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SURVEY OF FLUE GAS DESULFURIZATION SYSTEMS

DICKERSON STATION, POTOMAC ELECTRIC POWER CO.

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

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SURVEY OF FLUE GAS DESULFURIZATION SYSTEMS

DICKERSON STATION, POTOMAC ELECTRIC POWER CO.

by

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September 1975

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

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SUMMARY

A flue gas desulfurization (FGD) system utilizing the Chemico-Basic $MgO-SO_2$ removal/recovery process has been retrofitted to handle approximately one-half the exhaust gas from the 190 MW Unit 3 at the Dickerson Station of Potomac Electric Power Company. The dry-bottom, pulverized-coal-fired boiler, designed and installed by Combustion Engineering in 1962, is equipped with a Research-Cottrell electrostatic precipitator that operates with an estimated particulate collection efficiency of 94 percent. Coal burned at the station has an average gross heating value of 11,700 BTU/lb, an ash content of 14 percent, and a sulfur content of 2 percent.

A single, two-stage scrubber/absorber is used. The first stage (scrubber) incorporates an adjustable venturi for particulate removal, and the second stage (absorber) uses a fixed venturi configuration to remove sulfur dioxide. The liquor streams for the two stages are separate and independent. Both streams are operated in a closed-loop mode. Magnesium oxide (MgO) is regenerated using an EPA financed facility at the Essex Chemical Company sulfuric

acid manufacturing plant in Rumford, Rhode Island, where by-product SO_2 from the regeneration process is converted to a sulfuric acid. Excessive transportation costs for this particular prototype demonstration project are incurred in shipping magnesium compounds back and forth between Maryland and Rhode Island. The Rhode Island acid plant was used because it was available and was of proper size for the demonstration program.

The system was started up in September 1973 and was operated intermittently for shakedown purposes until January 1974. The system was then shut down because the Rumford facility was at that time still being used for a desulfurization project with Boston Edison. The longest continuous run during the first phase of operation was 271 hours. The system was restarted in July 1974 and operated until January 1975. The boiler was shut down for a major turbine overhaul from January 28, 1975 through August 11, 1975. The FGD system started up on August 11, 1975, and is anticipated to run for 3 to 4 weeks. Operation is limited by the MgO on hand at Dickerson, since the Essex facility has been shut down. Particulate and SO_2 removal efficiency guarantees have been demonstrated. Pipe and pump corrosion problems have frequently caused FGD unit outages. This is attributed mainly to improper material selection (mild steel) for the second stage recirculation system. Rubber-lined pumps and piping have been suggested to minimize these problems.

The FGD system was installed at a cost of $6.5 million. This cost does not include substantial engineering and development costs incurred by Chemico and Potomac Electric Power Company, nor does it include the cost of MgO regenerating facilities. A station transformer spare was used to power the FGD system in order to avoid an additional expenditure of $200,000 to $500,000 for a separate substation.

The Dickerson Station is presently operating under a variance from the State of Maryland. Additional installation of desulfurization equipment at this station is contingent on further evaluation of the system to be initiated around mid-1975. Operation of the FGD system will be indefinitely terminated at the conclusion of this evaluation since the Essex facility has been permanently shut down.

Pertinent operational data are summarized in the following table.

SUMMARY OF PERTINENT FGD DATA

FGD unit rating	95 MW (net)
Fuel characteristics	Coal; 11,700 BTU/lb, 14% ash, 2% S
FGD system supplier	Chemico
Process	Magnesium oxide
New or retrofit	Retrofit
Start-up date	September 1973
FGD modules	One
Efficiency,	
Particulate	99.3%
SO_2	90%
Make-up water	3.2 gpm/MW
Unit cost	Capital estimate: $6.5 million

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 FGD systems on coal-fired utility boilers in the United States. This report on the Dickerson Station of Potomac Electric Power Company (PEPCO) is one of a series of reports on such systems. It presents values of key process design and operating parameters, describes the major start-up and operational problems encountered at the facility and the measures taken to alleviate such problems, and identifies the total installed and annualized operating costs.

This report is based upon information obtained during a plant inspection on February 11, 1975 and on data provided by PEPCO and Chemico 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 FGD system, and Section 4.0 analyzes FGD system performance.

2.0 FACILITY DESCRIPTION

The Dickerson Station of PEPCO is located on the Potomac River outside the town of Dickerson, Maryland. The plant is situated in a rural, nonindustrialized area about 30 miles northwest of Washington, D. C. Coal is delivered to the plant by rail.

The station has three electric generators each rated at 190 MW. A fourth generator, rated at 800 MW is scheduled for installation nearby by 1982. The installed 95 MW FGD system is sized to handle approximately one-half the exhaust gas flow from Unit No. 3.

Unit No. 3 has a dry-bottom coal-fired boiler that was designed by Combustion Engineering and installed in 1962.

The coal presently burned has an average gross heating value of 11,700 BTU/lb. Average ash and sulfur contents are 14 percent and 2 percent, respectively.

The boiler is fitted with an electrostatic precipitator (ESP) designed and installed by Research-Cottrell in 1962. Particulate collection efficiency is estimated to be 94 percent. The FGD system is installed so that it can receive exhaust gas either from the outlet or from the breeching ahead of the ESP. Figure 2.1 is a gas-flow schematic for this installation. Table 2.1 gives pertinent data on plant design, operation and atmospheric emissions.

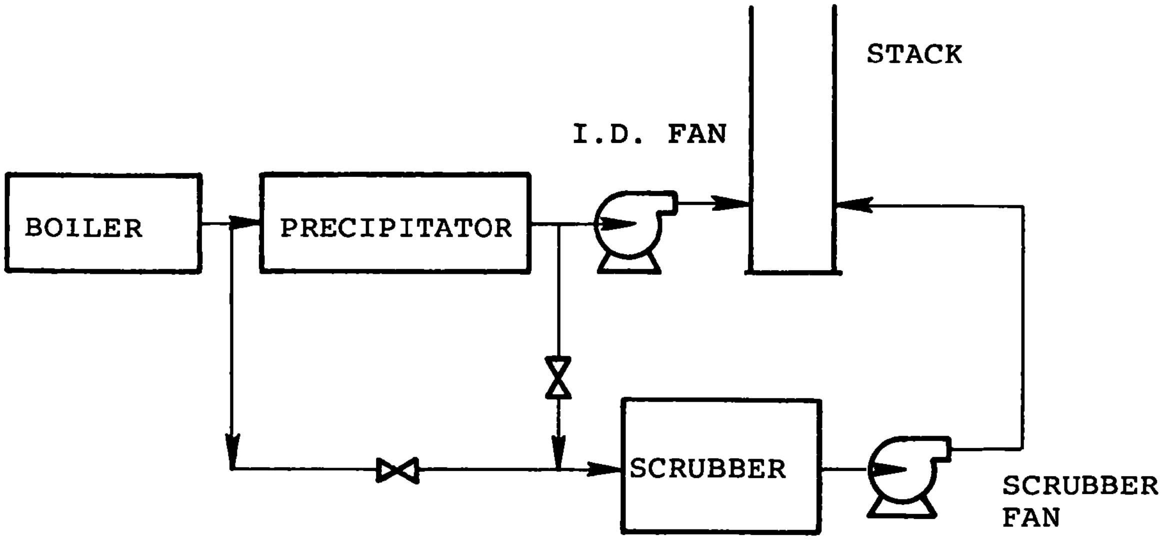

Figure 2.1 FGD gas flow schematic
Dickerson No. 3 - PEPCO.

