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IMPROVED AIR POLLUTION CONTROL FOR A KRAFT RECOVERY BOILER:

RECOVERY BOILER NO. 4

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IMPROVED AIR POLLUTION CONTROL FOR A KRAFT RECOVERY BOILER:

RECOVERY BOILER NO. 4

by

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ABSTRACT

The purpose of this report is to document the cost of and the emission control capability associated with construction and operation of a "controlled odor" kraft recovery boiler.

The evaluation of this installation was accomplished by means of an extensive emission testing program.

The testing program also investigated process variables that affect the operation of a kraft recovery boiler and the emissions resulting therefrom in order to establish the proper conditions of boiler operation required to minimize emissions. Variables investigated included boiler loading and liquor distribution.

The analysis of test data collected was accomplished statistically with the aid of an IBM 370 computer using the multiple regression analysis technique. Particulate emissions were found to be primarily affected by and directly proportional to the amount of black liquor solids burned in the recovery furnace (boiler loading). The emissions of SO_2 were primarily affected by the sulfidity level of the cooking liquor being recovered, the higher the sulfidity level the higher the emissions of SO_2. Total reduced sulfur (TRS) emissions were similarly affected by liquor sulfidity.

The emissions of both TRS and particulates were sufficiently low to enable the new system to meet Montana State Emission Standards.

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CONTENTS

Section		Page
I	Conclusions	1
II	Introduction	2
III	Plan Implementation	4
IV	System Shake-down	9
V	Evaluation of the No. 4 Recovery System	10
VI	EPA Testing Program for No. 4 Recovery Boiler	23
VII	Data Analysis and Discussion of Results	32

Appendices

A	Design Parameters for the Major Components of the System	42
B	Particulate Sampling Test Procedures	45
C	Complete EPA Test Data for No. 4 Recovery Program	51
	1. Glossary for Data Sheets	51
	2. Table of Conversion Factors (English to Metric Units)	53

TABLES

		Page
1.	Capital Cost Summary for No. 4 Recovery System	8
2.	Summary of No. 4 Precipitator Performance (1972-1974)	11
3.	Analysis of Daily Average Values for TRS (1973-1974)	12
4.	Analysis of Daily Average Values for SO_2 (1973-1974)	13
5.	Measurements and Tests Included in EPA Test Program	25
6.	Confidence Limits (95%) for Individual Values about a Regression Line for Figures 12, 13, 14	33
7.	Summary of Computer Analysis Results	37
8.	Various Liquor Distribution Conditions Evaluated	39
9.	Full Boiler Loading Data Summary	40
10.	Low Boiler Loading Data Summary	41

FIGURES

		Page
1.	Photograph of Completed Black Liquor Recovery System	3
2.	Flow Diagram for No. 4 Recovery System	5
3.	Analysis of TRS Emission Levels (Cumulative Percentage) for Various Sulfidity Ranges	15
4.	Analysis of all TRS Data Compiled	16
5.	Analysis of SO_2 Emission Levels (Cumulative Percentage) for Various Sulfidity Ranges	17
6.	Analysis of all SO_2 Data Compiled	18
7.	Lear Siegler Calibration Curve for No. 4 Recovery Stack, Particulate Emissions vs. Optical Density Reading	20
8.	Lear Siegler Recording Chart Indicating Upset Condition in No. 3 Precipitator due to Rapper Malfunction	22
9.	Lear Siegler Recording Chart Indicating a Reduction in Stack Particulate Resulting from a Decrease in Boiler Loading	22
10.	Instrumentation and Sample Points for No. 4 Recovery System	24
11.	Barton Titrator Setup	27
12.	Steam Production vs. Boiler Loading (Overall Analysis)	34
13.	Boiler Exit Dust Load vs. Boiler Loading (Overall Analysis)	35
14.	Precipitator Outlet Dust Load vs. Boiler Loading (Overall Analysis)	36

SECTION I

CONCLUSIONS

Phase II of the air pollution abatement plan for the Hoerner Waldorf pulp mill in Missoula, Montana involved the construction of a new "controlled odor" recovery boiler having a nominal capacity of 1000 tons per day to replace two smaller and older conventional recovery boilers. This project took 20 months to complete at a capital cost of $11,253,000. In addition to the new No. 4 recovery boiler, a black liquor evaporator concentrator and a dry bottom, high efficiency (99.7%) electrostatic precipitator were also installed as part of the overall program for Phase II.

