EPA-650/2-75-057-d

August 1975

Environmental Protection Technology Series

SURVEY OF FLUE GAS DESULFURIZATION SYSTEMS

PADDY'S RUN STATION, LOUISVILLE GAS AND ELECTRIC

UNITED STATES · ENVIRONMENTAL PROTECTION AGENCY

EPA-650/2-75-057-d

SURVEY OF FLUE GAS DESULFURIZATION SYSTEMS

PADDY'S RUN STATION, LOUISVILLE GAS AND ELECTRIC

by

Gerald A. Isaacs

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

Contract No. 68-02-1321, Task 6d
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

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-d

ACKNOWLEDGMENT

This report was prepared under the direction of Mr. Timothy W. Devitt. The principal author was Dr. Gerald A. Isaacs.

Mr. Wade H. Ponder, former EPA Project Officer, had primary responsibility within EPA for this project report. Information and data on plant operation were provided by Mr. R. P. Van Ness, Louisville Gas and Electric Company and by Mr. Peter Maurin, Combustion Engineering, Inc. during and subsequent to the survey visit. Mr. Charles D. Fleming was responsible for editorial review of this report.

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

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY

The flue gas desulfurization (FGD) system on Unit No. 6 at the Paddy's Run Power Station of Louisville Gas and Electric Company was designed by Combustion Engineering, Inc. System start-up occurred in April 1973. The system utilizes a slurry of carbide lime in a marble-bed scrubber. The carbide lime, a waste by-product obtained from a nearby acetylene manufacturing plant, contains 90 to 92 percent calcium hydroxide, 2 to 2.5 percent silica, 3 to 8 percent calcium carbonate, and 0.1 percent magnesium oxide. The system operates in a closed-loop mode. Sludge is stabilized by mixing thickener underflow with carbide lime before vacuum filtration. The sludge, containing about 40 percent solids, is trucked to a nearby ten-acre borrow pit that is used as a landfill area.

The Paddy's Run Power Station is used primarily to meet summer peaking loads. The No. 6 boiler is operated infrequently because of its low thermal efficiency (heat rate is about 13,000 BTU/KWH). The entire station may be phased-out in the near future. However, on the basis of the performance of the Paddy's Run FGD system, Louisville Gas and Electric Company is pursuing plans to install similar carbide lime FGD systems at other power stations.

SUMMARY OF FGD DATA, PADDY'S RUN UNIT NO. 6

Unit rating	65 MW (nameplate), 70 MW (maximum continuous, net)
Fuel characteristics	Coal: 11,000 BTU/lb;, 14% ash, 3-4% sulfur (as-received)
FGD vendor	Combustion Engineering, Inc.
Process	Lime scrubbing
New or retrofit	Retrofit
Start-up date	April 1973
FGD modules	Two
Efficiency, %	
Particulates	99.1 (precipitator)
SO_2	85
Make-up water	0.7 gpm/MW (net)
Sludge disposal	Stabilized sludge disposed in off-site landfill
Unit cost	$3.7 million ($53/net KW) - Capital $905,000 (2.5 mills/net KWH) - Operating[a]

[a] Annualized cost projected for 60% capacity factor includes 15% fixed charge.

1.0 INTRODUCTION

The Control Systems Laboratory (CSL) of the U.S. Environmental Protection Agency (EPA) has initiated a study to evaluate the status of flue gas desulfurization (FGD) systems on coal-fired boilers in the United States. This report on the Paddy's Run Power Station of the Louisville Gas and Electric Company (LG&E) 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 total installed and annualized operating costs.

This report is based upon information obtained during a plant inspection on July 9, 1974, and on data provided by LG&E and Combustion Engineering, Inc. 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. Appendices present details of plant and system operation and photos of the installation.

2.0 FACILITY DESCRIPTION

2.1 PLANT LOCATION

The Paddy's Run Power Station of Louisville Gas and Electric Company is located on the Ohio River in Rubbertown, about 10 miles southwest of the center of Louisville, Kentucky. The terrain around the Paddy's Run Station is relatively flat and highly industrialized.

Of the six generators at Paddy's Run only the boiler on Unit 6 is retrofitted with an FGD system.

2.2 BOILER DATA

The boiler on Unit 6, is a dry-bottom, pulverized-coal-fired unit designed and installed by Foster-Wheeler in 1951. The generator operates as a peaking unit and has a nameplate rating equivalent to 65 MW. Its maximum electrical generating capacity is 70 MW. The station operated at an approximate 5 percent load factor in 1974. The heat rate for Unit 6 ranges from 13,000 to 13,500 BTU/KWH.

The coal now being burned has an average heating value (as-received) of 12,400 BTU/lb. Ash and sulfur contents are 14 and 3-4 percent, respectively.

2.3 POLLUTION CONTROLS

A Research-Cottrell electrostatic precipitator (ESP), operating with an efficiency of 99.1 percent provides primary control of particulate emissions. Particulate loading at the outlet of the ESP unit is approximately 0.05 grains per standard cubic foot (gr/scf).

The maximum particulate emission allowed under the Air Pollution Control Regulation No. 3.1.3 of Jefferson County, dated April 19, 1972 is 0.1 lb/MM BTU of heat input. Present particulate emissions from the unit were indicated to be in compliance with that regulation.

Atmospheric emissions of sulfur dioxide are limited by Regulation No. 4.0.1 to 1.2 lb/MM BTU of heat input. Continuous monitoring equipment shows that SO_2 emissions are within the 1.2 lb/MM BTU limit.

All six generators at the Paddy's Run Station operate intermittently, on demand, to meet peak load demands only. For that reason there are no plans to retrofit additional boilers at the station with FGD systems. Data on plant operation and emissions appear in Table 2.1.

