EPA-650/2-75-057-f

September 1975

Environmental Protection Technology Series

SURVEY OF FLUE GAS DESULFURIZATION SYSTEMS

EDDYSTONE STATION, PHILADELPHIA ELECTRIC CO.

U.S. Environmental Protection Agency
Office of Research and Development
Washington, D.C. 20460

EPA-650/2-75-057-f

SURVEY OF FLUE GAS DESULFURIZATION SYSTEMS

EDDYSTONE STATION, PHILADELPHIA ELECTRIC CO.

by

Gerald A. Isaacs

PEDCo-Environmental Specialists, Inc.
Suite 13
Atkinson Square
Cincinnati, Ohio 45246

Contract No 68-02-1321, Task 6f
ROAP No. 21ACX-130
Program Element No. 1AB013

EPA Project Officer: Norman Kaplan

Industrial Environmental Research Laboratory
Office of Energy, Minerals, and Industry
Research Triangle Park, North Carolina 27711

Prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Development
Washington, D. C. 20460

September 1975

EPA REVIEW NOTICE

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, U.S. Environmental Protection Agency, have been grouped into series. These broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and maximum interface in related fields. These series are:

1. ENVIRONMENTAL HEALTH EFFECTS RESEARCH
2. ENVIRONMENTAL PROTECTION TECHNOLOGY
3. ECOLOGICAL RESEARCH
4. ENVIRONMENTAL MONITORING
5. SOCIOECONOMIC ENVIRONMENTAL STUDIES
6. SCIENTIFIC AND TECHNICAL ASSESSMENT REPORTS
9. MISCELLANEOUS

This report has been assigned to the ENVIRONMENTAL PROTECTION TECHNOLOGY series. This series describes research performed to develop and demonstrate instrumentation, equipment and methodology to repair or prevent environmental degradation from point and non-point sources of pollution. This work provides the new or improved technology required for the control and treatment of pollution sources to meet environmental quality standards.

This document is available to the public for sale through the National Technical Information Service, Springfield, Virginia 22161.

Publication No. EPA-650/2-75-057-f

ACKNOWLEDGMENT

This report was prepared under the direction of Mr. Timothy W. Devitt. The principal author was Dr. Gerald A. Isaacs. Mr. Charles D. Fleming was responsible for editorial review and preparation of graphic materials.

Mr. Wade H. Ponder, former EPA Project Officer, had primary responsibility within EPA for this project report. Information and data on the plant operation were supplied by Mr. George Kotnick, Philadelphia Electric Company, and by Dr. J. T. Pinkston, United Engineers and Constructors, Inc., during and subsequent to the plant survey visit.

The author appreciates the efforts and cooperation of everyone who participated in the preparation of this report.

TABLE OF CONTENTS

	Page
ACKNOWLEDGMENT	iii
LIST OF FIGURES	vi
LIST OF TABLES	vi
SUMMARY	vii
1.0 INTRODUCTION	1-1
2.0 FACILITY DESCRIPTION	2-1
2.1 Plant Location	2-1
2.2 Boiler Data	2-1
2.3 Pollution Controls	2-1
3.0 FLUE GAS DESULFURIZATION SYSTEM	3-1
3.1 Process Description	3-1
3.2 Design Parameters	3-3
3.3 Installation Schedule	3-5
3.4 Cost Data	3-5
APPENDIX A PLANT SURVEY FORM	A-1
APPENDIX B PLANT PHOTOGRAPHS	B-1

LIST OF FIGURES

Figure		Page
3.1	General Flow Diagram of the FGD System on Eddystone No. 1 - PECO	3-2

LIST OF TABLES

Tables		Page
2.1	Pertinent Data on Plant Design, Operation and Atmospheric Emissions	2-3

SUMMARY

The magnesium oxide based flue gas desulfurization (FGD) system on Boiler No. 1 at the Eddystone Station of Philadelphia Electric Company (PECO) was designed and installed by United Engineers and Constructors, Inc. The system consists of three first-stage scrubber modules in parallel for particulate control (two are Environeering Ventri-Rod Units; one is a Peabody-Lurgi Venturi Unit) and a second-stage Environeering absorber module with two ventri-rod beds for SO_2 removal.

The three first-stage scrubbers together are sized to handle all the exhaust gas from Unit 1 which has a net electric generating capacity of 316 MW. The second-stage absorber is sized to handle one-third of the gas flow, equivalent to about 105 MW (net). The system is designed to remove 90 percent of the SO_2 from boiler stack gas.

As of April 1, 1975 the second-stage module had not yet been operated. This report therefore necessarily emphasizes design parameters rather than operating parameters and experience.

Pertinent data on the facility and the FGD system are presented in the following table.

SUMMARY OF FGD DATA, GENERATING UNIT NO. 1

EDDYSTONE STATION

Generator rating, MW (net)	308[a]
Fuel:	Coal
Gross heating value, BTU/lb	12,100
Ash, percent	12
Sulfur, percent	2.3
FGD vendor:	United Engineers
Process:	Magnesium oxide scrubbing
New or retrofit:	Retrofit
Start-up date:	1975
FGD modules:	1 (105 MW)
Efficiency, percent overall:	
Particulates	99.9
SO_2	90
Make-up water, gpm/MW	1.1
Unit cost: $/KW (net)	193[b]

[a] 316 MW net rating minus 8 MW auxiliary power for this FGD System.

[b] This cost is not representative since it includes the installed cost of three first-stage particulate scrubbers to handle the exhaust gases from the complete 308 MW unit. The FGD module size of 105 MW is the basis for this calculation.

1.0 INTRODUCTION

The Industrial Environmental Research Laboratory (formerly Control Systems Laboratory) of the U.S. Environmental Protection Agency (EPA) has initiated a study to evaluate the performance characteristics and degree of reliability of flue gas desulfurization (FGD) systems on coal-fired utility boilers in the United States. This report on the Eddystone Station of Philadelphia Electric Company (PECO) is one of a series of reports on such systems. It presents values of key process design and operating parameters and describes the major system problems encountered at the facility. The report also discusses the measures taken to alleviate such problems and identifies available capital and operating costs.

This report is based upon information obtained during a plant inspection on February 11, 1975, and on subsequent data provided by PECO and United Engineers and Constructors, Inc. (UE) personnel.

Section 2.0 presents pertinent data on facility design and operation, including actual and allowable particulate and SO_2 emission rates. Section 3.0 describes the flue gas desulfurization system. Appendices present details of plant and system operation and photos of the installation.

2.0 FACILITY DESCRIPTION

2.1 PLANT LOCATION

The Eddystone Station of PECO is located on the Delaware River in Eddystone, Pennsylvania, about 11 miles southwest of the center of Philadelphia. The plant is about five miles west of one of the main runways of Philadelphia International Airport.

2.2 BOILER DATA

The station has four generators with a total net capacity of 1370 MW. Units 1 and 2 burn coal with an average gross heating value of 12,100 BTU/lb and ash and sulfur contents of 12 percent and 2.3 percent, respectively. Steam conditions are 5000 psi and 1150°F. These are the highest utility plant operating pressure and temperature conditions in the United States. Units 1 and 2, base-load units, operated at 68 percent capacity in 1974. Units 3 and 4, peak-load generators, burn No. 6 oil.

2.3 POLLUTION CONTROLS

At the present time an FGD system has been installed to handle about one-third of the exhaust gas from Unit 1. The unit will have an estimated net generating capacity of about 308 MW with the three particulate scrubbers and the SO_2 absorber operating.

There are two furnaces on the Unit 1 boiler. Each furnace was installed with particulate controls consisting of mechanical collectors and an electrostatic precipitator.

The wet particulate and SO_2 system, designed and installed by UE, consists of three, first-stage water scrubbers for particulate control and a single, 105 MW second-stage magnesium oxide absorber for SO_2 removal. The particulate scrubber system was started up for initial shakedown purposes in February 1975. Table 2.1 gives pertinent data on plant design parameters.

