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SURVEY OF FLUE GAS DESULFURIZATION SYSTEMS

LAWRENCE POWER STATION, KANSAS POWER AND LIGHT CO.

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

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LAWRENCE POWER STATION, KANSAS POWER AND LIGHT CO.

by

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The authors appreciate the efforts and cooperation of everyone who participated in the preparation of this report.

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SUMMARY

The flue gas desulfurization (FGD) systems on Boilers 4 and 5 at the Lawrence Power Station of Kansas Power and Light Company (KP&L) were designed and installed by Combustion Engineering, Inc. (C-E). The process used is based on injection of pulverized limestone in the furnace followed by tail-end wet scrubbing.

Unit 4 has a net capacity of 102 MW when burning Wyoming coal and with the FGD system operating. The unit is equipped with two FGD modules which were placed in service in November 1968. These modules have undergone several major modifications since that time in order to improve system performance and availability. The experience gained was later incorporated in the design and construction of the FGD system on Unit 5 which has a net generating capacity of 320 MW. This system consists of eight modules and was installed concurrently with and as an integral part of that boiler. Boiler 5 and its SO_2 pollution controls both started up in November 1971.

The performance of the FGD units on Boilers 4 and 5 has steadily improved, and their availability has increased with operating experience. Availability figures for both units have been recently reported to be close to 100 percent.

However, these figures are somewhat misleading because of the particular load cycle for this plant. Both boilers operate only at half-load at night. Half of the modules are shut down for cleaning or repair on a daily basis. Thus, forced outages are infrequent because the scrubber demand factor is fairly low.

Present outstanding problems for both boilers include localized corrosion in some equipment, unsatisfactory damper operation, demister fouling, expansion joint failures and rapid wear of slurry recirculating pumps. In addition to the above, Boiler 5 is plagued with poor flue gas distribution to the eight FGD modules which, unlike the modules on Boiler 4, are all interconnected to one common stack.

The spent lime/limestone slurry from both FGD units is sent to three interconnected unlined sludge disposal ponds. About 500 gal./min of make-up water to the system is supplied from the cooling tower blowdown line. This make-up water is pumped to the last pond. The clarified water from this pond is recycled to FGD Units 4 and 5. The remainder of the cooling tower blowdown is returned to the river.

Since the spent slurry contains fly ash and unreacted lime, ingredients considered effective sludge stabilizers, the sludge in the unlined ponds is not further treated and is reported to solidify in the ponds.

Data are not available at the present time on capital and operating costs of FGD Units 4 and 5. However, the initial capital cost to KP&L in 1968 for the installation of FGD Units 4 and 5 was reported to be about 3.5 million dollars. The cost of subsequent modifications to these units was borne by C-E.

Further modifications to the FGD systems are planned. The two existing modules on Unit 4 will be phased out and replaced by two new modules. Each module will consist of a venturi followed by a spray chamber. Also an electrostatic precipitator (ESP) unit will be installed to handle the fly ash. These main changes are scheduled for completion by January 1977. Unit 5 will be converted to a tail-end wet limestone scrubbing process by the fall of 1975.

Pertinent plant and FGD operational data are summarized in the following table.

SUMMARY OF FGD DATA, BOILERS 4 AND 5

LAWRENCE POWER STATION

System data	Boiler 4	Boiler 5
Unit rating (net MW)[a]	102[b]	320[b]
Fuel characteristics	Kansas Coal: 12% ash, 3.75% S, 12,000 BTU/lb Wyoming Coal: 9.8% ash, 0.6% S, 10,000 BTU/lb	
FGD vendor	Combustion Engineering	
Process	Limestone injection with tail-end scrubbing	
New or retrofit	Retrofit	New
Start-up date	November 1968	November 1971
FGD modules	2	8
Efficiency, %		
Particulates	99.3	99.3
SO_2	65	65
Water make-up gpm/Mw	2.94	3.75
Sludge disposal	Stabilized sludge disposed in unlined pond	

[a] With FGD system operating.

[b] When burning Wyoming coal.

1.0 INTRODUCTION

The Industrial Environmental Research Laboratory, formerly the 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 Lawrence Power Station of Kansas Power and Light Company (KP&L) 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 as made available by the user and/or vendor.

This report is based upon information obtained during a plant inspection on August 13, 1974 and on data provided by KP&L 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 analyses FGD system performance. Appendices present details of plant and system operation and photos of the installation.

2.0 FACILITY DESCRIPTION

The Lawrence Power Station of Kansas Power and Light Company is located in a lightly industralized area on the outskirts of Lawrence, Kansas.

The plant operates two steam boilers which are equipped to burn coal, natural gas supplemented with oil or a combination of these three fuels. Boiler 4 is the older of the two units. It was first placed in service in 1959 and operated as a cyclic load boiler. The maximum electric generating capacity of this unit varies with the type of fuel being burned; when burning natural gas the unit's output can be as high as 143 MW, and decreases to 125 MW when burning coal plus natural gas. The retrofitting of this boiler with an FGD system in 1968 has introduced additional pressure drop in the flue gas system and further reduced the boiler capacity to 115 MW.

The second unit at the plant is Boiler 5. Its rated capacity, when burning coal plus natural gas, is 400 MW. The unit, together with the FGD system, was placed in service in November 1971. Similar to Boiler 4, it is also classified as a cyclic load unit.

Both boilers at the Lawrence Power Station were built by C-E, which also designed and installed the FGD systems on these boilers. These FGD systems consist of limestone furnace injection with flue gas wet scrubbing.

Until recently the grade of coal burned at the Lawrence Power Station had a gross heat content of 12,000 BTU/lb. Its average ash and sulfur contents were 12 and 3.75 percent, respectively. The company has now switched from this high-sulfur Kansas coal to Wyoming coal which contains from 0.4 to 0.8 percent sulfur and 10 percent ash. The coal has a gross heating value of 10,000 BTU/lb. This change was necessitated by the curtailment of strip-mining operations at the Kansas coal supply site.

As mentioned earlier, coal, gas and oil can be burned in this boiler. Oil is used as a supplementary fuel. Thus, SO_2 emissions can vary widely.

Both Boilers 4 and 5 burn some natural gas in the summer, when the demand for home heating is low. In 1969-70, approximately 65 percent of the plant's generating capacity was from the combustion of natural gas. It is estimated that gas usage will be phased out completely at the Lawrence Power Station by 1981.

The maximum particulate emissions allowed under the State of Kansas Regulation 28-19-31A are 0.19 lb/MM BTU of heat input to Unit 4 and 0.16 lb/MM BTU of heat input to Unit 5. The calculated maximum particulate emissions from Units 4 and 5 are equivalent to 0.09 lb/MM BTU of heat input to each boiler.

Atmospheric emissions of sulfur dioxide are limited by the State of Kansas Regulation 28-19-31C. This regulation limits the SO_2 emissions from Units 4 and 5 to 1.5 lb/MM BTU of heat input to the boilers. The calculated SO_2 emissions, based on an FGD SO_2 removal efficiency of 65 percent, while burning Wyoming coal, is 0.43 lb/MM BTU of heat input to each boiler. Therefore, the SO_2 emission limit can be met by burning Wyoming coal, even without the use of an FGD system. Nevertheless, KP&L is proceeding to replace the FGD system on Unit 4 for several reasons:

1. It was not anticipated that low sulfur fuel would be burned at the station when the replacement FGD system was planned and engineered.
2. C-E has committed to provide an operable FGD system on Unit 4. The existing system is in such a state of deterioration that it cannot be repaired for that purpose.
3. Low sulfur coal has reduced the efficiency of the existing ESP, and there is insufficient space for the installation of an adequately sized ESP. A particulate scrubbing system is therefore necessary, and an FGD system can conveniently be operated in conjunction with the particulate system. Pertinent data on Units 4 and 5 are given in Table 2.1.

Table 2.1 PERTINENT DATA ON PLANT DESIGN, OPERATION AND ATMOSPHERIC EMISSIONS - LAWRENCE STATION, KP&L (Wyoming Coal)

Boiler Data	Unit 4	Unit 5
Maximum continuous generating capacity (MW, net)	102	320
Served by stack No.	4A, 4B	5
Boiler manufacturer	C-E	C-E
Year placed in service	1959	1971
Maximum coal consumption, ton/hr	63	178
Maximum heat input, MM BTU/hr	1260	3560
Unit heat rate, BTU/KWH	11,667	11,125
Stack height above grade, ft	120	375
Maximum flue gas rate, acfm @ 290°F	367,000[a]	1,036,000[a]
Emission controls		
Particulate	FGD scrubber	FGD scrubber
SO_2	FGD scrubber	FGD scrubber
Particulate emission rate		
Allowable, lb/MM BTU	0.19	0.16
Actual, lb/MM BTU	0.09[b]	0.09[b]
SO_2 emission rate		
Allowable, lb/MM BTU	1.5	1.5
Actual, lb/MM BTU	0.43[c]	0.43[c]

[a] Calculated, 22% excess air.
[b] Calculated, assuming 99% scrubber particulate efficiency.
[c] Calculated, assuming 65% SO_2 removal efficiency.

3.0 FLUE GAS DESULFURIZATION SYSTEM

3.1 PROCESS DESCRIPTION

The FGD systems on Boilers 4 and 5 are identical in basic design and operation. The FGD system on Boiler 4 underwent several major modifications since its start-up in November 1968. Many of these modifications were later incorporated in the design of the FGD system on Boiler 5.

The present FGD system for each boiler includes facilities for pulverizing and injecting finely ground limestone rock into the boilers' furnace chamber where the bulk of it is calcined. This calcined limestone, along with the fly ash, is transported by the flue gas to the tail-end wet scrubber modules, where the SO_2 in the gas reacts with the scrubbed lime/limestone in the recirculated slurry and is substantially removed, along with the fly ash, from the gas stream. The cleaned gas is then demisted and reheated (to prevent condensation in the downstream equipment) and finally discharged from the stack by the I.D. fans.