The No. 4 recovery system has been able to maintain sufficiently low emissions of both TRS and particulates so as to meet the Montana State Emission Standards of 17.5 ppm TRS (daily average) and 52 lb/hr. (daily average) of particulate matter. However, to avoid exceeding the latter emission level it has been necessary to limit the liquor loading of No. 4 recovery boiler to 90-95% of design capacity. The most recent test data on the No. 4 precipitator indicates a collection efficiency of 99.3-99.5%. Considerable debugging of the precipitator was necessary and many modifications were required to obtain present performance levels. Additional modifications are anticipated to bring the precipitator up to its guaranteed performance level at 100% loading. A Lear Siegler transmissometer has been installed on the stack to provide the operators with a continuous record of particulate emissions. This monitoring instrument can be used to spot upsets in the recovery operation and to alert the operators to particulate emissions exceeding permissible limits (State Standards).

Both boiler exit dust load and stack particulate were found to be almost entirely dependent on boiler loading (i.e., the amount of black liquor solids burned in the recovery furnace). At design loading, boiler exit dust load averaged 9777 lb/hr. Stack particulate averaged 56 lb/hr. at 100% boiler loading.

Both TRS and SO_2 emissions were affected by the sulfidity of the liquor being burned, the higher the sulfidity level the greater the concentration of gaseous emissions.

The completion of Phases I and II in the recovery complex rebuild program at Missoula, Montana, together with the extensive testing program carried out to evaluate those improvements, has made Hoerner Waldorf the first company in the United States to successfully modify older, existing recovery facilities by the implementation of new low-odor technology to enable the mill to meet current air pollution standards. This program was completed without a corresponding increase in the production capacity of the mill.

SECTION II

INTRODUCTION

The air pollution abatement plan carried out at the Hoerner Waldorf pulp mill in Missoula, Montana consisted of two phases. Phase I involved the conversion of a conventional kraft recovery boiler with a nominal capacity of 470 tons per day to a "controlled odor" design unit by the elimination of the direct contact evaporator. The complete story of this conversion as well as a detailed description of an intensive testing program carried out on the No. 3 recovery boiler will be found in EPA Report No. 650/2-74-071-a issued in August, 1974.

Phase II involved the construction of a 1000 ton (nominal capacity) "controlled odor" recovery boiler to replace two smaller, older recovery boilers. The conversion of these two smaller recoveries was not attractive because of the lengthy outage time required for their conversion. The implementation of major modifications to them would have been quite difficult due to their relative inaccessibility. Construction on Phase II began in February, 1971 and was completed in October, 1972. Figure I is a photograph of the entire black liquor recovery complex at Missoula taken after the completion of Phase II.

Following a rather lengthy shake-down period involving several modifications made to the electrostatic precipitator, an extensive testing program was carried out on the No. 4 recovery system. This testing program was carried out over a period of two months and was intended to complement an earlier testing program carried out on the modified No. 3 recovery boiler. The No. 4 testing program primarily investigated the effect of liquor distribution in the furnace on particulate and gaseous emissions. Whereas the earlier test program for No. 3 recovery investigated the effect of several process variables (i.e., liquor feed, sulfidity, air flow, and air distribution) on gaseous and particulate emissions, the test program for No. 4 recovery focused primarily on the effect of liquor nozzle orientation in the furnace. Two distinct levels of boiler loading (liquor feed) were also investigated. A total of 52 sets of data were collected.

This report presents design detail and capital cost for the new No. 4 recovery boiler as well as a summary of the testing program carried out and an analysis of results.