Table 2.1 PERTINENT DATA ON PLANT DESIGN, OPERATION AND ATMOSPHERIC EMISSIONS

Boiler data - Eddystone No. 1 - PECO	
Maximum generating capacity, MW (net)	308[a]
Average capacity factor (1974), %	68
Boiler manufacturer	C-E Sulzer
Year placed in service	1959
Unit heat rate, BTU/KWH	9455
Maximum coal consumption, ton/hr	120
Maximum heat input, MM BTU/hr	2912
Stack height above grade, ft	249
Flue gas rate - maximum, acfm	927,000
Flue gas temperature, °F	294
Emission controls:	
Particulate	Mechanical and ESP and ventri-rod scrubber
SO_2	Ventri-rod magnesium oxide absorber on one-third of the gas flow
Particulate emission rates:	
Allowable, lb/MM BTU	0.1
Design, lb/MM BTU	0.04
SO_2 emission rates:	
Allowable, lb/MM BTU	0.6
Design, lb/MM BTU	0.3

[a] Existing particulate scrubbers and FGD absorber in operation.

3.0 FLUE GAS DESULFURIZATION SYSTEM

3.1 PROCESS DESCRIPTION[a]

Figure 3.1 is a schematic flow diagram for this magnesium oxide scrubbing system installed to handle approximately one-third (309,000 acfm at 294°F) of the exhaust gas from Unit 1. The maximum continuous net generating capacity for the unit was 316 MW before the scrubbing system was installed. The particulate scrubbers and the SO_2 absorber consume about 8 MW to derate the unit to about 308 MW. If additional second-stage SO_2 absorber capacity is installed on the rest of the unit it will derate the unit by an additional 2 MW.

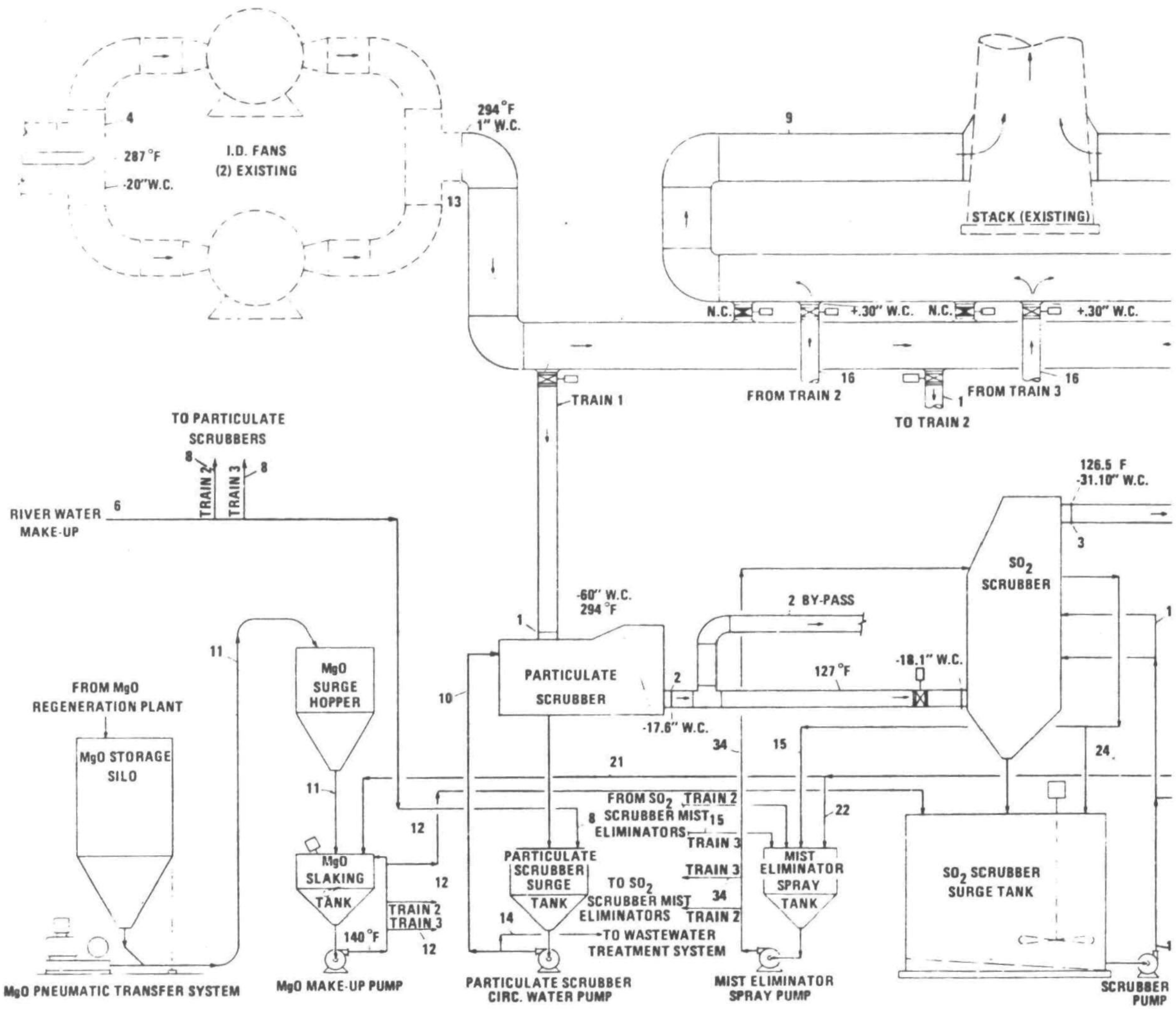
Two of the three first-stage particulate scrubbers were manufactured by Environeering, Inc., and are ventri-rod units. The third unit is a Peabody-Lurgi venturi scrubber.

A portion of the particulate scrubber liquid circulating stream is diverted to on-site ash ponds. Make-up water from the river is pumped into the surge tanks for the three particulate scrubbers at the rate of 351 gpm (total).

Exhaust gas is drawn from the two boiler furnaces by four induced-draft fans. It then passes through the particulate

---

[a] Adapted from "Design and Installation of a Prototype Magnesia Scrubbing Installation", B. M. Anz et al, United Engineers and Constructors Inc., May 15, 1973, and supplemented with data from field visit.

