TRADITIONAL VERSUS NON-TRADITIONAL FLUE GAS CONDITIONING FOR ELECTROSTATIC PRECIPITATORS

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Abstract

Ohio Edison tested two types of flue gas conditioning systems as part of developing its acid rain strategy. These tests were performed on Toronto No. 11 boiler while burning a low sulfur eastern coal (0.8 percent sulfur). The first test was the traditional conditioners, SO_3 and NH_3 gases injected into the flue gas prior to the electrostatic precipitator. The second test was with a liquid conditioner injected into the flue gas prior to the electrostatic precipitator. The liquid conditioner contained 25 percent sodium nitrate, 25 percent ammonium nitrate, and a proprietary polymer.

In this specific test program, the non-traditional liquid conditioner performed better than the conventional SO_3/NH_3 conditioning. Compliance with Ohio's particulate emission limit of 0.10 pound of particulate per million Btu's required derating the boiler from 645,000 to 600,000 pounds of steam per hour during the tests with SO_3/NH_3 conditioning. No derate was required with the liquid conditioner. In addition, the economics, in this specific test program favored the liquid conditioner. The Toronto Boiler No. 11 is a 65-MW, pulverized coal, non-reheat, cycling unit with an electrostatic precipitator with a specific collecting area of 190 square feet per 1000 ACFM and an inlet temperature of 350°F.

Introduction

Toronto Unit No. 9, Boiler No. 11, is rated at 66 GMW. The precipitator on this unit was designed for coal with a minimum sulfur content of 2.5 percent; the unit is currently burning coal with a sulfur content of 3 to 3.5 percent. The precipitator is a Buell, installed in 1970 and upgraded in 1980. It is a four-field, weighted-wire, precipitator with an SCA of 192 ft^2/1000 ACFM.

As a result of acid rain legislation, it was decided to test this unit with a low sulfur, eastern, bituminous coal (about 0.8 percent sulfur) to aid in the determination of Ohio Edison's options. In 1991, a test burn of low sulfur coal was performed with the traditional SO_3 conditioning and with SO_3/NH_3 conditioning. In 1992, a test burn of low sulfur eastern coal was performed with a nontraditional liquid flue gas conditioning.

The Test Program

A test burn of low sulfur eastern coal was performed on June 6, 1991 with SO_3 flue gas conditioning. After the SO_3 condition rate was adjusted to minimize opacity, a particulate emission test was performed. This test demonstrated that SO_3 conditioning alone was unacceptable. This was probably due to the flue gas temperature of 350°F, which resulted in high levels of reentrainment when the precipitator was rapped. At the completion of this test, the boiler load was reduced to a level where the opacity was acceptable, and the bunkers were refilled with the high sulfur coal normally burned at this plant.

Three test burns of low sulfur eastern coal were performed in July, August, and October 1991 with SO_3/NH_3 flue gas conditioning. These tests demonstrated that compliance with the Ohio particulate emission standard of 0.1 lb/mmBtu could consistently be achieved if the boiler load was limited to 600,000 pounds steam/hour. This was a derate of 45,000 pounds steam/hour (4 to 5 MW). In all cases, there were a large number of opacity spikes, although they were considerably lower in intensity as compared to conditioning with SO_3 only.

It should be recognized that the operating conditions were not optimized. We probably could recover some of the derate on this boiler by reducing the boiler inleakage, tuning up the boiler controls, optimizing the pulverizers and by some adjustment of the rapper program and the intensity of the rappers. However, there are limits to these corrections. The historic steam flow limit on the boiler could not be achieved because the low sulfur eastern coal is harder to grind; therefore, reducing the pulverizer capacity. If the pulverizers were pushed too hard, an unacceptable level of unburned carbon resulted, which reduced the performance of the precipitator.

A test burn of low sulfur eastern coal was performed from July 27 to August 6, 1992 with Calgon Fact 5000 flue gas conditioning. The Calgon Fact 5000, a liquid containing 25 percent sodium nitrate, 25 percent ammonium nitrate and a proprietary polymer, is diluted and sprayed into the inlet duct of the precipitator using air atomizing nozzles. The tests demonstrated compliance with the Ohio particulate emission standard of 0.10 lb particulate/mmBtu. During the tests, there was no need to limit the boiler load and, as the test period continued, the particulate emission rate dropped. In addition, the

opacity spikes were lower in intensity, duration, and frequency when compared with SO_3 and NH_3/SO_3 conditioning.