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

Boiler data - Dickerson No. 3 - PEPCO	
Rated generating capacity, MW	190
Average capacity factor (1974), %	81
Boiler manufacturer	Combustion Engineering
Year placed in service	1962
Unit heat rate, BTU/KWH	9180
Maximum coal consumption, ton/hr	74.5
Maximum heat input, MM BTU/hr	1744
Stack height above grade, ft	400
Flue gas rate - maximum, acfm	590,000
Flue gas temperature, °F	259
Emission controls:	
Particulate	ESP and venturi scrubber
SO_2	Venturi - absorber on half of the gas flow
Particulate emission rates:	
Allowable, gr/scf	0.03
Actual, gr/scf	0.02
SO_2 emission rates:	
Allowable, lb/MM BTU	1.6[a]
Actual, lb/MM BTU	0.3[b]

[a] 1% sulfur coal equivalent.

[b] Based on 2 percent sulfur in coal, 95 percent conversion of sulfur to SO_2 and 90 percent FGD efficiency.

3.0 FLUE GAS DESULFURIZATION SYSTEM

3.1 PROCESS DESCRIPTION[a]

Figure 3.1 is a schematic flow diagram for the Chemico-Basic FGD system installed to handle approximately one-half (295,00 acfm at 259°F) of the exhaust gas from Unit 3 of the Dickerson Station of PEPCO. The maximum gross continuous generating capacity for the unit is 190 MW. The boiler was manufactured by Combustion Engineering, Inc., and was placed in service in 1962. The generator, a base load unit, operated with an 81 percent capacity factor in 1974. The FGD system incorporates six major processing steps, i.e., 1) ash removal, 2) SO_2 absorption, 3) solids concentration, 4) drying, 5) dry solids storage, and 6) calcination. Only the first five steps are accomplished on-site at the Dickerson facility.

3.1.1 Ash Removal

A two-stage scrubber/absorber is used at this plant. The first stage is an adjustable throat venturi where the gas is cooled from 250°F to 120°F and saturated. This stage is used for fly ash (particulate) control only, and recir-

[a] Adapted from "Chemico-Basic Magnesium Based SO_2 Recovery Scrubbing Systems," by P.M. Wechselblatt and Robert H. Quig - Presented at AIChE 71st National Meeting, Dallas, Texas, February 20-23, 1972, and supplemented with data from field visit.

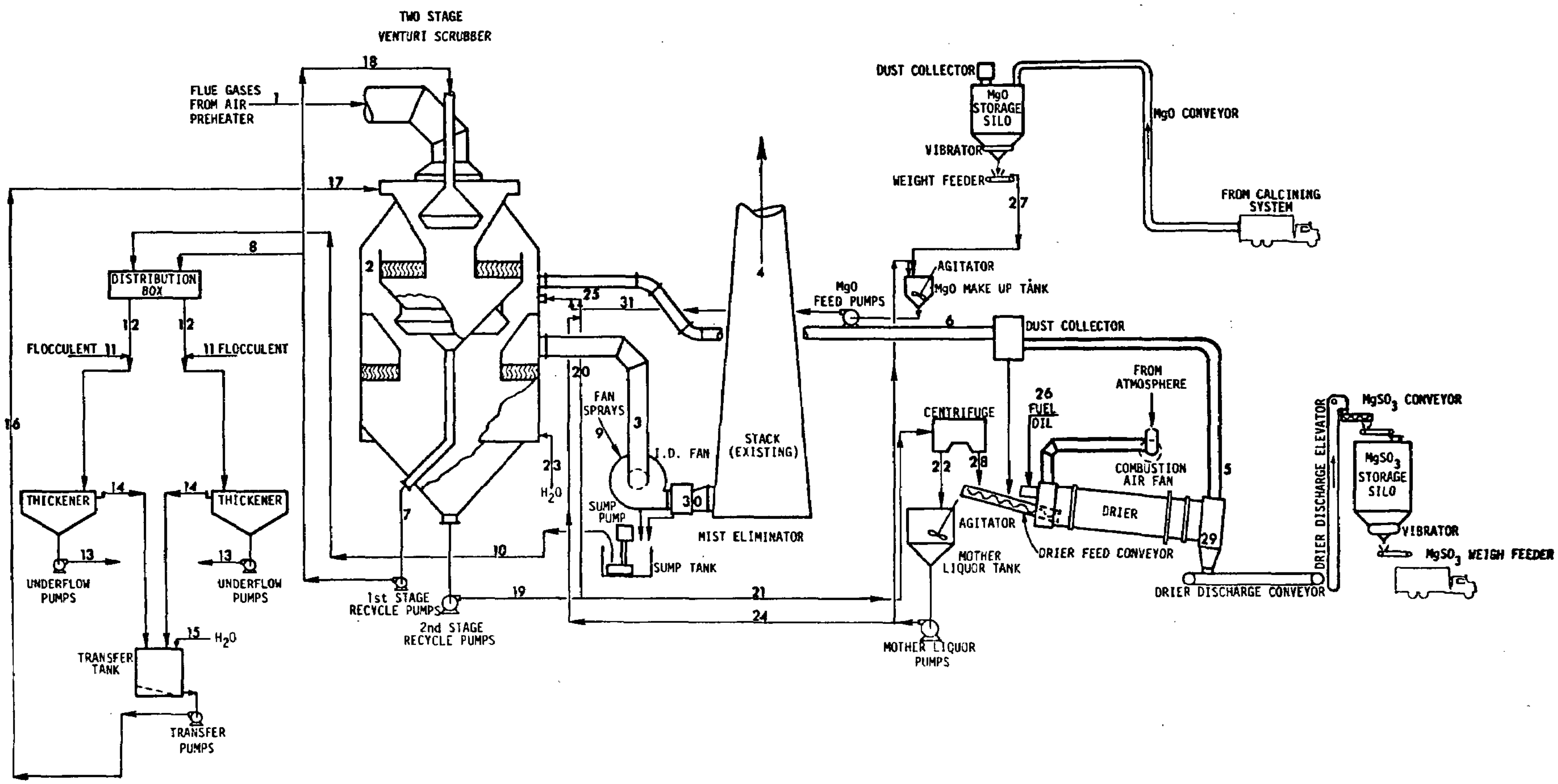

Figure 3.1 General flow diagram of the FGD system on Dickerson No. 3 - PEPCO.

culating streams for the two stages are separate and independent. Ash-laden water is circulated at a two percent solids concentration. The adjustable venturi automatically controls the first stage pressure drop at 11 in. H_2O. Overall design system particulate collection efficiency is 99 percent. Actual efficiency was measured to be 99.3 percent when the ESP was bypassed. The ESP was designed to attain 97.5 percent efficiency, but it attains only about 94 percent efficiency, burning coal containing 2 percent sulfur.