Table 2.1 PERTINENT DATA ON PLANT DESIGN, OPERATION AND ATMOSPHERIC EMISSIONS LG&E - PADDY'S RUN, UNIT NO. 6

Boiler Data	Item
Maximum continuous generating capacity, MW (net)	70
Average capacity factor (1974), %	5.0
Boiler manufacturer	Foster-Wheeler
Year placed in service	1951
Maximum heat input, MM BTU/hr	910
Stack height above grade, ft	250
Maximum flue gas rate, acfm @ 335°F	400,000
Emission controls:	
Particulate	Electrostatic precipitator
SO_2	Marble-bed tower
Particulate emission rate:	
Allowable, lb/MM BTU	0.1
Actual, lb/MM BTU	0.1
SO_2 emission rate:	
Allowable, lb/MM BTU	1.2
Actual, lb/MM BTU	1.2

3.0 FLUE GAS DESULFURIZATION SYSTEM

3.1 PROCESS DESCRIPTION[a]

The FGD system at the Paddy's Run Station of LG&E was designed by Combustion Engineering, Inc. Start-up for the FGD plant occurred in April 1973. The lime scrubbing system utilizes calcium hydroxide sludge which is generated as a waste by-product from a nearby acetylene manufacturing plant. In this FGD process a slurried mixture of calcium hydroxide and calcium sulfite in water constitutes the scrubbing liquor. Reaction with SO_2 in the flue gas takes place in the liquid phase, where dissolution of calcium sulfite is the rate-controlling step for SO_2 absorption.

Following are the principal chemical reactions involved in this FGD process:

Sulfite formation $$Ca(OH)_2 + SO_2 \longrightarrow CaSO_3 + H_2O \quad (1)$$

Bisulfite formation $$CaSO_3 + SO_2 + H_2O \longrightarrow Ca(HSO_3)_2 \quad (2)$$

Bisulfite neutralization

$$Ca(HSO_3)_2 + Ca(OH)_2 \longrightarrow 2\ CaSO_3 + 2H_2O \quad (3)$$

Sulfate formation $$2\ CaSO_3 + O_2 \longrightarrow 2\ CaSO_4 \quad (4)$$

Sulfate formation (Reaction 4) is detrimental to FGD systems because the sulfate scales and plugs process equipment.

---

[a] Adapted from "The Combustion Engineering Lime Wet Scrubbing Process: from Concept to Commercial Operation," by J.R. Martin, B.M. Minor, and A.L. Plumley, Combustion Engineering, Inc. October 22-24, 1974, and supplemented with information obtained during plant visit.

The FGD system consists of two identical modules each sized to handle 175,000 acfm of flue gas at 350°F. Figure 3.1 is a general process flow diagram for the installation. Each scrubber module is constructed of mild steel coated with a 1/2-in.-thick fiberglass reinforced polyester (FRP) flake lining. Internal supports are constructed of type 316 stainless steel. Flue gas enters each scrubber module near the base and contacts nonatomizing sprays which provide a constant supply of slurry to the underside of the two stages of marble beds. This slurry of calcium sulfite and calcium hydroxide also serves to cool the flue gas adiabatically to its saturation temperature before it enters the marble bed. The wetted flue gas rises through the bed (consisting of a 3-inch-thick layer of 1-inch-diameter marbles when at rest) and carries the slurry with it. The vigorous action of the marbles mixes the flue gas and slurry to form a "turbulent layer" above the marble bed. The thickness of the layer is controlled by the height of the overflow pots. The turbulent layer provides necessary retention time and mixing intensity to obtain the required degree of SO_2 absorption and particulate removal. After emerging from the second marble bed, the clean flue gas passes through a two-stage chevron mist eliminator where entrained water droplets are agglomerated and removed. The flue gas then passes through a gas-fired reheater, through a booster fan, and out the stack.

