (1) taxi/idle (out), (2) take off, (3) climb out, (4) approach, and (5) taxi/idle (in). Piston engines are included in the standards beginning in 1979.

In general, the influence of the regulations will be to contribute to the maintenance of the quality of the air in

and around major air terminals throughout the post-1979 era in which air traffic is undergoing expansion. The timing of these standards will not make contributions to achievement of ambient air-quality levels required by 1975 through the state implementation programs. Present aircraft emission standards and their estimated cost impact are listed in Table 1-13. Costs of fuel-venting and smoke emission controls through 1978, totaling \$17 million, are minor in comparison to costs of controlling other sources in that time period.

\$d  
Table 1-13.  
Aircraft Emission Standards and Estimated Cost Impacts

Calendar Year	Standards	Implementation Technology	Estimated Cost of Implementation
1974	JT8D smoke standards.	Combustor and fuel nozzle retrofit.	None (already voluntarily completed).
1974	Fuel venting restrictions for new and in-use engines (1975 for business-aircraft engines)	Plumbing and/or operational changes.	\$2 million.
1976	Smoke standards, new turbine engines except JT3D, JT8D, and supersonic.	--	None.
1978	JT3D smoke standards.	Fuel nozzle retrofit.	\$15 million.
1979	Gaseous emission (HC, CO, and NOx) standards for all engines manufactured.	Modified engine hot section.	\$66 million.
1980	Same as 1979.	Same as 1979.	\$5 million.
1981-85	Gaseous emission standards for newly certified engines.	Advanced combustor and engine concepts.	\$8 million
		1985 Cumulative Total	\$93 million

Sources: EPA, References 18 and 33.

Principally development and recertification costs. Includes additional engine hardware costs which will be incurred in 1979. Maximum additional engine cost estimate to be:

- \$10,000 per large turbine engine
- 6,000 per small turbine engine over 8,000 lb thrust
- 2,000 per small turbine engine under 8,000 lb thrust, and per turboprop or APO engine
- 52 per piston engine.

Estimated \$29 million in piston engine fuel savings per year for 1979 and 1980 is included.

Estimated \$3.5 million for hardware and \$1.5 million for certification. \$s\$R

The estimated cost of development and recertification efforts for compliance with the 1979 gaseous-emission standards is \$65 million, and the additional engine-hardware costs, which will be incurred in 1979, are estimated to be \$3.5 million. The costs incurred in 1980 for compliance with the 1979 standards are estimated to be \$3.5 million for hardware and \$1.5 million for certification for a total of \$5.0 million. The 1979 standards promulgated for piston-type aircraft are expected to result in significant fuel savings: \$29 million over 10 years. Credit for these savings has been assumed at a uniform rate of \$2.9 million per year in estimating the cost of aircraft emission controls for 1979 and 1980. In total, cumulative national costs through 1980 for aircraft emission control are expected to total approximately \$85 million (including \$5.8 million for fuel savings).

#### \$bDiscussion of Unregulated Mobile Source Emission\$R

As stated in the introduction, a number of mobile sources are presently unregulated. These include: railroad locomotives, motorcycles, marine engines, and offroad farm, construction, and garden equipment.

Emission inventories have been performed on many of these unregulated mobile sources .

As a general conclusion, most small-engined mobile sources (such as motorcycles, garden equipment, outboard engines, and snowmobiles) each contribute less than 1 percent of the total hydrocarbon and carbon monoxide from mobile sources, and less than 0.1 percent of the total nitrogen oxide (based on 1970 data). While these percentages are increasing as passenger cars and trucks come under more stringent control, it would not appear to be cost-effective to regulate these mobile sources until some future time.

In a publication by HEW , it was estimated that the total carbon monoxide emissions from railroad locomotives in 1968 constituted about 1.6 percent of the emissions from all transportation sources. Percentages for hydrocarbon, total particulates, and sulfur oxides were 1.8, 16.7, and 12.5, respectively. At present, there are no proposed regulations for railroad locomotive exhaust emissions.

**\$bTotal National Costs for Federal Mobile-Source Emission  
Controls**

Table 1-14 summarizes the total national costs attributable to Federal regulations controlling mobile source emissions for the period 1968-85. The \$115.7 billion light-duty emission control costs substantially surpass other mobile-source costs in this time period. Total cumulative costs for mobile-source controls are estimated to be \$126.6 billion.

Table 1-14.  
 Estimated Total National Costs for  
 Mobile Source Emission Control, 1968-1985

Calendar Year	Annual National Investment and O&M Expenditures (Billions of Dollars)				Total Annual Cost
	Light-Duty Vehicle Emission Control	Heavy-Duty Vehicle Emission Control	Aircraft Emission Control		
1968	0.35	--	--		0.35
1969	0.76	--	--		0.76
1970	1.28	0.04	--		1.32
1971	1.67	0.07	--		1.74
1972	2.08	0.09	--		2.17
1973	3.57	0.14	--		3.71
1974	4.59	0.23	--		4.82
1975	6.10	0.38	--		6.48
1976	6.23	0.51	--		6.74
1977	6.22	0.63	--		6.85
1978	8.79	0.73	0.02		9.54
1979	8.95	0.82	0.07		9.84
1980	10.00	0.95	--		10.95
1981	10.03	1.06	0.002		11.09
1982	10.56	1.17	0.002		11.73
1983	11.02	1.28	0.002		12.30
1984	11.51	1.39	0.002		12.90
1985	11.98	1.50	0.002		13.48
1968-85	115.69	10.99	0.093		126.77

Current dollars used 1968-74; December 1974 dollars used 1975-80. Interest not applied to annual investments.

Includes passenger cars and trucks under 6,000 pounds gross vehicle weight.

Includes all trucks over 6,000 pounds gross vehicle weight.\$R

CONVERSION OF MOBILE SOURCE CONTROL COSTS TO 1975  
DOLLARS

The preceding costs estimates for mobile source air pollution controls are expressed in December 1974 dollars. In order to convert to December 1975 dollars, an inflation rate of 8.7 percent was employed after conferring with Battelle Laboratories. Table 1-15 shows the major cost estimates expressed in 1975 dollars.

Table 1-15.  
 Estimated Total National Costs for Mobile Source  
 Emission Control, 1968-1985

Years	Annual National Investment and O&M Expenditures (Billions of 1975 Dollars)			
	Light-Duty Vehicle Emission Control	Heavy-Duty Vehicle Emission Control	Aircraft Emission Control	Total Annual Cost
1968	0.51	--	--	0.51
1969	1.07	--	--	1.07
1970	1.72	0.05	--	1.77
1971	2.16	0.09	--	2.25
1972	2.63	0.11	--	2.74
1973	4.28	0.17	--	4.45
1974	4.99	0.25	--	5.24
1975	6.63	0.41	--	7.04
1976	6.77	0.55	--	7.32
1977	6.76	0.68	--	7.44
1978	9.55	0.79	0.02	10.36
1979	9.73	0.89	0.08	10.70
1980	10.87	1.03	--	11.90
1981	10.90	1.15	--	12.05
1982	11.48	1.27	0.002	12.75
1983	11.98	1.39	0.002	13.37
1984	12.51	1.51	0.002	14.02
1985	13.02	1.63	0.002	14.65
<b>TOTALS</b>	<b>127.56</b>	<b>11.97</b>	<b>0.108</b>	<b>139.63</b>

Interest not applied to annual investments.\$R

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## \$b2. TRANSPORTATION CONTROL PLANS

### Summary\$R

When new-vehicle emission standards and stationary-source control are fully implemented, twenty-seven Air Quality Control Regions (AQCR) are still expected to exceed the oxidant and carbon monoxide air quality standards of 1975. To meet the air quality standards, these AQCR's will be required to implement Transportation Control Plans (TCP).

The aim of the TCP's is to reduce total emissions of in-use vehicles by implementing either or both of the following strategies to control emissions of in-use vehicles:

- Measures that reduce emissions per vehicle mile of travel
- Measures that reduce total vehicle miles travelled (VMT).

The first strategy includes the application of retrofit control systems, inspection and maintenance of vehicles, and service station vapor controls. The second strategy contains mass transit improvements, car pool programs, and

Other methods that will reduce the use of low-occupancy automobiles.

A detailed discussion of measures contained in the TCP's is given in the following paragraphs. Costs for implementing the inspection and maintenance programs, installation of retrofit devices, and service station vapor control systems are estimated for each AOCR for the period 1976 to 1985 inclusive. The costs to the vehicle owners of implementing these measures are estimated to be \$344 million in 1976, and thereafter remaining relatively constant through 1985. However, a net benefit results by taking into account the fuel savings that are expected to result from tune-ups required by the inspection and maintenance strategies. Hence, the cumulative benefit for the period 1976-85 is estimated to be about \$540 million (see Table 2-13). The cumulative total for 1976 to 1985 is approximately \$3.8 billion (see Table 2-13). Of the total estimated costs, approximately 18 percent or \$677 million will be for capital investment with the remainder going for operation and maintenance of the program (see Table 2-14).