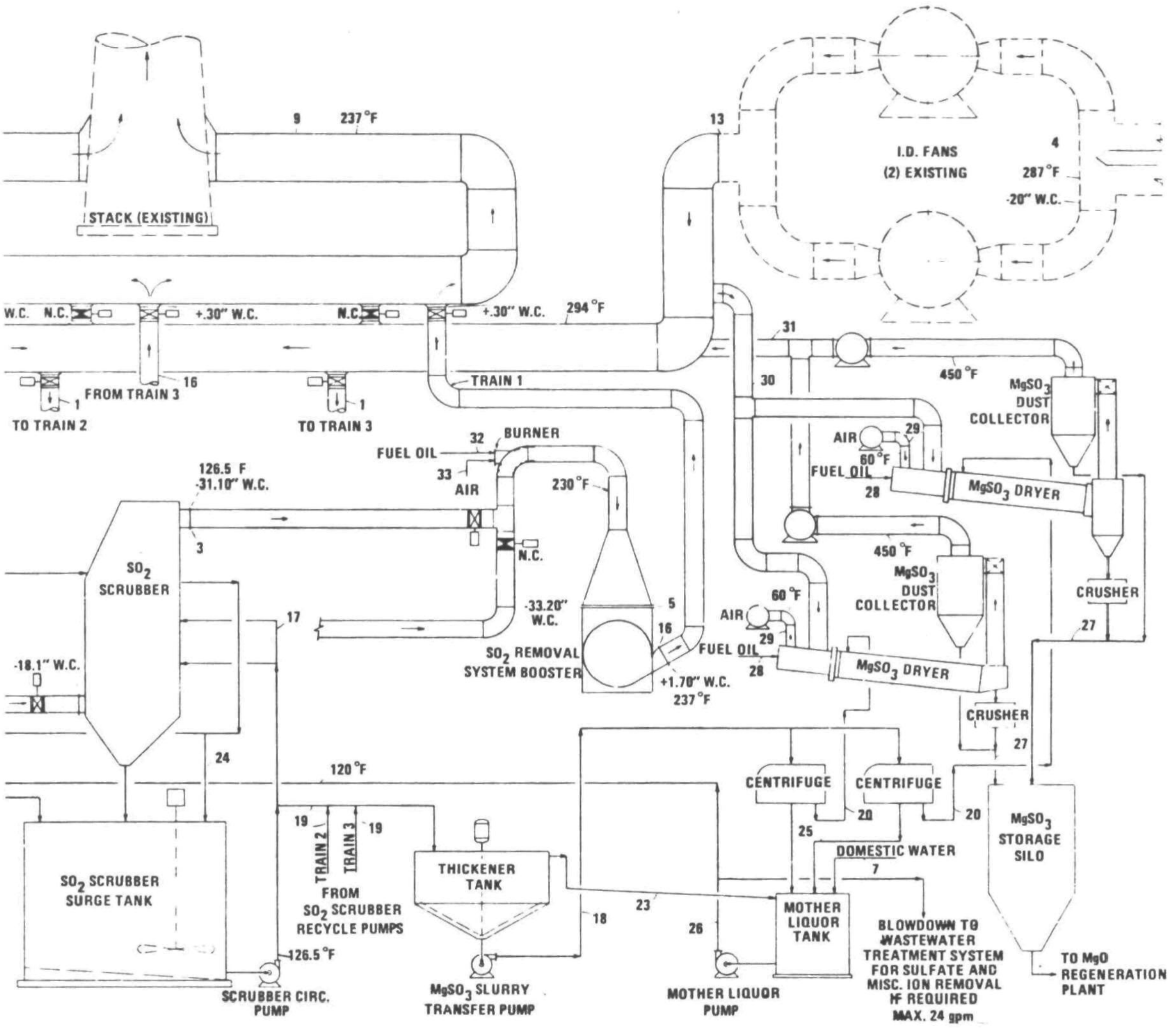


STREAM NO.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DRY GAS	lb/min.	15,560	15,560	15,560	23,119	16,162				24,243							
H_2O VAPOR	lb/min.	947	1,657	1,620	1,255	1,658				2,481							
SO_2	lb/min.	55.3	55.3	5.5	83	5.5				8.25							
H_2O LIQUID	lb/min.						2,922	186	974		10,811		252		264	3,476	
ASH	lb/min.	3.33	0.67	0.67	5	0.67				1	109				2.66		
MgO	lb/min.											93.9	31 3				
$MgSO_3$	lb/min.												6*			72.2*	
$MgSO_3$-$6H_2O$	lb/min.															131.2	
AIR	lb/min.																
FUEL OIL	lb/min.																
$MgSO_4$	lb/min.												40*			613*	
$Mg(HSO_3)_2$*	lb/min.												3.8*			47.4*	
	lb/min.																
	lb/min.																
TOTAL	lb/min.	16,565.6	17,273	17,186	24,462	17,826	2,922	186	974	26,733	10,920	93.9	372.1		266.67	4,339.8	
gpm OR acfm		309,000	268,000	276,000	475,000	339,000	351	22.3	117	468,000	1,300		35.8		32	445	
SPECIFIC GRAVITY OR MOLECULAR WEIGHT		29.4	28.7	28.7	29.4	28.7	1.0	1.0	1.0	28.7	1.01		1.25		1.01	1.17	
DESIGN FLOW (3%S or 355MW)		321,000	280,000	287,000	492,000	351,000				487,000		122	46.5				
MAX. FLOW acfm		345,000	301,000	311,000	535,000	380,000				530,000	1,600			512,000			351,000

*DISSOLVED SOLIDS.

BASIS: AVERAGE CONDITION OF 2.3% S COAL.

Figure 3.1. General flow diagram of the FGD system on Eddystone No. 1 - PECO.



17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
													1,105	1,505			
												2.7	59	388		7.85	
													4	4			
100,800	1,156	1,486	25	845	3,749	3,302	1,897	553	4,594								4,726
2,140*	25*	32*	0.54*	17.5*	77.5*	71*	39.5*	12*	95*	122							98*
11,200	195.3	165.1	247.6				71.8										[illegible]
												206				503	
											14.85				29.0		
18,300*	210*	270*	4.55*	147*	653*	600*	335*	100*	800*	4.55							830.5*
1,400*	16*	21*	0.35*	11.4*	50.6*	47*	25.9*	7.6*	62*								64.3*
133,340	1,902.3	1,974.1	278	1,021	4,530	4,020	2,369.2	672.6	5,551	126.55	14.85	208.7	1,168	1,897	29.0	610.85	5,350
13,384	179	197		106	469	415	243	70	575		1.96	2,730	21,500	47,000	3.82	8,000	600
1.20	1.28	1.20		1.16	1.16	1.16	1.17	1.16	1.16		0.91	29	29.5	26.6	0.91	29	1.17
	232	256	256	138	612	540		90	750		2.55	3,550	28,000	61,000			

Figure 3.1 (continued). General flow diagram of the FGD system on Eddystone No. 1 - PECO.

scrubber and through the SO_2 absorber. From there it is reheated and drawn through a booster fan before it is discharged through the stack. Dampers in the system permit gas to bypass the SO_2 absorber or any of the particulate scrubbers.

The second-stage SO_2 absorber was designed by Enviro-neering, Inc. The ventri-rod unit contains two absorber sections in series, each consisting of an adjustable set of cylindrical rods that are sprayed underneath with magnesium sulfite slurry. A louvered, continuous-waterwash demister is installed at the scrubber exit. Slurry flows through the unit and into an agitated absorber surge tank. Slurry make-up is also added to this tank from an MgO slaking tank. The slurry is recirculated to the scrubber from the surge tank. A portion of the recirculating slurry is bled from the scrubber circulation pump discharge to the thickener. Thickener underflow is pumped to a centrifuge. Solid $MgSO_3$ from the centrifuge is then dried in a direct-fired, cocurrent rotary dryer.

Thickener tank overflow and mother liquor from the centrifuge flow into a mother liquor tank. The liquid is then pumped back to the MgO slaking tank and a mist eliminator spray tank. A portion of the liquid stream can be bled into the wastewater treatment system, so that the possible buildup of iron or other impurities can be purged. Make-up water is added to the first stage demister system from the mother liquor tank.

3.2 DESIGN PARAMETERS

Each of the three particulate scrubbers is designed to cool 309,000 acfm of exhaust gas from 294°F to 127°F and to remove about 150 pounds of ash per hour from the exhaust gas stream. The design water recirculation rate through each particulate scrubber is 1300 gpm. The liquid-to-gas ratio (L/G) through each scrubber is therefore calculated to be about 5.4 gallons of water per 1000 actual cubic feet of air at 127°F. Approximately 32 gpm are bled from the recirculation pump discharge to the wastewater treatment system. The particulate scrubber recirculation stream carries about one percent solids by weight. River water make-up to each scrubber, about 117 gallons per minute, is supplied to the scrubber surge tank.

The SO_2 absorber is designed to receive 268,000 acfm of essentially particulate-free exhaust gas at 127°F. Design pressure drop through the absorber is 12 inches of H_2O. Evaporative heat transfer through the scrubber is negligible. Slurry is circulated from the SO_2 scrubber surge tank at 13,400 gpm. L/G is 50 gallons per 1000 actual cubic feet of gas at 127°F for this stage. The design SO_2 removal efficiency for the absorber is 90 percent. It is reported that magnesium sulfite is precipitated in the absorber surge tank per the following equations:

$$Mg(HSO_3)_2 + Mg(OH)_2 + 10\ H_2O \longrightarrow 2\ MgSO_3 \cdot 6H_2O$$

$$Mg(HSO_3)_2 + Mg(OH)_2 + 4\ H_2O \longrightarrow 2\ MgSO_3 \cdot 3H_2O$$

Slurry pH is controlled at 6 by regulating the rate of addition of slaked $Mg(OH)_2$ slurry. The scrubber surge tank with a capacity of 60,000 gallons, provides a slurry residence time of about four minutes in order to minimize plugging problems in the recirculating pipes and scrubber.

The thickener receives 197 gpm of slurry recirculation bleed. With an approximate capacity of 120,000 gallons, residence time is close to ten hours. Underflow from the thickener contains about 25 percent solids ($MgSO_3 \cdot 6\ H_2O$ and $MgSO_3 \cdot 3\ H_2O$).

Wet solids from the stainless steel, solid bowl centrifuge are conveyed directly into a rotary-kiln, oil-fired, direct-heat, concurrent-flow dryer. $MgSO_3$ crystals are conveyed from the dryer to storage silos.