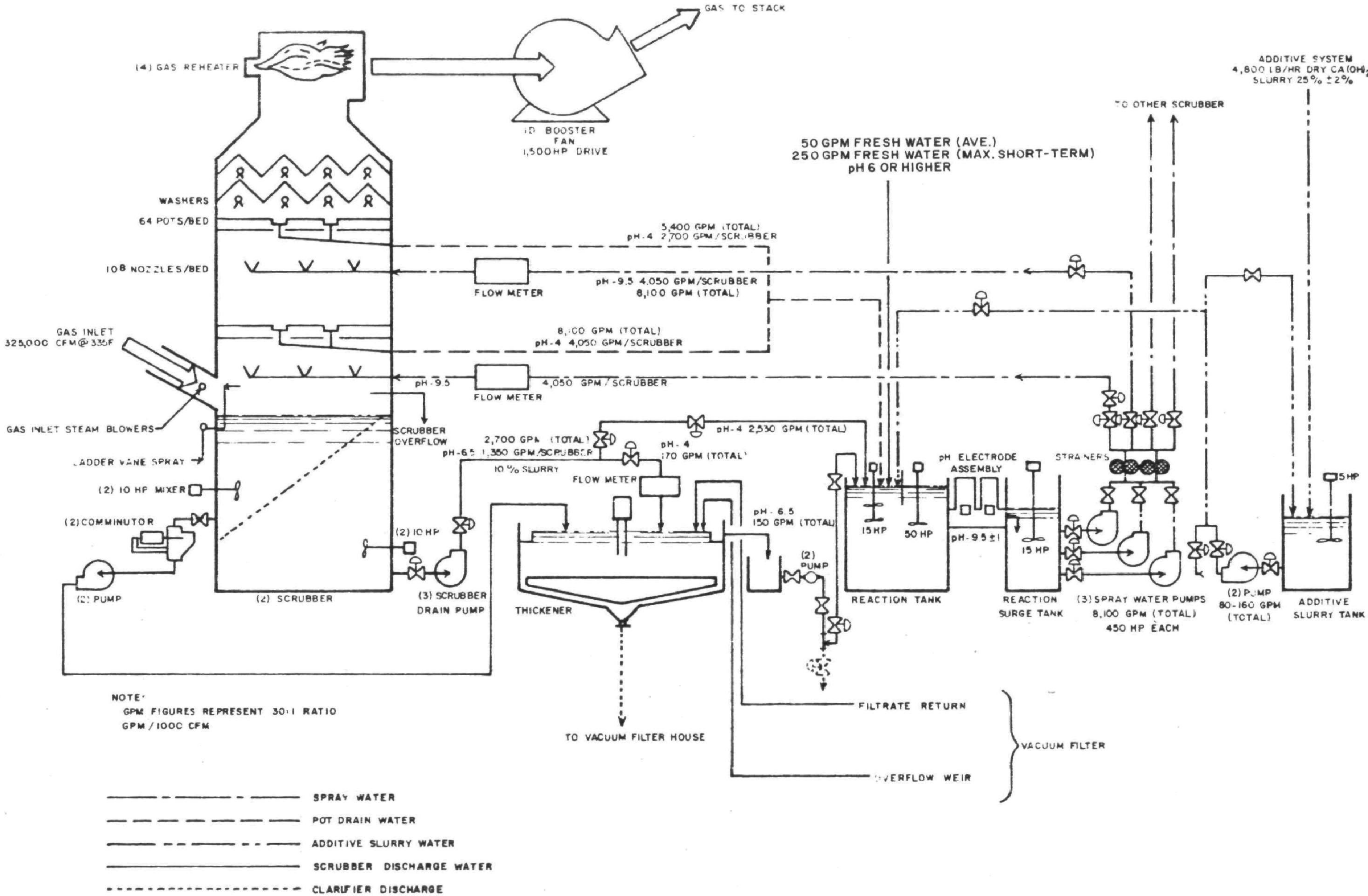

Figure 3.1 General flow diagram of the FGD system at Paddy's Run.
(Courtesy: Combustion Engineering, Inc.)

The underflow from the thickener is sent to a rotary vacuum filter. Filter cake is trucked to an off-site landfill area. Vacuum filtrate is recycled to the thickener, and pumped back to the reaction tank to close the liquid effluent loop.

Slurry rejected from below the first bed falls onto a sloping screen in the scrubber bottom. Large particles in the slurry, such as mud or stray marbles are pulverized and purged periodically from the system to the thickener via a comminutor unit. Most of the remainder of the reject slurry is returned to the reaction tank for reuse. All the calcium bisulfite slurry that leaves the beds through the overflow pots is fed by gravity back to the reaction tank, where it is contacted by fresh slaked carbide lime and converted to calcium sulfite. Other streams entering the reaction tank include weir water from the thickener, return water from the vacuum filter, make-up water, and slurry additives. Mechanical agitators in the tank thoroughly blend the ingredients to maximize the dissolution of additives and to complete calcium salt precipitation reactions. A reaction surge tank downstream from the reaction tank further ensures that if any short circuiting of the reaction tank occurs, precipitation of calcium salts (scale) will occur in the surge tank rather than in the slurry piping. Slurry is pumped back to the scrubber spray nozzles from the reaction surge tank via two half-size slurry pumps. Part of the slurry is bled to the thickener tank to prevent buildup of waste by-product solids in the scrubber.

3.2 DESIGN PARAMETERS

Unit 6 at the Paddy's Run Station is a 65 MW generator with a maximum continuous output capability of 70 MW. At peak load the gas flow from the boiler is 400,000 acfm at 335°F. This exhaust gas is handled by two absorber modules, each 17 x 18 ft x 50 ft high overall. System design incorporates the use of an existing ESP operating at a particulate removal efficiency of 99.1 percent.

The solids content of the slurry leaving the absorber ranges between 9.5 and 10.5 percent. The ratio of sulfite to sulfate in the recirculating slurry ranges between 40 and 50 on a weight basis. Liquid to gas ratio (L/G) ranges between 15 and 18 gal./1000 ft^3 of gas at 125°F per stage. Slurry additive contains 20 to 30 percent solids and has a pH of 12.6. Lime is added to the thickener tank to stabilize the sludge that is formed. Lime consumption at that point is about 100 lb/ton of dry sludge solids generated. The sludge is trucked and landfilled in a ten-acre borrow pit that ranges from 20 to 30 feet in depth. Solids content of the effluent from the thickener averages about 25 percent. This material is then dewatered by vacuum filtration to form a stabilized sludge containing 45 percent solids. An experiment is planned in which the thickener effluent will be mixed with dry fly ash and lime to form stabilized sludge with a 45 percent solids content.

The liquid system operates in a closed-loop mode. About 40 gallons of make-up water are added per lb-mol of

SO_2 removed. Pressure drop across the absorber ranges from 11 to 12 in. H_2O. Total pressure drop across the FGD system is 15 to 16 in. H_2O. Two rotary drum filters, each having an effective filtering area of 150 ft^2, are used to dewater sludge. The filters utilize nylon cloth and do not require a precoat. Each filter has a wet cake capacity of approximately 10 ton/hr. Operating parameters are summarized in Tables 3.1. and 3.2.