There are two FGD modules on Boiler 4 and eight FGD modules on Boiler 5. They are all identical in size and each is designed to handle approximately 150,000 scfm of flue gas. A typical module is shown in Figure 3.1. It

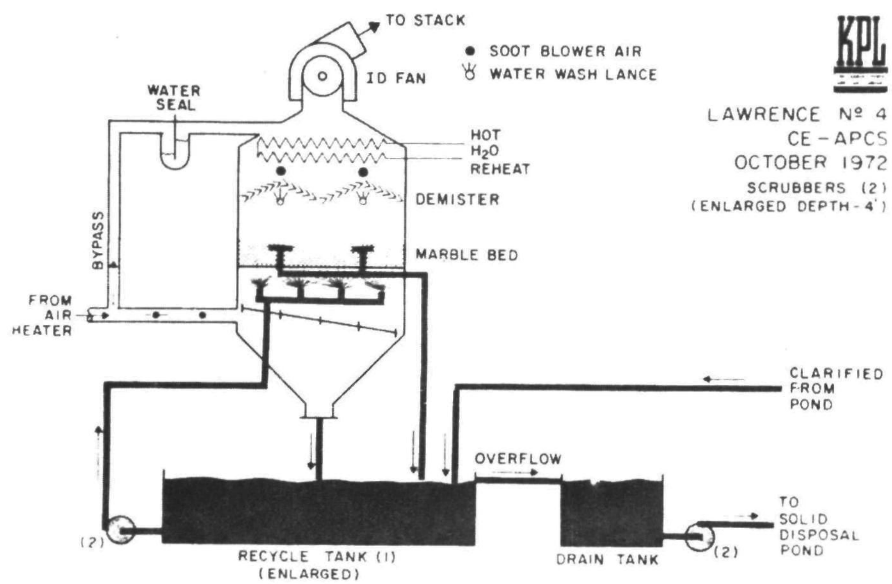


Figure 3.1 Sketch of a typical FGD module at the Lawrence Power Station.

Source: Kansas Power and Light Company

consists of a single stage of 3/4" glass marbles. The bed is about 3 to 4 inches thick and is fitted with overflow pots to collect and drain the liquor from the top of the bed. The scrubbing liquor is sprayed through nozzles located below the bed.

Chevron demisters are located about 4 1/2 feet above the marble bed (7 1/2 feet in six of the eight modules of Boiler 5). There are two layers of demisters each 6 inches thick spaced 12 inches apart. They are cleaned once a day for one hour by 150 psig pond water sprayed from retractable wash lances.

The present reheater bundles are made of carbon steel tubes and each is rated at 10 MM BTU/hr. The heating medium is boiler feed water which is available at 260°F. The tube bundles are located about 6 1/2 feet directly above the demisters. They are cleaned six times a day for 3 minutes each time by high pressure compressed air blown from lances located under the tubes.

Each one of the two modules on Boiler 4 is connected (through an I.D. fan) to a separate 120 ft stack, while the gases from all eight modules on Boiler 5 are discharged through a common stack, 375 feet tall.

Originally, all modules were fitted with bypass ducts and hydraulic seal dampers. However, because of extensive corrosion and plugging problems with the systems on the two modules of Boiler 4, the bypass ducts on these modules were removed.

The spent liquor from the scrubber tower drains into a recycle tank. The 30-40 minute retention time of this tank ensures complete conversion of the scrubbed SO_2 to calcium sulfite and calcium sulfate. The spent liquor from this tank overflows to a drain tank from which it is pumped to the sludge disposal ponds.

Presently there are three unlined sludge ponds on site, 4 acres, 16 acres, and 28 acres. The sludge first enters the 16-acre pond and overflows into the 4- and 28-acre ponds. Approximately 800 gpm of sludge containing 9 percent solids, are fed to the unlined ponds. Because of the presence of unreacted lime as well as fly ash in the sludge (ingredients which are usually added to stabilize limestone sludge) the sludge sets up very hard like concrete, without any additives. Including an additional 30-acre on-site location, for future sludge ponds, it is anticipated that sludge can be stored on-site for about 20 more years.

3.2 DESIGN PARAMETERS

As noted earlier, and further discussed under Section 4.1, the FGD modules of Boiler 4 have undergone several major modifications since they were originally designed and installed. Therefore, the figures presented in Tables 3.1, 3.2, and 3.3 refer to present operating conditions instead of original design parameters. These data (except where noted) also apply to the FGD system of Boiler 5, since many of the modifications on Unit 4 were incorporated in the design of the FGD system on Boiler 5.

Table 3.1 SUMMARY OF DATA: SO_2 SCRUBBER

Item	SO_2 scrubber tower
L/G ratio, gallons/1000, acf	22
Superficial gas velocity, ft/sec	6.5
Equipment size	
Equipment internals	3.5-inch thick bed of 3/4-inch diameter marbles
Material of construction	
Shell	C.S. lined with Ceilcote epoxy with glass flakes
Internal supports	316 L SS

Table 3.2 SUMMARY OF DATA: FGD SYSTEM RECYCLE TANKS

Item	Recycle tank on Boiler 4	Recycle tank on Boiler 5
Total number of tanks	1	1
Tank size		
Retention time at full load, minutes	40	30
Temperature, °F	290	
pH	9.5-10	9.5-10
Solids concentration, %	8.5-9.5	8.5-9.5
Specific gravity		
Material of construction		

Table 3.3 TYPICAL PRESSURE DROP ACROSS COMPONENTS OF FGD MODULE

Equipment	Pressure drop, inches W.G.
SO_2 scrubber tower	6 - 8
Demister, Reheater, Ductwork	1-1/2 - 2
Total FGD system	10

3.3 INSTALLATION SCHEDULE

The decision to install an FGD system on Boilers 4 and 5 was made during 1967. The company had assumed that by 1971 there would be some ambient and/or emission regulations in effect for particulate matter and sulfur dioxide.

Based on this assumption and the availability of coal containing 3 to 4 percent sulfur and 12 percent ash, the decision was made to install as original equipment, facilities to remove the fly ash and SO_2 from the flue gas of Boiler 5 which was then in the planning stage. The FGD process was based on C-E's limestone-furnace injection with tail-end wet scrubbing.

In order to gain experience in the operation of such a system, KP&L further decided to retrofit a similar FGD system on the existing Boiler 4. Construction on this FGD system began in March 1968 and the initial start-up of the FGD system took place in November of the same year.

Construction of Boiler 5 and its FGD system also began in 1968, side by side with the work on retrofitting Boiler 4. The initial start-up of Boiler 5 and its pollution control equipment began in March 1971. Shakedown and debugging of the equipment was completed in November 1971.

Kansas State emission standards require that new installations utilize the latest available technology; KP&L interprets this as a requirement for the installation of scrubbers. Accordingly, the company has proceeded to incorporate scrubbers into the design of their Jeffery Energy Center, a new power plant to be built at St. Mary's, Kansas, about 30 miles west of Topeka. The new plant will consist of four 700 MW units. The first two units are to be operational in 1978 and 1979, burning Wyoming coal containing 0.2 to 0.45 percent sulfur. ESP's will be used for particulate control, and C-E scrubbers will be used to attain 50 to 60 percent SO_2 control. The units will be designed to limit SO_2 emissions to about 0.5 lb/MM BTU, considerably lower than the Federal New Source Performance Standard (NSPS) of 1.2 lb/MM BTU.

3.4 COST DATA

Detailed data on the capital and operating costs of the FGD installations at the Lawrence Power Station are not available. In 1968, KP&L paid C-E a lump sum of about 3.5 million dollars (equivalent to $8.3/KW net) for retrofitting Boilers 4 and 5 with FGD systems. Since that time the systems have not met performance specifications and therefore have not yet been accepted by KP&L. Consequently, the expenses incurred in many subsequent modifications to the systems were largely borne by C-E. Since these costs occurred over a period of many years, no meaningful conclusion can be drawn as to the present cost of a comparable system. It is significant to note that it was not necessary to expand the size of the operating staff, nor to upgrade operator qualification grades as a result of the scrubber installations. However, maintenance requirements have increased considerably as a result of the FGD installation.

4.0 FGD SYSTEM PERFORMANCE

4.1 GENERAL DISCUSSION

The several major modifications completed by C-E and KP&L on Unit 4 have significantly improved the units performance and availability. Availabilities close to 100 percent were reported for July and August 1974. The SO_2 removal efficiency has been around 65 percent, which is sufficient for the plant to comply with the applicable pollution control regulations. SO_2 removal efficiencies as high as 85 percent were achieved over a short period, but only at the expense of an accelerated rate of scale formation in the scrubbers, resulting in decreased FGD system availability.

Boiler 5 has recently been firing natural gas. When the boiler is firing coal and the FGD system is in operation, the problems experienced are similar to those encountered with the modules on Boiler 4. However, the main outstanding problem with Unit 5 is improper flue gas distribution to the eight modules. Combustion Engineering is presently performing some tests on Unit 5 to alleviate this problem.

4.2 START-UP PROBLEMS AND SOLUTIONS

Analysis of the problems encountered during and since start-up reveals that nearly all were due to improper control of process chemistry. In the limestone furnace injection process, satisfactory control of the degree of limestone calcination as well as the amount of lime/limestone carried in the flue gas to the tail-end scrubbers, is difficult to achieve. This situation is further aggravated when the boiler is operating as a cyclic load boiler and is fired with a variable combination of coal, natural gas and oil.

Figure 4.1 illustrates the configuration of each of the two modules when the FGD system initially started operating in 1968. This design presented many operating problems and shortcomings. Among these were (1) scale buildup and plugging of the hot gas inlet duct, (2) erosion of the scrubber walls and corrosion of the scrubber internals, (3) plugging and scaling of drain lines, tanks, pumps, marble bed, demister, reheater and (4) scale buildup on I.D. fan rotors, which resulted in fan imbalance and vibration.

In addition to the above mentioned operating problems, the SO_2 removal was quite low due to the over burning of limestone in the furnace and the dropout of the lime with the ash in the bottom of the scrubbers.