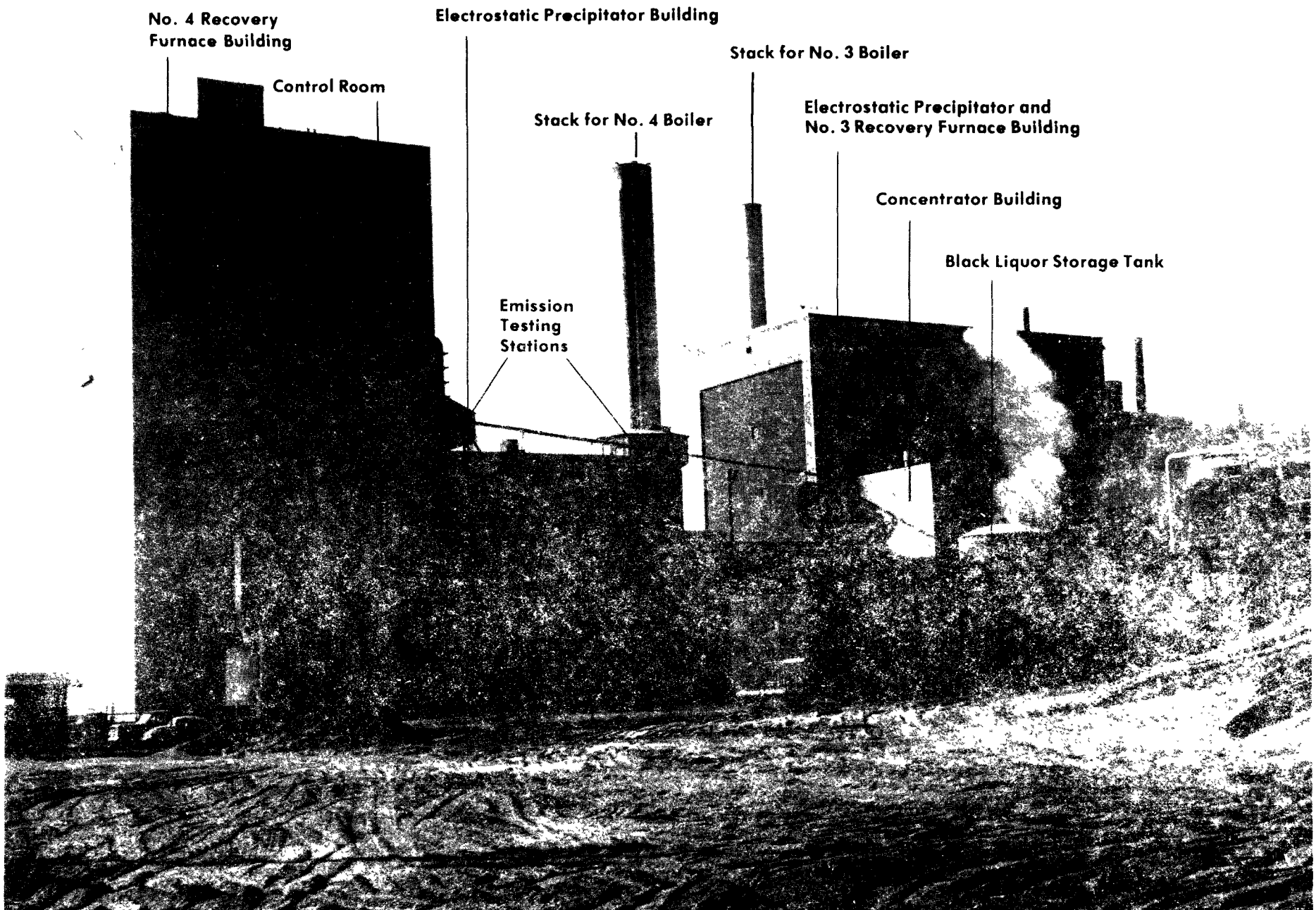

Figure 1: Completed black liquor recovery system for Hoerner Waldorf

SECTION III

PLAN IMPLEMENTATION

Figure 2 is a flow diagram showing the No. 4 recovery system, consisting primarily of a large "controlled odor" recovery boiler, a 3-effect liquor concentrator, and a dry bottom electrostatic precipitator.

Phase II of the pollution abatement plan for the Missoula mill was announced to the general public in June, 1970 following the issuance of a construction permit No. 186-909270 by the State of Montana on June 23, 1970. Simons-Eastern Engineering Company was retained to perform the detailed engineering. Mr. Newton Betts was hired on August 24, 1970 as project engineer for Phase II.

The decision was made to order a new large "controlled odor" recovery boiler from Babcock and Wilcox. Stringent guarantees for both TRS and SO_2 emissions were obtained from the vendor based on earlier test work carried out on the No. 3 recovery boiler.

The new No. 4 recovery boiler was constructed in 1971. It has a design load rating of 3,000,000 lb/day of dry solids based on 6600 BTU/lb dry solids (D.S.). This is equivalent to a nominal capacity of 1000 tons/day of pulp processing capacity (based on 3000 lb D.S./ pulp ton). Steam capacity of the boiler is 485,000 lb/hr. at 750°F and 600 psi. Under design load conditions the dust concentration in the boiler exit gases should not exceed 8.0 grains/SDCF.

The unit has a water-cooled, full studded sloping floor arranged for continuous smelt tapping; a boiler generating bank, superheater, and economizer. Liquor is sprayed into the furnace through two oscillating nozzles to effect proper distribution of liquor on the furnace walls. The latter are of gas-tight membrane welded construction.

A nose baffle, located beneath the superheater, shields the high temperature sections from direct furnace radiation and distributes the gas to produce a desirable flow pattern over the furnace screen and superheater tubes. The superheater is a pendant type, located behind the furnace screen. It is arranged for parallel flow of steam and flue gas. A multi-header vertical steel tube economizer is installed directly behind the boiler tank.