3.3 INSTALLATION SCHEDULE

In 1970 LG&E requested Combustion Engineering, Inc. to determine if their lime scrubbing system could be adapted to the Paddy's Run Power Station. The unique aspect of this station is that it is located near an Airco acetylene manufacturing plant that generates a calcium hydroxide sludge by-product that can be used as a scrubbing agent in the FGD process. Laboratory pilot plant studies were conducted in early 1971, and a process was developed and tested using a prototype 12,000 acfm scrubber in June 1971. After the successful completion of a 100-hour continuous test, Combustion Engineering, Inc. was given a contract to design and build a full-size system to control Boiler 6 at the Paddy's Run Power Station (July 1971). On-site construction of the FGD system was begun in June 1972 and completed in April 1973. Initial start-up occurred on April 5, 1973. No major delays or start-up problems were indicated. System shakedown was completed by July 1973.

Table 3.1 SUMMARY OF DATA - SCRUBBER MODULES

Item	
L/G ratio gal./1000 acf @ 125°F	15 - 18
Superficial gas velocity, ft/sec	8 - 10
Module size, (2 modules)	17' x 18' x 50' high
Equipment intervals	Marble bed
Material of construction	
Shell	Mild steel 2 1/2" thick FRP flake lining
Internals	316 stainless

Table 3.2 SUMMARY OF DATA - FGD SYSTEM TANKS

Item	Scrubber recirculation tank	Thickener	Reaction tank	Reaction surge tank	Additive slurry tank
No. of units	2	1	1	1	1
Unit size and capacity	15' x 17' x 16' high (16,300 gal.)	50' dia x 14' high (205,500 gal.)	48' dia x 17' high (210,000 gal.)	20' dia x 15' high (35,200 gal.)	8 dia x 17' high (6,400 gal.)
Retention time at full load	3 min	4.3 hr	20 min	3 min	2 1/2 hrs
Temp., °F	126	100-110	125	125	ambient
pH	4.6-5.3	5-6	8	8	12.6
Solids Conc., %	10	10 in 20-24 out	10	10	30
Specific gravity	1.1	1.1	1.1	1.1	1.2
Material of construction	mild steel with 1/2" thick FRP flake lining	mild steel	mild steel	mild steel	mild steel

3.4 COST DATA

The installed capital cost for this unit was $3.7 million ($53/net KW). Annualized operating costs are projected to be $350,000 at a 60 percent load factor for the unit, in addition to fixed charges (14 to 17%). Using a fixed charge factor of 15 percent, the annualized cost is calculated to be $905,000 or 2.5 mills/net KWH.

4.0 FGD SYSTEM PERFORMANCE

4.1 START-UP PROBLEMS AND SOLUTIONS[a]

No major start-up problems were encountered that were associated with the scrubbers. Problems with other system components were described as follows:

Thickener Size - The original thickener was undersized to handle the untreated slurry at full load. Preliminary data had indicated that the slurry material entering the thickener would contain more calcium sulfate than was actually encountered. The slurry actually contained a high ratio of calcium sulfite to calcium sulfate. Calcium sulfite crystals are flakier and less dense than calcium sulfate crystals and, having a high surface area, require a flocculant to aid settling. The flocculant, Betz 1100, agglomerated the calcium sulfite crystals so that settling was sufficiently improved and a larger thickener did not have to be installed. The flocculant was injected into the thickener at a rate sufficient to maintain a 4-7 ppm concentration in the thickener.

Carbide Lime Feed System - Some early problems were experienced with plugging of the mesh strainer on the

---

[a] Adapted from "Operational Status and Performance of the Louisville FGD System at the Paddy's Run Station," R.P. Van Ness, Louisville Gas and Electric Co., Nov. 2-7, 1974 and supplemented with data obtained during plant visit.

additive tank. This problem was solved by installing a Rietz mechanical disintegrator in the carbide feed line to the additive tank.

Mist Eliminator Wash System - The original mist eliminator wash system consisted of rotating nonretractable wash lances with 3/16-inch diameter nozzles every 6 inches. The system would not efficiently clean the upper mist eliminator. The nonretractable lances were replaced with retractable half-track lances with oscillating 1/2 inch nozzles. The larger solid stream of water from these nozzles keeps the mist eliminators clean. At full load 200 gal./min of river water are required per scrubber for about 8 to 12 minutes every 8 hours for demister washing.

Scaling - At this plant scale formation does not occur as long as both of the following conditions are met: 1) fly ash must not constitute more than about 6 percent of the slurry solids, and 2) slurry pH must be maintained between 8.0 and 9.5. Slurry pH is measured downstream from the reaction tank. Additive lime is pumped to the reaction tank from the additive slurry tank. Scaling potential does not seem to be influenced by the oxygen content of the exhaust gas which typically ranges between 6 and 9 percent.

On one occasion while burning low sulfur coal calcium sulfite scale deposits began to accumulate on the upper bed because the SO_2 concentration there was too low to keep the bed pH less than 6.2. The scale was dissolved by temporarily lowering the overall system pH.

Damper Leakage - The FGD system can be bypassed by means of louvered dampers. Deposits on these dampers were found to prevent them from sealing completely so that leakage through the dampers resulted in the formation of a visible plume. By cleaning the dampers periodically the leakage was maintained at a minimum, and the plume effectively suppressed.

4.2 PERFORMANCE TEST RUN

Efficiency tests on the FGD system were performed during a 35-day demonstration period beginning October 26, 1973. The "B" scrubber module was operated continuously at full load conditions throughout the test period, and an SO_2 removal efficiency exceeding 85 percent was demonstrated.

4.3 PERFORMANCE PARAMETERS

System availability has been tabulated by LG&E since April 1973. Availability is defined as the percent ratio of FGD module operating hours to boiler operating hours. Since the unit is a peak load boiler, boiler runs are frequently short, and on several occasions the FGD system was bypassed although it could have been operated. Thus, in some months the availability figures would have been higher if the system had been operated to its full potential. Table 4.1 lists the availability figures for both modules of the system.