After the first few months of operation, the scrubbers were modified. These modifications, which are shown in Figure 4.2, include (1) addition of soot blowers in the gas inlet duct and under the reheater bundle, to minimize plugging problems, (2) raising of the demister to reduce plugging from solids carry-over, (3) directing the overflow liquor from the pots to the pond, and the installation of a large recycle

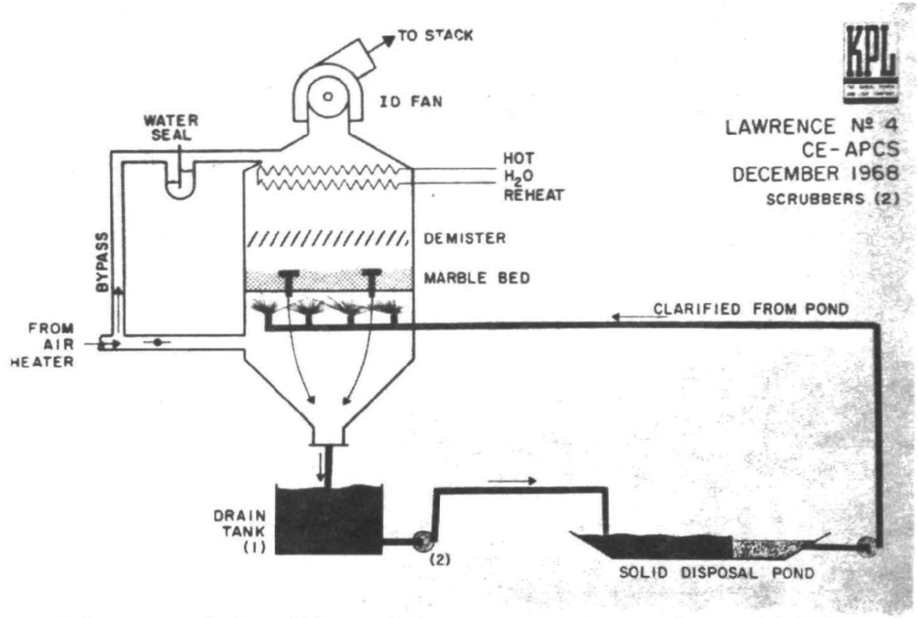


Figure 4.1 Flow Diagram - December 1968

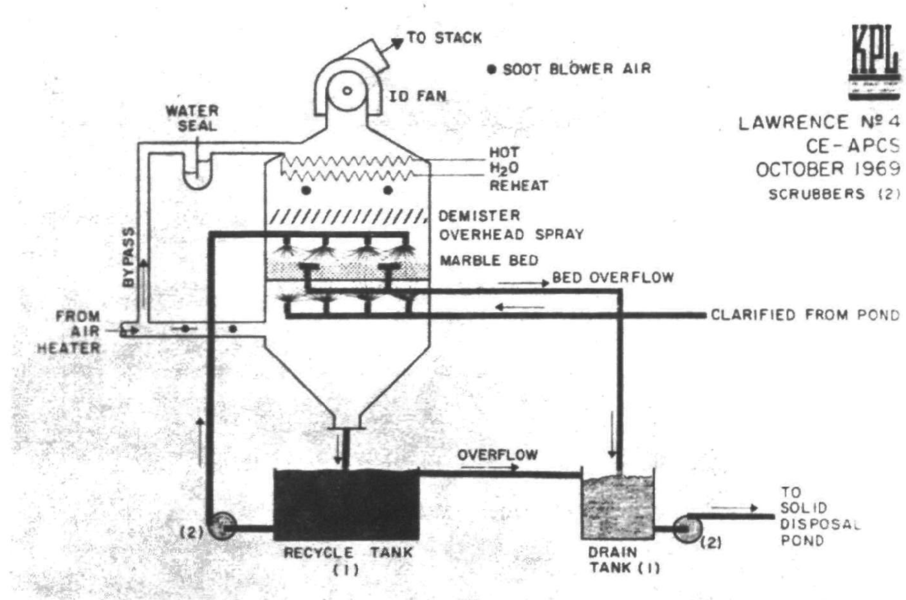


Figure 4.2 Flow Diagram - October 1969

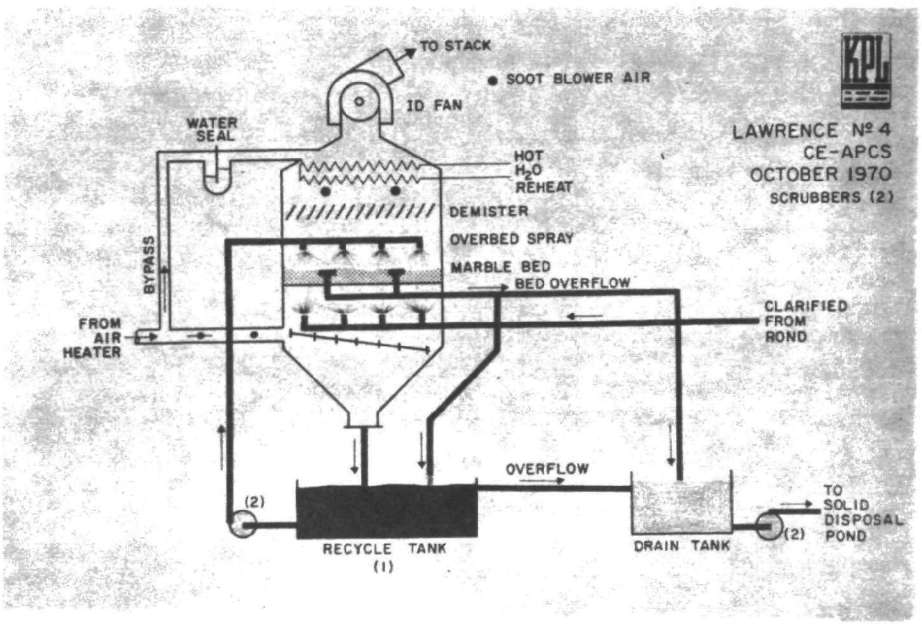


Figure 4.3 Flow Diagram - October 1970

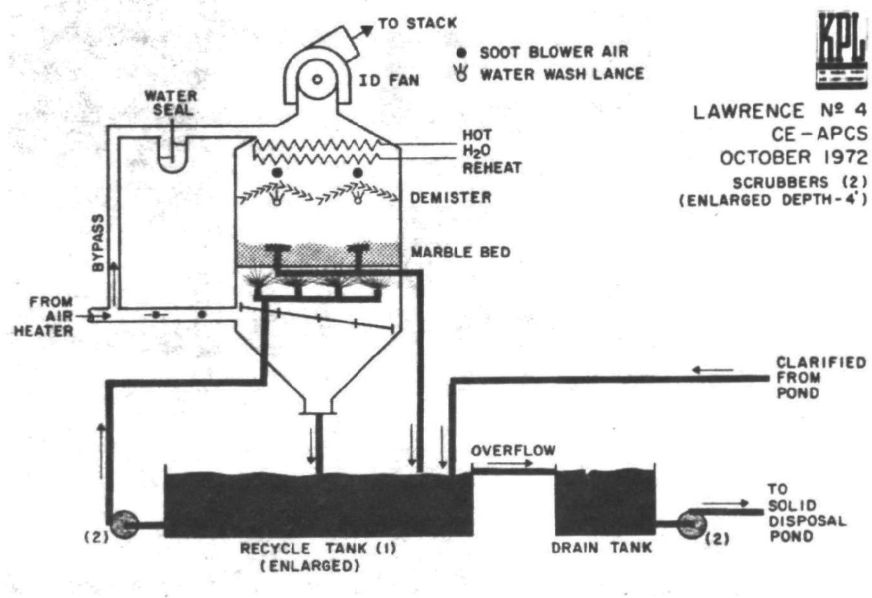


Figure 4.4 Flow Diagram - October 1972

tank and pump to catch and recirculate the highly alkaline underflow back to the marble bed. Other modifications to combat corrosion and plugging were the installation of a new type of spray nozzle and lining the bottom section of the scrubber tanks with gunite. Hydraulic variable speed drives were installed on all the fans. It was found that a slight readjustment of fan speed would often eliminate vibrations caused by deposit buildup on the rotor. Thus, operation could be continued without shutting down the fan for a thorough cleaning.

Most of the problems were reduced but not eliminated by these modifications. Furthermore, the new recirculation system improved the SO_2 removal efficiency.

To further minimize corrosion, erosion, scaling and plugging problems, additional revisions were made during the summer of 1970. The resulting scrubber configuration is shown in Figure 4.3. The major revisions were:

1. Sandblasting and coating the interior of the scrubbers with two coats of glass flake lining.
2. Replacement of all internal steel pipes with plastic and fiberglass piping.
3. Replacement of the stainless steel demisters with fiberglass demisters.
4. Addition of a ladder vane under the marble beds to improve gas distribution.
5. Modification of the pot overflow drain piping to allow the liquor to return to the recycle tank.
6. Removal and replacement of the original copper fin tubes of the reheater coils with a carbon steel fin tube coil. Because of the close spacing of

the fins on the copper tubes, the reheaters plugged easily. Also the fins were flattened by the soot blower jets.

Demister plugging continued to create serious problems. Manual washing was necessary every other night to maintain the required unit output.

In the summer of 1972, the scrubbers (on Units 4 and 5) were modified to operate using a high solid slurry crystallization process to control saturation and precipitation of scale within the scrubber. These latest major modifications, shown in Figure 4.4, included the enlargement of the liquor recirculation tank as well as the replacement of many components, such as piping, nozzles, pumps and mixers. Also the demisters were replaced with a new two-bank fiberglass unit fitted with high pressure wash water lances.

Operation of the two FGD systems since the fall of 1973 has been the most successful to date. Some of the remaining problems are:

a) Isolated corrosion areas

b) Expansion joint failure

c) Demister fouling

d) Rapid wear of slurry pumps

e) Valve failures

The load cycle at this station is such that the boilers are cut to half-load every night. Therefore, half of the modules are shut down nightly and can be cleaned or repaired regularly. Thus forced outages are infrequent.

The FGD system availability averaged 86 percent during the first 11 months of 1974. Availability was 50 percent in December due to outages for repairs on the modules.

4.3 FUTURE MODIFICATIONS

Future modifications to the FGD systems on each boiler will be primarily concerned with alleviating the problems which are inherent in the furnace injection of limestone. Therefore, Unit 5 will be converted to a tail-end, wet limestone scrubbing process by fall 1975. Beyond that the future of Unit 5 is uncertain.

After six years and several major modifications, the current plans for Unit 4 are as follows:

a) Engineering of two 2-stage scrubbers (ventri-rod followed by spray) will be started. Foundation work due to start Spring, 1975.

b) By September 1976, the two new scrubber modules are to be operational. The present scrubbers will be kept in service while the new scrubbers are being built.

c) By September 1977, the present scrubbers will be razed, and an ESP will be installed. It is anticipated that the ESP/ventri-rod/spray flue gas cleaning system will be operational by September 1977. The new system will have forced oxidation of via aeration to produce calcium sulfate.