Flue gases leaving the economizer enter the electrostatic precipitator at about 400°F. The precipitator has two parallel chambers with four electrical sections (fields) in each. The cross section of each chamber is divided into 42 gas passages by the collecting electrode plates. The dust particles, electrically charged in the corona of the discharge wires, are attracted to the ground plates, and adhere to the plates as they lose their charge.

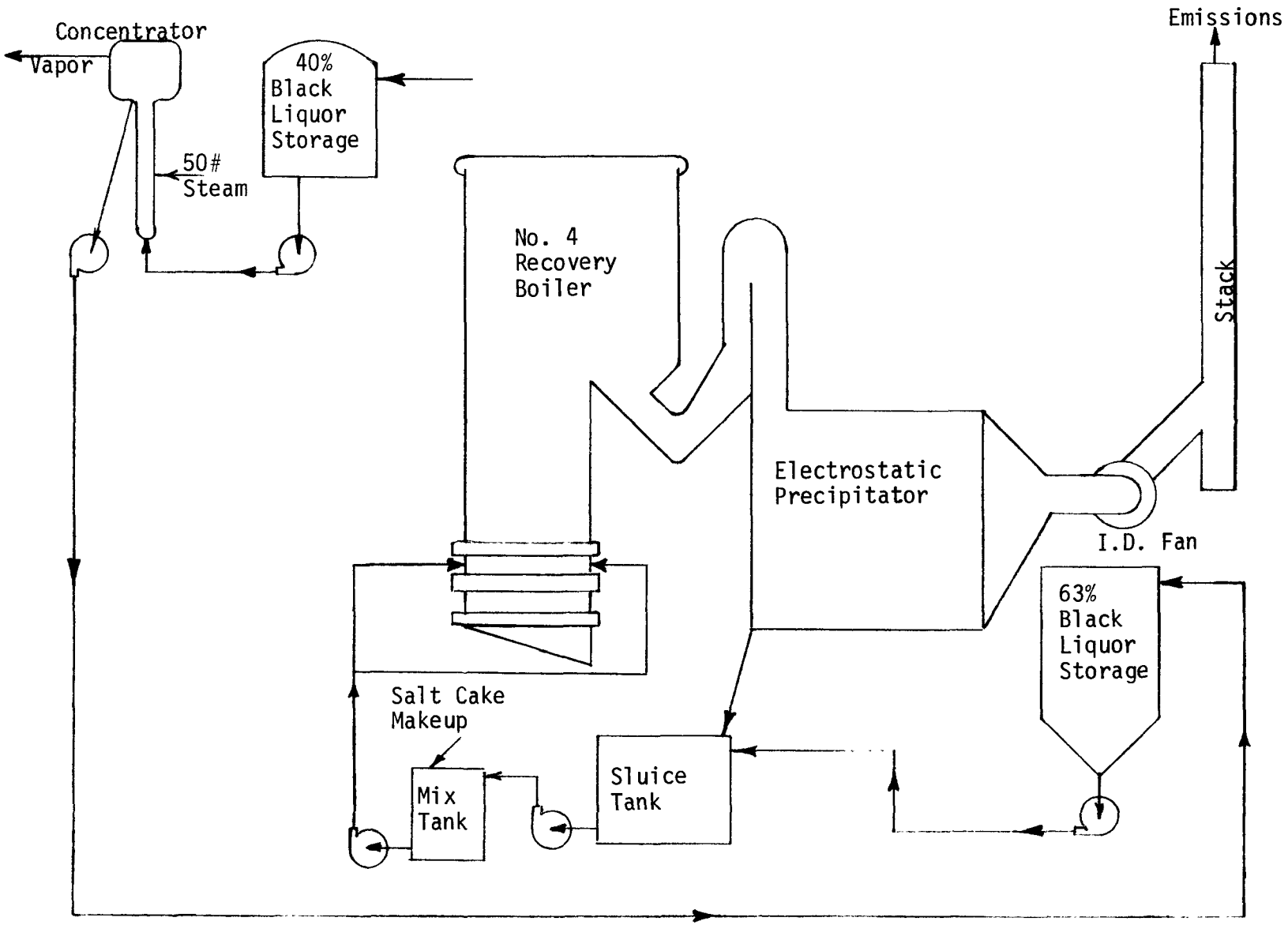

Figure 2 Flow Diagram for No. 4 Recovery System

Periodically, the plates and wire frames are vibrated or "rapped" to dislodge the adhering salt cake. The dislodged dust falls to the bottom of the precipitator where drag scrapers remove the material to screw conveyor hoppers. From these hoppers, recovered salt cake is conveyed to the sluice tank where it mixes with the heavy (63% solids) black feed liquor.