A 980 gpm bleed stream from the recycle line carries ash to the thickeners. A flocculant is used to aid settling in the thickeners. Thickener underflow, 20 gpm at 40 percent solids, is discharged to a dilution tank where water is added, and the mixture is pumped to a settling pond. The overflow cascades through a total of four ponds in series, and the water from the lowest pond is then pumped back to the dilution tank. The thickener overflow is pumped back into the first stage of the scrubber so that closed-loop operation is maintained.

3.1.2 SO_2 Absorption

The flue gas leaves the first stage passing upward through an annular mist eliminator and then downward through the second stage of the scrubber which is designed to remove 90 percent of the SO_2 from the flue gas stream. The SO_2 gas diffuses into the surface of the water droplets and chemically reacts with the MgO forming hydrated magnesium sulfites. Some $MgSO_4$ is also formed as a result of the reaction of SO_3

with MgO and as a result of the oxidation of $MgSO_3$. The slurry solids have a relative composition of 89.6 percent $MgSO_3 \cdot 6\ H_2O$ and $MgSO_3 \cdot 3\ H_2O$ ($MgSO_3 \cdot 6\ H_2O$ predominantly), 5.0 percent $MgSO_4 \cdot 7\ H_2O$, and 5.4 percent MgO.

$$MgO + SO_2 + 6\ H_2O \longrightarrow MgSO_3 \cdot 6\ H_2O$$

$$MgO + SO_2 + 3\ H_2O \longrightarrow MgSO_3 \cdot 3\ H_2O$$

Other reactions that occur are:

$$MgO + SO_3 + 7\ H_2O \longrightarrow MgSO_4 \cdot 7\ H_2O$$

$$MgSO_3 + 1/2\ O_2 + 7\ H_2O \longrightarrow MgSO_4 \cdot 7\ H_2O$$

The flue gas and entrained liquor then enter the separator portion of the absorber through a central downcomer. The liquor falls to the lower section of the separator which serves as an integral storage reservoir while the gas containing less than 150 ppm SO_2 passes upward through the second stage mist eliminators and is exhausted through the stack to the atmosphere.

3.1.3 Solids Concentration

A 170 gpm bleed from the absorption system enters a 36 in. x 72 in. solid-bowl centrifuge where the crystals of $MgSO_3 \cdot 6\ H_2O$, $MgSO_3 \cdot 3\ H_2O$ and $MgSO_4 \cdot 7\ H_2O$ and unreacted MgO are separated from the mother liquor. The mother liquor is returned to the absorption system and the centrifuged wet cake enters the dryer.

3.1.4 Drying

The wet cake containing $MgSO_3 \cdot 6\ H_2O$, $MgSO_3 \cdot 3\ H_2O$, $MgSO_4 \cdot 7\ H_2O$, MgO and surface moisture is dried by direct-firing to remove surface and bound moisture. Dry solids total about 100 lb/min. The drying reactions are as follows:

$$MgSO_3 \cdot 6\ H_2O \xrightarrow{\text{Heat}} MgSO_3 + 6\ H_2O\ (g)$$

$$MgSO_3 \cdot 3\ H_2O \xrightarrow{\text{Heat}} MgSO_3 + 3\ H_2O\ (g)$$

$$MgSO_4 \cdot 7\ H_2O \xrightarrow{\text{Heat}} MgSO_4 + 3\ H_2O\ (g)$$

$$H_2O\ (l) \xrightarrow{\text{Heat}} H_2O\ (g)$$

Exhaust gas from the dryer passes through a cyclone dust collector and back into the second stage of the scrubber.

3.1.5 Dry Solids Storage

The anhydrous $MgSO_3$ and $MgSO_4$ material is conveyed from the dryer to a storage silo where it is kept until it is transported by covered trucks, barges or rail cars to the sulfuric acid manufacturing plant. Regenerated MgO is returned (with make-up) and stored in an MgO silo at the power plant. The MgO slurry is prepared using regenerated MgO, make-up MgO and mother liquor. The MgO slurry is added as make-up to the absorption recycle liquid system. The $MgSO_3$ storage silo has a design capacity of 200 tons (7 days). The MgO storage silo has a design capacity of 100 tons (7 days).

3.1.6 Calcination

Figures 3.2 and 3.3 show the schematic process flow sheets of the calciner plant and sulfuric acid plant. Both processes are external to the Dickerson Station. The dry crystals of $MgSO_3$, $MgSO_4$ and MgO are received, weighed, and conveyed to the $MgSO_3$ silo. The crystals are fed from there to the direct-fired rotary calciner at a metered rate and