The $MgSO_3$ will be trucked to a sulfuric acid plant about twenty miles away. There it will be decomposed in an oil-fired, fluidized-bed reactor to form MgO and SO_2. The SO_2 will be converted to sulfuric acid, and the regenerated MgO will be trucked back to the Eddystone Station.

3.3 INSTALLATION SCHEDULE

On-site construction for this plant began in April 1972. Construction was essentially completed in late 1974, and the particulate scrubber was started up in December of that year. As of June 1, 1975 the SO_2 absorber had not been put on line, mainly because of corrosion problems encountered in the particulate system. These problems are now being ameliorated by neutralization, increased blowdown of scrubber fluid and start-up procedure revisions. Defective polyurethane-coated tanks will be repaired before operation of the SO_2 system will be attempted.

3.4 COST DATA

The particulate and FGD system, consisting of three first-stage particulate scrubbers and one second-stage SO_2 absorber, was installed at a total cost of $20,273,000 or $193/KW (net). About two-thirds of this amount is for the particulate scrubbers and the SO_2 absorption and recovery equipment with the remaining one-third for site improvements, land, access roads, engineering and contractor's fees and interest on capital during construction. The figure does not include magnesium oxide regenerating facilities. A considerably lower figure would be realized if the costs for two-thirds of the 308 MW particulate scrubbing system were separated out. Since the FGD system has not yet been operated, actual operating costs cannot be reported at the present time.

APPENDIX A

PLANT SURVEY FORM

PLANT SURVEY FORM[a]

REGENERABLE FGD PROCESSES

A. COMPANY AND PLANT INFORMATION

1. COMPANY NAME Philadelphia Electric Company
2. MAIN OFFICE 2301 Market Street, Phila., Pa. 19101
3. PLANT SUPERINTENDENT Henry J. Wylie, Jr.
4. PLANT NAME Eddystone Station
5. PLANT LOCATION #1 Industrial Highway, Chester, Pa. 19013
6. PERSON TO CONTACT FOR FURTHER INFORMATION George Kotnick
7. POSITION Supervising Engineer
8. TELEPHONE NUMBER 215/841-4540
9. DATE INFORMATION GATHERED February 11, 1975
   Supplemented - February 28, 1975, March 18, 1975
10. PARTICIPANTS IN MEETING

PARTICIPANTS IN MEETING	AFFILIATION
Wade H. Ponder	EPA - Research Triangle Park
John Busik	EPA - Washington, D. C.
Gerald A. Isaacs	PEDCo
Larry Yerino	PEDCo
Bertrand M. Anz	United Engineers & Const., Inc.
Henry F. Scheck	Philadelphia Electric Co.
Matthew M. Troyan	Philadelphia Electric Co.
James A. Gille	Philadelphia Electric Co.

[a] These data were obtained on February 11, 1975. Some of the data have been updated in the text of the report.

B. PLANT DATA. (APPLIES TO ALL BOILERS AT THE PLANT).

	BOILER NO.				
	1	2	3	4	
CAPACITY, MW (net)	316	334	360	360	
SERVICE (BASE, PEAK)	base	base	peak	under construction	
FGD SYSTEM USED	MgO	none	none	none	

C. BOILER DATA. COMPLETE SECTIONS (C) THROUGH (R) FOR EACH BOILER HAVING AN FGD SYSTEM.

1. BOILER IDENTIFICATION NO. 1
2. MAXIMUM CONTINUOUS HEAT INPUT 2912 MM BTU/HR
3. MAXIMUM CONTINUOUS GENERATING CAPACITY 316 MW (net)
4. MAXIMUM CONTINUOUS FLUE GAS RATE, 927,000 ACFM @ 294 °F
5. BOILER MANUFACTURER Combustion Engineering-Sulzer
6. YEAR BOILER PLACED IN SERVICE 1959
7. BOILER SERVICE (BASE LOAD, PEAK, ETC.) base load
8. STACK HEIGHT 249 ft.
9. BOILER OPERATION HOURS/YEAR (197) 6549 hours
10. BOILER CAPACITY FACTOR * 67.65%
11. RATIO OF FLY ASH/BOTTOM ASH 80/20

* DEFINED AS: $\frac{\text{KWH GENERATED IN YEAR} \quad 1,872,648 \text{ (net)}}{\text{MAX. CONT. GENERATED CAPACITY IN KW x 8760 HR/YR}}$
316 MW (net)

D. FUEL DATA

1. COAL ANALYSIS (as received)

	MAX.	MIN.	AVG.
GHV (BTU/LB.)	12,490	11,444	12,131
S %	3.49	1.14	2.34
ASH %	21.54	7.79	11.83

2. FUEL OIL ANALYSIS (exclude start-up fuel) (not applicable)

GRADE			
S %			
ASH %			

E. ATMOSPHERIC EMISSIONS

1. APPLICABLE EMISSION REGULATIONS

	PARTICULATES	SO_2
a) CURRENT REQUIREMENTS Metro Phila. III 6/8/73 FR	--	--
AQCR PRIORITY CLASSIFICATION	III	III
REGULATION & SECTION NO. Pa.DER	Title 25 Part 1 Chapt. 123.11	Article III Chapt. 123.22B
MAX. ALLOWABLE EMISSIONS LBS/MM BTU	0.1	0.6
b) FUTURE REQUIREMENTS, COMPLIANCE DATE		
REGULATION & SECTION NO.		
MAXIMUM ALLOWABLE EMISSIONS LBS/MM BTU		

2. PLANT PROGRAM FOR PARTICULATES COMPLIANCE

Program is presented in consent orders signed with EPA and DER on September 25, 1974.

3. PLANT PROGRAM FOR SO_2 COMPLIANCE

Program is prepared in consent orders signed with EPA and DER on September 25, 1974.

F. PARTICULATE REMOVAL

	MECH.	E.S.P.	FGD
1. TYPE	MECH.	E.S.P.	FGD
MANUFACTURER	American Standard	Western Precipitation	1 - Peabody 1 - Environeering
EFFICIENCY: DESIGN/ACTUAL	72/70	95/92	90/not avail.
MAX. EMISSION RATE* LB/HR	7500	600	60
GR/SCF			
LB/MMBTU			

DESIGN BASIS, SULFUR CONTENT 2.3% by wt.

G. DESULFURIZATION SYSTEM DATA

1. PROCESS NAME Magnesium Base Wet Scrubbing
2. LICENSOR/DESIGNER NAME: United Engineers & Constructors, Inc.
   ADDRESS: 1401 Arch Street
   PERSON TO CONTACT: J. T. Pinkston
   TELEPHONE NO.: 215/422-4812
3. ARCHITECTURAL/ENGINEERS, NAME: United Engineers & Constructors, Inc.
   ADDRESS: 1401 Arch Street, Phila. 19105
   PERSON TO CONTACT: J. T. Pinkston
   TELEPHONE NO.: 215/422-4812
4. PROJECT CONSTRUCTION SCHEDULE: DATE
   a) DATE OF PREPARATION OF BIDS SPECS. Not Applicable
   b) DATE OF REQUEST FOR BIDS Not Applicable
   c) DATE OF CONTRACT AWARD Not Applicable
   d) DATE ON SITE CONSTRUCTION BEGAN 4/72
   e) DATE ON SITE CONSTRUCTION COMPLETED 11/74
   f) DATE OF INITIAL STARTUP 12/74
   g) DATE OF COMPLETION OF SHAKEDOWN Not Available