The design gas flow specified for the unit is 470,000 ACFM at a temperature of 440°F. The precipitator has a guaranteed collection efficiency of 99.7% (by weight) based on a dust load of 10.0 grains/SDCF in the entering gas stream for 100% boiler loading.

The cleaned flue gas is drawn from the precipitator by the induced draft fan which discharges into a new stack. A circular, enclosed test station was installed on the stack to provide the necessary means for exit gas sampling and emissions determination.

Additional evaporator capacity was necessary in Phase II to replace the direct contact evaporation lost with the shutdown of the two small recovery boilers (No. 1 and No. 2). Two additional Unitech concentrator effects were added to the existing one to provide the necessary total evaporator capacity of 177,000 lbs of water per hour. An additional 39,000 sq. ft. of heating surface was required.

The incoming liquor is pumped to the third effect where solids are increased to about 45%. From the third effect, liquor is pumped to the first effect, and then to the second effect where the desired product solids level is reached. Each effect is divided in half with each half containing a preheat, falling film and rising film section. Liquor feed to each effect can be alternated between halves and this procedure is followed routinely to prevent tube pluggage by chemical salt deposits.

Heavy black liquor (63% solids) from storage is introduced into the recovery system through the sluice tank where the collected particulate from the precipitator is returned to the liquor cycle. From the sluice tank the liquor is pumped to the salt cake mixing tank where fresh make-up chemical is added. Salt cake is metered from the storage silo to the mix tank by means of a dry feeding device. Liquor from the mix tank is pumped through direct steam heaters to the oscillating spray nozzles at the furnace.

Smelt, consisting primarily of molten sodium carbonate and sodium sulfide, is continuously tapped from the bottom of the No. 4 recovery furnace through four water-cooled smelt spouts into the dissolving tank. Steam and recirculating weak wash are used to break up the smelt stream as it runs from the furnace bottom into the tank.

To prevent excessive particulate emissions from the dissolving tank, a packed tower scrubber manufactured by the Ershig Company was installed above the tank. Weak wash is used as the scrubbing

medium in the counter-current tower, removing any entrained particulate matter from the vapors emitted from the dissolving tank that pass up and through the tower before their final discharge to the atmosphere.

The smelt contacts weak wash in the dissolving tank to form green liquor which is further processed in the recausticizing area to produce white liquor which is subsequently used in the cooking operation (wood chip digestion).

The design details for the major components of the No. 4 recovery system described above are given in Appendix A.

The capital cost summary for the No. 4 recovery system is given in Table 1.

Table 1

*CAPITAL COST SUMMARY FOR NO. 4 RECOVERY SYSTEM

Building		$ 1,758,760
Concentrator		495,370
Electrostatic Precipitator		945,824
Recovery Boiler		3,376,000
Auxiliary Equipment		982,792
I.D. Fan	$ 34,283	
I.D. Fan Turbine	45,000	
F.D. Fans (2)	50,000	
Sluice Tank & Agitator	15,200	
Mix Tank & Agitator	21,000	
Dissolving Tank Scrubber	52,000	
Recovery Auxiliaries	755,931	
Evaporator Auxiliaries	4,880	
Precipitator Auxiliaries	4,498	
Testing Stations		40,000
Mechanical Work		1,875,456
Electrical Work		699,838
Instrumentation Work		364,209
Engineering Service		715,170
	Total	$11,253,419

*Detailed Design and Engineering Data are given in APPENDIX A

SECTION IV

SYSTEM SHAKE-DOWN

The entire No. 4 recovery system became operational on October 14, 1972. Of all the equipment started up, only the electrostatic precipitator gave any appreciable operating difficulty. This resulted primarily from equipment deficiencies that required many months of continuous effort to correct. Mechanical problems with the rapping mechanism required a great deal of attention. A severe wire (electrode) burning problem was also encountered that appeared to be related to wire swinging.

Joy 1 pneumatic rappers were originally installed on the precipitator but they proved to be inadequate. The four original vertical rappers on the inlet distribution plate were first replaced with sixteen horizontal Martin vibrolators in April and May, 1973. Eight of the latter were eventually replaced in May, 1974 with Eriez rappers to eliminate the dust buildup on the distribution plate. Eriez pneumatic rappers replaced all Joy 1 rappers on the plate and electrode frames in May, 1973 to provide better rapping. Lubrication for the rappers was also improved at that time.

The correction of the wire burning problem was a very lenghty and complex effort. Ceramic stablizers were installed at the bottom of the electrode weight frame in May, 1973 to minimize wire frame swinging. Additional weight was added to the wires and individual suspension was provided in December 1973 to prevent particulate buildup under them. All the original stiff electrodes were removed. These measures did not completely correct the electrode oscillation problem, but did permit raising the boiler loading from a level of 80% to a level of 90-100% which permitted a more meaningful evaluation of precipitator performance.