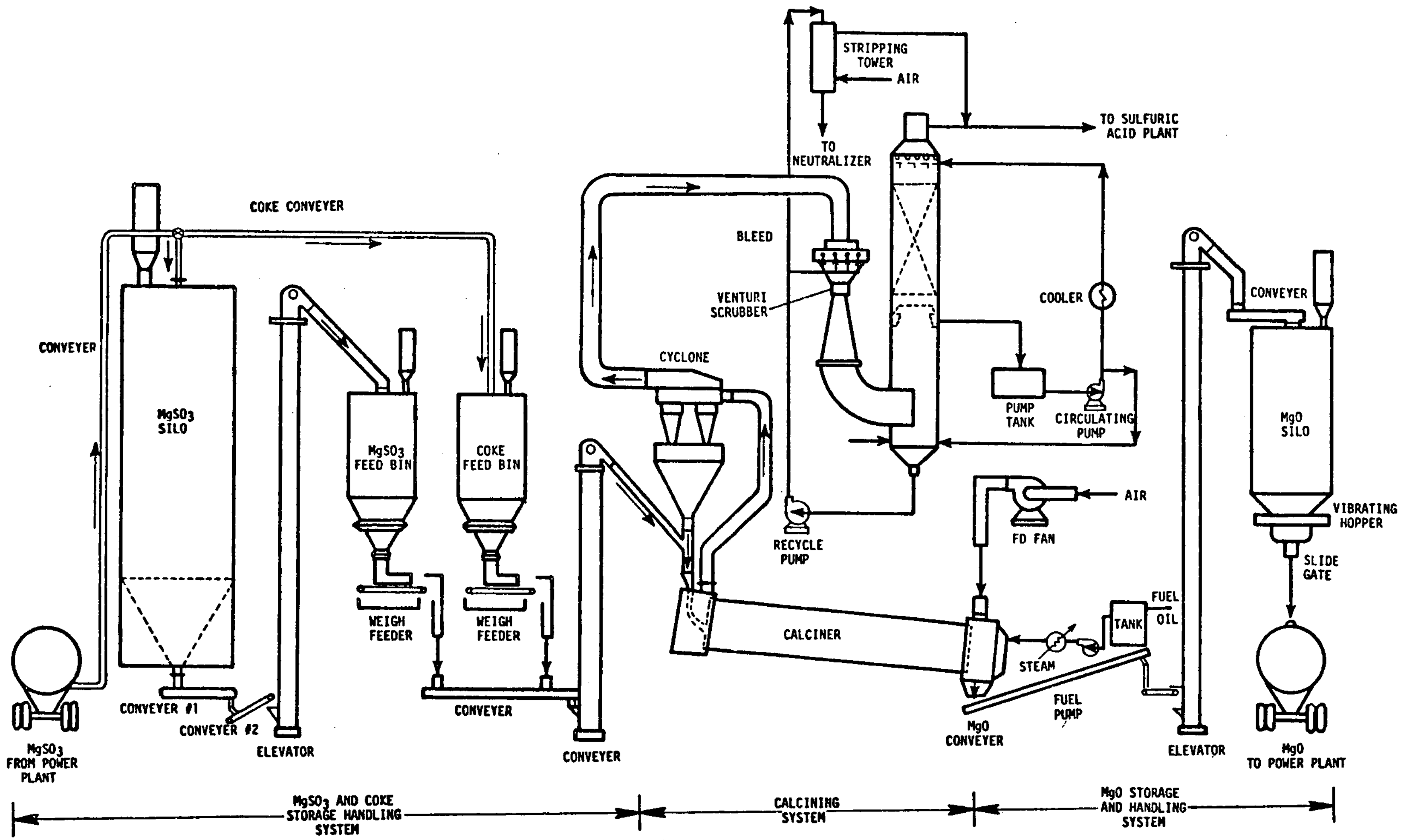

Figure 3.2 Calcining system process flow diagram at Essex Chemical Company Rumford, Rhode Island.

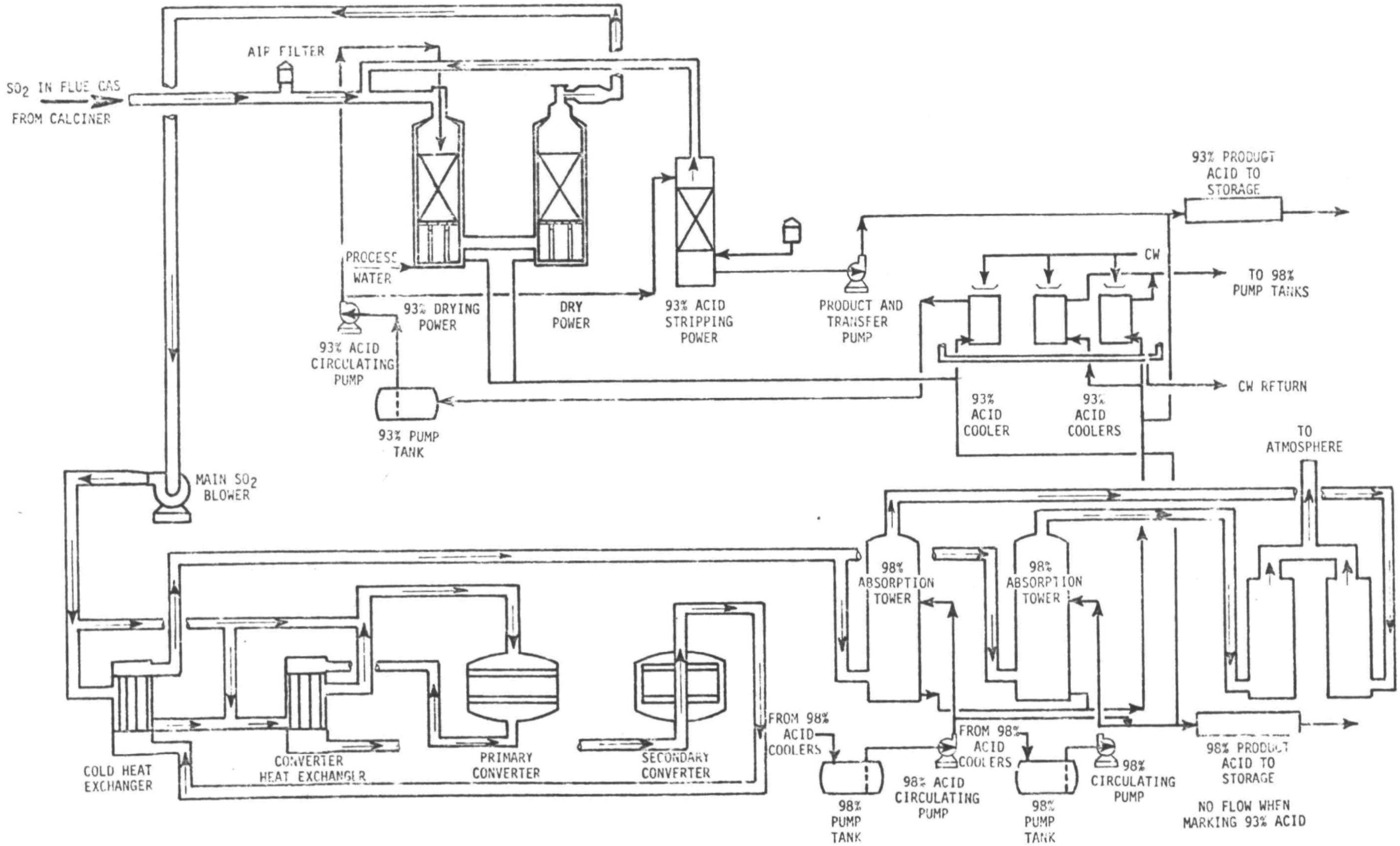

Figure 3.3 Sulfuric acid plant - process flow diagram
At Essex Chemical Company, Rumford, Rhode Island.

calcined to generate SO_2 gas and regenerate MgO. Coke is added to reduce the residual $MgSO_4$ to MgO and SO_2. The reactions are:

$$MgSO_3 \xrightarrow{\text{Heat}} MgO + SO_2$$

$$MgSO_4 + 1/2\ C \xrightarrow{\text{Heat}} MgO + SO_2 + 1/2\ CO_2$$

The calciner effluent gas containing 7 - 10 percent SO_2 and the MgO dust enter a hot cyclone where essentially all of the dust is collected and returned to the calciner. The gas then enters a venturi scrubber, where final dust cleaning is accomplished and the gas is adiabatically saturated. The saturated gas is cooled to 100°F in a direct contact cooler. The cleaned, cooled gas enters the drying tower and the sulfuric acid plant for production of 98 percent sulfuric acid. Alternately, the gas can be reduced to elemental sulfur. The regenerated MgO is cooled, conveyed to the MgO storage silo, and recycled back to the power plant site for reuse.