4.4 PROCESS MODIFICATIONS FOR FUTURE INSTALLATIONS

In the existing installation sludge filter cake containing about 45 percent solids is trucked to a landfill

Table 4.1 AVAILABILITY SUMMARY - PADDY'S RUN

Period	Boiler operating hours	FGD operating hours		Availability, %[a]	
		Module A	Module B	Module A	Module B
4/73	320	58	179	18	56
5/73	265	29	172	11	65
6/73	255	0.25	15	0.1	6
7/73	240	50	50	21	21
8/73	330	175	211	53	64
9/73	390	332	281	85	72
10/73	690	338	649	49	94
11/73	720	252	720	35	100
12/73	190	84	148	44	78
1/74	0	0	0	0	0
2/74	142	0	0	0	0
3/74	54	0	0	0	0
4/74	52	0	0	0	0
5/74	167	0	0	0	0
6/74	5	0	0	0	0
7/74	306	156	248	51	81
8/74	31	15.5	24	50	77
9/74	43	0	0	0	0
10/74	245	245	245	100	100
11/74	122	0	0	0	0
12/74	0	0	0	0	0
1/75	0	0	0	0	0
2/75	0	0	0	0	0

[a]Availability is defined as the percent ratio of FGD module operating hours to boiler operating hours.

area and mixed with fly ash to produce a reasonably stable material. In future installations it is anticipated that the sludge handling system will be considerably modified. It has been suggested that material from the thickener or filter should be thoroughly mixed with appropriate quantities of fly ash and lime at the power plant and pumped to the landfill area. The fixated material would then solidify to an environmentally acceptable material.

APPENDIX A

PLANT SURVEY FORM

PLANT SURVEY FORM

NON-REGENERABLE FGD PROCESSES

A. COMPANY AND PLANT INFORMATION

1. COMPANY NAME Louisville Gas and Electric Co.
2. MAIN OFFICE 311 West Chestnut Street
3. PLANT MANAGER Walter Carter
4. PLANT NAME Paddy's Run
5. PLANT LOCATION Rubbertown, Kentucky
6. PERSON TO CONTACT FOR FURTHER INFORMATION R.P. Van Ness
7. POSITION Manager-Environmental Affairs
8. TELEPHONE NUMBER (502) 582-3511 Ext. 216
9. DATE INFORMATION GATHERED July 9, 1974
10. PARTICIPANTS IN MEETING

PARTICIPANTS IN MEETING	AFFILIATION
R. P. Van Ness	LG&E
John Busik	U.S. EPA
T. W. Devitt	PEDCo
F. K. Zada	PEDCo

These data were reported on July 9, 1974. Some 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	5	6
CAPACITY, MW	30 each	65	65	65	65
SERVICE (BASE, PEAK)	PEAK	PEAK	PEAK	PEAK	PEAK
FGD SYSTEM USED	No	No	No	No	Yes

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

1. BOILER IDENTIFICATION NO. No. 6
2. MAXIMUM CONTINUOUS HEAT INPUT 810 MM BTU/hr
3. MAXIMUM CONTINUOUS GENERATING CAPACITY 70 MW
4. MAXIMUM CONTINUOUS FLUE GAS RATE, Approx. 350,000 ACFM @ 350 °F
5. BOILER MANUFACTURER Foster Wheeler
6. YEAR BOILER PLACED IN SERVICE 1951
7. BOILER SERVICE (BASE LOAD, PEAK, ETC.) PEAK
8. STACK HEIGHT 250'
9. BOILER OPERATION HOURS/YEAR (1973) 3667
10. BOILER CAPACITY FACTOR * 5% (1974)
11. RATIO OF FLY ASH/BOTTOM ASH 8 to 1

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

 5/17/74

D. FUEL DATA

1. COAL ANALYSIS (as received)

	MAX.	MIN.	AVG.
GHV (BTU/LB.)	13,000	11,500	12,400
S %	4.6	1.4	3.71
ASH %	15.4	9.4	13.8

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

GRADE			
S %			
ASH %			

E. ATMOSPHERIC EMISSIONS

1. APPLICABLE EMISSION REGULATIONS

	PARTICULATES	SO_2
a) CURRENT REQUIREMENTS	.1	1.2
AQCR PRIORITY CLASSIFICATION	1	1
REGULATION & SECTION NO.	APC Regs. of Jefferson Cnty Dated 4/19/72	
MAX. ALLOWABLE EMISSIONS LBS/MM BTU	.1	1.2
b) FUTURE REQUIREMENTS, COMPLIANCE DATE		
REGULATION & SECTION NO.		
MAXIMUM ALLOWABLE EMISSIONS LBS/MM BTU		

2. PLANT PROGRAM FOR PARTICULATES COMPLIANCE

In compliance

3. PLANT PROGRAM FOR SO_2 COMPLIANCE

No further compliance planned due.

Plant being a peaking facility.