The particulate (salt cake) collected in the precipitator is conveyed to the sluice tank located below the "B" field of the precipitator where it mixes with the heavy black liquor. From the mix tank the liquor is pumped to the furnace spray nozzles. A severe problem of salt cake buildup in the "B" fields resulted from water vapor entering the precipitator through the particulate discharge chute. To correct this problem, a fan was installed in the sluice tank vent in December, 1973 to discharge the vapor into the flue gas duct between the boiler and the precipitator.

SECTION V

EVALUATION OF THE NO. 4 RECOVERY SYSTEM

The operating efficiency of the No. 4 recovery system must be sufficient to permit it to meet the emission regulations promulgated by the State of Montana. These specify a maximum daily average emission of 17.5 ppm for total reduced sulfur gases (TRS) and a maximum daily average for particulate emissions of 52 lb/hr. (over a 24-hour period at design solids loading) for No. 4 recovery boiler.

PARTICULATES

Electrostatic Precipitator

The particulate emissions from the No. 4 precipitator exceeded the specified state standard when the unit was first put into operation. As previously described in Section IV, a number of modifications and improvements were made over a period of several months before the unit came close to its design "guarantee" specifications.

The most recent data obtained on the unit indicates a collection efficiency of 99.3-99.5% for a boiler loading of 90-95%.

A summary of precipitator emissions and collection efficiencies for the above two-year period of equipment modifications and improvements is given in Table 2. This data indicates that an increase in boiler loading (liquor feed) has been possible during this period while still maintaining an acceptable collection efficiency.

It must be recognized that much debugging of the precipitator was necessary and many modifications required before present performance levels could be attained. Additional modifications are anticipated to bring the precipitator up to its guaranteed performance level at 100% loading.

Dissolving Tank

The installation of a packed tower scrubber above the dissolving tank, which receives the smelt runoff from the No. 4 recovery boiler, permitted the dissolving tank stack to meet state emission standards. Average particulate emissions from the vent stack were found to be 290 lb/day vs. a state emission standard (maximum allowable) of 1344 lb/day.

TRS AND SO_2

A detailed analysis of TRS and SO_2 emission levels at various sulfidity ranges is presented in Tables 3 and 4. Daily average data for the period January, 1973 - April, 1974 (inclusive) were

Table 2

Summary of No. 4 Precipitator Performance (1972-1974)

Test Period	Boiler Loading(%) Ave.	Boiler Loading(%) Range	Dust Loss(lb/hr.) Ave.	Dust Loss(lb/hr.) Range	Collect.Eff.(%) Ave.	Collect.Eff.(%) Range	No.of Tests
11/29/72	83	-	226	-	97.0	-	1
12/1-12/15/72	75	67-83	8.5	7-10	99.8	-	2
5/23-6/1/73	67	64-71	111	80-131	98.5	98.3-98.9	3
6/12-6/13/73	80	-	25	18-32	99.7	-	2
6/28-8/1/73	81	70-88	27	10-84	99.7	99.0-99.9	7
8/16-8/31/73	83	79-87	29	17-50	99.7	99.5-99.8	6
9/17-10/15/73	99	96-100	69	38-99	99.2	98.6-99.5	5
12/17-12/20/73	102	98-105	46	40-56	99.5	99.4-99.6	3
2/8-2/28/74	97	84-102	64	44-111	99.3	98.9-99.6	9
3/16-3/31/74	91	90-98	60	28-178	99.3	98.0-99.7	6
4/1-4/30/74	95	90-100	45	21-95	99.5	98.8-99.6	19
8/1-9/5/74	86	82-90	21	14-28 no boiler tests run			4

Table 3

*ANALYSIS OF DAILY AVERAGE VALUES FOR TRS
(for Period of January 1973-April 1974)