*At Max. Continuous Capacity

5. LIST MAJOR DELAYS IN CONSTRUCTION SCHEDULE AND CAUSES:

____

____

____

____

____

____

6. NUMBER OF SO_2 SCRUBBER TRAINS USED — Three

7. DESIGN THROUGHPUT PER TRAIN, ACFM @ 127 °F — 300,000

8. DRAWINGS: 1) PROCESS FLOW DIAGRAM AND MATERIAL BALANCE

2) EQUIPMENT LAYOUT

H. SO_2 SCRUBBING AGENT

1. TYPE — Magnesium Oxide

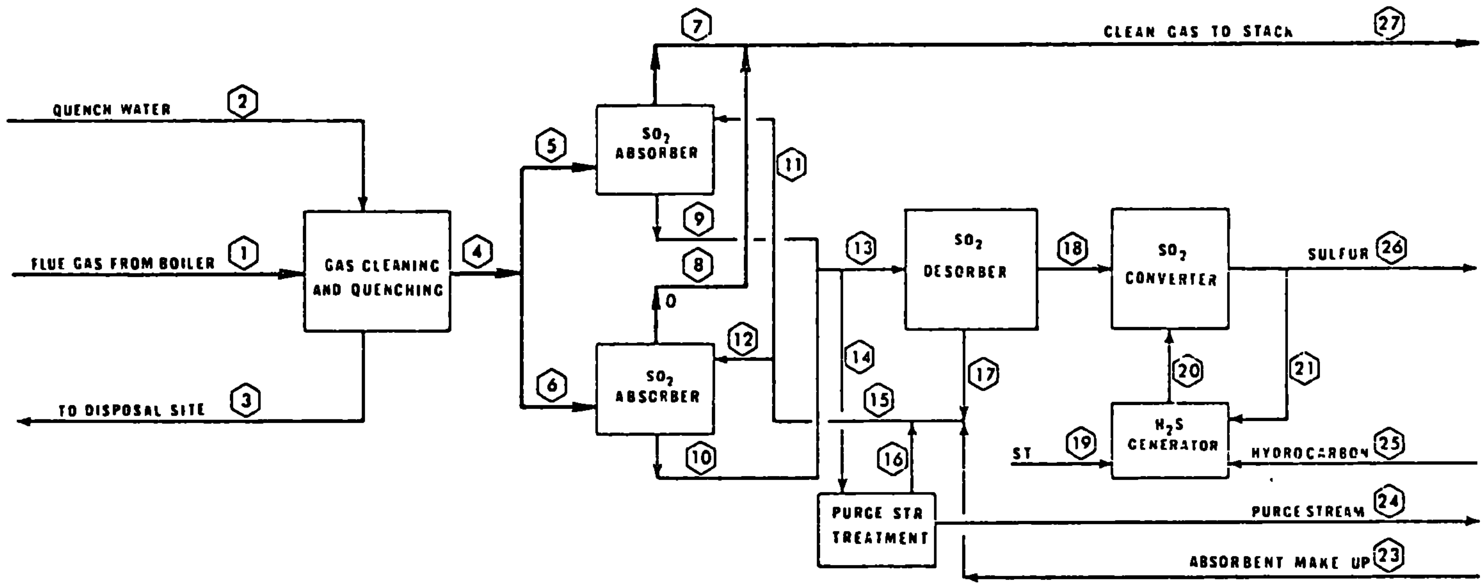
2. SOURCES OF SUPPLY — Basic Chemical, Martin Marietta Chemicals

3. CHEMICAL COMPOSITION (for each source) 97.5% MgO

4. EXCESS SCRUBBING AGENT USED ABOVE STOICHIOMETRIC REQUIREMENTS — None

5. MAKE-UP WATER POINT OF ADDITION — Mother Liquor Tank

6. MAKE-UP ALKALI POINT OF ADDITION — Scrubber Surge Tanks



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
RATE lb/min	16,600	2,922	265						133,890		133,840		131,916	1974
ACFM	309,000			268,000	268,000		276,000							
GPM		351	32						13,384		13,384		13,187	197
PARTICULATES lb/hr														
SO_2. lb/min	165		2.66											
H_2S. lb/hr														
SULFUR lb/min														
SULFATES lb/min									N.A.		N.A.			N.A.
TEMPERATURE °F	294	80	127	127	127		127		127		127			127

	15	16	17	18	19	20	21	22	23	24	25	26	27	28
RATE lb/hr		1788							31.3	85				
SCFM														
GPM		214												
PARTICULATES, lb/hr														
SO_2, lb/hr														
H_2S, lb/hr														
SULFUR, lb/hr														
SULFATES, lb/hr														
TEMPERATURE, °F		127							100	400				

1. Representative flow rates based on operating data at maximum continuous load

J. SCRUBBER TRAIN SPECIFICATIONS

1. SCRUBBER NO. 1 [(a)]

TYPE (TOWER/VENTURI)	Ventri-Rod
LIQUID/GAS RATIO, G/MCF @ °F	4-5
GAS VELOCITY THROUGH SCRUBBER, FT/SEC	Not Applicable
MATERIAL OF CONSTRUCTION	316L S/S
TYPE OF LINING	
INTERNALS:	
TYPE (FLOATING BED, MARBLE BED, ETC.)	Adjustable ventri-rod
NUMBER OF STAGES	One
TYPE AND SIZE OF PACKING MATERIAL	Not Applicable
PACKING THICKNESS PER STAGE [(b)]	
MATERIAL OF CONSTRUCTION, PACKING:	Not Applicable
SUPPORTS:	Not Applicable

2. SCRUBBER NO. 2 [(a)]

TYPE (TOWER/VENTURI)	Ventri-Rod
LIQUID/GAS RATIO, G/MCF @ °F	40-50
GAS VELOCITY THROUGH SCRUBBER, FT/SEC	Not Applicable
MATERIAL OF CONSTRUCTION	Lined Carbon Steel
TYPE OF LINING	Polyurethane
INTERNALS:	
TYPE (FLOATING BED, MARBLE BED, ETC.)	Adjustable Ventri-rod
NUMBER OF STAGES	Two
TYPE AND SIZE OF PACKING MATERIAL	Not Applicable

a) Scrubber No. 1 is the scrubber that the flue gases first enter. Scrubber 2 (if applicable) follows Scrubber No. 1.

b) For floating bed, packing thickness at rest.

PACKING THICKNESS PER STAGE[b] Not Applicable

MATERIAL OF CONSTRUCTION, PACKING: Not Applicable

SUPPORTS: Not Applicable

3. CLEAR WATER TRAY (AT TOP OF SCRUBBER)

TYPE	Not Applicable
L/G RATIO	Not Applicable
SOURCE OF WATER	Not Applicable

4. DEMISTER

TYPE (CHEVRON, ETC.)	Chevron
NUMBER OF PASSES (STAGES)	Two
SPACE BETWEEN VANES	Proprietary Vendor Information
ANGLE OF VANES	Proprietary Vendor Information
TOTAL DEPTH OF DEMISTER	Proprietary Vendor Information
DIAMETER OF DEMISTER	Proprietary Vendor Information
DISTANCE BETWEEN TOP OF PACKING AND BOTTOM OF DEMISTER	Proprietary Vendor Information
POSITION (HORIZONTAL, VERTICAL)	Vertical
MATERIAL OF CONSTRUCTION	FRP
METHOD OF CLEANING	Clean liquor and water sprays
SOURCE OF WATER AND PRESSURE	River, 50 PSIG
FLOW RATE DURING CLEANINGS, GPM	1st stage - 600 GPM Liquor 2nd stage - 400 GPM Water
FREQUENCY AND DURATION OF CLEANING	1st stage - Continuous 2nd stage - As Required

REMARKS ______

5. REHEATER

TYPE (DIRECT, INDIRECT) Direct

b) For floating bed, packing thickness at rest.

DUTY, MMBTU/HR 40 MM BTU/hr. Max.

HEAT TRANSFER SURFACE AREA SQ.FT Not Applicable

TEMPERATURE OF GAS: IN 127°F OUT 230°F Max.

HEATING MEDIUM SOURCE Fuel oil

TEMPERATURE & PRESSURE 200°F & 75 PSIG

FLOW RATE 1800 LB/HR

REHEATER TUBES, TYPE AND MATERIAL OF CONSTRUCTION Not Applicable

REHEATER LOCATION WITH RESPECT TO DEMISTER
75' downstream of SO_2 Scrubber Demister
40' downstream of Particulate Scrubber Demister

METHOD OF CLEANING Not Applicable

FREQUENCY AND DURATION OF CLEANING Not Applicable

FLOW RATE OF CLEANING MEDIUM Not Applicable LB/HR

REMARKS

6. SCRUBBER TRAIN PRESSURE DROP DATA

	INCHES OF WATER
PARTICULATE SCRUBBER	12" - 17" W.C.
SO_2 SCRUBBER	12" W.C.
CLEAR WATER TRAY	Not Applicable
DEMISTER	1" W.C.
REHEATER	None
DUCTWORK	4.2" W.C.
TOTAL FGD SYSTEM	29.2 - 34.2" W.C.