APPENDIX A

PLANT SURVEY FORM

PLANT SURVEY FORM[a]

NON-REGENERABLE FGD PROCESSES

A. COMPANY AND PLANT INFORMATION

1. COMPANY NAME Kansas Power and Light Company
2. MAIN OFFICE Topeka, Kansas
3. PLANT MANAGER Lee Brunton
4. PLANT NAME Lawrence Power Station
5. PLANT LOCATION Lawrence, Kansas
6. PERSON TO CONTACT FOR FURTHER INFORMATION Kelly Green
7. POSITION Production Engineer
8. TELEPHONE NUMBER (913) 233-1351
9. DATE INFORMATION GATHERED 8-13-74
10. PARTICIPANTS IN MEETING

PARTICIPANTS IN MEETING	AFFILIATION
Kelly Green	KPL
Lee Brunton	KPL
Wade Ponder	EPA
John Busik	EPA
Tim Devitt	PEDCo
Fouad Zada	PEDCo

[a] These data were obtained on August 13, 1974. Some of the data may have been updated in the body of the report

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

	BOILER NO.				
	4	5			
CAPACITY, MW	125	400			
SERVICE (BASE, PEAK)	Cyclic	Cyclic			
FGD SYSTEM USED	✓	✓			

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

1. BOILER IDENTIFICATION NO. 4
2. MAXIMUM CONTINUOUS HEAT INPUT ~ 1000 MM BTU/HR
3. MAXIMUM CONTINUOUS GENERATING CAPACITY 102** MW
4. MAXIMUM CONTINUOUS FLUE GAS RATE, 165000/module ACFM @ 290 ^{O}F
5. BOILER MANUFACTURER Combustion Engineering
6. YEAR BOILER PLACED IN SERVICE 1959
7. BOILER SERVICE (BASE LOAD, PEAK, ETC.) Cyclic
8. STACK HEIGHT 120' (each module has its own stack)
9. BOILER OPERATION HOURS/YEAR (1973) 8100
10. BOILER CAPACITY FACTOR * 50%
11. RATIO OF FLY ASH/BOTTOM ASH 85/15

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

** Net - Wyoming coal.

5/17/74

D. FUEL DATA

1. COAL ANALYSIS (as received)

	MAX.	MIN.	AVG.
GHV (BTU/LB.)			12,000
S %	4.00%	3.5%	3.75%
ASH %			12%

2. WYOMING COAL ANALYSIS

GRADE			10,000
S %	0.8%	0.4%	0.53%
ASH %			10%

E. ATMOSPHERIC EMISSIONS

1. APPLICABLE EMISSION REGULATIONS

	PARTICULATES	SO_2
a) CURRENT REQUIREMENTS		
AQCR PRIORITY CLASSIFICATION		
REGULATION & SECTION NO.		
MAX. ALLOWABLE EMISSIONS LBS/MM BTU	0.19	1.5
b) FUTURE REQUIREMENTS, COMPLIANCE DATE		
REGULATION & SECTION NO.		
MAXIMUM ALLOWABLE EMISSIONS LBS/MM BTU		

2. PLANT PROGRAM FOR PARTICULATES COMPLIANCE

Test results 99.2% efficiency by York Co. tests.

Source is in compliance. All tests ranged between

98-99.3%

3. PLANT PROGRAM FOR SO_2 COMPLIANCE

Removal efficiency is about 65%.

F. PARTICULATE REMOVAL

	MECH.	E.S.P.	FGD
1. TYPE			
MANUFACTURER			C.E
EFFICIENCY: DESIGN/ACTUAL			99.0/98-99.3
MAX. EMISSION RATE* LB/HR			
GR/SCF			
LB/MMBTU			

DESIGN BASIS, SULFUR CONTENT ______________

G. DESULFURIZATION SYSTEM DATA

1. PROCESS NAME ______________
2. LICENSOR/DESIGNER NAME: ______________
   ADDRESS: ______________
   PERSON TO CONTACT: ______________
   TELEPHONE NO.: ______________
3. ARCHITECTURAL/ENGINEERS, NAME: ______________
   ADDRESS: ______________
   PERSON TO CONTACT: ______________
   TELEPHONE NO.: ______________
4. PROJECT CONSTRUCTION SCHEDULE:

	DATE
a) DATE OF PREPARATION OF BIDS SPECS.	
b) DATE OF REQUEST FOR BIDS	
c) DATE OF CONTRACT AWARD	
d) DATE ON SITE CONSTRUCTION BEGAN	3/68
e) DATE ON SITE CONSTRUCTION COMPLETED	
f) DATE OF INITIAL STARTUP	11/68
g) DATE OF COMPLETION OF SHAKEDOWN	

*At Max. Continuous Capacity

5. LIST MAJOR DELAYS IN CONSTRUCTION SCHEDULE AND CAUSES:

______

______

______

______

______

______

6. NUMBER OF SO_2 SCRUBBER TRAINS USED ... Two

7. DESIGN THROUGHPUT PER TRAIN, ACFM @ °F 165000 SCFM

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

   2) EQUIPMENT LAYOUT

H. SO_2 SCRUBBING AGENT

1. TYPE Limestone

2. SOURCES OF SUPPLY N.R. Hamm Quarry (local quarry)

3. CHEMICAL COMPOSITION (for each source)

   SILICATES ______

   SILICA 6%

   CALCIUM CARBONATE 93%

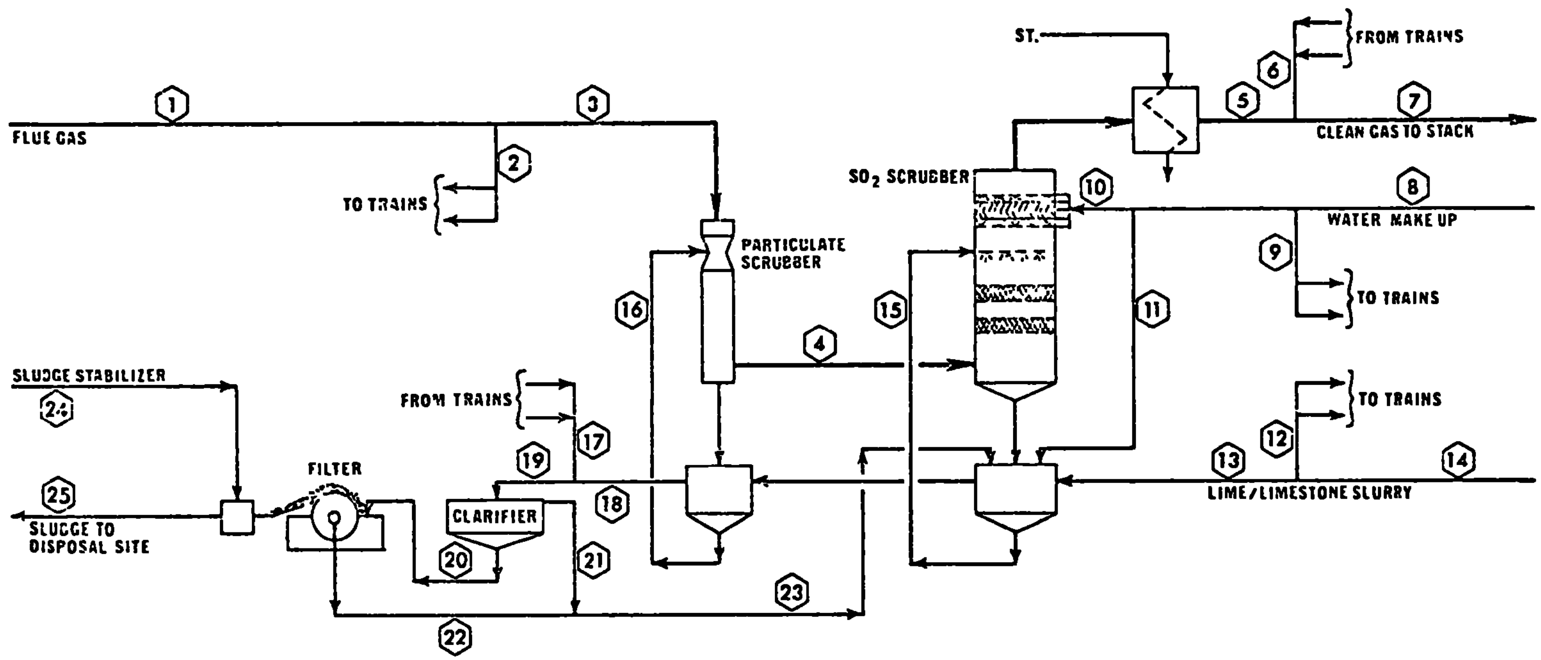
   MAGNESIUM CARBONATE 1%

4. EXCESS SCRUBBING AGENT USED ABOVE STOICHIOMETRIC REQUIREMENTS 60-65% *

5. MAKE-UP WATER POINT OF ADDITION Recirculation Tank

6. MAKE-UP ALKALI POINT OF ADDITION Injection into furnace

* Rate adjusted to give 5.5 pH in marble bed.