TRS Level (ppm)	Total No.Of Data Points	26.1-28.0% Sulfidity Range			28.1-31.0% Sulfidity Range			31.1-33.0% Sulfidity Range		
		No.	%	C.P.	No.	%	C.P.	No.	%	C.P.
1	102	64	32.5	32.5	35	17.5	17.5	3	6	6
2	68	33	17	49.5	31	15.5	32	4	8	14
3	63	27	14	63.5	29	14.5	46.5	7	13	27
4	48	26	13	76.5	17	8.5	55	5	10	37
5	37	10	5	81.5	22	11	66	5	10	47
(1-5)	(318)	(160)			(134)			(24)		
6	15	10	5	86.5	5	2.5	68.5	0	0	47
7	25	6	3	89.5	10	5	73.5	9	17	64
8	12	5	2.5	92	5	2.5	76	2	4	68
9	9	4	2	94	4	2	78	1	2	70
10	15	4	2	96	6	3	81	5	10	80
(6-10)	(76)	(29)			(30)			(17)		
11	8	1	0.5	96.5	5	2.5	83.5	2	4	84
12	9	2	1	97.5	6	3	86.5	1	2	86
13	3	0	0	97.5	2	1	87	1	2	88
14	5	0	0	97.5	4	2	89	1	2	90
15	10	2	1	98.5	8	4	93	0	0	90
(11-15)	(35)	(5)			(25)			(5)		
16-20	9	1	0.5	99	4	2	95	4	8	98
21-25	6	1	0.5	99.5	4	2	97	1	2	100
26-30	2	0	0	99.5	2	1	98	0	0	
31-35	4	1	0.5	100	3	1.5	99.5	0	0	
36-40	0	0	0		0	0	99.5	0	0	
41-50	1	0	0		1	0.5	100	0	0	
Totals	451	197			203			51		

*Barton Titrator Data

Table 4

*ANALYSIS OF DAILY AVERAGE VALUES FOR SO_2
(for Period of January 1973-April 1974)

SO_2 Level (ppm)	Total No. Of Data Points	(26.1-28.0% Sulfidity Range			28.1-31.0% Sulfidity Range			31.1-33.0% Sulfidity Range		
		No.	%	C.P.	No.	%	C.P.	No.	%	C.P.
1-20	138	98	54	54	39	21	21	1	2	2
21-40	70	28	15.5	69.5	36	19.5	40.5	6	12	14
41-60	50	17	9.5	79	31	17	57.5	2	4	18
61-80	37	11	6	85	21	11.5	69	5	10	28
81-100	19	10	5.5	90.5	6	3.5	72.5	3	6	34
(1-100)	(314)	(164)			(133)			(17)		
101-120	16	5	3	93.5	11	6	78.5	0	0	34
121-140	9	3	1.5	95	4	2	80.5	2	4	38
141-160	19	5	3	98	6	3.5	84	8	16	54
161-180	10	0	0	98	6	3.5	87.5	4	8	62
181-200	7	1	0.5	98.5	5	2.5	90	1	2	64
(100-200)	(61)	(14)			(32)			(15)		
201-220	7	0	0	98.5	3	1.5	91.5	4	8	72
221-240	4	0	0	98.5	2	1	92.5	2	4	76
241-260	6	0	0	98.5	2	1	93.5	4	8	84
261-280	6	1	0.5	99	4	2	95.5	1	2	86
281-300	4	0	0	99	3	1.5	97	1	2	88
(201-300)	(27)	(1)			(14)			(12)		
301-400	10	2	1	100	3	1.5	98.5	5	10	98
401-500	4	0			3	1.5	100	1	2	100
Totals	416	181			185			50		

*Barton Titrator Data

collected in order to develop this data for three sulfidity ranges. The cumulative percentage (C.P.) data points for each sulfidity range are plotted on semilog paper in Figures 3 and 5. This graphic presentation indicates the increasing percentage of high levels of both TRS and SO_2 that results as the sulfidity level of liquor increases.

The TRS plot (Figure 3) indicates that at a sulfidity range of 26-28%, approximately 99% of the daily average data falls at or below 17.5 ppm, the Montana Air Emission Standard for TRS. At the higher sulfidity levels of 28-33% the percentage of all data meeting this criteria is 93-94%. This is considerably better operating control than found for the No. 3 recovery boiler in an earlier study where 89% of the data obtained for the 26-28% sulfidity range met State Emission Standards as compared with only 65% of the data obtained for the higher 31-33% sulfidity range.

The TRS plot of all data presented in Figure 4 illustrates the percentage of operating time that a particular level of emissions is exceeded. For 5 ppm, the percentage is 30%; for 17.5 ppm, the percentage is only 3%.

The SO_2 plot (Figure 5) indicates that at the lower sulfidity range of 26-28%, 92% of the daily average data falls at or below 100 ppm and 98% below 200 ppm. For the sulfidity range of 28-31%, 74% falls below 100 ppm and 90% below 200 ppm. For the high sulfidity range of 31-33%, only 31% of the data falls at or below 100 ppm and 64% below 200 ppm. Here again as was found in the case of No. 3 recovery boiler, a major upward shift in SO_2 occurs at the higher sulfidity levels above 31%.

The SO_2 plot of all data presented in Figure 6 illustrates the percentage of operating time that a particular level of emissions is exceeded. For 100 ppm, the percentage is 26%; for 200 ppm, the percentage is 10%. At the present time there is no point source emission standard for SO_2 in the State of Montana.