3.2 PROCESS CONTROL

The control process for this FGD system is relatively simple. Basically, the liquid flow rates through the scrubber are constant and independent of gas load. The first stage of the venturi is automatically adjusted to maintain an 11 in. H_2O pressure drop across the venturi. MgO additive feed rate is varied to maintain the slurry pH at a preset point, about 7. The pH is measured at the discharge of the second stage recirculation pump. A downward pH movement triggers the addition of MgO to the system from the MgO make-up tank. The control system has been found to be reliable and relatively trouble-free.

3.3 INSTALLATION SCHEDULE

This system was designed by Chemico who also performed the architectural and engineering work. Construction work was performed by Brown & Root, Inc. On-site construction began July 1972, and was completed in September 1973. Plant start-up occurred in September 1973, but shakedown tests were not completed until July 1974. The long interval between start-up and shakedown occurred because the calcination facility at Rumford, Rhode Island was unavailable during that period. This was the only major delay in the demonstration schedule. Start-up was originally scheduled for June 30, 1973. Some design modifications based on ongoing experience at the Mystic Station of Boston Edison caused slight construction delays. Dryer delivery was delayed about one month beyond scheduled delivery. Structural steel reinforcement in the boiler room required more time than construction schedules had allotted.

3.4 COST DATA

In 1969 PEPCO estimated that the capital cost of a scrubber system was 12 to $20/KW. In the January 1974 EPA report on the October 1973 scrubber hearings the capital cost was given as 50 to $65/KW. PEPCO's current in-house estimate in 1974 dollars is in excess of $100/KW. This installation has cost PEPCO about $6.5 million ($68/KW).

Operating costs are incomplete because MgO make-up costs and maintenance cost estimates have not been reported by PEPCO. Their experience indicates that two additional operators per shift will be required. Maintenance requirements for the present system average 50-60 man-hours/week. Operation and maintenance costs were estimated to be $500,000 in 1974. This figure does not include fixed charges on the total capital costs to account for interest, depreciation, insurance and taxes. The figure also does not include FGD system fuel costs, project management, engineering, air, electricity, or water costs. Freight charges and operation charges by the Rumford acid plant cost PEPCO an additional $440,000. If the FGD plant had operated at capacity in 1974, freight costs alone would have been approximately $1.7 million.

The power consumption for the existing FGD system is about 3.5 MW. The estimated increase in power cost for the Dickerson Station if it were to be fully equipped with FGD facilities, operating at an 85 percent capacity factor, would be about 5 mills per kilowatt hour. Over 3 mills of that amount would be the fixed charge on investment. These costs assume an on-site MgO regeneration system. The assumption is also made that the sale of elemental sulfur or sulfuric acid will cover all fixed and operating costs associated with an on-site sulfur or acid plant.

4.0 FGD SYSTEM PERFORMANCE

4.1 START-UP PROBLEMS AND SOLUTIONS[a]

The FGD system was placed in operation on September 13, 1973. Operation since that time can be divided into the following phases:

Phase I	September 13, 1973 to January 14, 1974 - Initial operation and debugging.
Phase II	January 14 to April 15, 1974 - Maintenance and modification.
Phase III	April 15 to July 1, 1974 - Modification verification.
Phase IV	July 1 to January 28, 1975 - Performance testing, optimization and reliability.
Phase V	January 28, 1975 to August 11, 1975 - Maintenance and modification
Phase VI	August 11, 1975 to about early September 1975 - Modification verification

<u>Phase I</u>

Initial start-up and operation was reasonably smooth. There were two shutdowns caused by failures of stainless steel expansion bellows which allowed first stage slurry to leak into the second stage. Examination verified that the bellows were not made of the specified 316 stainless.

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[a] Adapted from "Mag-Ox Scrubbing Experience at the Coal-Fired Dickerson Station - Potomac Electric Power Company," by Donald A. Erdman, Project Engineer, PEPCO.

The major problem was with the MgO feed system. Continual plugging occurred in the MgO mix tank and suction lines to the MgO make-up pumps. The problem was remedied by the installation of a premix tank ahead of the mix tank to ensure that scale-forming reactions would occur before the fresh slurry entered the piping system. Steam sparging lines were also added to heat the MgO slurry to about 160°F. This preheat was found to be necessary to ensure MgO dissolution and slurry homogeneity.

The longest continuous run during this phase was 271 hours. Approximately midway through this run the boiler was forced out for 24 hours with a tube leak. All liquid flows and levels were maintained and flue gas was returned to the scrubber as soon as the boiler returned to service. Phase I concluded when the boiler shut down January 14 for annual maintenance.

Phase II

Inspection of the scrubber system was made after about 700 hours operation. The system was basically in good condition with absolutely no sign of scaling or buildup. However, in the first stage where the operating pH is less than two, there was corrosion of nuts, bolts, hanger rods, spray nozzles, bellows and the vessel itself. Examination determined that many corroded parts were not constructed of specified material. There was some very minor corrosion on 316 stainless. The corrosion of the vessel occurred only in a few places where the protective flake glass lining had cracked. The problem here was partly due to improper application and partly due to construction damage after the lining was installed.

Phase III

Operation resumed with start-up on April 15, 1974. The intent was to operate to verify the modifications and then to shut down to prepare the unit for performance testing. The premix tank improved slaking but not to an acceptable standard for long-term operation. It was decided that at the end of April the system could be operated for performance testing. However, further checks revealed that the inventory of MgO was insufficient for such a test and that the remaining storage space for sulfite was also insufficient. At that time 130 tons of sulfite were at Rumford waiting to be calcined. Boston Edison was using the calciner and it appeared there was no chance of PEPCO's material being calcined before July. Additional virgin MgO had not been ordered as PEPCO had been expecting to be able to conduct the test using recycled MgO. A short operation in May emptied the MgO silo.

Chemico decided to replace the premix tank with a "solids liquid mixing eductor" to improve slaking.

Phase IV

PEPCO received permission to use the calciner at Rumford, Rhode Island July 1, 1974. Virgin MgO, ordered to supplement the expected recycled MgO, arrived near the end of July. The first start-up was August 1. The mixing eductor proved totally unsatisfactory, plugging continually. After 10 hours the FGD system was shut down, and the premix tank was modified and reinstalled. Preliminary tests operating on virgin MgO indicated an SO_2 removal in the 70 percent range. When the pressure drop across the absorber throat was increased to the design specification, a removal efficiency in excess of 90 percent was demonstrated, using virgin MgO.

Recycled MgO was first received and introduced into the system on August 16. The dryer feed material became sticky and caused caking in the dryer. This was believed to be caused by unreacted MgO in the centrifuge cake. During the next run steam sparging was used to raise the temperature in the MgO mix tank to correct this problem. It was also necessary to change the dryer operating temperature on recycled MgO. Slaking with the modified premix tank was satisfactory on both virgin and recycled MgO.