## \$bIntroduction\$R

The Clean Air Act Amendments of 1970 (hereafter referred to as the Act) directed EPA to set national primary and secondary ambient air quality standards. The primary standards must be established so that their attainment and maintenance will protect the public health with an adequate margin of safety. The secondary standards will protect the public welfare from any known or anticipated adverse effects associated with the presence of air pollutants. In 1971, air quality control standards were established for six pollutants, including the four primary pollutants associated with motor vehicles: carbon monoxide, nitrogen dioxide, photochemical oxidant, and hydrocarbons. Hydrocarbons are reactants in the formation of oxidants, and they have no known health effects at ambient concentrations. The primary and secondary standards for these pollutants are identical and are shown in Table 2-1.

The standards for the motor-vehicle-related pollutants have been exceeded in a number of major urban areas. From the State Implementation Plans (SIP) submitted to EPA by the states in February 1972, it was found that of the 247 AQCR's in the United States, 54 regions exceeded the air quality standard for oxidants, 29 exceeded the carbon monoxide standard, and 2 exceeded the nitrogen dioxide standard. In

total, sixty-six AQCR's, representing roughly 60 percent of the nation's population, exceeded one or more of these standards.

The Act established three principal approaches to achieving the air quality standards:

Table 2-1.  
National Primary and Secondary Ambient Air  
Quality Standards

Pollutant	Air Quality Standard (ppm)	Averaging Time
Hydrocarbons	0.24 or 9.00	3 hours or 8 hours
Carbon Monoxide	35.00	1 hour
Nitrogen Dioxide	0.05	Annual
Photochemical Oxidant	0.08	1 hour

Primary and secondary standards for these pollutants are identical. Standards are not to be exceeded more than once a year.

Source: Reference 1.  
- Emissions standards for new automobiles

- Emissions standards for new stationary sources (power plants, industrial sources, and general area sources)

- In-use vehicle emissions controls.

EPA is authorized to promulgate and enforce emissions standards for new automobiles, trucks, and motorcycles. EPA has used this authority to establish increasingly stringent emissions standards for cars and initial standards for trucks. More stringent truck standards as well as motorcycle emissions standards are now under development. The Energy Supply and Environmental Coordination Act of 1974 extended the 1975 and 1976 deadlines of the Act for two years. The EPA's plan to achieve the air quality standards on a national basis also includes the implementation of controls on new stationary sources. New Source Performance Standards (NSPS) already have been promulgated for 12 stationary source categories.

The anticipated reductions in pollutant concentrations resulting from the implementation of new-vehicle emissions standards and stationary-source controls are projected to reduce the number of AQCR's exceeding the oxidant or carbon monoxide air quality standards to 27 by 1975. These include approximately 40 percent of the nation's population. Table 2-2 presents a list of these AQCR's together with the ambient concentrations for carbon monoxide and photochemical oxidants measured through 1972. Having controlled the emissions from stationary sources and new vehicles to the extent possible, those states containing the AQCR's that are still projected to exceed the air quality standards will be

required to implement transportation control plans. i.e., control of in-use vehicles, to meet the requirements of the Act. This section describes the ICP's to be implemented in those states containing the AQCR's listed in Table 2-2, and it includes the estimated costs to the nation.

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 Table 2-2.  
 1971-1972 Air Quality Levels in Regions Projected to Exceed Primary Ambient Air  
 Quality Standards in 1975

Carbon Monoxide - 8 Hour Average (ppm)		
10-15	16-20	21-24
Indianapolis Minneapolis-St. Paul	San Diego San Francisco San Joaquin District of Columbia Seattle Spokane Chicago	Sacramento Baltimore Boston Springfield Portland Pittsburgh Salt Lake City
	25-35	36-42
	Fairbanks Phoenix-Tucson Denver Philadelphia	Los Angeles New York City
Oxidant - 1 Hour Average (ppm)		
0.10-0.15	0.16-0.20	0.21-0.30
Phoenix-Tucson Philadelphia Pittsburgh Dallas-Ft. Worth San Antonio Indianapolis Rochester Cincinnati Portland Seattle Springfield	Denver District of Columbia New York City	Sacramento San Joaquin Baltimore Boston
	0.31-0.40	Greater than 0.40
	San Diego San Francisco Houston-Galveston	Los Angeles

Source: Reference 2, p. 22.\$s

### Overall Strategies

TCP's make use of either or both of the following strategies to control emissions of in-use vehicles:

- Measures that reduce emissions per vehicle mile of travel
- Measures that reduce total vehicle miles travelled (VMT).

The first strategy includes the inspection and maintenance of vehicles in use and the application of retrofit control systems. The second strategy contains mass transit improvements, carpool programs, and other methods that will reduce the use of low-occupancy automobiles. TCP's mainly pursue the above strategies with respect to automobile travel. The goals are to reduce emissions per vehicle mile and/or to reduce VMT for automobiles. Although motor vehicles are not the only source of hydrocarbons, carbon monoxide and nitrogen oxide emissions, Table 2-3 clearly indicates the significance of automotive emissions.

Table 2-3.  
 Mix of Emission Sources in Urban Areas - 1971

Pollutants	Percent of Total Emissions		
	Automobiles	Trucks, Buses & Motor- cycles	Stationary Sources
Carbon Monoxide	77-87	8-10	3-15
Hydrocarbons	50-65	5-10	25-45
Nitrogen Oxides	40-50	8-13	37-52

Source: Reference 4, p. III-23.

**Measures that Reduce Emissions Per Vehicle Mile**

**Inspection and Maintenance Programs.** The term "inspection and maintenance" covers a variety of strategies for reducing air pollutant emissions from light-duty motor vehicles that are currently in use by establishing procedures that will ensure proper maintenance of vehicles. Emissions from most vehicles tend to increase with use until the vehicle on the road is properly tuned. Thus, most vehicles on the road are emitting more than they were designed to emit on more than they would be emitting after a tune-up. The inspection and maintenance programs will systematically reduce the emissions from an automobile population.

Most of the inspection and maintenance programs have two distinct phases:

- An inspection phase. In which motorists are required to periodically present their vehicles for examination
- A maintenance phase. In which vehicles that fail the examination must be tuned up to bring them into compliance.

Three classifications cover the major alternative approaches in an inspection and maintenance program .

- Exhaust emissions inspection
- Engine parameter inspection
- Mandatory maintenance.

The exhaust emissions inspection will be the only one discussed because it is the only approach that is being used at present in those states that have initiated the program.

Exhaust Emissions Inspection. This inspection technique involves sampling the exhaust gases from the examined vehicle and passing the samples through suitable analytical instrumentation, to measure the quantities of air polluting compounds they contain. If the concentration of each compound falls below the applicable emissions standards, the vehicle passes the examination. If the concentration of any pollutant is above the standard, the vehicle fails. If a

vehicle fails the test, it must then be adjusted or repaired to bring the emissions into compliance. Following the maintenance, the vehicle would normally be resubmitted for an emission test to ensure that it is in compliance.

There are two types of vehicle operating modes that can be used in an emissions inspection test. In the idle mode test, emissions from the vehicle are measured using a tailpipe concentration while the vehicle is running in neutral. In the loaded mode test, the emissions are measured while the vehicle is running in gear on a treadmill-like device called a dynamometer. When operating in this test mode, the vehicle can be drive in several conditions, such as acceleration, cruise, deceleration, and idle. A driving cycle composed of a series of different driving modes more accurately represents actual driving conditions. Thus, emissions measurements taken in the loaded mode test are more representative of actual driving emissions than the measurements taken in the idle test. However, due to its more sophisticated equipment, the need for larger testing and facility areas, and a longer testing time per vehicle, the cost of a loaded mode program is higher than the cost of an idle mode program for a given vehicle population.

The choice of which inspection and maintenance program to implement is a function of several factors, including the

desired emissions reduction, ownership and operation of the inspection stations (public or private), and the relationship of the inspection and maintenance program with existing vehicle safety inspection programs.

In general, it is desirable to incorporate the inspection and maintenance program with a vehicle safety inspection program when one exists. If this approach is taken, the manner in which the safety program is operated will have an effect on the type of inspection and maintenance program that is chosen. Of the thirty-two states, including the District of Columbia, which have safety programs, only three states have publicly owned and operated stations. Safety programs in the remaining states are operated through private garages and service stations. Loaded mode inspection and maintenance programs could be incorporated into a state-owned safety program, but it would be difficult to incorporate the loaded mode test program into a state-licensed safety program because of the high cost of the test equipment. Therefore, in most cases idle mode tests could be incorporated with state-licensed stations and loaded mode tests with state-owned safety inspection stations. If a loaded mode test is required in a state with a state-licensed safety inspection program, it is most likely that a separate state-operated emission test program would have to be started.