During the test burn with liquid conditioning, neither the boiler nor the precipitator operating conditions were optimized, as was the case with SO_3 and SO_3/NH_3 conditioning and the baseline tests.

The attachments show typical sections of the opacity charts and precipitator electrical readings recorded during the baseline tests, and the tests with various conditioners.

Discussion of Test Results

It can clearly be seen from the test results that the particulate emissions were lower during the tests with the liquid flue gas conditioner and that, as the treatment continued with the FACT 5000 flue gas conditioner, the particulate emission rate dropped. The typical sections from the opacity chart show a lower frequency and intensity of opacity spikes with the liquid flue gas conditioner. The electrostatic precipitator transformer/rectifier sets' electrical readings were very stable with the FACT 5000 conditioner and were unstable with the SO_3 and SO_3/NH_3 flue gas conditioning as shown by the typical electrostatic precipitator data.

The treatment flow rate with the liquid flue gas conditioner was not optimized and a considerable amount of time was spent in optimizing the treatment flow rate with the SO_3/NH_3 flue gas conditioner. The operating conditions of the boiler and precipitator were not optimized during any of the tests.

The estimated total annual liquid, levelized capital, including the chemical cost, for Toronto Boiler No. 11 was $366,400 for the SO_3/NH_3 flue gas conditioning system and $112,436 with the liquid flue gas conditioning system. The estimated costs for the chemicals for both systems were based on a capacity factor of 36 percent, and the costs for the liquid flue gas conditioning system would have been lower than the SO_3/NH_3 system even if this unit had been base-loaded.

Conclusions

In conclusion, this test program on Toronto Plant Boiler No. 11 shows a cost savings and lower particulate emissions with the liquid flue gas conditioning system. The costs for the chemical could have been lowered if the time had been taken to optimize the treatment flow rate.

This test program shows that we should evaluate traditional and nontraditional flue gas conditioning systems if a switch to lower sulfur coal requires flue gas conditioning -- especially in cases where the boilers are small, the precipitator on the unit is small (200 SCA), the unit is basically used for peaking, and the capital cost difference between the various flue gas conditioning is large.

The conditions at each location will vary, and each location must be evaluated to determine the optimum flue gas condition system for that location.

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TORONTO BOILER 11
EMISSION TESTS USING FLUE GAS CONDITIONING WHILE BURNING LOW SULFUR EASTERN COAL

DATE OF TEST	STEAM FLOW X 1000 POUNDS PER HOUR	CONDITIONING AGENT			COST OF CONDITIONING AGENT PER TON OF COAL (DOLLARS)	EMISSION RATE (POUNDS OF PARTICULATE PER MILLION BTU'S)	LOI	COAL DATA		
		SO3 INJECTION RATE (PPM)	NH3 INJECTION RATE (PPM)	CALGON FACT 5000 (POUNDS/TON COAL)			(%)	SULFUR (%)	ASH (%)	HEAT CONTENT (BTU'S/LB)
BASE LINE, NORMAL COAL										
5/30/91	612	---	---	---	---	0.032	---	4.43	16.30	11,120
6/03/92	618	---	---	---	---	0.017	---	3.91	13.77	11,794
SO3 CONDITIONING, LOW SULFUR COAL										
6/06/91	618	17	---	---	0.09	0.143	14.2	0.74	12.99	12,258
SO3 & NH3 CONDITIONING, LOW SULFUR COAL										
7/16/91	595 TO 655	17	11	---	0.11	0.145	---	0.82	9.01	12,759
7/16/91	601	17	11	---	0.11	0.088	---	0.84	-----	12,917
7/24/91	606	17	11	---	0.11	0.173(1)(2)	---	0.73	10.55	12,653
7/25/91	618	15	8	---	0.09	0.084(3)	---	0.75	9.40	12,747
8/22/91	587	16	12	---	0.11	0.063	---	0.89	11.89	12,030
8/22/91	619	16	12	---	0.11	0.115	11.56	0.88	11.52	12,182
8/22/91	630	16	12	---	0.11	0.131	---	0.96	11.47	12,215
8/23/91	627	18	22	---	0.13	0.094(4)	---	0.87	10.84	12,244
10/02/91	621	18	22	---	0.13	0.086	10.25	0.72	10.83	11,921
10/02/91	605	18	22	---	0.13	0.103	24.12	0.70	10.79	11,968
CALGON CONDITIOING, LOW SULFUR COAL										
7/29/92	612	---	---	0.93	0.74	0.09	14.58	1.09	10.18	11,757
7/31/92	618	---	---	0.88	0.70	0.076	9.61	0.89	10.26	11,582
8/04/92	605	---	---	0.59	0.47	0.037	14.36	0.88	10.44	11,756
8/05/92	606	---	---	0.94	0.94	0.027	11.13	0.81	10.11	11,760