In conjunction with Chemico, Basic, Essex and EPA, from July to December 1974, PEPCO conducted a 6-month program to test the FGD system, optimize operating conditions, improve reliability and gain operating experience. There have been no problems to rule out the technical feasibility of this process for SO_2 removal. There are still some problems in the sulfite handling equipment which is somewhat undersized for actual operating conditions. The centrifuge hopper and the dryer tend to hold up material and then release it in a slug that overloads the sulfite conveyors.

Several minor problems continue to cause shutdowns. Examples include corrosion leaks in damaged rubber-lined pipes, erosion leaks in second stage piping, pump seal problems, and bearing failure in sulfite bucket elevator.

Present plans call for repairing the FGD system during a current outage for a turbine overhaul. The system is to be subjected to an approximate three-month test-and-demonstration program, beginning around July 1975.

Phase V

Pipe linings and some materials of construction were changed. Corroded equipment was repaired. Other modifications included changing the hopper feed to the centrifuge.

Phase VI

Length of this phase of operation is limited by the existing supply of MgO, about 3-4 weeks. The purpose of this phase is to verify the modifications and repairs that were made. At the conclusion of this phase a complete site inspection will be performed by PEPCO.

4.2 PERFORMANCE TEST RUN

A performance test program has been completed by York Research and while formal results are not available, the indicated SO_2 removal efficiency is in the 88 to 96 percent range as gas flow varies from 150,000 to 300,000 acfm. Overall particulate removal efficiency exceeds 99 percent whether or not the existing ESP is used.

4.3 PERFORMANCE PARAMETERS

The FGD system at the Dickerson Power Station operated intermittently throughout 1974. Availability figures appear in Table 4.1. The boiler capacity factor was 81 percent in 1974. PEPCO has defined availability as the length of time the FGD system was operating or ready for operation divided by the total number of hours in the period. This definition differs slightly from the more usual definition of availability, i.e., FGD operating hours divided by boiler operating hours.

4.4 PROCESS MODIFICATIONS AND ECONOMICS FOR FUTURE INSTALLATION

This installation is not entirely suitable for the determination of economic parameters, mainly because it is tied to the operation of an outdated, undersized acid manufacturing plant located approximately 400 miles away. Future installation will probably be predicated on on-site calcination and across-the-fence transfer of materials to and from a modern, economically sized acid plant. All the Dickerson units together, including Unit 4, an 800 MW generator to be in service by 1982, would supply enough $MgSO_3$ to operate a 1000 ton/day sulfuric acid plant; this is about the minimum economical size for a modern plant. It is estimated that at best the revenue from the sale of sulfuric acid would pay operation and maintenance costs associated with the acid plant.

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Corrosion and erosion problems have been encountered in the existing scrubber, especially in the first stage where pH is low. Corrosion and erosion of mild steel piping and pumps for the second stage absorber indicate that these items should have been rubber-lined.

The plant does not have a spare centrifuge or dryer, which makes the FGD system quite vulnerable. A full-scale system would likely employ more redundant critical equipment items in several areas. All pumps are spared in this installation.

Demister deposits have not occurred. The principal problems with the demisters have been in the form of physical abuse from being walked on by maintenance personnel during scrubber inspections. Although it has not been necessary to replace the demisters it is probable that a sturdier design will be specified for replacement units or for additional installations.

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The wet scrubber I.D. fan has not caused any problems. The wheel is constructed of Inconel 625, and the housing is rubber-lined.

The centrifuge tends to freeze when it is shut down unless it is carefully and thoroughly cleaned.

Bypass dampers tend to bind and do not seal completely, but operation has not been seriously affected and major design modifications have not been suggested.

It was mentioned earlier that the original MgO slurry mixing system was ineffective and that a premix tank had to be installed. The mix tank temperature must be closely controlled in order to obtain proper dissolution of the recycled MgO.

The bucket elevator to the $MgSO_3$ silo cannot handle the surges that normally occur when the dryer is running at capacity. Either a surge bin between the dryer and the elevator or a larger elevator should be installed. The present system will only accommodate a flow equivalent to 70 percent of dryer design capacity.

APPENDIX A

PLANT SURVEY FORM

PLANT SURVEY FORM

REGENERABLE FGD PROCESSES

A. COMPANY AND PLANT INFORMATION

1. COMPANY NAME Potomac Electric Power Company
2. MAIN OFFICE 1900 Pennsylvania, Washington, D.C.
3. PLANT MANAGER W. C. Jensen, Jr.
4. PLANT NAME Dickerson Station
5. PLANT LOCATION Dickerson, Maryland
6. PERSON TO CONTACT FOR FURTHER INFORMATION Don Erdman
7. POSITION Project Engineer
8. TELEPHONE NUMBER (202) 872-2441
9. DATE INFORMATION GATHERED February 10, 1975
10. PARTICIPANTS IN MEETING

PARTICIPANTS IN MEETING	AFFILIATION
T. Devitt, L. Yerino	PEDCo
G. Isaacs	PEDCo
J. Busik, F. Biros	EPA Washington, D.C.
W. Ponder, R. Atherton	EPA Research Triangle Park, North, Carolina
D. Erdman	PEPCO
J. Harvey	PEPCO
G. Koehler	Chemico

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

	BOILER NO.				
	1	2	3	4***	
CAPACITY, MW (Gross)	190	190	190**	800	
SERVICE (BASE, PEAK)	B	B	B	B	
FGD SYSTEM USED			95 MW		

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

1. BOILER IDENTIFICATION NO. 3
2. MAXIMUM CONTINUOUS HEAT INPUT 1456.4 MM BTU/HR
3. MAXIMUM CONTINUOUS GENERATING CAPACITY 190 MW
4. MAXIMUM CONTINUOUS FLUE GAS RATE, 590,000 ACFM @ 259 °F
5. BOILER MANUFACTURER C-E
6. YEAR BOILER PLACED IN SERVICE 1962
7. BOILER SERVICE (BASE LOAD, PEAK, ETC.) Base
8. STACK HEIGHT 400'
9. BOILER OPERATION HOURS/YEAR (1974) 7992.7
10. BOILER CAPACITY FACTOR * 81
11. RATIO OF FLY ASH/BOTTOM ASH 9 (Est.)

* DEFINED AS: $\frac{\text{KwH GENERATED IN YEAR}}{\text{MAX. CONT. GENERATED CAPACITY IN KW} \times 8760 \text{ HR/YR}}$.