Twenty-four areas are required to have some form of inspection and maintenance program within the next two years under the TCP's which have been approved or promulgated. There are mandatory safety inspections in 21 of these TCP areas. The plans specifically call for 20 idle mode and 7 loaded mode programs. The number of plans do not add to 24 because some AQCR's will include both idle mode and a loaded mode or privately and publicly owned inspection facilities as shown in Table 2-8.

The expected emission reductions from an inspection and maintenance program are a function of the mode type, the frequency of the inspection, and the percentage of the vehicle population that fail the inspection. In general, inspection programs will be conducted on an annual cycle. Reductions in hydrocarbons and carbon monoxide emissions, but not nitrogen oxide emissions, can be expected. Table 2-4 provides expected emission reductions for the idle and loaded mode programs for various failure rates.

Table 2-4.  
**Inspection and Maintenance Emission Reduction Effectiveness**  
**Hydrocarbon Emission Reductions**  
**(Percentages of Emissions from All Vehicles Inspected)**

Mode Type	Failure Rate				
	(Percentage of Vehicles Tested)				
Idle	10	20	30	40	50
Loaded	8	11	13	14	15

Mode Type	Failure Rate				
	(Percentage of Vehicles Tested)				
Idle	3	6	8	9	10
Loaded	4	7	9	11	12

The failure rate is only a convenient shorthand way of referring to the stringency of the emission standards. Actually, the state will adopt specific emission standards which each vehicle will be required to meet. When the emission standards are compared to the distribution of emissions for the total vehicle population, the percentage of vehicles that are above the emission standard can be determined. The resultant percentage represents these vehicles that will fail the inspection and is termed the failure rate. Thus, the more stringent the standard, the higher the failure rate. Since the emissions distribution

for the vehicle population can change from year to year, the failure rate would also vary accordingly.

Costs will vary positively with the failure rate. Vehicles that fail the test must receive corrective maintenance and be retested. Program capacity must therefore be based not only on the projected failure rate, but also on the rate of retesting. Increased vehicle capacity must be met by adding additional testing facilities and/or increasing the hours of operation.

#### RETROFIT CONTROL PROGRAMS

A retrofit approach can be defined as the addition of any device or system and/or any modification or adjustment on a motor vehicle after its initial manufacture to achieve a reduction in emissions. Retrofit programs go beyond the attempt made by inspection and maintenance programs to keep in-use vehicles at minimum emission levels consistent with their type and original design. The only way to reduce the rate of emissions from vehicles in-use further than the level attained through inspection and maintenance is to require retrofits. The objective of a retrofit program is to reduce the emission levels of an in-use vehicle below its "well-maintained" levels through the addition of a device or

system and/or a modification or adjustment after its initial manufacture.

Normally, a retrofit program will not be planned unless additional stationary-source controls, inspection and maintenance, and some modest VMT reduction measures are not enough to meet the national air quality standards. This is principally because of the relatively short life-span of retrofit effectiveness, i.e., as older vehicles leave the population, so do the retrofit devices, and the effect of the low emitting new vehicles becomes more predominant. All retrofit programs must embody several important factors in order to be an effective program. These factors include:

1. Choosing the retrofit system that is most closely matched to the particular pollutant problem in the area, since the different retrofit systems provide different emission reductions for the three pollutants;
2. Assuring that a sufficient number of devices and trained installation personnel will be available;
3. Incorporating a testing requirement at the time of installation; and

4. Providing for annual inspection and maintenance of retrofitted vehicles to assure proper operation in subsequent years.

The two retrofit programs currently under consideration for wide-spread implementation are:

- Vacuum Spark Advance Disconnect (VSAD)
- Air Bleed to Intake Manifold

In addition, a high altitude modification to the air bleed retrofits has been under consideration for Denver and Salt Lake City. This modification involves timing and carburetor changes on the air bleed. Preliminary test runs in Denver by EPA showed that the high altitude modification would not significantly reduce emission levels. Instead, an air bleed system with exhaust gas recirculation appears to be more desirable.

The characteristics of the two main types of retrofit systems, including a description of the system, its applicability, the expected emission reductions from its implementation, and other considerations are discussed below.

Vacuum Spark Advance Disconnect (VSAD). Two basic engine modifications employed by motor vehicle manufacturers in meeting Federal emission standards have been the leaning of air/fuel ratios and the modification of ignition(spark) timing. The modification of these parameters in precontrolled (pre-1968) vehicles will reduce carbon monoxide emissions by 9 percent, hydrocarbon emissions by 25 percent, and nitrogen oxide emissions by 23 percent, resulting in a fuel penalty of up to 2 percent. Durability data developed by General Motors over 25,000 miles without maintenance show no deterioration in the reduction of hydrocarbons and nitrogen oxides over time, but do show approximately a 20 percent deterioration for carbon monoxide. Because the 1968 model and newer vehicles have utilized these modifications to some extent to meet Federal emission standards, this retrofit technique is considered to be applicable primarily to precontrolled vehicles, but not to approximately 10 percent of those precontrolled vehicles which do not employ vacuum spark advance.

Air Bleed to Intake Manifold. Many devices have been designed to introduce excess air in the fuel mixture prior to combustion by one means or another. The effect reduces hydrocarbon and carbon monoxide with possibly some small increase in nitrogen oxide emissions. The reductions achieved vary directly with the amount of air allowed into

the intake system. This technique is applicable to some extent to all light-duty vehicles through the 1971 model year, but because of the relatively lean air/fuel ratios on most controlled vehicles, the technique is primarily applicable to precontrolled vehicles (pre-1968).

Tests conducted on this system for EPA indicate an expected reduction of 23 percent for hydrocarbons and 50 percent for carbon monoxide emissions with a fuel benefit up to 4 percent. No significant effect on nitrogen oxide emissions has been observed. Durability data on the system are not adequate for judging the performance of this control technique over an extended time frame.

#### SCSERVICE STATION VAPOR CONTROLS

Although the hydrocarbon vapors emitted to the atmosphere from service stations cannot be considered in-use vehicle exhaust emissions, the relationship between these vapor losses and vehicle use is so directly related that their control can legitimately be thought of as a transportation control.

Gasoline is a volatile liquid that tends to evaporate at ordinary ambient temperatures. The vapors thus created become a significant source of hydrocarbon emissions and.

consequently, of photochemical oxidants. In some metropolitan areas these vapors contribute as much as 15 percent of the total hydrocarbon emissions. Gasoline may evaporate at any of the points at which it is stored or handled and enter the atmosphere either through "breathing" from vents in the storage tanks (at the bulk terminal, in tanker trucks, at the service station, or in the automobile tank) or during the process of transferring from or refilling of each of these tanks.

The California Air Resources Board estimates that 23 pounds of hydrocarbons are emitted by each thousand gallons of motor fuel sold at stations in an uncontrolled situation; 11 pounds from transferring fuel from transport to station storage; 11 pounds in moving fuel from storage to a car tank; and 1 pound in "breathing" losses from underground storage. A study by the Standard Oil of California reports similar results. The average service station sells approximately 25,000 gallons of gasoline per month which results in hydrocarbon emissions of 575 pounds per month. EPA estimates such emissions to be around 400 pounds per station per month 2. 3. 11. By 1975, uncontrolled vapor losses of this magnitude will make the service station as significant a source of hydrocarbon emissions as some of the vehicles it serves. When translated into grams per mile.

the hydrocarbon emissions from service stations exceed the 1977 new car hydrocarbon standards .

Vapor Control Stages and Techniques. Service station vapor losses result primarily from tank truck unloading (Stage I) and vehicle fueling (Stage II). The basic measures to reduce either the evaporation or subsequent emission of vapors to the atmosphere in Stage I include the following:

1. Floating roofs on large storage tanks. These devices reduce the airspace above the liquid where evaporation may occur.
2. Submerged filling of tanks. This allows new gasoline to flow into the old gasoline, thus eliminating splashing from above filling which increases the amount of vapors.
3. Restrictions on vent pipes on the stationary storage tanks. This technique limits the amount of "breathing" which occurs through the vents.
4. Use of vapor return lines. This method allows vapors in the tank being filled to be transferred back into the tank from which the gasoline is being taken.

5. Secondary recovery systems. Carbon absorption or refrigeration-condensation systems are used to neutralize or reprocess the vapors that otherwise might be emitted.

Of these control techniques, submerged tank fill is required for any new station storage container (in most regions) with a capacity greater than 250 gallons, and may exist on a container over 2,000 gallons. In addition, vapors displaced must be either transferred back to the delivery vessel through a vapor-tight return line, or they must be processed on the location by a refrigeration-condensation system or other appropriate system designed to recover or eliminate at least 90 percent (by weight) of the organic compounds in the displaced vapors. If the vapors are transferred to the delivery vessel, such as a tanker truck, it must be refilled at facilities equipped with processing systems (such as refrigeration-condensation, carbon absorption, etc.) which can recover at least 90 percent of the organic compounds in the vapors.