(1) Installed new rapper control 7/20/91 -- control failed 7/23/91 -- boiler off line 2200 hr -- control repaired 2400 hr
(2) Boiler on line approximately 1 1/2 hours without conditioning; opacity spikes all day
(3) Boiler tripped during test
(4) ESP hopper too full; started to degrade performance, first field, during test run No. 2

COST COMPARISON OF THE TWO FLUE GAS CONDITIONING SYSTEMS

SO3/NH3 SYSTEM		CALGON SYSTEM	
CAPITAL COST	$2,000,000	CAPITAL COST	$150,000
LEVELIZIED CAPITAL COST FOR 20 YEARS USING 17.52% FIXED CHARGED RATE	$350,400	LEVELIZIED CAPITAL COST FOR 20 YEARS USING 17.52% FIXED CHARGED RATE	$26,280
COAL USED PER YEAR (1)	123,080 TONS	COAL USED PER YEAR	123,080 TONS
CHEMICAL COST PER TON COAL FOR SO3/NH3	$0.13	CHEMICAL COST PER TON COAL FOR FACT 5000	$0.70/TON
TOTAL CHEMICAL COST PER YEAR SO3/NH3	$16,000	TOTAL CHEMICAL COST PER YEAR FACT 5000 (3)	$86,156
TOTAL ANNUAL COST OF CAPITAL & CHEMICAL (2)	$366,400	TOTAL ANNUAL COST OF CAPITAL & CHEMICAL (2)	$112,436

(1) TORONTO BOILER NO. 11 BURNED 123,080 TONS OF COAL IN 1991 WITH A 36% CAPACITY FACTOR.

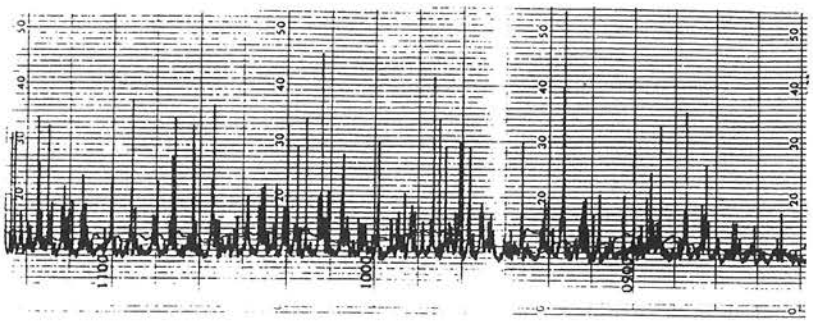
(2) THE YEARLY POWER COST WAS NOT INCLUDED FOR EITHER SYSTEM, HOWEVER IT WOULD HAVE BEEN HIGHER FOR THE SO3/NH3 SYSTEM.

(3) THE FEED RATE FOR THE FACT 5000 WAS NOT OPTIMIZED DURING THE TESTS. THE DATA SHOWS COMPLIANCE WITH THE PARTICULATE EMISSION LIMIT WITH A FEED RATE OF 0.59 POUNDS/TON OF COAL, WHICH EQUALS $0.47/TON OF COAL. THE ABOVE CALCULATION USES 0.88 POUNDS/TON OF COAL, WHICH EQUALS $0.70/TON OF COAL.

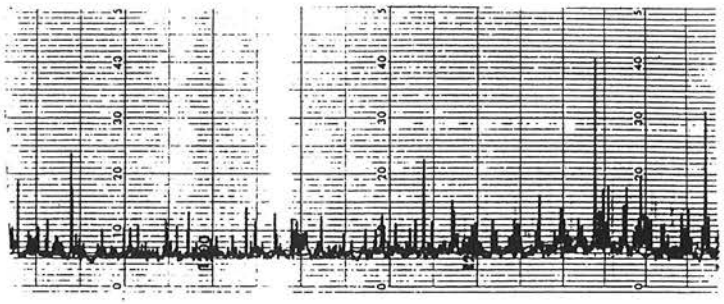
(4) THE CHEMICAL COSTS WERE BASED ON $200/TON FOR SO2 & NH3 AND $0.80/POUND FOR FACT 5000.