STREAM NO	1	2	3	4	5	6	7	8	9	10	11	12	13
RATE, lb/hr													
ACFM													
GPM													
PARTICULATES, lb/hr													
SO_2, lb/hr													
TEMPERATURE, °F													
TOTAL SOLIDS, %													
SPECIFIC GRAVITY,													

STREAM NO	14	15	16	17	18	19	20	21	22	23	24	25	26
RATE, lb/hr													
ACFM													
GPM													
PARTICULATES, lb/hr													
SO_2, lb/hr													
TEMPERATURE, °F													
TOTAL SOLIDS, %													
SPECIFIC GRAVITY													

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

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J. SCRUBBER TRAIN SPECIFICATIONS

1. SCRUBBER NO. 1 [a]

TYPE (TOWER/VENTURI)	Tower
LIQUID/GAS RATIO, G/MCF @ °F	22
GAS VELOCITY THROUGH SCRUBBER, FT/SEC	6-7 ft/sec
MATERIAL OF CONSTRUCTION	C.S.
TYPE OF LINING	Ceilcote epoxy w/glass flakes
INTERNALS:	
TYPE (FLOATING BED, MARBLE BED, ETC.)	Marble bed
NUMBER OF STAGES	one
TYPE AND SIZE OF PACKING MATERIAL	3/4" Pyrex glass
PACKING THICKNESS PER STAGE [b]	3-1/2"
MATERIAL OF CONSTRUCTION, PACKING:	glass
SUPPORTS:	316 SS - Plates 304 SS - Support

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: None

L/G RATIO: ______

SOURCE OF WATER: ______

4. DEMISTER

TYPE (CHEVRON, ETC.): Chevron

NUMBER OF PASSES (STAGES): Two

SPACE BETWEEN VANES: 2"

ANGLE OF VANES: 45°

TOTAL DEPTH OF DEMISTER: 24" (6"/demister + 12" space)

DIAMETER OF DEMISTER: ______

DISTANCE BETWEEN TOP OF PACKING AND BOTTOM OF DEMISTER: 4 - 4-1/2 ft

POSITION (HORIZONTAL, VERTICAL): ______

MATERIAL OF CONSTRUCTION: Fiberglass

METHOD OF CLEANING: ______

SOURCE OF WATER AND PRESSURE: Pond water, 150 psig

FLOW RATE DURING CLEANINGS, GPM: ______

FREQUENCY AND DURATION OF CLEANING: Once every 24 hrs.

REMARKS: One blower is turned on at a time

______

______

5. REHEATER

TYPE (DIRECT, INDIRECT): Indirect

b) For floating bed, packing thickness at rest.

DUTY, MMBTU/HR 21 (~ 10 per reheater)

HEAT TRANSFER SURFACE AREA SQ.FT ______

TEMPERATURE OF GAS: IN 120 OUT 150

HEATING MEDIUM SOURCE Boiler feed water

TEMPERATURE & PRESSURE 260°F

FLOW RATE 150 gpm/unit

REHEATER TUBES, TYPE AND MATERIAL OF CONSTRUCTION C.S.

REHEATER LOCATION WITH RESPECT TO DEMISTER

6' to 7' directly above top if demister

METHOD OF CLEANING Compressed Air Blower

FREQUENCY AND DURATION OF CLEANING 6 times/day for 3 min.

FLOW RATE OF CLEANING MEDIUM ______ LB/HR

REMARKS No cleaning problems

6. SCRUBBER TRAIN PRESSURE DROP DATA

	INCHES OF WATER
PARTICULATE SCRUBBER	
SO_2 SCRUBBER	6" - 8"
CLEAR WATER TRAY	N/A
DEMISTER	
REHEATER	1-1/2"-2"
DUCTWORK	
TOTAL FGD SYSTEM	10" max.

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

TO: DEMISTER ____________

QUENCH CHAMBER ____________

ALKALI SLURRYING ____________

PUMP SEALS Pond Water

OTHER ____________

TOTAL Evap. load 125 gpm, blowdown 175 gpm = 300 gpm

FRESH WATER ADDED PER MOLE OF SULFUR REMOVED ____________

8. BYPASS SYSTEM

CAN FLUE GAS BE BYPASSED AROUND FGD SYSTEMS No

GAS LEAKAGE THROUGH BYPASS VALVE, ACFM --

K. SLURRY DATA

	pH	% Solids	Capacity (gal)	Hold up time
LIME/LIMESTONE SLURRY MAKEUP TANK				
PARTICULATE SCRUBBER EFFLUENT HOLD TANK (a)				
SO_2 SCRUBBER EFFLUENT HOLD TANK (a)	9.5 to 10	8.5 to 9.5		40 min.

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

TYPE OF MILL (WET CYCLONE, ETC.) Old Coal Pulverizers

NUMBER OF MILLS One

CAPACITY PER MILL 15 T/HR

RAW MATERIAL MESH SIZE 1-1/4"

PRODUCT MESH SIZE 60% through 200 mesh

SLURRY CONCENTRATION IN MILL ________________

CALCINING In furnace

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 ________________

   DIMENSIONS ________________

   CONCENTRATION OF SOLIDS IN UNDERFLOW ________________

3. ROTARY VACUUM FILTER

   NUMBER OF FILTERS ________________

   CLOTH AREA/FILTER ________________

   CAPACITY ________________ TON/HR (WET CAKE)

   CONCENTRATION OF SOLIDS IN CAKE ________________

   PRECOAT (TYPE, QUANTITY, THICKNESS) ________________

   REMARKS ________________

   ____

   ____

4. SLUDGE FIXATION

   POINT OF ADDITIVES INJECTION None

   FIXATION MATERIAL COMPOSITION ________________

   FIXATION PROCESS (NAME) ________________

   FIXATION MATERIAL REQUIREMENT/TONS OF DRY SOLIDS OF SLUDGE

   ____

Plant has room for one more 30 acre x 16' pond

ESTIMATED POND LIFE, YRS. ~ 20 years

CONCENTRATION OF SOLIDS IN FIXED SLUDGE ____________

METHOD OF DISPOSAL OF FIXED SLUDGE ____________

INITIAL SOLIDIFICATION TIME OF FIXED SLUDGE ____________

5. SLUDGE QUANTITY DATA

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

IS POND/LANDFILL ON OR OFFSITE ____________

TYPE OF LINER ____________

IF OFFSITE, DISTANCE AND COST OF TRANSPORT ____________

POND/LANDFILL DIMENSIONS AREA IN ACRES ____________
DEPTH IN FEET ____________

DISPOSAL PLANS; SHORT AND LONG TERM ____________

____

____

____

____

N. <u>COST DATA</u>

1. TOTAL INSTALLED CAPITAL COST ____________

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 SCRUBBER TRAINS	☐	☐	______
LIMESTONE MILLING FACILITIES	☐	☐	______
SLUDGE TREATMENT & DISPOSAL POND	☐	☐	______
SITE IMPROVEMENTS	☐	☐	______
LAND, ROADS, TRACKS, SUBSTATION	☐	☐	______
ENGINEERING COSTS	☐	☐	______
CONTRACTORS FEE	☐	☐	______
INTEREST ON CAPITAL DURING CONSTRUCTION	☐	☐	______
B. ANNUALIZED OPERATING COST			
FIXED COSTS			
INTEREST ON CAPITAL	☐	☐	______
DEPRECIATION	☐	☐	______
INSURANCE & TAXES	☐	☐	______
LABOR COST INCLUDING OVERHEAD	☐	☐	______
VARIABLE COSTS			
RAW MATERIAL	☐	☐	______
UTILITIES	☐	☐	______
MAINTENANCE	☐	☐	______

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: SUPERVISOR ________ HOURS/WEEK ______ WAGE

OPERATOR ________ ______

OPERATOR HELPER ________ ______

MAINTENANCE ________ ______

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

1. SO_2 SCRUBBER, CIRCULATION TANK AND PUMPS.

a. PROBLEM/SOLUTION

Numerous problems and modifications. Refer to section 4.0 of the report for details.

2. DEMISTER

PROBLEM/SOLUTION Demisters vanes thin and fragile would break easily as result of operators walking on them or from high pressure of wash water. Installed new deminsters of different design and wall thickness.

3. REHEATER

PROBLEM/SOLUTION Original tubes had closely spaced fins which caused buildup of solids between adjoining fins over short periods. Replace reheater bundle with one having widely spaced fins.

4. VENTURI SCRUBBER, CIRCULATION TANKS AND PUMPS

PROBLEM/SOLUTION

5. I.D. BOOSTER FAN AND DUCT WORK

PROBLEM/SOLUTION No major problem, but have to sandblast shaft and blades about twice/yr. Wished they had speed regulator on fans so that they can be operated at slower speed when they are slightly out of balance.

6. LIMESTONE MILLING SYSTEM OR LIME SLAKING

PROBLEM/SOLUTION Some problems (wear of internals) on grinders but nothing serious.

7. SLUDGE TREATMENT AND DISPOSAL

PROBLEM/SOLUTION

8. MISCELLANEOUS AREA INCLUDING BYPASS SYSTEM

PROBLEM/SOLUTION

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.

pH of circulated slurry controlled to predetermine level as load is changed.

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 = $\frac{[a - \chi (b + c)]100}{a - \chi c}$ = %

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PLANT SURVEY FORM

NON-REGENERABLE FGD PROCESSES

A. COMPANY AND PLANT INFORMATION

1. COMPANY NAME Kansas Power and Light Company
2. MAIN OFFICE Topeka, Kansas
3. PLANT MANAGER Lee Brunton
4. PLANT NAME Lawrence Power Station
5. PLANT LOCATION Lawrence, Kansas
6. PERSON TO CONTACT FOR FURTHER INFORMATION Kelley Green
7. POSITION Production Engineer
8. TELEPHONE NUMBER ____________
9. DATE INFORMATION GATHERED -13-74
10. PARTICIPANTS IN MEETING

PARTICIPANTS IN MEETING	AFFILIATION
Kelley Green	KPL
Lee Brunton	KPL
Wade Ponder	EPA
John Busik	EPA
Tim Devitt	PEDCo
Fouad Zada	PEDCo

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

	BOILER NO.				
	4	5			
CAPACITY, MW	125	400			
SERVICE (BASE, PEAK)	cyclic	cyclic			
FGD SYSTEM USED	✓	✓			

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

1. BOILER IDENTIFICATION NO. 5
2. MAXIMUM CONTINUOUS HEAT INPUT ~ 3200 MM BTU/HR
3. MAXIMUM CONTINUOUS GENERATING CAPACITY ________ MW
4. MAXIMUM CONTINUOUS FLUE GAS RATE, ____________ ACFM @ ____ °F
5. BOILER MANUFACTURER Combustion Engineering
6. YEAR BOILER PLACED IN SERVICE ____________
7. BOILER SERVICE (BASE LOAD, PEAK, ETC.) cyclic
8. STACK HEIGHT ____________
9. BOILER OPERATION HOURS/YEAR (197) ____________
10. BOILER CAPACITY FACTOR * ____________
11. RATIO OF FLY ASH/BOTTOM ASH ____________