On February 8, 1974, sources were required to submit control plans to EPA for Stage I vapor recovery by June 1, 1974. EPA has been unable to approve many control plans submitted because sources failed to include sufficient information or technical justification. Guidelines for Stage I vapor

recovery are being prepared by EPA and will be made available to sources in the very near future. Therefore, EPA has recently postponed the date for sources to enter and sign contracts for control systems from November 1, 1974 to March 1, 1975, and the date for sources to initiate on-site construction or installation of control equipment from January 1, 1975 to May 1, 1975 .

Stage II controls, recovery of vapors displaced during refueling of automobiles, could theoretically make use of any of the Stage I control techniques described above. However, submerged fill, collapsible bladders (the small scale equivalent of a floating roof), and carbon canisters to absorb all vapors during fueling would require redesign of present automobiles and are not considered by EPA for Stage II controls. Restrictions on vent pipes (often including small carbon canisters on the vehicles) were introduced to comply with the Federal Motor Vehicle Control Program in the 1970 model year, although pre-1970 vehicles have vent pipes open to the atmosphere. The remaining control technique is the collection of vapors displaced during fueling, the return of the vapors by means of vapor return lines, and the subsequent processing of them.

Essentially two techniques have been developed for the collection of vapors displaced from automobile tanks through

vapor return lines, simple displacement and blower-assist. After the vapors are collected, they can be recovered or reprocessed either at the service station or at the bulk terminal. Thus, recovery systems, such as carbon absorption, refrigeration-condensation, or incineration, can be installed either at the service station or at the bulk terminal. A substantial controversy has recently arisen over the effectiveness of simple displacement systems and the reliability of blower-assist systems. EPA recently determined that there is sufficient uncertainty about which system will be able to comply with the regulations. Comment period has been reopened, and EPA has postponed the requirement for submission of control plans from June 1, 1974, to January 1, 1975, and the requirement for signing contracts or placing orders from November 1, 1974, to March 1, 1975. Also, initiation of construction has been delayed from January 1, 1975, to May 1, 1975 .

**Measures that Reduce Total Vehicle Miles Travelled**

**THE NEED FOR VMT REDUCTIONS**

In the previous section, three measures to reduce emissions per vehicle mile (in-use controls) were described. In this section, which has been adopted from Reference 2, a brief description of measures which reduce VMT is presented.

The potential air quality benefits of in-use vehicle controls is shown in Table 2-5. The table shows that if in-use vehicle and stationary-source controls are fully implemented by 1977, at least eight regions in 1980 and five regions in 1985 are expected to fail to comply with oxidant and/or carbon monoxide standards. Therefore, if further control of motor vehicle emissions is necessary, reductions in automobile use are required to comply with the air quality standards.

Table 2-5.  
Number of AQCR's Failing to Comply with Oxidant and/or  
Carbon Monoxide Standard in Indicated Year

Conditions	Calendar Year		
	1977	1980	1985
Without In-use Vehicle Controls	21-24	12-14	9-10
Chapter 3 With In-use Vehicle Controls	12-17	8-10	5-10

Ranges reflect uncertainty in degree of stationary source control that will be achieved. Air quality projections are based on linear rollback for carbon monoxide and Reference 14 for oxidant. Analysis excludes New York, Denver, and Fairbanks.

Control strategy consists of stationary source controls and Federal Motor Vehicle Emission Control Plan (FMVECP).

Control strategy consists of stationary source controls, FMVECP, inspection and maintenance, retrofit (including catalyst retrofit), and vapor controls.

Source: Reference 2.

In any particular AQCR, the adequacy of transportation emission control strategies for achieving the national ambient air quality standards will depend on the severity of the air pollution problem within the region, the relative contribution of mobile and stationary emission sources, and the relative growth rates of these sources.

Thus, the extent of automobile use reductions will vary substantially among the AQCR's in which they are needed.

Table 2-6 displays the distribution of automobile use

reductions (measured as vehicle miles of travel) necessary to achieve nationwide compliance with the ambient air quality standards in 1977 and 1985; the projected VMT reductions needed in 1985 and beyond are highly uncertain. This is due to their extreme sensitivity to a number of parameters used in the projection calculation; namely, the relative contributions of different emission sources, the growth rates of these sources, and the extent of stationary source control achievable. Accordingly, a broad range of the number of cities in each of two categories is shown: one category shows the number of cities needing between zero and 25 percent VMT reductions, the other shows the number of cities requiring VMT reductions greater than 25 percent. The actual reductions needed by the cities in this latter category will depend primarily upon the degree of stationary-source control that can be achieved in 1985.

Table 2-6.  
 Number of AQCR's Requiring Automobile Use Reduction to  
 Achieve Compliance with Oxidant and/or  
 Carbon Monoxide Standards

Calendar Year	Automobile Reduction			
	Less than 10%	10%-30%	30%-50%	50% or more
1977	8	5	4	4
1985	0-25% 6-8	25% or more 4-6		

The VMT reductions estimated for each AQCR are based on the additional control of motor vehicle emissions required, assuming the regional I/M and retrofit programs for in-use vehicles are fully implemented by 1977. Air quality projections are based on linear rollback for carbon monoxide and Reference 14 for oxidant. The number of AQCR's whose current transportation control plans include auto use reductions exceeds the number used here because some plans have substituted VMT reduction for retrofit. Auto use reductions are expressed as percent reductions VMT.

Ranges reflect uncertainty in the degree of stationary-source control that will be achieved and the future growth in automobile use.

Source: Reference 2.

The automobile use projections, upon which the analyses presented in Table 2-6 are based, reflect trends as of 1973. Thus, nationwide automobile use (VMT) is projected to be about 55 percent greater in 1985 than in 1972. This projection assumes an increasing number of vehicles per person and an increasing annual mileage per vehicle. If the recent downward trend in automobile sales per person continues for a number of years so that the number of vehicles per person and the annual mileage per vehicle

remains constant through 1985. automobile use would be only about 18 percent above current levels. This represents a VMT reduction of 25 percent from the projected baseline assumed for Table 2-6 which reduces significantly the number of AQCR's requiring VMT reductions to achieve compliance with the standards.

#### STRATEGIES TO REDUCE VMT

There are generally two strategies to achieve VMT reductions:

- Improvements in transit systems to encourage automobile drivers to reduce trips.
- Carpools to increase the number of passengers per automobile.

Transit Improvements. To attract significant numbers of automobile drivers out of their cars, a transit system must at least satisfy three conditions:

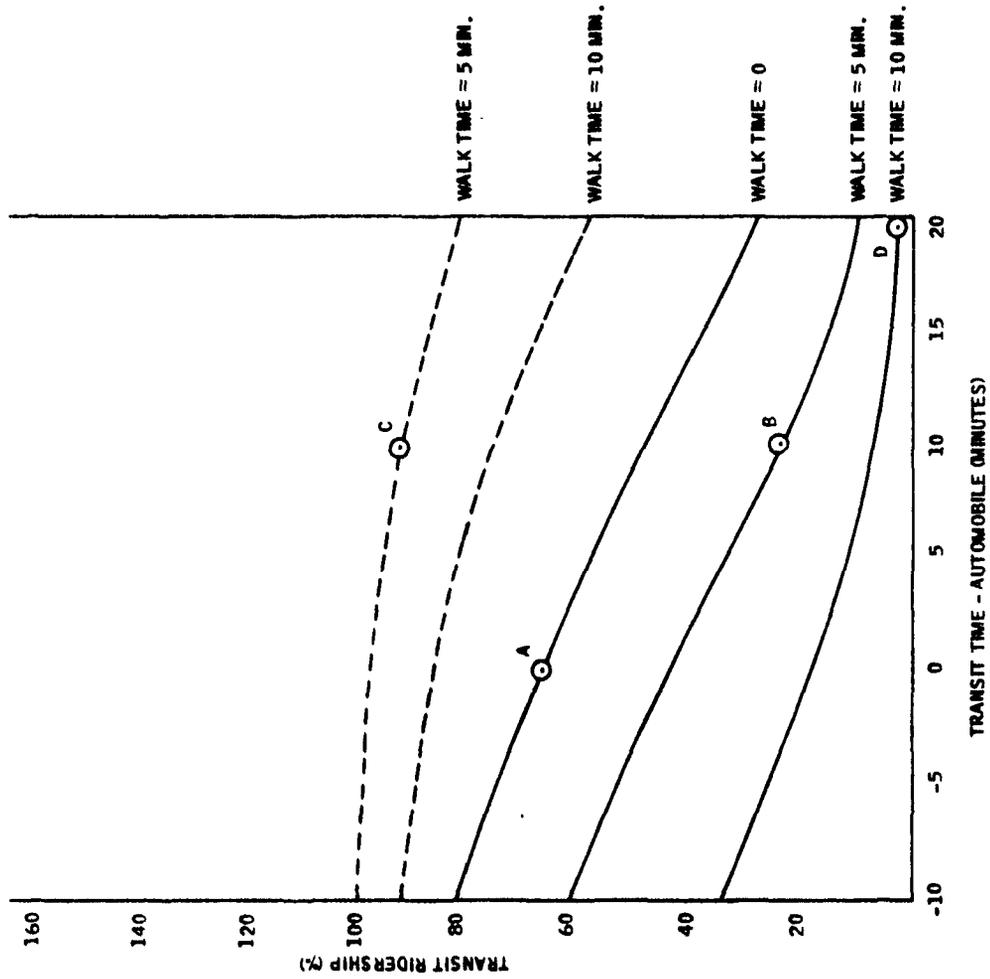
- It must have enough vehicles to carry the new riders.