** 182 MW (NET) when scrubber is not operating.
178.5 MW (NET) when scrubber is operating.

*** To be in service by 1983.

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D. FUEL DATA

1. COAL ANALYSIS (as received)

	MAX.	MIN.	AVG.
GHV (BTU/LB.)			11,737
S %	2.2	1.7	2.2
ASH %			14.06

2. FUEL OIL ANALYSIS (exclude start-up fuel)

GRADE			
S % N/A			
ASH %			

E. ATMOSPHERIC EMISSIONS

1. APPLICABLE EMISSION REGULATIONS

	PARTICULATES	SO_2
a) CURRENT REQUIREMENTS		2.25% S (max)
AQCR PRIORITY CLASSIFICATION		
REGULATION & SECTION NO.		
MAX. ALLOWABLE EMISSIONS LBS/MM BTU		
b) FUTURE REQUIREMENTS, COMPLIANCE DATE	Currently under review	
REGULATION & SECTION NO.	Currently under review	
MAXIMUM ALLOWABLE EMISSIONS LBS/MM BTU		

2. PLANT PROGRAM FOR PARTICULATES COMPLIANCE

Particulate and SO_2 compliance tied together.

Mitre Corp. Recommended Study underway -

Report due in April.

3. PLANT PROGRAM FOR SO_2 COMPLIANCE Awaiting Mitre Report.

Retrofit est. to take 44 months from contract to start-up.

F. PARTICULATE REMOVAL

1. TYPE

	MECH.	E.S.P.	FGD
MANUFACTURER	Chemico	R-C	
EFFICIENCY: DESIGN/ACTUAL	99/99.3	97.5/94 est.	
MAX. EMISSION RATE* LB/HR			
GR/SCF	0.02		
LB/MMBTU			

DESIGN BASIS, SULFUR CONTENT ______

G. DESULFURIZATION SYSTEM DATA

1. PROCESS NAME Chemico-Basic
2. LICENSOR/DESIGNER NAME: Chemico
   ADDRESS: 1 Penn Plaza - NYC
   PERSON TO CONTACT: J. Lagakos
   TELEPHONE NO.: (212) 239-5345
3. ARCHITECTURAL/ENGINEERS, NAME: Chemico
   ADDRESS: ______
   PERSON TO CONTACT: ______
   TELEPHONE NO.: ______
4. PROJECT CONSTRUCTION SCHEDULE:

	DATE
a) DATE OF PREPARATION OF BIDS SPECS.	N/A
b) DATE OF REQUEST FOR BIDS	1/71
c) DATE OF CONTRACT AWARD	7/71
d) DATE ON SITE CONSTRUCTION BEGAN	7/72
e) DATE ON SITE CONSTRUCTION COMPLETED	8/73
f) DATE OF INITIAL STARTUP	9/73
g) DATE OF COMPLETION OF SHAKEDOWN	7/74

*At Max. Continuous Capacity

5. LIST MAJOR DELAYS IN CONSTRUCTION SCHEDULE AND CAUSES:

Minor delays only. Original start-up scheduled for June 30, 1973. Some design mod. based on ongoing experience - Boston. Dryer delay approximately 1 month; Brown & Root underestimated time to install steel in building. Rumford facility unavailable until July 1974.

6. NUMBER OF SO_2 SCRUBBER TRAINS USED 1

7. DESIGN THROUGHPUT PER TRAIN, ACFM @ 259 °F 295,000

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

2) EQUIPMENT LAYOUT

H. SO_2 SCRUBBING AGENT

1. TYPE MgO

2. SOURCES OF SUPPLY Sea Water or Calcined magnesite

3. CHEMICAL COMPOSITION (for each source) 90% Purity

4. EXCESS SCRUBBING AGENT USED ABOVE STOICHIOMETRIC REQUIREMENTS 3.5% XS in C'fuge Cake *

5. MAKE-UP WATER POINT OF ADDITION 100 gpm 1st stage
12 gpm 2nd stage

6. MAKE-UP ALKALI POINT OF ADDITION 2nd Stage

* In addition to 2-3% unavoidable MgO loss.

J. SCRUBBER TRAIN SPECIFICATIONS

1. SCRUBBER NO. 1 [(a)]

TYPE (VENTURI) 2-Stage

LIQUID/GAS RATIO, G/MCF @ 117 °F 20 (First) 40 (Second)

GAS VELOCITY THROUGH SCRUBBER, FT/SEC ______

MATERIAL OF CONSTRUCTION -Shell Carbon Steel

TYPE OF LINING FRP - Dudick

INTERNALS:

TYPE (FLOATING BED, MARBLE BED, ETC.) Venturi

NUMBER OF STAGES ______

TYPE AND SIZE OF PACKING MATERIAL ______

PACKING THICKNESS PER STAGE [(b)]

MATERIAL OF CONSTRUCTION, PACKING: ______

SUPPORTS: ______

2. SCRUBBER NO. 2 [(a)]

TYPE (TOWER/VENTURI) ______

LIQUID/GAS RATIO. G/MCF @ °F ______

GAS VELOCITY THROUGH SCRUBBER, FT/SEC ______

MATERIAL OF CONSTRUCTION ______

TYPE OF LINING ______

INTERNALS:

TYPE (FLOATING BED, MARBLE BED, ETC.) ______

NUMBER OF STAGES ______

TYPE AND SIZE OF PACKING MATERIAL ______

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) ____________

MATERIAL OF CONSTRUCTION, PACKING: ____________

SUPPORTS: ____________

3. CLEAR WATER TRAY (AT TOP OF SCRUBBER)

TYPE ____________

L/G RATIO ____________

SOURCE OF WATER ____________

4. DEMISTER - **Identical each stage**

TYPE (CHEVRON, ETC.) **Baffle**

NUMBER OF PASSES (STAGES) **3 Stage Impingement**

SPACE BETWEEN VANES **2 inch**

ANGLE OF VANES **45°**

TOTAL DEPTH OF DEMISTER **12 inch**

DIAMETER OF DEMISTER **annular - 10 ft/sec**

DISTANCE BETWEEN TOP OF PACKING AND BOTTOM OF DEMISTER ____________

POSITION (HORIZONTAL, VERTICAL) ____________

MATERIAL OF CONSTRUCTION **FRP**

METHOD OF CLEANING **Centrate Up-Spray**

SOURCE OF WATER AND PRESSURE ____________

FLOW RATE DURING CLEANINGS, GPM ____________

FREQUENCY AND DURATION OF CLEANING **Once/Day**

REMARKS **Demister wash velocity 10 ft/sec. Washed once per shift 2 gal/ft^2 12 sections at 5 to 10 min. each.**

5. REHEATER **N/A**

TYPE (DIRECT, INDIRECT) ____________

b) For floating bed, packing thickness at rest.