TYPICAL ELECTROSTATIC PRECIPITATOR READING TORONTO UNIT NO. 7 BOILER NO. 11				
DATE	8/5/92	6/6/91	10/2/91	6/3/92
CONDITIONER	CALGON FACT 5000	SO3 ONLY	S03/NH3	BASELINE
PRECIP. INLET TEMPERATURE F	345	337	340	347
FIELD A				
AC AMPERES	45	45	25 to 60	70
AC VOLTS	260	240	230 to 270	310
DC MILLIAMPERES	250	260	230 to 260	440
DC KILOVOLTS	32	30	29 to 32	36
FIELD B				
AC AMPERES	80	55 to 75	60 to 95	100
AC VOLTS	280	240 to 260	240 to 290	300
DC MILLIAMPERES	540	260 to 460	350 to 600	620
DC KILOVOLTS	32	26 to 30	29 to 32	34
FIELD C				
AC AMPERES	120	55 to 90	115 to 135	135
AC VOLTS	290	230 to 270	240 to 290	300
DC MILLIAMPERES	840	400 to 700	800 to 940	930
DC KILOVOLTS	34	29 to 34	32 to 34	35
FIELD D				
AC AMPERES	135	85 to 125	132	135
AC VOLTS	310	270 to 320	290	300
DC MILLIAMPERES	980	560 to 920	940	950
DC KILOVOLTS	34	32 to 36	32	32

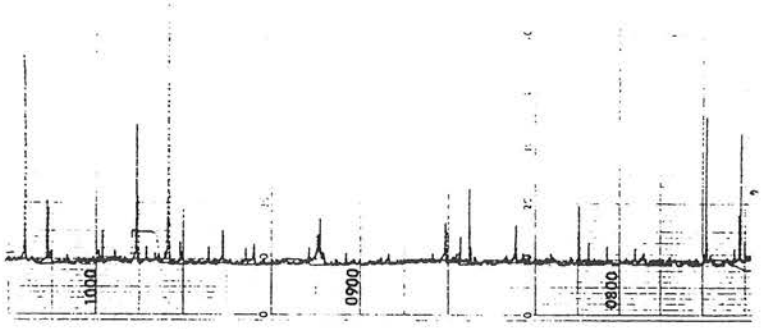
TYPICAL SECTION OF THE TORONTO PLANT OPACITY CHART DURING THE TESTS ON BOLIER NO. 11