F. PARTICULATE REMOVAL

1. TYPE

	MECH.	E.S.P.	FGD
MANUFACTURER		Res. Cot.	C.E.
EFFICIENCY: DESIGN/ACTUAL		97.5/99.1	80/85-90 SO_2 99+ (P.
MAX. EMISSION RATE* LB/HR		9-9.5	7-9
GR/SCF		.05	.05G/SCF
LB/MMBTU		.1	1.2

DESIGN BASIS, SULFUR CONTENT 3.5

G. DESULFURIZATION SYSTEM DATA

1. PROCESS NAME Lime wet tail-end scrubber system
2. LICENSOR/DESIGNER NAME: Combustion Engineering
   ADDRESS: Windsor, Conn.
   PERSON TO CONTACT: Peter Maurin
   TELEPHONE NO.: 203-688-1911
3. ARCHITECTURAL/ENGINEERS, NAME: Pioneer Services
   ADDRESS: Chicago, Illinois
   PERSON TO CONTACT: Jack Byrnes
   TELEPHONE NO.: 312-822-2600
4. PROJECT CONSTRUCTION SCHEDULE:

	DATE
a) DATE OF PREPARATION OF BIDS SPECS.	Approx. 10/70
b) DATE OF REQUEST FOR BIDS	Dec. 1970
c) DATE OF CONTRACT AWARD	July 1971
d) DATE ON SITE CONSTRUCTION BEGAN	June 1972
e) DATE ON SITE CONSTRUCTION COMPLETED	April 1973
f) DATE OF INITIAL STARTUP	4/5/73
g) DATE OF COMPLETION OF SHAKEDOWN	July 1973

*At Max. Continuous Capacity

5. LIST MAJOR DELAYS IN CONSTRUCTION SCHEDULE AND CAUSES:

No particular difficulties.

6. NUMBER OF SO_2 SCRUBBER TRAINS USED — Two

7. DESIGN THROUGHPUT PER TRAIN, ACFM @ 350 °F — 350,000/175,000

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

2) EQUIPMENT LAYOUT

H. SO_2 SCRUBBING AGENT

1. TYPE — Carbide Lime

2. SOURCES OF SUPPLY — Airco, Inc.

3. CHEMICAL COMPOSITION (for each source)

$Ca(OH)_2$	90-92
SILICA	2.0-2.5
CALCIUM CARBONATE	3-8
MAGNESIUM OXIDE	.1

4. EXCESS SCRUBBING AGENT USED ABOVE STOICHIOMETRIC REQUIREMENTS — -0-

5. MAKE-UP WATER POINT OF ADDITION — - -

6. MAKE-UP ALKALI POINT OF ADDITION — 20-30% Solids from C_2H_2 Plant

J. SCRUBBER TRAIN SPECIFICATIONS

1. SCRUBBER NO. 1 [(a)] **Two scrubbers in parellel.**

TYPE (TOWER/VENTURI)	Tower
LIQUID/GAS RATIO, G/MCF @ 126 °F	30-15/stage
GAS VELOCITY THROUGH SCRUBBER, FT/SEC	8-12
MATERIAL OF CONSTRUCTION	Mild steel-Stainless Fibre glass
TYPE OF LINING	Flake glass
INTERNALS:	
TYPE (FLOATING BED, MARBLE BED, ETC.)	Marble Bed
NUMBER OF STAGES	2
TYPE AND SIZE OF PACKING MATERIAL	Glass marbles-1"
PACKING THICKNESS PER STAGE [(b)]	3"
MATERIAL OF CONSTRUCTION, PACKING:	Glass
SUPPORTS:	316 stainless

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 NA

SOURCE OF WATER ________

4. DEMISTER

TYPE (CHEVRON, ETC.) Chevron

NUMBER OF PASSES (STAGES) Two

SPACE BETWEEN VANES 1"

ANGLE OF VANES 45°

TOTAL DEPTH OF DEMISTER 5'

DIAMETER OF DEMISTER Rectangular

DISTANCE BETWEEN TOP OF PACKING AND BOTTOM OF DEMISTER 4'-5'

POSITION (HORIZONTAL, VERTICAL) Horizontal

MATERIAL OF CONSTRUCTION Fibre Glass

METHOD OF CLEANING Water Wash-River

SOURCE OF WATER AND PRESSURE River - 60 psi

FLOW RATE DURING CLEANINGS, GPM 100-200

FREQUENCY AND DURATION OF CLEANING 8-12 min/8 hours

REMARKS No problems of scaling or plugging.

5. REHEATER

TYPE (DIRECT, INDIRECT) Direct

b) For floating bed, packing thickness at rest.

DUTY, MMBTU/HR 10/Scrubber

HEAT TRANSFER SURFACE AREA SQ.FT --

TEMPERATURE OF GAS: IN 126 OUT 165

HEATING MEDIUM SOURCE Natural gas

TEMPERATURE & PRESSURE 20

FLOW RATE -- LB/HR

REHEATER TUBES, TYPE AND MATERIAL OF CONSTRUCTION N.A.

REHEATER LOCATION WITH RESPECT TO DEMISTER Above

--

METHOD OF CLEANING None

FREQUENCY AND DURATION OF CLEANING --

FLOW RATE OF CLEANING MEDIUM -- LB/HR

REMARKS --

6. SCRUBBER TRAIN PRESSURE DROP DATA

	INCHES OF WATER
PARTICULATE SCRUBBER	--
SO_2 SCRUBBER	11-12
CLEAR WATER TRAY	--
DEMISTER	1.5
REHEATER	--
DUCTWORK	2.5
TOTAL FGD SYSTEM	15-16

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

TO: DEMISTER Approx. 2500 gal./scrubber/ 8 hrs

QUENCH CHAMBER - -

ALKALI SLURRYING - -

PUMP SEALS 30-40 gallons/min.

OTHER 5 gpm

TOTAL Approx. 50 gpm ±

FRESH WATER ADDED PER MOLE OF SULFUR REMOVED 38 gal./lb mol

8. BYPASS SYSTEM

CAN FLUE GAS BE BYPASSED AROUND FGD SYSTEMS Yes

GAS LEAKAGE THROUGH BYPASS VALVE, ACFM Relatively small

K. SLURRY DATA

	pH	% Solids	Capacity (gal)	Hold up time
LIME/SLURRY MAKEUP TANK	12.6	20-30	9000	1-2 hours
PARTICULATE SCRUBBER EFFLUENT HOLD TANK (a)	NA	NA	NA	NA
SO_2 SCRUBBER EFFLUENT HOLD TANK (a)	8-9.5	10±1/2	200,000	30 min.