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

D. FUEL DATA

1. COAL ANALYSIS (as received)

	MAX.	MIN.	AVG.
GHV (BTU/LB.)			12,000
S %	4.0%	3.5%	3.75%
ASH %			12%

2. WYOMING COAL ANALYSIS

GRADE			10,000
S %	0.8%	0.4%	0.53%
ASH %			10%

E. ATMOSPHERIC EMISSIONS

1. APPLICABLE EMISSION REGULATIONS

	PARTICULATES	SO_2
a) CURRENT REQUIREMENTS		
AQCR PRIORITY CLASSIFICATION		
REGULATION & SECTION NO.		
MAX. ALLOWABLE EMISSIONS LBS/MM BTU	0.16	1.5
b) FUTURE REQUIREMENTS, COMPLIANCE DATE		
REGULATION & SECTION NO.		
MAXIMUM ALLOWABLE EMISSIONS LBS/MM BTU		

2. PLANT PROGRAM FOR PARTICULATES COMPLIANCE

Unit never been tested and probably would not meet compliance level because of poor gas distribution

3. PLANT PROGRAM FOR SO_2 COMPLIANCE

* Plant has ~400,000 tons on hand and consumes ~3000 TPD for both No. 4 and 5

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F. PARTICULATE REMOVAL

1. TYPE

	MECH.	E.S.P.	FGD
MANUFACTURER			C.E.
EFFICIENCY: DESIGN/ACTUAL			
MAX. EMISSION RATE* LB/HR			
GR/SCF			
LB/MMBTU			

DESIGN BASIS, SULFUR CONTENT ____________

G. DESULFURIZATION SYSTEM DATA

1. PROCESS NAME ____________

2. LICENSOR/DESIGNER NAME: ____________

   ADDRESS: ____________

   PERSON TO CONTACT: ____________

   TELEPHONE NO.: ____________

3. ARCHITECTURAL/ENGINEERS, NAME: ____________

   ADDRESS: ____________

   PERSON TO CONTACT: ____________

   TELEPHONE NO.: ____________

4. PROJECT CONSTRUCTION SCHEDULE:

	DATE
a) DATE OF PREPARATION OF BIDS SPECS.	
b) DATE OF REQUEST FOR BIDS	
c) DATE OF CONTRACT AWARD	
d) DATE ON SITE CONSTRUCTION BEGAN	1968
e) DATE ON SITE CONSTRUCTION COMPLETED	
f) DATE OF INITIAL STARTUP	3/71
g) DATE OF COMPLETION OF SHAKEDOWN	11/71

*At Max. Continuous Capacity

5. LIST MAJOR DELAYS IN CONSTRUCTION SCHEDULE AND CAUSES:

____

____

____

____

____

____

6. NUMBER OF SO_2 SCRUBBER TRAINS USED — eight

7. DESIGN THROUGHPUT PER TRAIN, ACFM @ °F — ~ 150,000 SCFM

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

2) EQUIPMENT LAYOUT

H. SO_2 SCRUBBING AGENT

1. TYPE — Limestone

2. SOURCES OF SUPPLY — N.R. Hamm Quarry CA.5 Roadroak (local quarry)

3. CHEMICAL COMPOSITION (for each source)

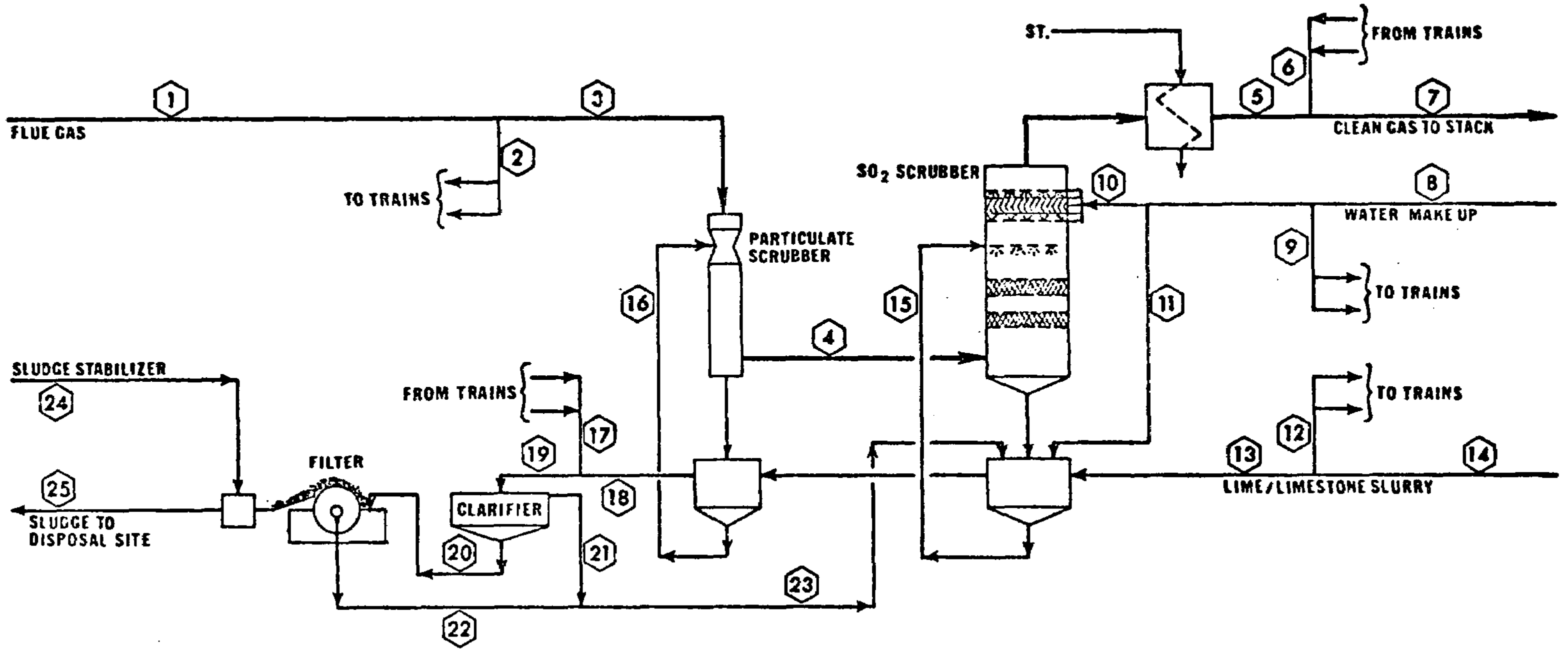
SILICATES	
SILICA	6%
CALCIUM CARBONATE	93%
MAGNESIUM CARBONATE	1%

4. EXCESS SCRUBBING AGENT USED ABOVE STOICHIOMETRIC REQUIREMENTS — 60-65% *

5. MAKE-UP WATER POINT OF ADDITION — Slurry Circ. tank

6. MAKE-UP ALKALI POINT OF ADDITION — Injection into furnace

* Rate adjusted to give 5.5 pH in marble bed.



STREAM NO.	1	2	3	4	5	6	7	8	9	10	11	12	13
RATE, lb/hr													
ACFM													
CPM													
PARTICULATES, lb/hr													
SO_2, lb/hr													
TEMPERATURE, °F													
TOTAL SOLIDS, %													
SPECIFIC GRAVITY,													

STREAM NO.	14	15	16	17	18	19	20	21	22	23	24	25	26
RATE, lb/hr													
ACFM													
CPM													
PARTICULATES, lb/hr													
SO_2, lb/hr													
TEMPERATURE, °F													
TOTAL SOLIDS, %													
SPECIFIC GRAVITY													

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

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J. SCRUBBER TRAIN SPECIFICATIONS

1. SCRUBBER NO. 1 [(a)]

TYPE (TOWER/VENTURI)	Town
LIQUID/GAS RATIO, G/MCF @ °F	22
GAS VELOCITY THROUGH SCRUBBER, FT/SEC	6 to 7 ft/sec
MATERIAL OF CONSTRUCTION	C.S.
TYPE OF LINING	Celcote epoxy with glass flakes
INTERNALS:	
TYPE (FLOATING BED, MARBLE BED, ETC.)	Marble bed
NUMBER OF STAGES	One
TYPE AND SIZE OF PACKING MATERIAL	3/4" Pyrex glass
PACKING THICKNESS PER STAGE [(b)]	3-1/2"
MATERIAL OF CONSTRUCTION, PACKING:	Glass
SUPPORTS:	304 SS
Plate	316L SS

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	None
L/G RATIO	
SOURCE OF WATER	

4. DEMISTER

TYPE (CHEVRON, ETC.)	Chevron
NUMBER OF PASSES (STAGES)	Two
SPACE BETWEEN VANES	2"
ANGLE OF VANES	45°
TOTAL DEPTH OF DEMISTER	24" (6" per demister 12" spacing)
DIAMETER OF DEMISTER	
DISTANCE BETWEEN TOP OF PACKING AND BOTTOM OF DEMISTER	7'-8' for original 6 modules
POSITION (HORIZONTAL, VERTICAL)	
MATERIAL OF CONSTRUCTION	Fiberglass
METHOD OF CLEANING	Power washing lances
SOURCE OF WATER AND PRESSURE	Pond, 150 psig
FLOW RATE DURING CLEANINGS, GPM	
FREQUENCY AND DURATION OF CLEANING	Once every 24 hrs. for one hour.

REMARKS ______

5. REHEATER

TYPE (DIRECT, INDIRECT) Indirect

b) For floating bed, packing thickness at rest.

DUTY, MMBTU/HR ~80 (10 per reheater)

HEAT TRANSFER SURFACE AREA SQ.FT ______

TEMPERATURE OF GAS: IN 120 OUT 150

HEATING MEDIUM SOURCE Boiler feed water

TEMPERATURE & PRESSURE 260°F

FLOW RATE 150 gpm Unit

REHEATER TUBES, TYPE AND MATERIAL OF CONSTRUCTION C.S.

REHEATER LOCATION WITH RESPECT TO DEMISTER ______

6' to 7' above top of demister

METHOD OF CLEANING ______

FREQUENCY AND DURATION OF CLEANING 6 times/day for 3 minutes

FLOW RATE OF CLEANING MEDIUM ______ LB/HR

REMARKS No cleaning problem

6. SCRUBBER TRAIN PRESSURE DROP DATA

	INCHES OF WATER
PARTICULATE SCRUBBER	
SO_2 SCRUBBER	6"-8"
CLEAR WATER TRAY	N/A
DEMISTER	
REHEATER	1-1/2"-2.0"
DUCTWORK	
TOTAL FGD SYSTEM	10" max.