- It must provide service whose quality is comparable or superior to that of the automobile. The most important component of service quality is travel time.

- Its cost to the rider must be attractive relative to the cost of operating an automobile.

An example of the relationship between travel time, cost, and transit ridership for work trips is illustrated in Figure 2-1, which is based upon the results of a study of travel behavior in Pittsburgh, Pennsylvania. The variables included in the figure are the time required to walk to and from the transit stop, the difference between automobile and transit travel times, the difference between automobile and transit costs, and the percentage of work trips taking place by transit. The importance of the time and cost variables in determining transit ridership can be illustrated by considering the case where transit and automobile travel times and costs are equal (Point A of Figure 2-1). The figures indicate that 66 percent of work trips would take place by transit. In contrast, average work-trip transit ridership in the United States is currently less than 15 percent.

Dependence of Work-Trip Transit Ridership on Service Quality | 10424  
 | 10425



LEGEND: ——— AUTO COST = TRANSIT FARE  
 - - - - - AUTO COST = TRANSIT FARE + \$2.00

In practice, it is unlikely that a transit system can offer widespread service which is as fast as that of the automobile. A more realistic example of a high-quality transit system is illustrated by Point B of Figure 2-1. Here, the walk time is five minutes, transit travel time exceeds automobile travel time by 10 minutes, and the transit fare and automobile cost are equal; transit ridership is 21 percent. If the walk and travel times remain unchanged and the automobile costs \$2.00 per work trip more than transit owing to free transit, parking charges, or other reasons, transit ridership for work trips increases to about 90 percent (Point C).

The reductions in the combined emissions of automobiles and transit vehicles thus achieved depend on the kinds of transit vehicles used, and the design and operation of the transit system. For example, if diesel buses meeting the California 1975 heavy-duty diesel emission standards are used and these buses carry an average load of 20 passengers, the reductions in combined bus and automobile emissions are roughly 30 percent for carbon monoxide and hydrocarbons and 15 percent for nitrogen oxides in 1977. In 1985, when automobile emissions will be less than in 1977, the carbon monoxide and hydrocarbon reductions are 20 percent and 25 percent, respectively. However, nitrogen oxide emissions increase by about 20 percent; this increase would be

eliminated if an average bus occupancy of 30 passengers were achieved.

These quantitative results are approximate because of their reliance on a single behavioral study and rather crude measures of trip characteristics. However, the conclusion that a high-quality transit system can attract high levels of ridership is also supported by the experience of existing high-quality transit operations, such as the Shirley Highway Express in the Washington, D.C. area .

Most transit systems in the United States do not provide the high-quality service needed to attract high ridership. For example, nearly 50 percent of urban area residences are located three or more blocks from the nearest transit stop. Transit routes are heavily downtown-oriented, but only about 10 percent of the trips go downtown. Transit trips take nearly twice as long as automobile trips. Moreover, subsidized free or reduced rate parking confers a cost advantage on the automobile. Transit service of this quality is illustrated by Point D of Figure 2-1, indicating a ridership of 4 percent.

Carpools. Average automobile occupancy in the United States is about two persons per car. Average occupancy for work trips is about 1.4 persons per car . Since most cars are

capable of carrying at least four persons, there is considerable room for reducing automobile use and emissions through carpooling. The principal obstacle to carpooling is that carpools are highly restrictive in terms of the service offered. Carpoolers must have trip origins and destinations that are close to one another, must travel at the same time, and, to minimize the problems of locating carpool partners, must make trips that are repetitive from day-to-day. As a result, the greatest potential for increased carpool use is in connection with peak-period work trips. These trips are responsible for about 25 percent of urban area automobile emissions .

The present automobile low occupancy rates for work trips indicate that substantial carpooling will not take place unless certain measures are implemented to encourage it. The limited experience to date with carpool programs has provided indications of the effectiveness of two possible approaches to encouraging carpools:

- Preferential treatment for carpools on streets and freeways.
- Parking restrictions combined with locator systems.

Preferential treatment for carpools has been observed to increase peak-period automobile occupancies by 10 to 30 percent. Locator systems combined with parking restrictions appear capable of doubling occupancies for downtown peak-period work trips to suburban locations. If these preliminary indications are confirmed by future experience, programs to encourage carpooling should be capable of reducing total urban area automobile emissions by 5 to 10 percent.

Carpooling and transit systems appear to be competitive, not complimentary, approaches to reducing automobile use. Both approaches operate most easily in connection with peak-period work trips to high density areas, and transit system improvements tend to attract passengers from their carpools. It is therefore unlikely that the effects of high-quality transit systems and carpooling on automobile use will be additive. For example, if transit system improvements alone can achieve a 15 percent reduction in automobile use and carpooling alone can achieve a 10 percent reduction, the automobile use reduction obtained from implementing both approaches together is likely to be greater than 15 percent but less than 25 percent.

#### SCTRANSPORTATION CONTROL MEASURES TO REDUCE VMT\$R

In this section, specific VMT reduction measures considered by the states, localities, and EPA in developing TCP's will be briefly explained.

Bus and Carpool Priority Treatment. Priority treatment for buses and carpools consists of allocating highway facilities preferentially to these vehicles for the purpose of increasing their average speeds. The usefulness of bus priority treatment in attracting automobile drivers to use the transit is dependent on the quality of the transit system or subsystem that uses priority treatment. Hence, in areas where bus priority treatment is included in a TCP, the measure is a part of an integrated transit improvement program. For example, in the Washington, D.C. area, priority treatment is used in combination with bus fleet expansion, the addition of new transit routes, and improved bus scheduling.

Carpooling Programs. Many TCP's include measures that provide computerized carpool matching programs and preferential carpool treatment programs. The matching programs provide for the formation of carpools, and the preferential treatment programs provide incentives, such as free parking, to encourage carpools.

Computerized carpool locator programs have been established in cities such as Washington, D.C., Boston, Massachusetts, Knoxville, Tennessee, and Omaha, Nebraska.

Employer Transit Incentive Regulations. Employer incentive regulations applicable in several metropolitan areas require major employers to implement measures that encourage the use of carpools and mass transit, while at the same time discouraging the use of single-passenger automobiles for work-related commuting. Under this approach, the employer has the flexibility to develop his own plan to minimize the impact of his facility on the area's VMT. The concept is based on already existing programs that have been developed by employers to discourage energy-inefficient commuting habits. In addition, many employers have voluntarily started such programs to avoid the acquisition of land for additional parking facilities. Companies such as Minnesota Mining and Manufacturing, and Aerospace Corporation of El Segundo, California, have already illustrated the effectiveness of this approach in reducing commuter automobile usage.

Parking Programs. Regulatory parking programs are used in several TCP's to complement the improvement of mass transportation and carpooling alternatives. The transportation plans include two general types of parking

regulations: on-street parking controls and parking management programs. The on-street parking controls are similar to common regulations in various cities to prevent congestion and to discourage commuter parking on public streets.

Parking management regulations are required to ensure that new parking facilities, usually having 250 or more spaces, do not cause a localized carbon monoxide problem around the facility and to minimize the effects new parking facilities will have on an area's VMT. Parking management regulation programs must be accompanied by actions to improve mass transit or expand carpooling possibilities. The parking management program requires the owner or operator of a proposed new parking facility to obtain an air quality permit prior to construction of his new facility. (On July 15, 1975, the EPA suspended indefinitely the parking management regulations, 40 FR 29713.)

Under the parking management regulations, the states are encouraged to develop their own area-wide parking facility plans to replace the Federal Regulations. These plans would focus on the interrelationship of transportation alternatives and new parking facilities. The plans would set forth the manner in which the location, operation, and increase in the number of parking-related facilities would be kept

consistent with the air quality needs throughout the area.

The plans could also ensure that the new facilities complemented rather than competed with existing and developing transit facilities. Several areas, such as San Diego, Los Angeles, Portland, and Seattle, have begun such plans for parking restrictions as a traffic control approach.

Transit Expansion and Development. The improvement and expansion of mass transit facilities is one of the key elements for the success of transportation plans. Bus fleet expansion will allow service to be upgraded in several major respects:

- Existing routes can offer more frequent service.
- New routes can be established to allow more people the opportunity of transit.
- Older, uncomfortable vehicles can be replaced with smoother riding, air-conditioned vehicles.