7. FRESH WATER MAKE UP FLOW RATES AND POINTS OF ADDITION

TO: DEMISTER Water added separated from SO_2 System

QUENCH CHAMBER Not Applicable

ALKALI SLURRYING Not Applicable

PUMP SEALS 25 - 30 GPM

OTHER Water input based on liquor inventory control

TOTAL Not Available

FRESH WATER ADDED PER MOLE OF SULFUR REMOVED Not Available

8. BYPASS SYSTEM

CAN FLUE GAS BE BYPASSED AROUND FGD SYSTEMS Yes

GAS LEAKAGE THROUGH BYPASS VALVE, ACFM Essentially Zero

K. TANK DATA

	pH	% Solids	Capacity (gal)	Hold up time
ALKALI SLURRY MAKEUP TANK	10	8-10	12,000	5 Hrs. Phase
PARTICULATE SCRUBBER EFFLUENT HOLD TANK (a)	1-3	1	4,000	2.5 Min.
SO_2 SCRUBBER EFFLUENT HOLD TANK (a)	6-7	8-10	60,000	4 Min.

L. SO_2 RECOVERY

NAME OF PROCESS $MgSO_3$ Roasting

LICENSOR/DESIGNER Copeland Systems, Inc.

SYSTEM'S CAPACITY 3.5 Solids T/HR

RAW MATERIAL REQUIRED Not Applicable

M. DISPOSAL OF CONTAMINANTS

PURGE STREAM, gpm: Not Available

AMOUNT OF CONTAMINANTS IN STREAM: Not Available

DESCRIBE METHOD OF CONCENTRATION AND DISPOSAL OF CONTAMINANTS: Not Available

N. COST DATA

1. TOTAL INSTALLED CAPITAL COST: $20,273,000

2. ANNUALIZED OPERATING COST: Not Available

3. COST BREAKDOWN

COST ELEMENTS	INCLUDED IN ABOVE COST ESTIMATE YES	NO	ESTIMATED AMOUNT OR % OF TOTAL INSTALLED CAPITAL COST
A. CAPITAL COSTS			
SO_2 ABSORPTION/DESORPTION SYSTEM	X		50%
SO_2 RECOVERY SYSTEM INCLUDING H_2S GENERATOR	X		7%
GAS QUENCHING & CLEANING	X		10%
SITE IMPROVEMENTS	X		2%
LAND, ROADS, TRACKS, SUBSTATION	X		12%
ENGINEERING COSTS	X		1%
CONTRACTORS FEE	X		8%
INTEREST ON CAPITAL DURING CONSTRUCTION	X		10%
B. ANNUALIZED OPERATING COST			
FIXED COSTS			
INTEREST ON CAPITAL			Not for Publication
DEPRECIATION			Not for Publication
INSURANCE & TAXES			Not for Publication
LABOR COST INCLUDING OVERHEAD			Not for Publication
VARIABLE COSTS			
RAW MATERIAL			Not Available
UTILITIES			Not Available
MAINTENANCE			Not Available

5/17/74

4. COST FACTORS

a. ELECTRICITY Not for Publication

b. WATER Not Available

c. STEAM (OR FUEL FOR REHEATING) Not Available

d. SULFUR/SULFURIC ACID SELLING COST Not for Publication $/TON

e. RAW MATERIAL PURCHASING COST Not for Publication $/TON OF DRY SLUDGE

f. LABOR:

SUPERVISOR	Not for Publication	HOURS/WEEK	Not for Publication	WAGE
OPERATOR	Not for Publication			
OPERATOR HELPER	Not for Publication			
MAINTENANCE	Not for Publication			

O. MAJOR PROBLEM AREAS: (CORROSION, PLUGGING, ETC.)

1. SO_2 SCRUBBER, CIRCULATION TANK AND PUMPS.

a. PROBLEM/SOLUTION Not available at this time.

2. DEMISTER

PROBLEM/SOLUTION Not available at this time.

3. REHEATER

PROBLEM/SOLUTION Not available at this time.

5/17/74

4. VENTURI SCRUBBER, CIRCULATION TANKS AND PUMPS

PROBLEM/SOLUTION Not applicable

5. I.D. BOOSTER FAN AND DUCT WORK

PROBLEM/SOLUTION Not available at this time.

6. SO_2 RECOVERY AND CONVERSION

PROBLEM/SOLUTION Not available at this time.

7. GAS QUENCHING AND CLEANING

PROBLEM/SOLUTION Not available at this time.

5/17/74

8. MISCELLANEOUS AREA INCLUDING BYPASS AND PURGE STREAM SYSTEM

PROBLEM/SOLUTION Not available at this time.

P. DESCRIBE FACTORS WHICH MAY NOT MAKE THIS A REPRESENTATIVE INSTALLATION

1. Cost figures misleading, since full scale particulate removal installed but only 1/3 SO_2 scrubbing.

Q. DESCRIBE METHODS OF SCRUBBER CONTROL UNDER FLUCTUATING LOAD. IDENTIFY PROBLEMS WITH THIS METHOD AND SOLUTIONS. IDENTIFY METHOD OF pH CONTROL AND LOCATION OF pH PROBES.

1. Scrubber Control Under Fluctuating Load

   a. Scrubber liquor flow rate is held constant.

   b. Adjustable rod deck is automatically controlled to maintain a constant pressure drop at varying gas flow rate.

2. pH Control

   The pH of the SO_2 scrubber surge tank is maintained by the automatic addition of magnesium hydroxide slurry from the slaking tank. Either of two pH probe locations may be selected for control. One in the surge tank and one in slurry recirculating line to the scrubber.

5/17/74

R. COMPUTATION OF FGD SYSTEM AVAILABILITY FACTOR

BOILER RATING OR MAXIMUM CONTINUOUS CAPACITY, MW ______

PERIOD MONTH/YEAR	FLUE GAS DESULFURIZATION MODULES							
	MODULE A		MODULE B		MODULE C		MODULE D	
	DOWN DUE TO		DOWN DUE TO		DOWN DUE TO		DOWN DUE TO	
	BOILER (HRS)	MODULE (HRS)	BOILER (HRS)	MODULE (HRS)	BOILER (HRS)	MODULE (HRS)	BOILER (HRS)	MODULE (HRS)

Availability factor computation:

1. Divide boiler capacity by the number of modules and obtain MW/module = χ
2. Multiply boiler capacity by number of hours during period = a
3. Add all down times due to module trouble for all modules during period = b
4. Add all down times due to boiler trouble or reduction in electricity demand for all modules during period = c
5. Availability factor = $\frac{[a - \chi\ (b + c)]100}{a - \chi\ c}$ = %