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

TO: DEMISTER ______

QUENCH CHAMBER ______

ALKALI SLURRYING ______

PUMP SEALS Same water (pond water)

OTHER ______

TOTAL 1200 gpm

FRESH WATER ADDED PER MOLE OF SULFUR REMOVED ______

8. BYPASS SYSTEM

CAN FLUE GAS BE BYPASSED AROUND FGD SYSTEMS Yes

GAS LEAKAGE THROUGH BYPASS VALVE, ACFM zero

K. SLURRY DATA

	pH	% Solids	Capacity (gal)	Hold up time
LIME/LIMESTONE SLURRY MAKEUP TANK				
PARTICULATE SCRUBBER EFFLUENT HOLD TANK (a)				
SO_2 SCRUBBER EFFLUENT HOLD TANK (a)	9.5 to 10	8.5 to 9.5		30 minutes

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

TYPE OF MILL (WET CYCLONE, ETC.) ______

NUMBER OF MILLS Two

CAPACITY PER MILL ______ T/HR

RAW MATERIAL MESH SIZE 1-1/4"

PRODUCT MESH SIZE 60% through 200 mesh

SLURRY CONCENTRATION IN MILL ____________________

CALCINING In furnace ____________________

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 ____________________

DIMENSIONS ____________________

CONCENTRATION OF SOLIDS IN UNDERFLOW ____________________

3. ROTARY VACUUM FILTER

NUMBER OF FILTERS ____________________

CLOTH AREA/FILTER ____________________

CAPACITY ____________________ TON/HR (WET CAKE)

CONCENTRATION OF SOLIDS IN CAKE ____________________

PRECOAT (TYPE, QUANTITY, THICKNESS) ____________________

REMARKS ____

____

____

4. SLUDGE FIXATION

POINT OF ADDITIVES INJECTION None ____________________

FIXATION MATERIAL COMPOSITION ____________________

FIXATION PROCESS (NAME) ____________________

FIXATION MATERIAL REQUIREMENT/TONS OF DRY SOLIDS OF SLUDGE

____

There is room for one more 30 acre x 16' pond

ESTIMATED POND LIFE, YRS. 220 years

CONCENTRATION OF SOLIDS IN FIXED SLUDGE ____________

METHOD OF DISPOSAL OF FIXED SLUDGE ____________

INITIAL SOLIDIFICATION TIME OF FIXED SLUDGE ____________

5. SLUDGE QUANTITY DATA

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

IS POND/LANDFILL ON OR OFFSITE ____________

TYPE OF LINER ____________

IF OFFSITE, DISTANCE AND COST OF TRANSPORT ____________

POND/LANDFILL DIMENSIONS AREA IN ACRES ____________
DEPTH IN FEET ____________

DISPOSAL PLANS; SHORT AND LONG TERM ____________

____

____

____

____

N. COST DATA

1. TOTAL INSTALLED CAPITAL COST ____________

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 SCRUBBER TRAINS	☐	☐	____
LIMESTONE MILLING FACILITIES	☐	☐	____
SLUDGE TREATMENT & DISPOSAL POND	☐	☐	____
SITE IMPROVEMENTS	☐	☐	____
LAND, ROADS, TRACKS, SUBSTATION	☐	☐	____
ENGINEERING COSTS	☐	☐	____
CONTRACTORS FEE	☐	☐	____
INTEREST ON CAPITAL DURING CONSTRUCTION	☐	☐	____
B. ANNUALIZED OPERATING COST			
FIXED COSTS			
INTEREST ON CAPITAL	☐	☐	____
DEPRECIATION	☐	☐	____
INSURANCE & TAXES	☐	☐	____
LABOR COST INCLUDING OVERHEAD	☐	☐	____
VARIABLE COSTS			
RAW MATERIAL	☐	☐	____
UTILITIES	☐	☐	____
MAINTENANCE	☐	☐	____

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 ____________________

2. DEMISTER

PROBLEM/SOLUTION ____________________

3. REHEATER

PROBLEM/SOLUTION ____________________

4. **VENTURI SCRUBBER, CIRCULATION TANKS AND PUMPS**

PROBLEM/SOLUTION

5. **I.D. BOOSTER FAN AND DUCT WORK**

PROBLEM/SOLUTION Poor distribution of flue gas to all modules is still an outstanding problem which have not been solved

6. **LIMESTONE MILLING SYSTEM OR LIME SLAKING**

PROBLEM/SOLUTION

7. **SLUDGE TREATMENT AND DISPOSAL**

PROBLEM/SOLUTION

8. MISCELLANEOUS AREA INCLUDING BYPASS SYSTEM

PROBLEM/SOLUTION

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.

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:
Unit did not run long enough to have availability factor.

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

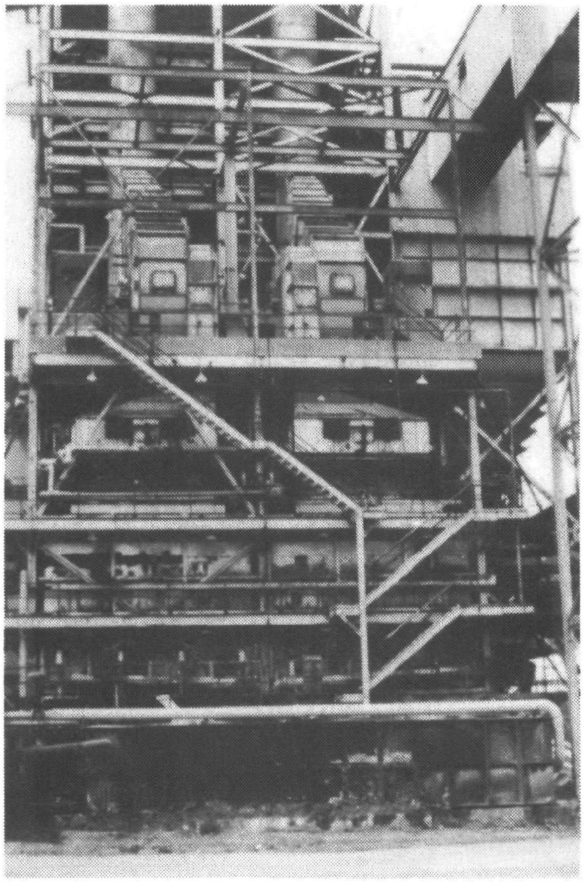

Photo No. 1 General view of the two FGD modules installed on Lawrence 4. Each module consists of a single-stage marble bed, a mist eliminator, a flue gas reheater and a separate booster fan (shown on the uppermost level) and a separate stack. Both modules share a common slurry recirculation tank shown in the foreground.

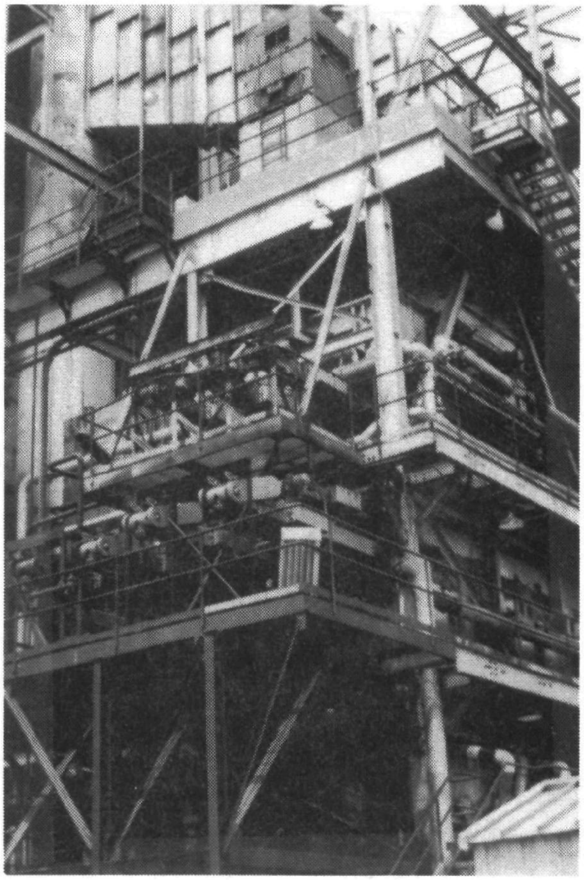

Photo No. 2 A side view of one of the two modules on Lawrence 4 showing the bank of mist eliminator's water wash lances. The reheater soot blowers which use compressed air are shown on the second level.

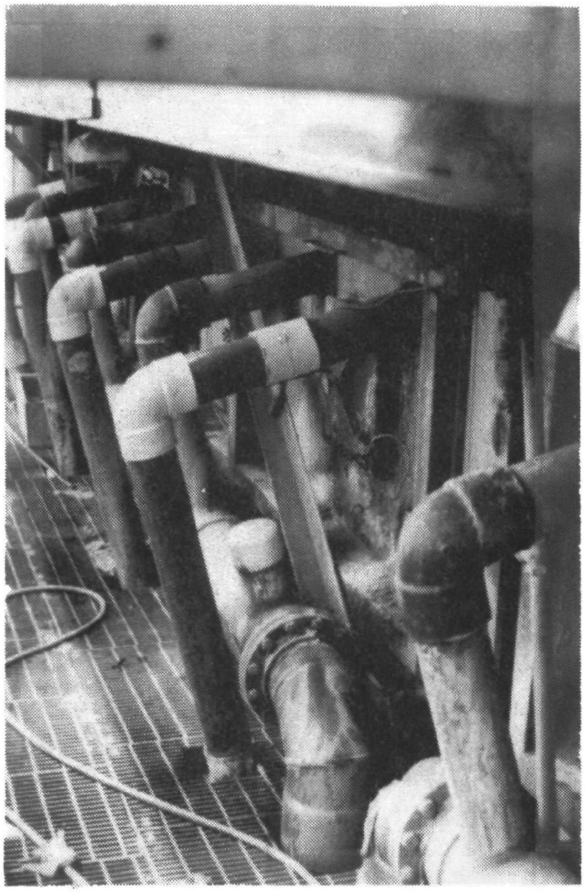

Photo No. 3 Close-up view of the slurry recirculation headers as they enter the walls of the module below the marble bed level. The light colored fiberglass elbows which replaced worn-out fittings, points to the areas which are mostly susceptible to erosion in the slurry recirculation loop.