Within the last two years, many areas have established programs to improve and upgrade existing transit systems. Therefore, in the near future many areas will begin to offer the type of alternative transit that is required to help

achieve the required VMT reductions. An example of the type of improvement which can effect a reduction in VMT is the Seattle "Magic Carpet" program. City-wide fare reductions along with free fares within the CBD were associated with a fleet expansion and exclusive bus lanes. The increased ridership will help Seattle achieve the VMT reductions necessary to meet the National Ambient Air Quality Standards.

Sufficient Federal funding is necessary if areas are to expand transit systems to the level necessary to provide assistance in achieving the VMT reduction goals contained in the plans. EPA has been working with DOT to assure the availability of such funding. In addition, states and localities must be willing to increase their support for mass transit. Ideas such as using sales tax revenues for capital and operating expenses and therefore stabilizing fares have been successfully implemented in Atlanta, Georgia. Other areas must continue to provide the necessary local commitment if expanded mass transit is to become a reality.

Parking Surcharge and Parking Fees. Several of the plans promulgated by EPA called for the implementation of surcharges on commercial rates for parking. The use of such fees both discourages non-carpool commuting and provides a

source of financing for transit improvements. The measure can help bring about a significant change in urban driving habits with a minimum of social disruption if the fees are properly formulated and integrated with transit improvements. The program offers a wide latitude of individual choice to the driver. Those whose needs or preferences are strongly in favor of using the single passenger automobile may continue to do so, although at a somewhat higher cost; those who can easily adapt to other modes of transit or a carpool will have the incentive to take such action. The Energy Supply and Environmental Control Coordination Act of June 1974 (P.L. 93-319) forbids the EPA from promulgating surcharges.

The use of parking surcharges was limited to three parts of the country in the TCP's: Washington, D.C., Boston, Massachusetts, and five metropolitan areas in California: Los Angeles, San Diego, San Francisco, Fresno, and Sacramento.

Gasoline Supply Limitations. Gasoline supply limitations are, at least in theory, one of the most effective methods of reducing VMT. At the time the TCP's were first proposed, gasoline supply limitations were considered to be included in several plans. Two types of regulations were proposed:

1. A gasoline supply lid would have become effective during 1974 or 1975, which would have limited the quantity of gasoline sold in an area to fiscal 1973 levels.

2. A regulation, which would be implemented on May 31, 1977, would reduce an area's gasoline supply and thus VMT to the extent necessary to achieve the ambient air quality standards.

The gasoline supply lid was dropped as a primary control measure by EPA at the time the plans were finally promulgated. The determination not to include gasoline supply lids as a "reasonably attainable" alternative was based upon the comments received during the public hearings held on each plan and the Agency's evaluation of the feasibility of implementing and administering an effective program. Moreover, possibilities of evasion, the likelihood of noncompliance, and the difficulty of enforcement appeared too great to make this measure practicable.

However, the gasoline supply reduction to be implemented on May 31, 1977, has been retained in plans for several areas. In these areas, this measure was included as a final resort measure to fulfill the statutory requirement that a plan must achieve the ambient air quality standards by 1977. In

each of these areas, even with additional stationary-source controls, inspection and maintenance programs, reasonable VMT control measures, and retrofit strategies, additional VMT reductions were necessary to demonstrate attainment of the standards. As the EPA Administrator has stated on several occasions, this measure has been included in these plans to meet the technical requirements of the law, and the EPA does not intend to implement this measure unless it is legally required to do so. EPA has submitted a proposed amendment to the Clean Air Act which would allow additional flexibility in these heavily impact areas.

#### SCADDITIONAL VMT REDUCTION MEASURES

Several other measures were considered and accepted or rejected for use in TCP's. Measures used by the states or EPA to a limited extent include bicycle lane programs, vehicle-free zones, selective vehicle exclusion strategies, and gasoline truck delivery bans. Of these, the first two measures are being implemented on a limited basis, such as the bicycle lane program now underway in Denver, Colorado, and the vehicle-free zones in Springfield, Massachusetts, the Camden-Trenton area of New Jersey, and Salt Lake City, Utah. The last two measures (selective vehicle exclusion and gasoline truck delivery bans) were considered for implementation but were rejected.

**STATUS OF MEASURES TO REDUCE VMT**

A variety of VMT reduction measures have been either adopted by states or promulgated by EPA in 30 AQCR's. Table 2-7 shows the summary status of these measures by AQCR's, together with VMT reductions necessary to meet ambient air quality control standards. The measures which have a wide implementation are parking management (20 regions), carpool matching (14 regions), and exclusive bus/carpool lanes (13 regions).



**SbCosts of Transportation Control Plans\$R**

In the preceding section, a brief description of the TCP's was offered. This section will deal with estimating the aggregate costs to the motor vehicle owners of implementing TCP's. In order to estimate aggregate costs for the period 1976-85, costs of implementing various transportation control measures at each AQCR have been computed. Table 2-8 presents the list of AQCR's which will implement specific measures that will reduce emissions per VMT; the table also describes the geographic and model year coverage of each measure.

Table 2-4. List of AQCR's which will Implement Measures to Reduce Emissions Per Vehicle Mile of Travel | 1973

AQCR	I/M			Retrofit				-SVC	
	Test Type	Ownership	Area Covered	VSAD		Air Bleed		Stages	Area Covered
				Vehicle Year	Area Covered	Vehicle Year	Area Covered		
Boston Springfield	Idle	Private	AQCR Springfield SMSA	Pre-68	AQCR	1968-71	AQCR	I & II	AQCR
NY-NJ-Conn.	Idle	Public	N. J. part of AQCR N. Y. SMSA Penn. part of AQCR	Pre-71	N. J. part of AQCR	Pre-71	N. J. part of AQCR	I & II	N. J. part of AQCR
Philadelphia	Loaded	Private	Penn. part of AQCR	Pre-68	Penn. part of AQCR SMSA	Pre-68	Penn. part of AQCR	I	N. J. part of AQCR
Southwest Penn.	Idle	Public	N. J. part of AQCR	Pre-71	N. J. part of AQCR	Pre-71	N. J. part of AQCR	I & II	N. J. part of AQCR
Baltimore Natl. Capital	Idle	Private	AQCR	Pre-68	AQCR	1968-71	AQCR	I	Allegheny County
Chicago	Idle	Public	Va. part of AQCR D. C. & MD part of AQCR Cook Cty. Inc.	Pre-68	AQCR	Pre-68	AQCR	I & II	AQCR
Indianapolis	Idle	Private	AQCR	Pre-68	AQCR	Pre-68	AQCR	I & II	AQCR
Cincinnati	Idle	Public	D. C. & MD part of AQCR Cook Cty. Inc.	Pre-68	AQCR	Pre-68	AQCR	I	Marion County
San Antonio	Idle	Private	Chicago Marion Co.	Pre-68	AQCR	Pre-68	AQCR	I & II	San Antonio County
Houston - Galveston	Idle	Private	Hamilton County Note 1	Pre-68	AQCR	Pre-68	AQCR	I & II	AQCR
Denver	Idle	Public	AQCR	Pre-68	AQCR	Pre-68	AQCR	I & II	AQCR
Phoenix - Tucson	Loaded	Public	AQCR	Pre-68	AQCR	Pre-68	AQCR	I & II	AQCR
Wasatch Front	Idle	Public	Note 2	Pre-68	AQCR	Pre-68	AQCR	I & II	AQCR
Los Angeles San Francisco San Diego	Loaded	Public	AQCR	1955-65	AQCR	1955-65	AQCR	I & II	AQCR
	Loaded	Public	AQCR	1955-65	AQCR	1955-65	AQCR	I & II	AQCR
	Loaded	Public	AQCR	1955-65	AQCR	1955-65	AQCR	I & II	AQCR

NOTES: 1 San Antonio SMSA and Kentland, Medina, Wilson, Atascosa, Comal Counties.  
 2 Ogden, Salt Lake City, Provo-Orem SMSA's.  
 3 Boston and Houston - Galveston AQCR's have recently cancelled retrofit programs. Also, the EPA is presently considering the promulgation of I/M measures for Dallas-Fort Worth.