5/17/74

APPENDIX B

PLANT PHOTOGRAPHS

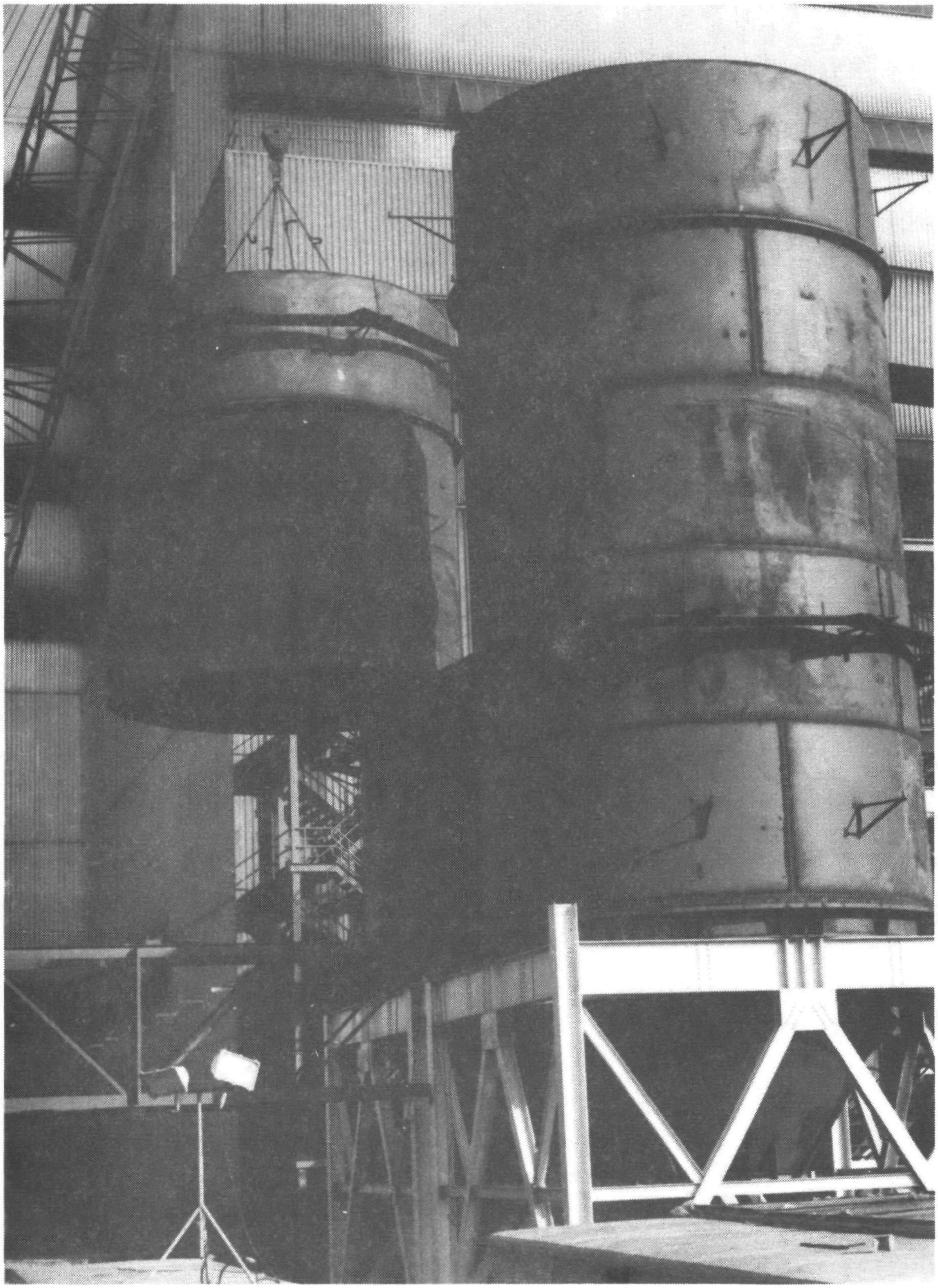


Photo No. 1 Construction photo showing installation of MgO silo at Eddystone. Boiler house appears in background.

(Courtesy Philadelphia Electric Co.)

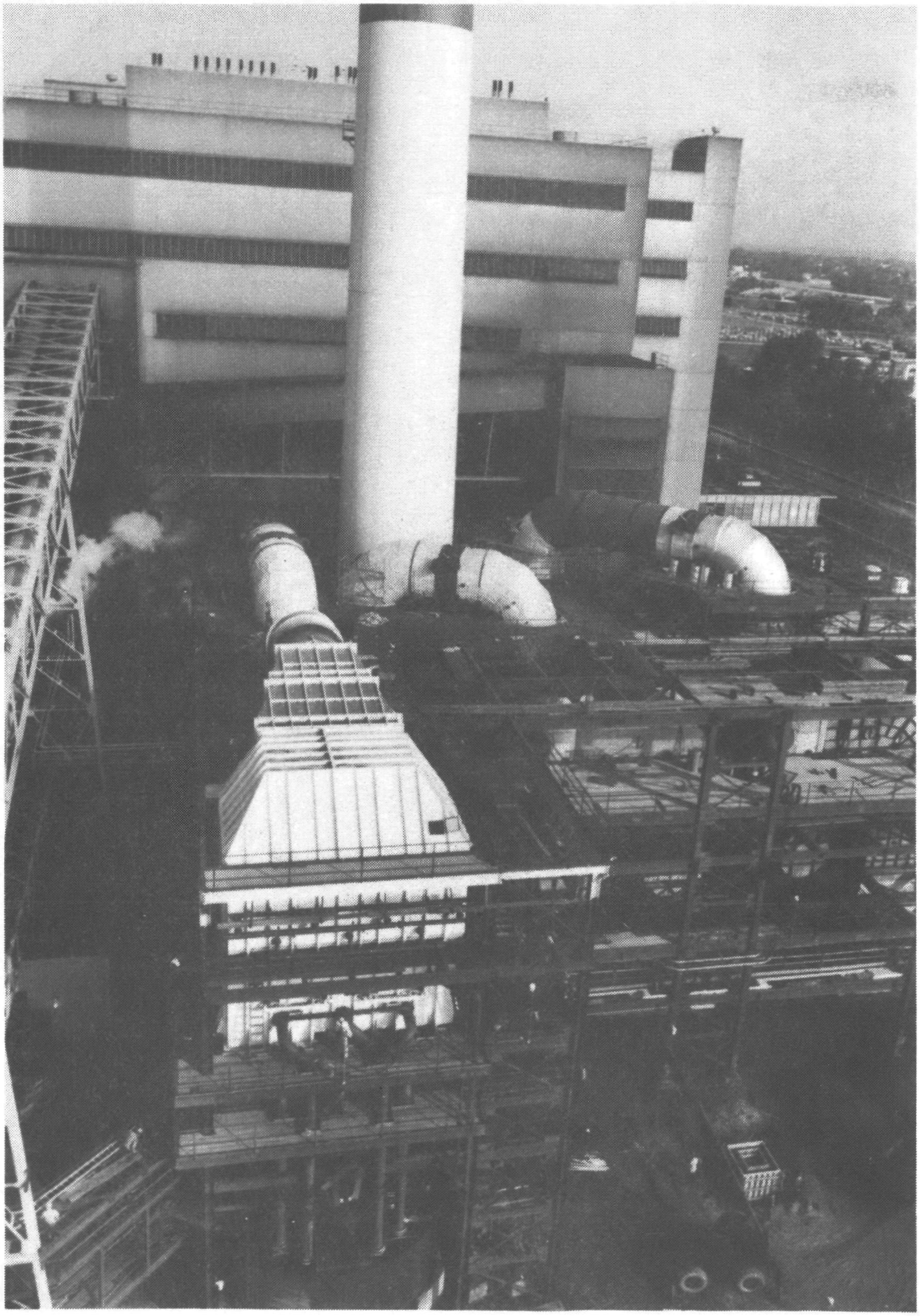


Photo No. 2 General view of Eddystone scrubber area. Supply ducts to three particulate scrubbers are visible, but scrubbers are obscured by strutural steel. FGD module is in foreground at left. Boiler 1 stack and boiler house are behind scrubbers.

(Courtesy Philadelphia Electric Co.)