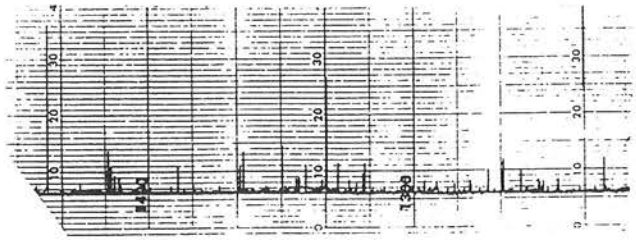
SO3 CONDITIONING WITH 0.8% SULFUR COAL



SO3/NH3 CONDITIONING WITH 0.8% SULFUR COAL



FACT 5000 CONDITIONING WITH 0.8% SULFUR COAL



BASELINE; NO CONDITIONING WITH 3.75% SULFUR COAL

BOILER AND ELECTRODESTATIC PRECIPTATOR DESIGN DATA

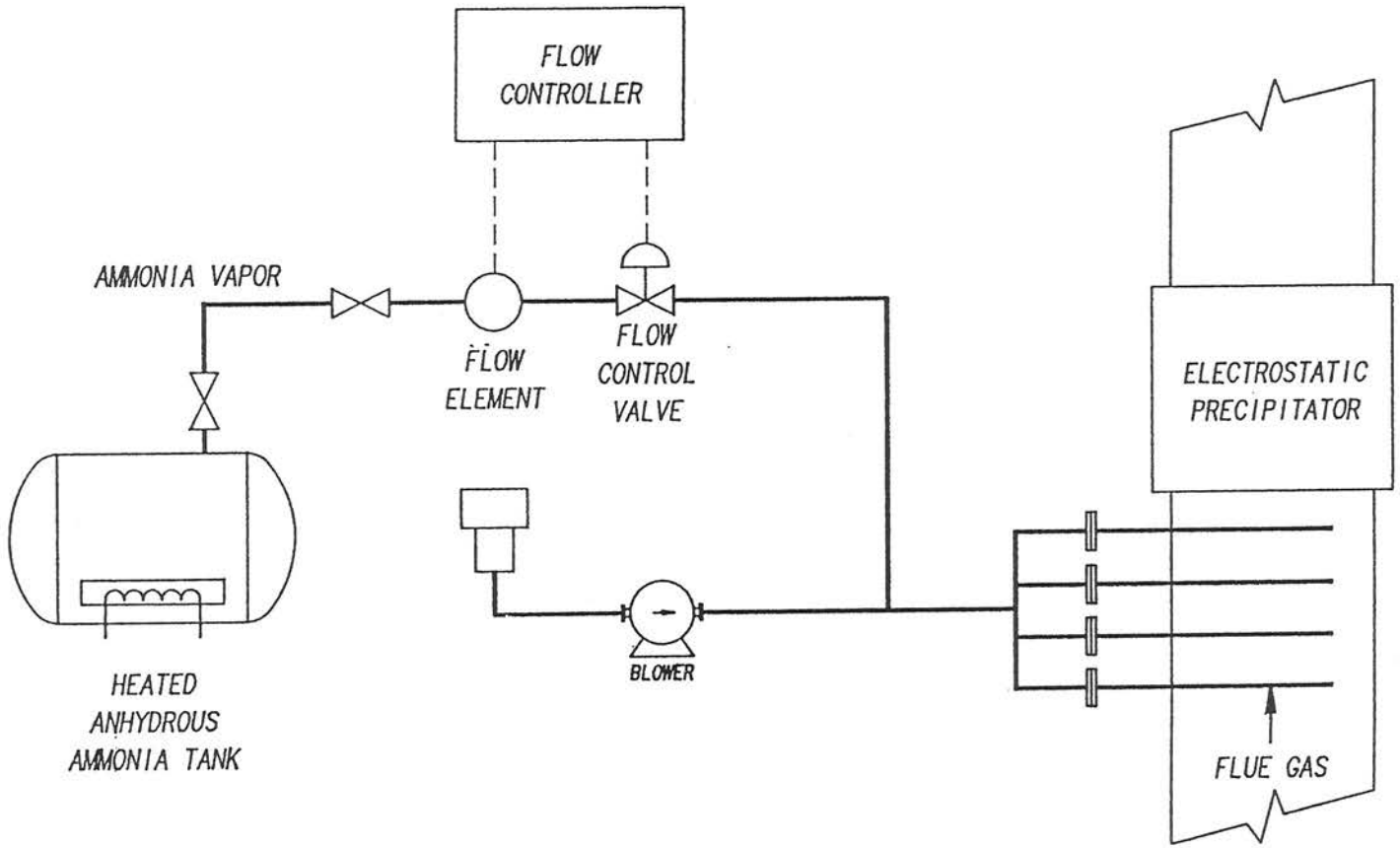
BOILER DEESIGN DATA:

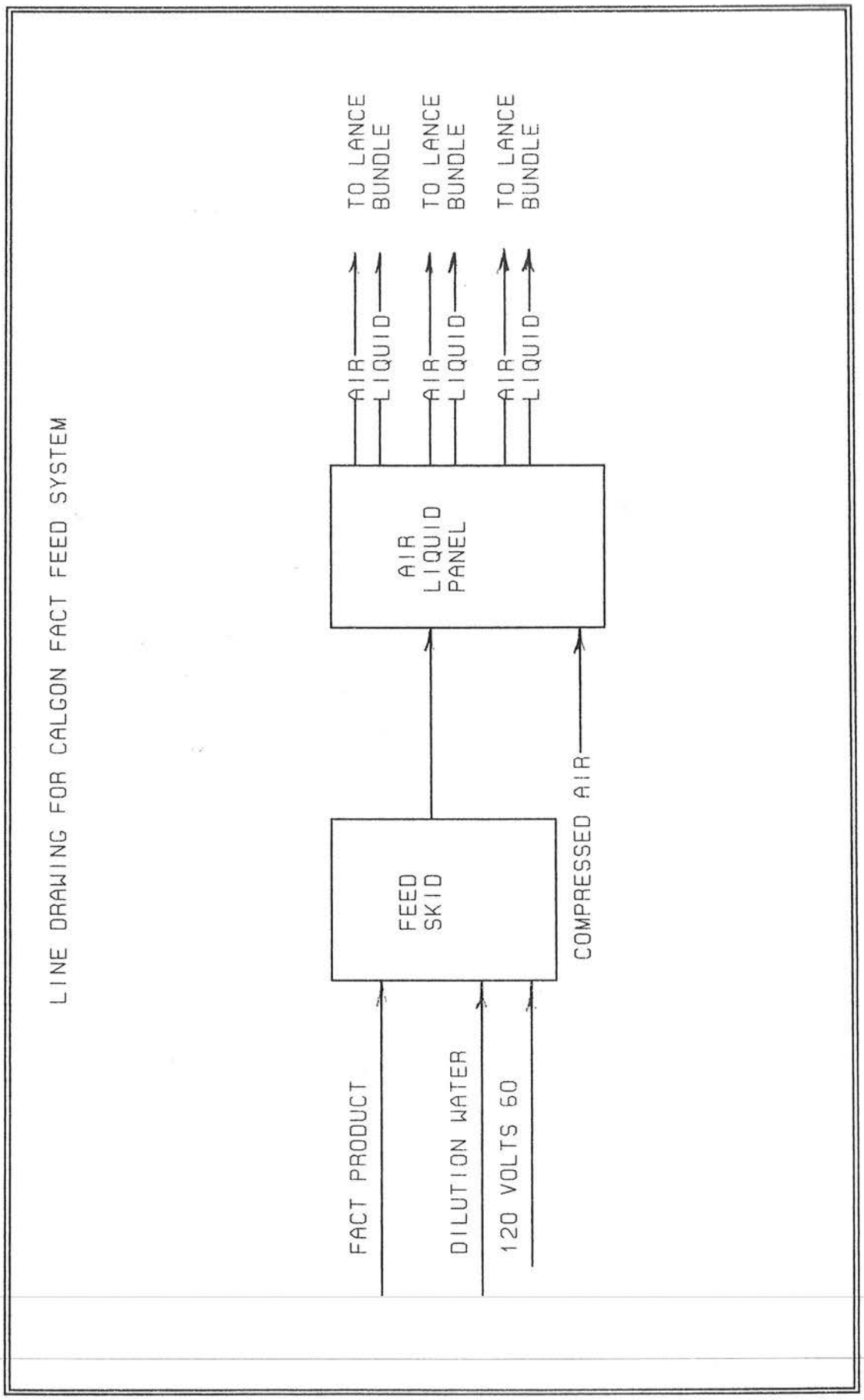
MANUFACTURER:	B & W
YEAR PLACED IN SERVICE:	1949
CAPACITY:	600,000 POUNDS STEAM/HOUR
DRUM PRESSURE:	925 PSIG
SUPERHEATER OUTLET PRESSURE:	825 PSIG
SUPERHEATER OUTLET TEMPERATURE:	900 DEGREES F
FUEL:	PULVERIZED COAL
PULVERIZERS:	3 B & W E64'S

ELECTROSTATIC PRECIPITATOR DATA:

MANUFACTURER:	BUELL
YEAR PLACED IN SERVICE	1970 UPGRADED 1980
TYPE:	WEIGHTED WIRE
SPACING:	9 INCHES
FLUE GAS FLOW:	390,000 ACFM
FLUE GAS INLET TEMPERATURE:	350 DEGREES F
FLUE GAS VELOCITY:	4.49 FEET/SECOND
NUMBER OF FIELDS:	8
DEPTH EACH FIELD:	3 FEET
PLATE HEIGHT:	30 FEET
NUMBER GAS PASSAGES:	50
NUMBER TRANSFORMERS/RECTIFIERS	4
SPECIFIC COLLESTION AREA	185 FT^2/1000 ACFM
COAL SPECICATIONS:	
ASH:	14.2 PERCENT
SULFUR:	1.5 PERCENT MIMIMUM

AMMONIA FLUE GAS CONDITIONING SYSTEM




LINE DRAWING FOR CALGON FACT FEED SYSTEM
TO LANCE BUNDLE
TO LANCE BUNDLE
TO LANCE BUNDLE
AIR
LIQUID
AIR
LIQUID
AIR
LIQUID
AIR LIQUID PANEL
FEED SKID
COMPRESSED AIR
FACT PRODUCT
DILUTION WATER
120 VOLTS 60

LIQUID SO_2 FLUE GAS CONDITIONING

SO_3 GENERATOR