2-455

Table 2-9. (Continued)  
 List of States which will Implement Measures to Reduce Emissions Per Vehicle Mile of Travels | 93c

AQCR	I/M		Retrofit				-SSVC		
	Test Type	Ownership	Area Covered	VSAD		Air Bleed		Stages	Area Covered
				Vehicle Year	Area Covered	Vehicle Year	Area Covered		
Sacramento San Joaquin Puget Portland	Loaded	Public	AQCR	1955-65	AQCR			I & II	AQCR
	Loaded	Public	AQCR	1965-65	AQCR			I & II	AQCR
	Idle	Private	AQCR Portland SMSA			Pre-68	AQCR Oregon part of AQCR		
	Idle	Public				Pre-68			
East Wash- ington, Klamo	Idle	Private	Spokane SMSA			Pre-68	Spokane SMSA		
	Idle	Public	City of Fairbanks & North Star Borough			Pre-68	AQCR		
Austin- Waco Dallas - Ft. Worth El Paso								I	AQCR
								I & II	AQCR
								I & II	El Paso SMSA & Texas Counties of AQCR

#### \$CINSPECTION AND MAINTENANCE PROGRAMS\$R

The experience so far on the inspection and maintenance program costs has been limited to the programs operating in Chicago and New Jersey. In both instances, the programs make use of the idle-mode tests, and the inspection stations are state owned and operated. Reference 11 presents a description of these inspection programs as well as estimated fixed and operating costs for a publicly owned and operated emissions inspection program. A brief description of the assumptions used in estimating costs inspection and maintenance programs follows. Cost elements have been computed by the EPA Office of Land Use and Transportation Policy, based on data provided by Northrop/Olsen Corporation. The City of Chicago, and the State of Arizona. It is assumed that the inspection facilities would be either publicly or privately owned and operated with the needed maintenance of rejected automobiles performed at privately owned garages or repair facilities. The number of inspection lanes required is computed from the projected light-duty vehicle population for that area for the year of program implementation and the following standard lane capacities:

. Idle-Mode - 32,000 vehicles per lane per year

• Loaded-Mode - 25,000 vehicles per lane per year.

These capacities assume an 8-hour working day for 250 days per year with an average of 40 percent idle time. Since vehicles are not expected to arrive at inspection stations at a uniform rate, some idle time is inevitable. However, the extent of this idle time largely depends on the inspection schedule and other measures in an area that would affect the distribution of vehicle arrivals. The success of each area in achieving greater uniformity in arrival rates cannot be estimated at this time; therefore, 40 percent idle facility time has been assumed. It should be recognized that as areas become experienced in administering inspection and maintenance programs the idle facility time is expected to be significantly lower than 40 percent. In this sense, the cost estimates appear to be overstated for the later years of the 10-year period. The number of stations required was computed assuming that all stations have two lanes.

The total annual cost of an inspection station is assumed to range from \$106,077 to \$130,974, depending on the following factors:

• Ownership (private versus public)

- Test type (loaded versus idle)
- Geographic location which determines the total site cost.

Table 2-9 presents the summary of costs assumed per two-lane station. Reference 11 gives the detailed breakdown of the cost estimate. The second cost area in the program is the maintenance of failed vehicles. An average tune-up cost of \$30 per failed vehicle of which \$15 is assumed to be attributable to the inspection and maintenance measure, is considered. Vehicles that fail the emissions inspection and subsequently are tuned are expected to incur fuel savings. The extent of annual fuel savings from the program is dependent, on the failure rate among other things. EPA's Office of Transportation and Land Use Policy estimates that on the basis of recent data the following relationship exists between the failure rate and annual fuel savings for serviced vehicles:  $Y = 31.5X$ , where X=percent failure rate and Y=annual fuel savings, expressed in percents, for serviced vehicles. Fleet-wide dollar savings are computed for each AQCR by computing the fuel saving rate from the above equation and assuming an annual vehicle use of 10,000 miles a fuel consumption rate of 13.58 miles per gallon, and a price of gasoline of \$0.75 per gallon.

Based on the inspection cost estimates given in Table 2-9 and the maintenance cost and fuel savings assumptions outlined above, the annual inspection and maintenance fixed and operating costs for each AOCR have been computed for the years 1976-85. The summary annual costs for the United States are presented in Table 2-10. As shown in the table, the fuel savings more than offset the costs of the inspection and maintenance program, and in fact, result in an overall net benefit, even after considering all TCP costs.

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 Table 2-9.  
 Fixed and Operating Cost of a Two-Lane Inspection Station  
 In 1975 Dollars)

Cost Category	Public		Private Idle
	Loaded	Idle	
<b>Capital Costs</b>			
Equipment			
- Instrumentation	11,870	\$11,870	\$11,870
- Automated system	14,850	14,850	0
- Dynamometer	6,400	0	0
Installation costs	5,000	3,000	6,000
Site costs	14,000-140,000	14,000-140,000	0
Construction costs	35,000	35,000	0
Administration and Miscellaneous Contingencies	3,000 4,500-10,800	3,000 4,090-7,000	3,000 1,040
<b>Total Capital Costs</b>	<b>\$94,620-226,920</b>	<b>\$85,810-214,720</b>	<b>21,910</b>
<b>Annual Costs:</b>			
Annual Capital Costs			
Operating Costs	\$17,064-30,974	\$15,630-28,907	\$6,077
- Salaries	64,000	64,000	64,000
- Supplies	2,940	2,940	2,940
- Administrative Support and Overhead	33,060	33,060	33,060
<b>Total Annual Costs</b>	<b>\$117,064-130,974</b>	<b>\$115,630-128,907</b>	<b>\$106,077</b>

Administrative and miscellaneous costs are assumed to be \$3,000 per station for the first year.

Unforeseen contingency costs are calculated as 5 percent of the total cost for equipment, installation, land, construction, and administration.

14,000 Square feet at \$1.00 to \$10.00 per square foot.

2,500 Square feet at \$14.00 per square foot. For private stations it is assumed that present facilities will be adequate to house the small amount of equipment needed for inspection.

Assuming an economic life of 40 years for land and 10 years for other capital costs at 10 percent annual interest and with zero scrap value. The administrative and miscellaneous costs which are incurred for the first year only are assumed to be non-depreciable.

One supervisor at \$16,000 and 5 inspectors at \$9,600 each per year.

Table 2-10.  
**Aggregate Cost (Edit) of Inspection and Maintenance Programs, 1976-85**  
(In Millions of 1975 Dollars)

Year	Operating Maintenance (O/M) Costs							
	Capital Investment (1)	Annualized Capital Costs (2)	Station O/M Costs (3)	Owners' Maintenance Cost (4)	Fuel Savings (5)	Net O/M (6)	Annual Costs (7)	Cumulative (8)
1976	141.9	18.4	104.4	186.0	385.9	(95.5)	(77.1)	(77.1)
1977	3.4	18.8	103.8	190.8	395.7	(101.1)	(82.3)	(159.4)
1978	3.3	19.2	106.4	195.5	405.5	(103.6)	(84.4)	(243.8)
1979	3.7	19.7	109.1	200.3	415.5	(106.1)	(86.4)	(330.2)
1980	3.8	20.2	111.9	205.2	425.6	(108.5)	(88.3)	(418.5)
1981	2.6	20.6	114.0	209.6	434.7	(111.1)	(90.5)	(509.0)
1982	3.2	21.0	116.4	214.2	444.0	(113.4)	(92.4)	(601.4)
1983	3.0	21.4	118.6	218.7	453.3	(116.0)	(94.6)	(696.0)
1984	3.4	21.8	121.1	223.4	462.9	(118.4)	(96.6)	(792.6)
1985	3.0	22.2	123.4	228.1	472.5	(121.0)	(98.8)	(891.4)
<b>Totals</b>	<b>171.3</b>	<b>203.3</b>	<b>1,129.1</b>	<b>2,071.8</b>	<b>4,295.6</b>	<b>(1,094.7)</b>	<b>(891.4)</b>	<b>-\$5</b>

#### RETROFIT PROGRAMS

Vacuum Spark Advance Disconnect (VSAD). VSAD retrofits are mainly applicable to pre-1968 vehicles as shown in Table 2-

8. It is assumed that the installation cost of a VSAD retrofit would be approximately \$20.00 per vehicle, and it is estimated that the annual maintenance cost would be approximately \$5.00 per vehicle. VSAD retrofits are expected to increase fuel use from 0 to 2 percent, which translates to a maximum annual fuel penalty of \$11.25 per vehicle, assuming a fuel consumption rate of 750 gallons at \$0.75 per gallon.

Air Bleed. The 11 AQCR's that will be implemented in air-bleed retrofit programs are listed in Table 2-8. Air bleed devices are primarily applicable to pre-1968 vehicles although some areas, such as Baltimore and Boston, extend the applicability to 1971 model year vehicles. The installation cost of an air bleed retrofit is assumed to be \$40 per vehicle for simple air bleed devices and \$55 per vehicle for air bleed devices with exhaust gas recirculation (EGR). It is further assumed that the life of the devices is 5 years, necessitating replacement of the equipment after that period at the same cost. However, air bleed devices are expected to increase the fuel economy by approximately 4 percent. This fuel economy benefit translates to \$22.50 per

year per vehicle. Therefore, the net benefit over the 5 year life of the units would be \$72.00 per vehicle with a simple air bleed device and \$57.50 per vehicle with an air bleed/EGR device.

Summary Costs of Retrofits. The summary aggregate costs of the retrofit programs for 1976 through 1985 are presented in Table 2-11.