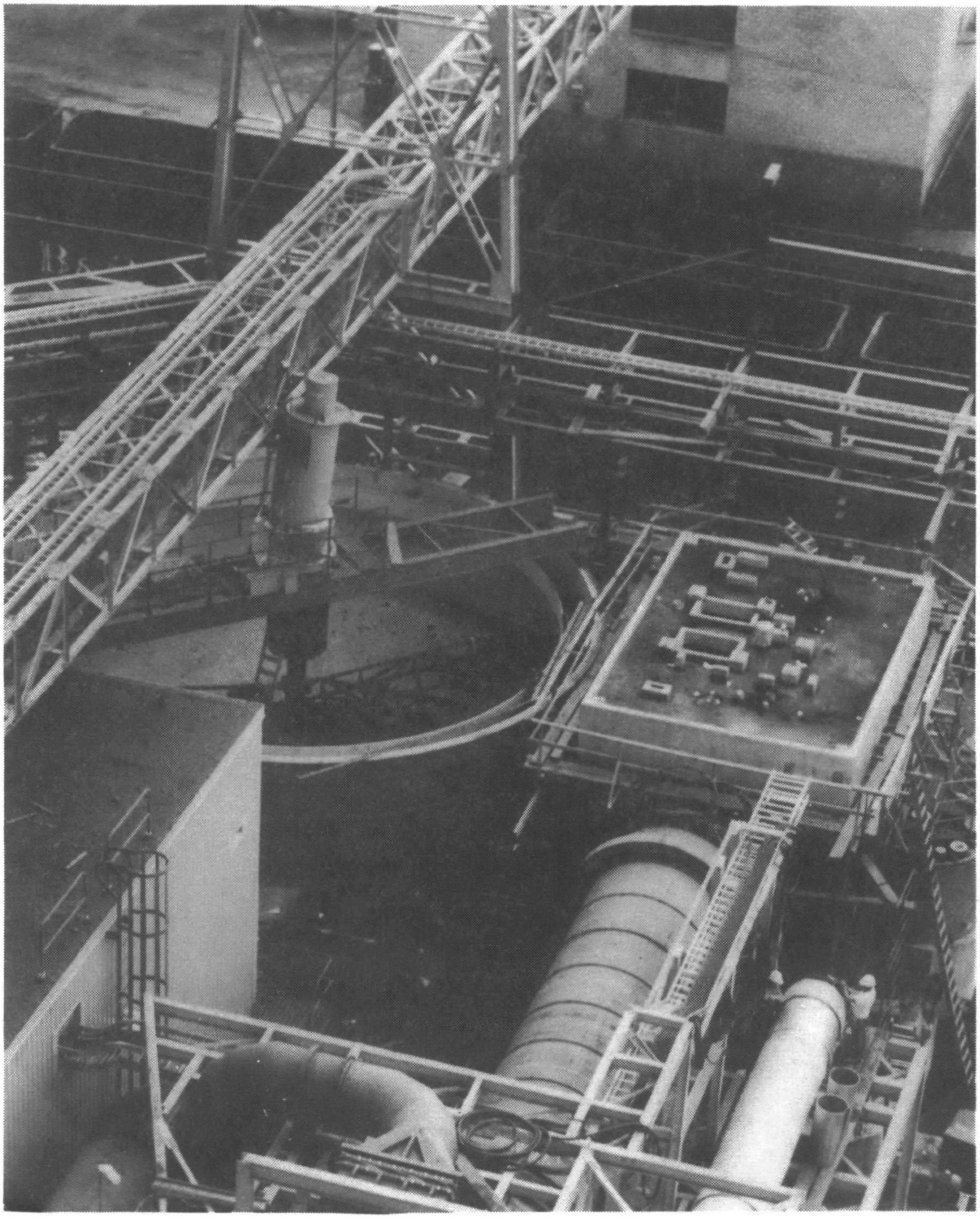


Photo No. 3 View of thickener tank, centrifuge foundations and $MgSO_3$ dryer. Overhead pipe rack carries coal to bunkers from coal handling building in background. Note empty coal cars behind thickener.

(Courtesy Philadelphia Electric Co.)

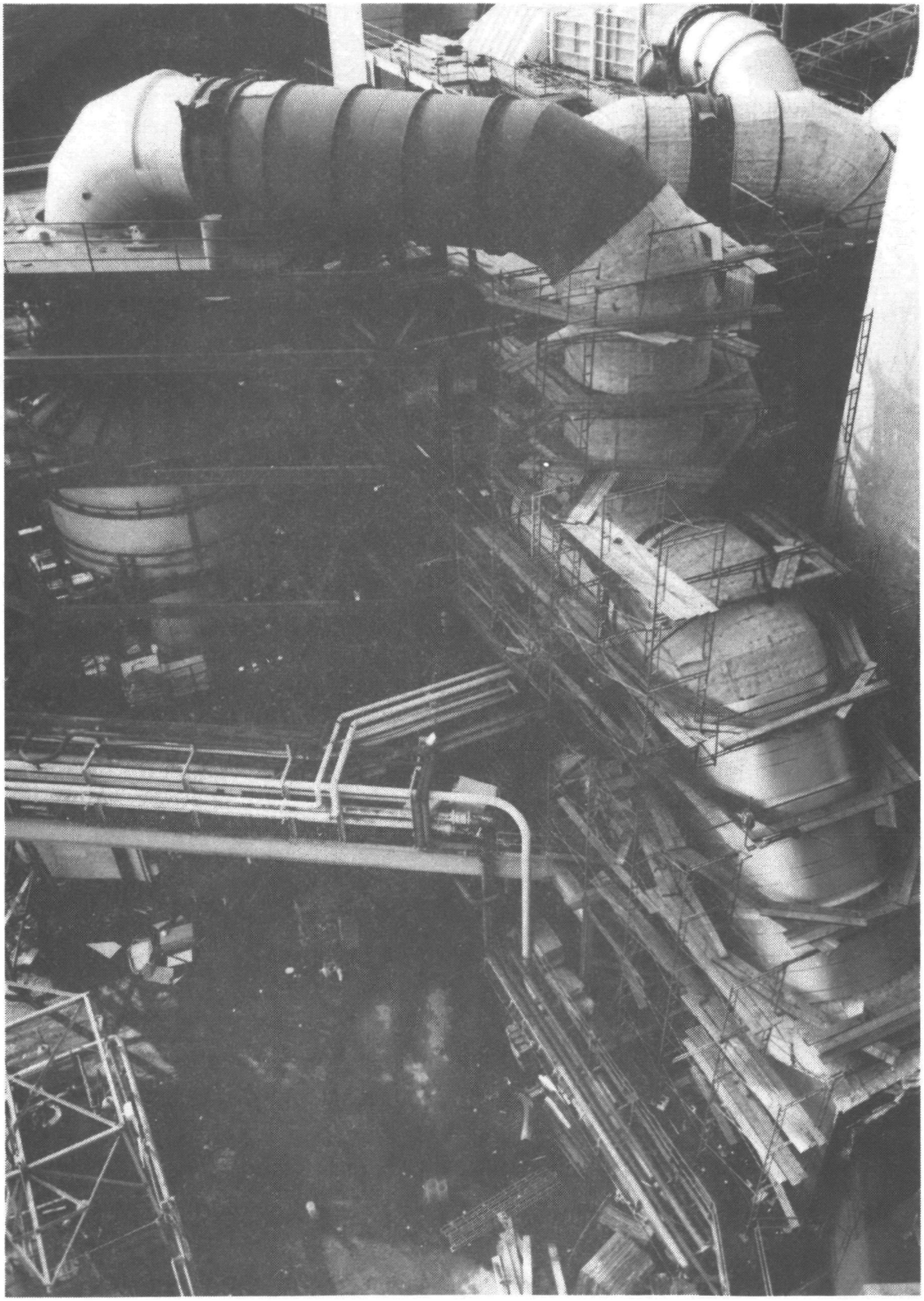


Photo No. 4 Construction photo showing installation of duct-work to Peabody scrubber from supply duct in foreground. Coal conveyor, FGD module, and coal pile are visible in background.

(Courtesy Philadelphia Electric Co.)

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-650/2-75-057-f	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Survey of Flue Gas Desulfurization Systems Eddystone Station, Philadelphia Electric Company		5. REPORT DATE September 1975
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Gerald A. Isaacs		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS PEDCo-Environmental Specialists, Inc. Suite 13, Atkinson Square Cincinnati, Ohio 45246		10. PROGRAM ELEMENT NO. 1AB013; 21ACX-130
		11. CONTRACT/GRANT NO. 68-02-1321, Task 6f
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Industrial Environmental Research Laboratory Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED Subtask Final: 2/75-9/75
		14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES		

16. ABSTRACT The report gives results of a survey of the magnesium-oxide-based flue gas desulfurization system on boiler 1 at Philadelphia Electric Co.'s Eddystone Station. The system, designed and installed by United Engineers and Constructors, Inc., consists of three first stage scrubber modules in parallel for particulate control (two are Environeering ventri-rod units; the third is a Peabody-Lurgi venturi unit) and a second stage Environeering absorber module with two ventri-rod beds for SO2 removal. The three first stage scrubbers, combined, are sized to handle all the exhaust gas from unit 1 which has a net electric generating capacity of 314 MW. The second stage absorber is sized to handle one-third of the gas flow, equivalent to about 105 MW (net). As of April 1, 1975, the second stage module had not yet been operated; therefore, this report necessarily emphasizes design, rather than operating, parameters and experience. The system is designed to remove 90 percent of the SO2 from boiler stack gas.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Air Pollution	Coal	Air Pollution Control	13B	21D
Flue Gases	Combustion	Stationary Sources	21B	
Desulfurization		Particulates	07A, 07D	
Sulfur Dioxide		Ventri-Rod Units	07B	
Magnesium Oxides		Venturi Units		
Scrubbers				

18. DISTRIBUTION STATEMENT Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 42
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)