L. LIMESTONE MILLING AND CALCINING FACILITIES: INDICATE BOILERS SERVED BY THIS SYSTEM.

TYPE OF MILL (WET CYCLONE, ETC.) _____

NUMBER OF MILLS _____

CAPACITY PER MILL NA T/HR

RAW MATERIAL MESH SIZE _____

PRODUCT MESH SIZE _____

SLURRY CONCENTRATION IN MILL ____________

CALCINING AND/OR SLAKING FACILITIES ____________

SOURCE OF WATER FOR SLURRY MAKE UP OR SLAKING TANK ____________

M. DISPOSAL OF SPENT LIQUOR

1. SCHEMATICS OF SLUDGE & FLY ASH DISPOSAL METHOD

(IDENTIFY QUANTITIES OR SCHEMATIC) ____________

2. CLARIFIERS (THICKENERS)

NUMBER 1

DIMENSIONS 50'x14'

CONCENTRATION OF SOLIDS IN UNDERFLOW 22-24%

3. ROTARY VACUUM FILTER

NUMBER OF FILTERS 2

CLOTH AREA/FILTER 150 ft^2/filter

CAPACITY Approx. 10 TON/HR (WET CAKE)

CONCENTRATION OF SOLIDS IN CAKE 35-45%

PRECOAT (TYPE, QUANTITY, THICKNESS) None

REMARKS ____________

4. SLUDGE FIXATION

POINT OF ADDITIVES INJECTION Thickener

FIXATION MATERIAL COMPOSITION Lime

FIXATION PROCESS (NAME) Ours

FIXATION MATERIAL REQUIREMENT/TONS OF DRY SOLIDS OF SLUDGE

3-5%

ESTIMATED POND LIFE, YRS. ______

CONCENTRATION OF SOLIDS IN FIXED SLUDGE 45

METHOD OF DISPOSAL OF FIXED SLUDGE Trucking

INITIAL SOLIDIFICATION TIME OF FIXED SLUDGE 30 days

5. SLUDGE QUANTITY DATA

POND/LANDFILL SIZE REQUIREMENTS, ACRE-FT/YR ______

IS POND/LANDFILL ON OR OFFSITE Landfill - offsite

TYPE OF LINER None

IF OFFSITE, DISTANCE AND COST OF TRANSPORT 1 mile - 50¢/T

POND/LANDFILL DIMENSIONS AREA IN ACRES 10 approx.
DEPTH IN FEET 20-30

DISPOSAL PLANS; SHORT AND LONG TERM Short

N. COST DATA

1. TOTAL INSTALLED CAPITAL COST $3,700,000

2. ANNUALIZED OPERATING COST $ 350,000

	COST ELEMENTS	INCLUDED IN ABOVE COST ESTIMATE: YES	NO	ESTIMATED AMOUNT OR % OF TOTAL INSTALLED CAPITAL COST
A.	CAPITAL COSTS			
	SO_2 SCRUBBER TRAINS	X		
	LIMESTONE MILLING FACILITIES			
	SLUDGE TREATMENT & DISPOSAL POND	X		
	SITE IMPROVEMENTS	X		
	LAND, ROADS, TRACKS, SUBSTATION	X		
	ENGINEERING COSTS	X		
	CONTRACTORS FEE			
	INTEREST ON CAPITAL DURING CONSTRUCTION		X	
B.	ANNUALIZED OPERATING COST			
	FIXED COSTS			
	INTEREST ON CAPITAL	X		}
177.	DEPRECIATION	X		} 14 - 17%
	INSURANCE & TAXES	X		}
	LABOR COST INCLUDING OVERHEAD	X		
	VARIABLE COSTS			
	RAW MATERIAL	X		
	UTILITIES	X		
	MAINTENANCE	X		

4. COST FACTORS

a. ELECTRICITY ______________

b. WATER ______________

c. STEAM (OR FUEL FOR REHEATING) ______________

d. FIXATION COST ______________ $/TON OF DRY SLUDGE

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

f. LABOR:

	HOURS/WEEK	WAGE
SUPERVISOR	________	________
OPERATOR	________	________
OPERATOR HELPER	________	________
MAINTENANCE	________	________

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

1. SO_2 SCRUBBER, CIRCULATION TANK AND PUMPS.

a. PROBLEM/SOLUTION None (normal wear and tear)

2. DEMISTER

PROBLEM/SOLUTION None

3. REHEATER

PROBLEM/SOLUTION None

5/17/74

4. VENTURI SCRUBBER, CIRCULATION TANKS AND PUMPS

PROBLEM/SOLUTION NA

5. I.D. BOOSTER FAN AND DUCT WORK

PROBLEM/SOLUTION No particular problem

6. LIMESTONE MILLING SYSTEM OR LIME SLAKING

PROBLEM/SOLUTION NA

7. SLUDGE TREATMENT AND DISPOSAL

PROBLEM/SOLUTION No problem to date.

5/17/74

8. MISCELLANEOUS AREA INCLUDING BYPASS SYSTEM

PROBLEM/SOLUTION None. Leakage of louvered dampers. not serious (adjustments).

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

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.

Automatic pH control - Control occurs after reaction tank.

5/17/74

APPENDIX B

PLANT PHOTOGRAPHS

Photo No. 1 View away from Paddy's Run Power Station. The large supply pile of carbide lime shows lightly across the background of the picture.

Photo No. 2 View of Paddy's Run sludge disposal area in borrow pit near highway.