Table 2-11.  
 Summary Costs of Retrofit Programs, 1976-85  
 (In Millions of 1975 Dollars)

\$t	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Retrofit Program	34.5	27.0	13.9	10.2	7.8	6.6	6.3	6.3	6.3	6.3
VSAD	34.5	61.4	75.4	85.6	93.4	100.0	106.3	112.6	118.9	125.2
Cumulative	--	69.2	(46.4)	(33.4)	(23.5)	(16.1)	12.1	(8.1)	(7.1)	(6.5)
Air Bleed		69.2	22.8	(10.6)	(34.1)	(50.2)	(38.1)	(46.2)	(53.3)	(59.8)
Cumulative		34.5	96.2	(23.2)	(15.7)	(9.5)	18.4	(1.8)	(0.8)	(0.2)
Totals	34.5	130.7	98.2	75.0	59.3	49.8	68.2	66.4	65.6	65.4
Cumulative										

Only California AQCR's will implement VSAD in 1976.

Numbers in parentheses indicate negative value, i.e., economies gained by implementation of these retrofits.\$s

## SCSERVICE STATION VAPOR CONTROLS\$R

The recent controversy about the Stage II Vapor Control Systems (simple displacement and blower-assist) creates uncertainty as to the type of system which will be implemented. The installation cost of blower-assist system is significantly higher than the simple displacement system. Using the simple displacement method, costs per station may run between \$2,000 (for a new station) and \$5,000 (for existing stations) for the required equipment labor. Blower-assist equipment costs anywhere from one and a half to two times as much. For a 75,000 gallon per month service station, the University of California, San Diego, estimates the investment costs at \$6,727 and \$14,681 for simple displacement and blower-assist systems, respectively.

In estimating the investment and operating cost of service station vapor control systems, it is assumed that for Stage II controls, one-third of the systems implemented will be simple displacement and two-thirds will be blower-assist. Based on EPA's most recent data, the investment and operating costs of the systems are assumed to be as follows:

Investment	Blower- Assist	Simple Displacement
Service station component (Stage II)	\$12,000	\$8,000
Support facilities component (Stage I)	1,300	1,300
Total per station	\$13,300	\$9,300
Operating costs per station per year	\$ 556	\$ 556

For Stage I systems, a fuel savings benefit of \$594 would result, assuming 90 percent efficiency in recovering 880 gallons per station at \$0-75 per gallon. For State II, the fuel savings benefit would be \$495 for simple displacement systems, assuming 75 percent recovery, and \$627 for blower-assist systems, assuming 95 percent recovery. Table 2-12 presents the summary costs of service station vapor controls for the 10 year period.

Table 2-12.  
Aggregate Costs of Service Station Vapor Control Programs, 1976-85

Year	Fixed	Operating	Total	Cumulative
1977	\$46.4	\$(14.2)	\$32.2	32.2
1978	46.4	(14.2)	32.2	64.4
1979	46.4	(14.2)	32.2	96.6
1980	46.4	(14.2)	32.2	128.8
1981	46.4	(14.2)	32.2	161.0
1982	46.4	(14.2)	32.2	193.2
1983	46.4	(14.2)	32.2	225.4
1984	46.4	(14.2)	32.2	257.6
1985	46.4	(14.2)	32.2	289.8

## SUMMARY COSTS

Table 2-13 shows the summary costs associated with measures that will reduce emissions per vehicle mile. Table 2-14 shows the breakdown between capital costs and operating and maintenance costs for each control program for the period from 1976 to 1985.

Approximately 90 percent of the total cost for reducing emissions per vehicle mile is attributable to the inspection and maintenance programs. Several factors account for the large costs of inspection and maintenance relative to retrofit and service station vapor controls. Perhaps the most significant is the annual operating cost, which is estimated to be \$100,000 per station. Furthermore, because of the random vehicle arrivals for inspection, it is assumed that the stations will be idle 40 percent of the time and therefore they will not operate at optimum capacity. This idle factor obviously offers some potential for economy and reduction of overall costs; however, the amount of idle time that could be utilized is indeterminable at this time.

A second factor that contributes to the large cost of inspection and maintenance programs is that essentially every vehicle in the control area must submit to the inspection, and those that fail will require maintenance and

reinspection, whereas retrofit systems usually apply only to a small portion of the total number of vehicles. Finally, retrofit and service station vapor control cost estimates include some partially compensatory economies, whereas to fuel economies are considered for inspection and maintenance programs.

\$d  
**Table 2-13.**  
**Summary of Costs for Measures that Reduce Emissions Per Vehicle Mile**  
**Annual Costs (in Millions of 1975 Dollars)**

\$t Measure	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Inspection/ Maintenance (I/M)	309	313	321	329	337	344	352	359	366	374
I/M Fuel Savings	(386)	(396)	(406)	(416)	(427)	(435)	(444)	(453)	(463)	(473)
Net I/M Costs	(77)	(83)	(85)	(87)	(90)	(91)	(92)	(95)	(97)	(99)
Retrofit	35	96	(33)	(23)	(16)	(10)	18	(2)	(1)	0
Service Station Vapor Control	--	32	32	32	32	32	32	32	32	32
Net TCP Costs	(42)	45	(86)	(78)	(74)	(69)	(42)	(65)	(66)	(67)
Cumulative	(42)	3	(83)	(161)	(235)	(304)	(346)	(411)	(477)	(544)

Note: Totals in this table differ somewhat from totals in other tables because of rounding.

Source: Tables 2-10, 2-11, and 2-12.\$sR

Table 2-14.  
Investment and Operating Maintenance Costs for Measures  
Which Reduce Emissions Per Vehicle Mile Travelled 1976-85  
(In Millions of 1975 Dollars)

	Total Program Costs	Investment Costs	Operating and Maintenance Costs	Fuel Savings
Retrofit				
VSAD	\$125.2	\$ 22.1	\$103.1	
Air bleed	(59.8)	153.4	(213.2)	
Subtotal	\$ 65.4	\$175.5	\$ (110.1)	
Inspection/ Maintenance	(\$891.4)	\$203.3	\$3,200.9	(\$4,295.6)
Service Station Vapor Controls	289.8	285.1	4.7	
Totals	(\$536.2)	\$663.9	\$3,095.5	(\$4,295.6)

Because the fuel savings associated with the inspection and maintenance measure have such a sizeable impact on overall TCP costs, they are broken out separately.

**\$COST OF IMPLEMENTING MEASURES TO REDUCE VMT\$R**

The implementation of measures to reduce automobile emissions by reducing VMT will affect many aspects of urban activity other than air quality. Some non-air quality aspects are:

- Energy consumption. Transit systems are considerably more energy efficient than the automobile. Bus transit uses approximately 3,600 Btu's per passenger mile compared to 8,000 Btu's in work trips by automobile. Therefore, reduction in automobile use achieved by diverting automobile travellers to transit buses will reduce energy consumption. Reductions in automobile use achieved through carpooling will also result in energy savings that are approximately proportional to VMT reductions.
- Transportation noise. The diversion of automobile travellers to public transit appears to be capable of reducing exposure to highway-generated noise. A study of the I-66 corridor indicates that the transit option decreases exposure to elevated noise levels by 10 to 20 percent, depending on the noise level, whereas the highway option increases exposure to noise by as much as 47 percent.

- Traffic safety. Transit buses have roughly one fatality per 100 million passenger miles compared to about 1.6 fatalities per 100 million passenger miles for automobiles in urban areas. Bus accident costs per passenger mile are roughly two-thirds that of automobiles.

- Traffic congestion and highway construction. Buses require roadway space of less than 2 automobiles, but carry up to 50 times as many passengers per vehicle as automobiles. Thus, the diversion of automobile drivers to public transit as well as to carpools will reduce traffic volumes and congestion. Furthermore, reduced congestion will result in reduced need for further highway construction.

- Travel times. Transit buses require more time than the automobile for access, collection, and distribution. These transit time disadvantages can be offset by the use of express bus routes and priority treatment for transit vehicles. Carpools have also a time disadvantage relative to the single-occupant automobile. This disadvantage is incurred during collection and distribution and, as in the case of bus transit, it can be offset to some extent by the provision of priority treatment.

Many of the non-air quality effects listed above are beneficial and would make the implementation of the control measures desirable even if air quality were not a problem. Indeed, the transportation measures that have been proposed to improve air quality have also been proposed to alleviate non-air quality related urban transportation problems.

There has been little direct experience with many transportation control measures or with changes in transportation system attributes of the magnitude contemplated in some TCR's. Certain types of costs, i.e., those associated with the changes in urban land use due to transportation control measures are in this category, are particularly difficult to estimate. Another source of difficulty stems from the joint benefits derived from transportation control measures. Although costs for a transit improvement program could be estimated with reasonable accuracy, it would be inappropriate to assign the full cost to the cause of achieving air quality. Other non-air quality benefits should share an appropriate portion of the total cost. Another source of difficulty of estimating costs of transportation control measures is that these costs are highly dependent on the specific control measures implemented and the manner and area in which they are implemented. Finally, AQCR's have not yet specified the specific VMT measures they will adopt. For these reasons,

the costs of transportation control measures related to  
reductions in VMT are not estimated in this report.

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