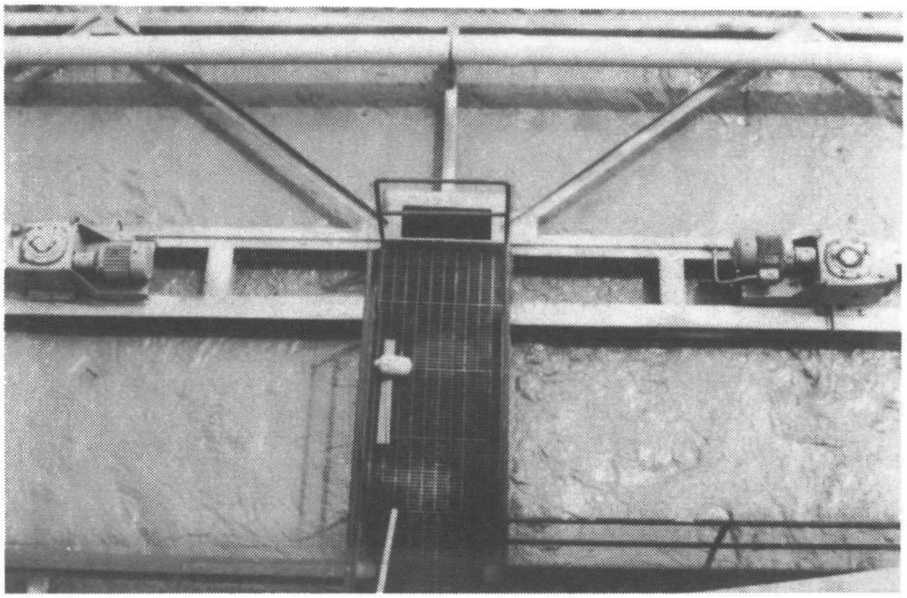

Photo No. 4 Top view of the slurry recirculation tank which serves the two modules on Lawrence 4. The overflow from this concrete tank is pumped to the fly ash and sludge disposal ponds.

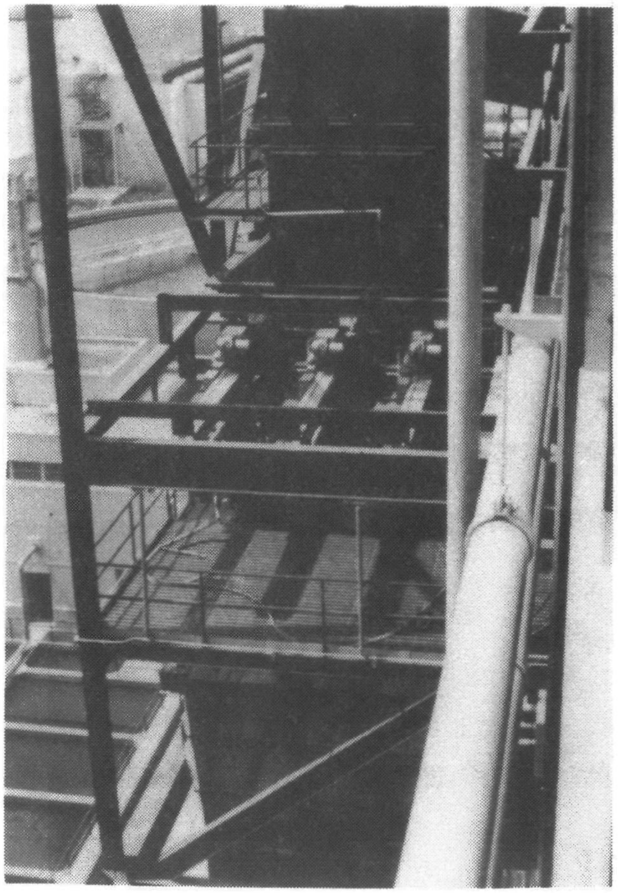

Photo No. 5 Partial view of 1 of the 8 FGD modules on Lawrence 5. The three retractable soot blowers which serve the reheater unit on each module are shown in the center of the picture.

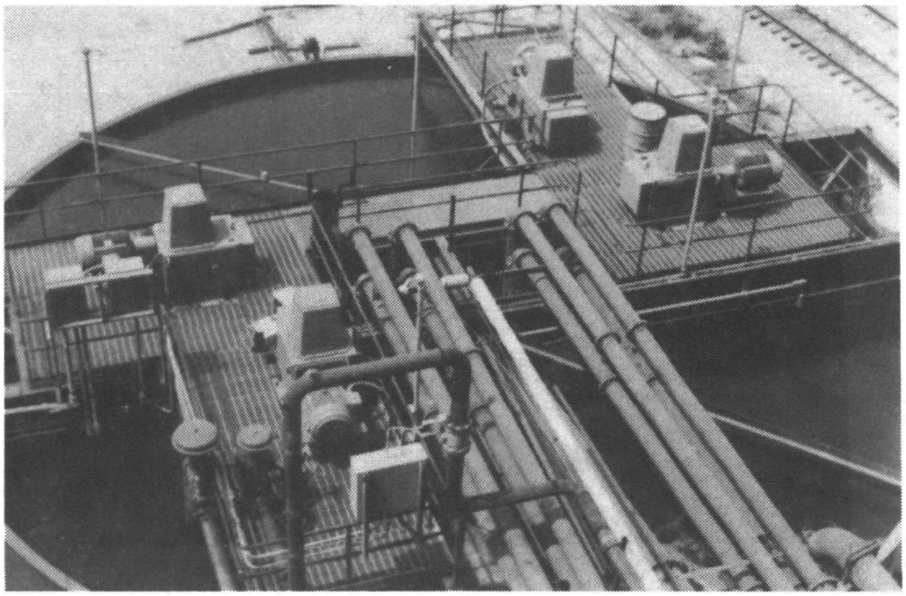

Photo No. 6 Top view of the slurry recirculation tank which is common to all the 8 modules on Lawrence 5. During the plant visit, Lawrence 5 was operating on natural gas and the FGD system was not in operation, as evidenced by the stagnant liquor in the tank.

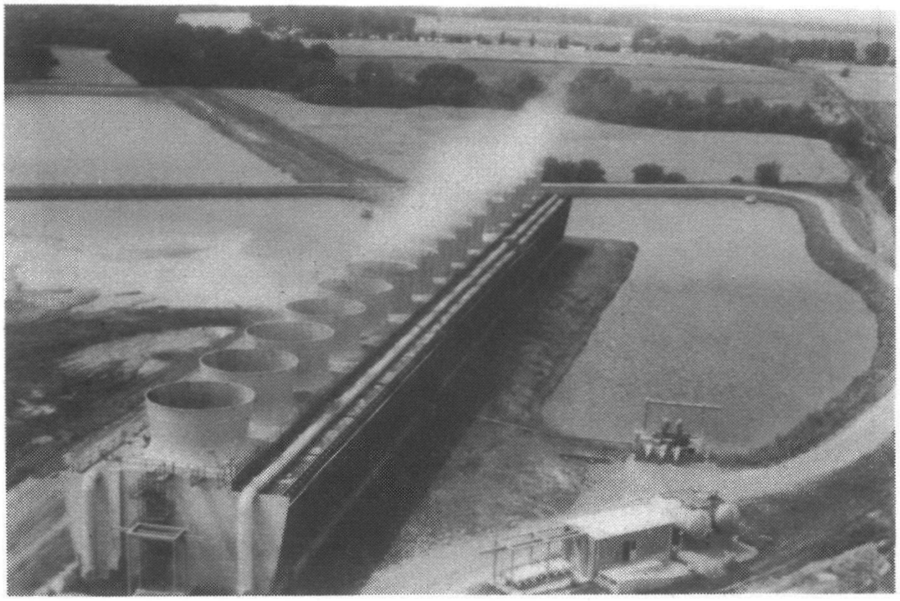

Photo No. 7 The spent slurry from both Lawrence 4 and 5 is discharged to three interconnected ponds. The slurry first enters the 16-acre pond (shown on the left) and the clarifier liquor overflows to the 28-acre pond (in the background) or the 4-acre pond shown on the right. The clarified liquor is recycled to the scrubber modules from the 4-acre pond.

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

1 REPORT NO EPA-650/2-75-057-e	2	3 RECIPIENT'S ACCESSION NO
4 TITLE AND SUBTITLE Survey of Flue Gas Desulfurization Systems Lawrence Power Station, Kansas Power and Light Company		5 REPORT DATE September 1975 6. PERFORMING ORGANIZATION CODE
7 AUTHOR(S) Gerald A. Isaacs and Fouad K. Zada		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 6e
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; 8/74-9/75 14. SPONSORING AGENCY CODE
15 SUPPLEMENTARY NOTES		

16 ABSTRACT The report gives results of a survey of the flue gas desulfurization (FGD) systems at Kansas Power and Light Co.'s Lawrence Power Station. The systems utilize boiler injection of pulverized limestone, followed by tail-end wet scrubbing: unit 4, with a net capacity of 102 MW, was retrofitted with two FGD modules and was placed in service in November 1968; and boiler 5, with a net capacity of 320 MW, and its FGD system were started up in 1971. Both boilers operate at half-load at night so that the modules can be shut down for regular maintenance. Forced outages are infrequent because the FGD demand factor is fairly low. Operating problems include corrosion, unsatisfactory damper operation, demister fouling, expansion joint failures, and pump failures. The spent slurry contains fly ash and unreacted lime which stabilize and solidify the sludge in unlined ponds without furthur treatment. KP and L's capital cost in 1968 for the installation of FGD units 4 and 5 was reported to be about $3.5 million. Substantial additional costs for the system were borne by the vendor, Combustion Engineering, Inc. Both FGD systems are to be modified: the two unit 4 modules will be replaced by January 1977; and the unit 5 system will be converted to a tail-end wet limestone process by the fall of 1975.

17 KEY WORDS AND DOCUMENT ANALYSIS

a DESCRIPTORS		b IDENTIFIERS/OPEN ENDED TERMS	c COSATI Field/Group
Air Pollution	Scrubbers	Air Pollution Control	13B
Flue Gases	Coal	Stationary Sources	21B 21D
Desulfurization	Combustion	Tail-End Wet Scrubbing	07A, 07D
Limestone	Cost Engineering		14A
Boilers			13A
Injection			

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