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DUTY, MMBTU/HR ______________

HEAT TRANSFER SURFACE AREA SQ.FT ______________

TEMPERATURE OF GAS: IN ________ OUT ______________

HEATING MEDIUM SOURCE ______________

TEMPERATURE & PRESSURE ______________

FLOW RATE ________ LB/HR

REHEATER TUBES, TYPE AND MATERIAL OF CONSTRUCTION ______________

REHEATER LOCATION WITH RESPECT TO DEMISTER ______________

____

METHOD OF CLEANING ______________

FREQUENCY AND DURATION OF CLEANING ______________

FLOW RATE OF CLEANING MEDIUM ________ LB/HR

REMARKS ______________

____

____

6. SCRUBBER TRAIN PRESSURE DROP DATA

	INCHES OF WATER
PARTICULATE SCRUBBER	11
SO_2 SCRUBBER	6-12
CLEAR WATER TRAY	
DEMISTER	1
REHEATER	
DUCTWORK	10
TOTAL FGD SYSTEM	35

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

TO: DEMISTER ____________________

QUENCH CHAMBER ____________________

ALKALI SLURRYING ____________________

PUMP SEALS ____________________

OTHER ____________________

TOTAL ____________________

FRESH WATER ADDED PER MOLE OF SULFUR REMOVED __________

8. BYPASS SYSTEM

CAN FLUE GAS BE BYPASSED AROUND FGD SYSTEMS __________

GAS LEAKAGE THROUGH BYPASS VALVE, ACFM __________

K. TANK DATA

	pH	% Solids	Capacity (gal)	Hold up time
ALKALI SLURRY MAKEUP TANK				
PARTICULATE SCRUBBER EFFLUENT HOLD TANK (a)				
SO_2 SCRUBBER EFFLUENT HOLD TANK (a)	7	5-10		

L. SO_2 RECOVERY

NAME OF PROCESS ____________________

LICENSOR/DESIGNER ____________________

SYSTEM'S CAPACITY ____________________ T/HR

RAW MATERIAL REQUIRED ____________________

M. DISPOSAL OF CONTAMINANTS

PURGE STREAM, gpm ______________________

AMOUNT OF CONTAMINANTS IN STREAM ______________________

DESCRIBE METHOD OF CONCENTRATION AND DISPOSAL OF CONTAMINANTS Purge requirement does not exceed 5% and is accomplished through natural losses. Present MgO loss is 10%.

N. COST DATA

1. TOTAL INSTALLED CAPITAL COST (95 MW) $\$6.5 \times 10^6$ (PEPCO)

2. ANNUALIZED OPERATING COST ______________________

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		
	SO_2 RECOVERY SYSTEM INCLUDING H_2S GENERATOR		X	
	GAS QUENCHING & CLEANING	X		
	SITE IMPROVEMENTS	X		
	LAND, ROADS, TRACKS,	X		
	ENGINEERING COSTS	X		
	CONTRACTORS FEE	X		
	SUBSTATION ($500 K)		X	
	INTEREST ON CAPITAL DURING CONSTRUCTION		X	Work in progress is capitalized.
B.	ANNUALIZED OPERATING COST			
	FIXED COSTS			
	INTEREST ON CAPITAL			15-1/2% (bracketed: interest on capital, depreciation, insurance & taxes)
	DEPRECIATION			
	INSURANCE & TAXES			
	LABOR COST INCLUDING OVERHEAD			
	VARIABLE COSTS			
	RAW MATERIAL			
	UTILITIES			
	MAINTENANCE			

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4. COST FACTORS

a. ELECTRICITY ____________________

b. WATER ____________________

c. STEAM (OR FUEL FOR REHEATING) ____________________

d. SULFUR/SULFURIC ACID SELLING COST __________ $/TON

e. RAW MATERIAL PURCHASING COST ________ $/TON OF DRY SLUDGE

f. LABOR:

		HOURS/WEEK	WAGE
	SUPERVISOR		
	OPERATOR	168	
	OPERATOR HELPER	168	
	MAINTENANCE	50-60	

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

1. SO_2 SCRUBBER, CIRCULATION TANK AND PUMPS.

a. PROBLEM/SOLUTION Corrosion and erosion of 2nd stage piping and pumps. Two-year pipe life. Six-month impeller life. Rubber lining is suggested. All pumps are spared. Centrifuge and dryer are not spared.

2. DEMISTER

PROBLEM/SOLUTION Broken by physical abuse. (People walking on demister).

3. REHEATER

PROBLEM/SOLUTION ____________________

4. VENTURI SCRUBBER, CIRCULATION TANKS AND PUMPS

PROBLEM/SOLUTION Rubber-lined fan with Inconel wheel is satisfactory.

5. I.D. BOOSTER FAN AND DUCT WORK

PROBLEM/SOLUTION

6.

PROBLEM/SOLUTION Occasional plow breakage in centrifuge. Occasional freeze-up during centrifuge shutdown indicates that a more thorough cleanout procedure is necessary.

7. GAS QUENCHING AND CLEANING

PROBLEM/SOLUTION

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8. MISCELLANEOUS AREA INCLUDING BYPASS AND PURGE STREAM SYSTEM

PROBLEM/SOLUTION Bypass dampers bind and leak. Piping leaks force shutdowns. MgO mixing problem forced installation of premix tank. Heat to 160°F. Boiling gels slurry. Bucket elevator to $MgSO_3$ silo limits drying to 70% design capacity. Larger buckets to be installed.

P. DESCRIBE FACTORS WHICH MAY NOT MAKE THIS A REPRESENTATIVE INSTALLATION No economical regen. facility. No surge provisions.

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.

pH Control. Measure pH in second stage system. Downward pH triggers MgO addition. Liquid flows are constant.

S. ADDITIONAL NOTES

Actual inlet gas at 259°F. Recycle liquor at 125-130°F.

Pennwalt acid cement in stack.

90% SO_2 efficiency at 270,000 acfm.

4:1 turndown capability

Breaker should be installed at $MgSO_3$ storage silo discharge.

Dryer fuel design 2 gpm. 87.3 lb/min dry $MgSO_3$.

Virgin MgO $150/ton FOB Florida

Compliance decision due June 1975. Also considering low sulfur fuel.

Purchased 100 coal cars @ $80 K - 1 year delivery

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-650/2-75-057-g	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Survey of Flue Gas Desulfurization Systems Dickerson Station, Potomac Electric Power 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; ROAP 21ACX-130
		11. CONTRACT/GRANT NO. 68-02-1321, Task 6g
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; 2/75-8/75
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

The report gives results of a survey of a flue gas desulfurization system, utilizing the Chemico/Basic MgO-SO2 removal/recovery process, that has been retrofitted to handle approximately half of the exhaust gas from the 190 MW unit 3 at Potomac Electric Power Company's Dickerson Station. The system was installed at a cost of $C.5 million. The boiler burns 2 percent sulfur coal and is equipped with a 94 percent efficient electrostatic precipitator. A single two-stage scrubber/absorber is used. The liquor streams for the two stages are separate, both operating in a closed-loop mode. Magnesium oxide (MgO) is regenerated off-site.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution	Combustion	Air Pollution Control	13B
Flue Gases	Electrostatic Precipitators	Stationary Sources	21B
Desulfurization		Chemico/Basic Process	07A, 07D
Sulfur Dioxide	Scrubbers	Scrubber/Absorber	07B
Magnesium Oxides	Absorbers		
Coal			21D

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