Photo No. 3 Carbide lime supply truck. The lime slurry mix tank appears at the left side of the picture. The Ohio River is in the background.

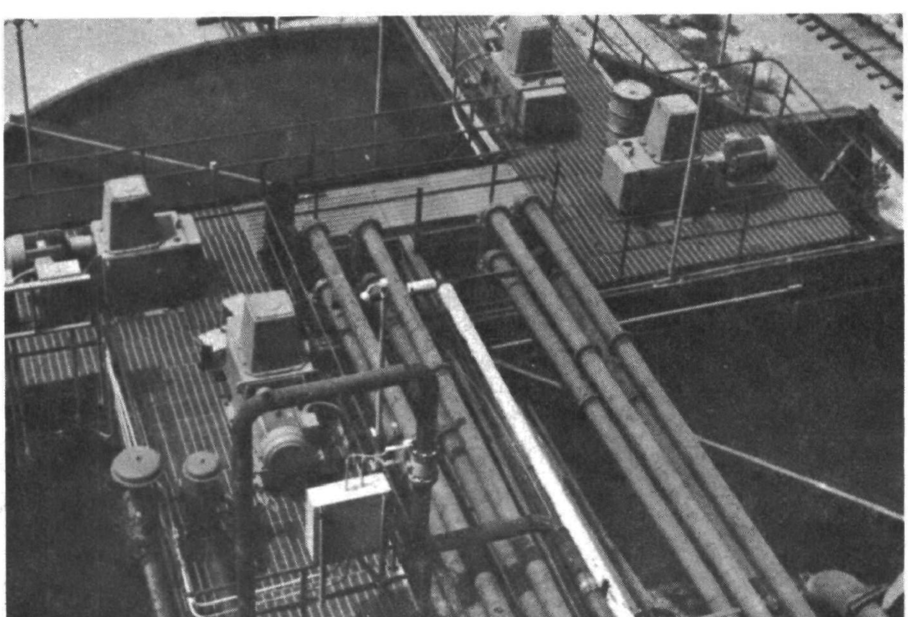

Photo No. 4 View looking down on the reaction tank at Paddy's Run.

Photo No. 5 Internal view of scrubber showing marble bed and screened overflow pots.

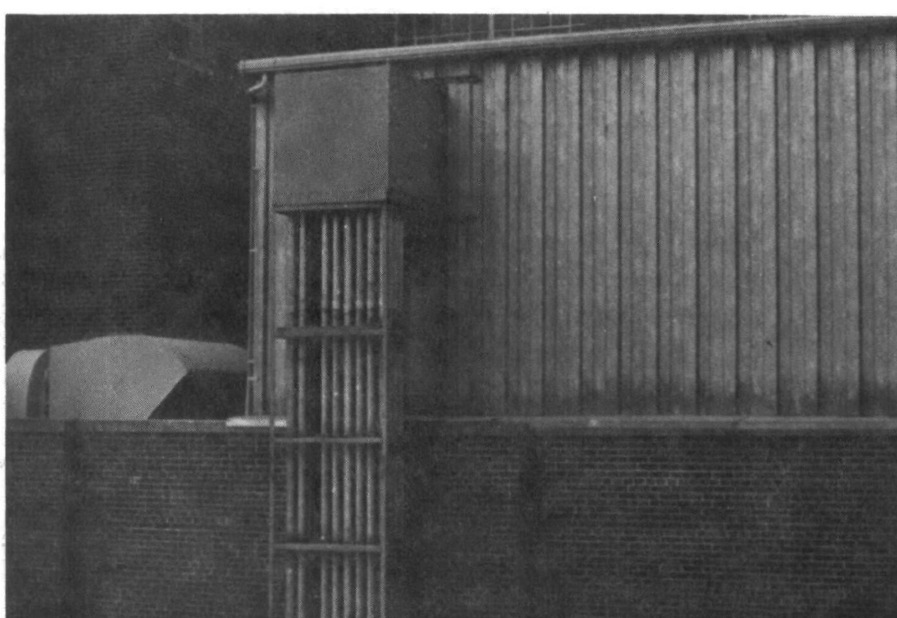

Photo No. 6 View of scrubber switchgear building showing conduit run for FGD system power supply.

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

1. REPORT NO. EPA-650/2-75-057-d	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Survey of Flue Gas Desulfurization Systems Paddy's Run Station, Louisville Gas and Electric		5. REPORT DATE August 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 6d
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 Task Final; 7/74 - 7/75
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT The report gives results of a survey of the flue gas desulfurization (FGD) system on Unit 6 of Louisville Gas and Electric Co.'s Paddy's Run Power Station. The closed-loop system, which was started up in April 1973, utilizes a slurry of carbide lime in a marble-bed scrubber. The carbide lime, a waste by-product from a nearby acetylene manufacturing plant, contains 90-92 percent calcium hydroxide, 2-2.5 percent silica, 3-8 percent calcium carbonate, and 0.1 percent magnesium oxide. Sludge is stabilized by mixing thickener overflow with carbide lime before vacuum filtration. The sludge, containing about 40 percent solids, is trucked to a nearby 10-acre borrow pit, used as a landfill area. The Paddy's Run Station is used primarily to meet summer peaking loads. Boiler No. 6 is operated infrequently because of its low thermal efficiency (heat rate is about 13,000 Btu/kWhr). On the basis of the performance at Paddy's Run, Louisville Gas and Electric Co. is pursuing plans to install similar carbide lime FGD systems at other power stations.

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	Cost Engineering	Marble-Bed Scrubber	07A,07D	14A
Scrubbers		Carbide Lime		
Sulfur Dioxide		Particulate	07B	
Calcium Oxides				
Carbides				

18. DISTRIBUTION STATEMENT Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 47
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)