LEAR SIEGLER TRANSMISSOMETER

Introduction

On September 4, 1973, an on-stack optical transmissometer, manufactured by Lear Siegler, Inc. was installed on the No. 4 recovery boiler stack. The optical transmissometer measures the opacity of stack emissions, which then can be correlated with the particulate concentration in the exit gas stream by manual testing. The purpose of this instrument is to provide the operators with a rapid and reliable readout of stack emissions to ensure continual compliance with Montana air standards.

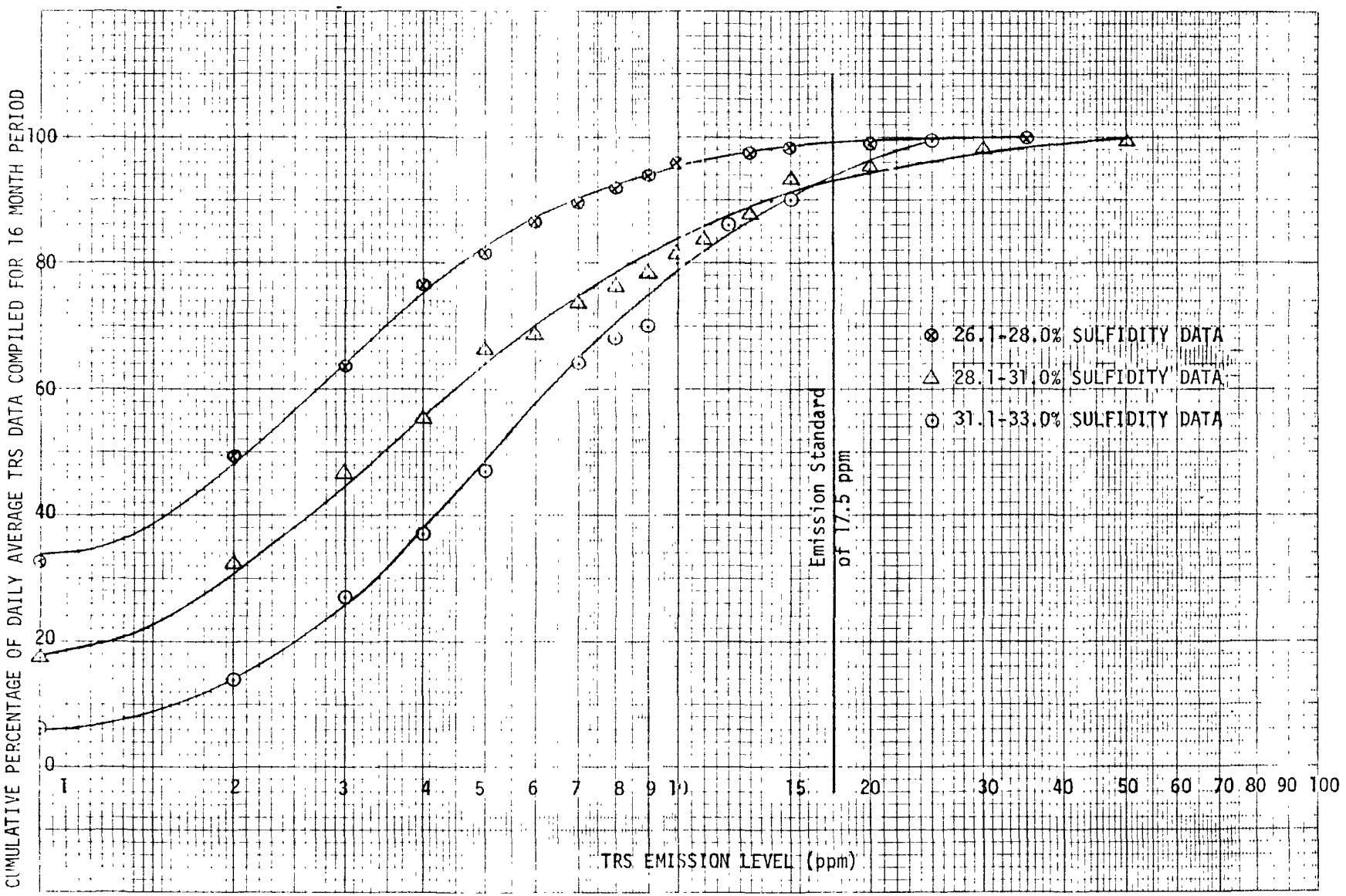

Figure 3 Analysis of TRS emission levels (cumulative percentage) for various sulfidity ranges

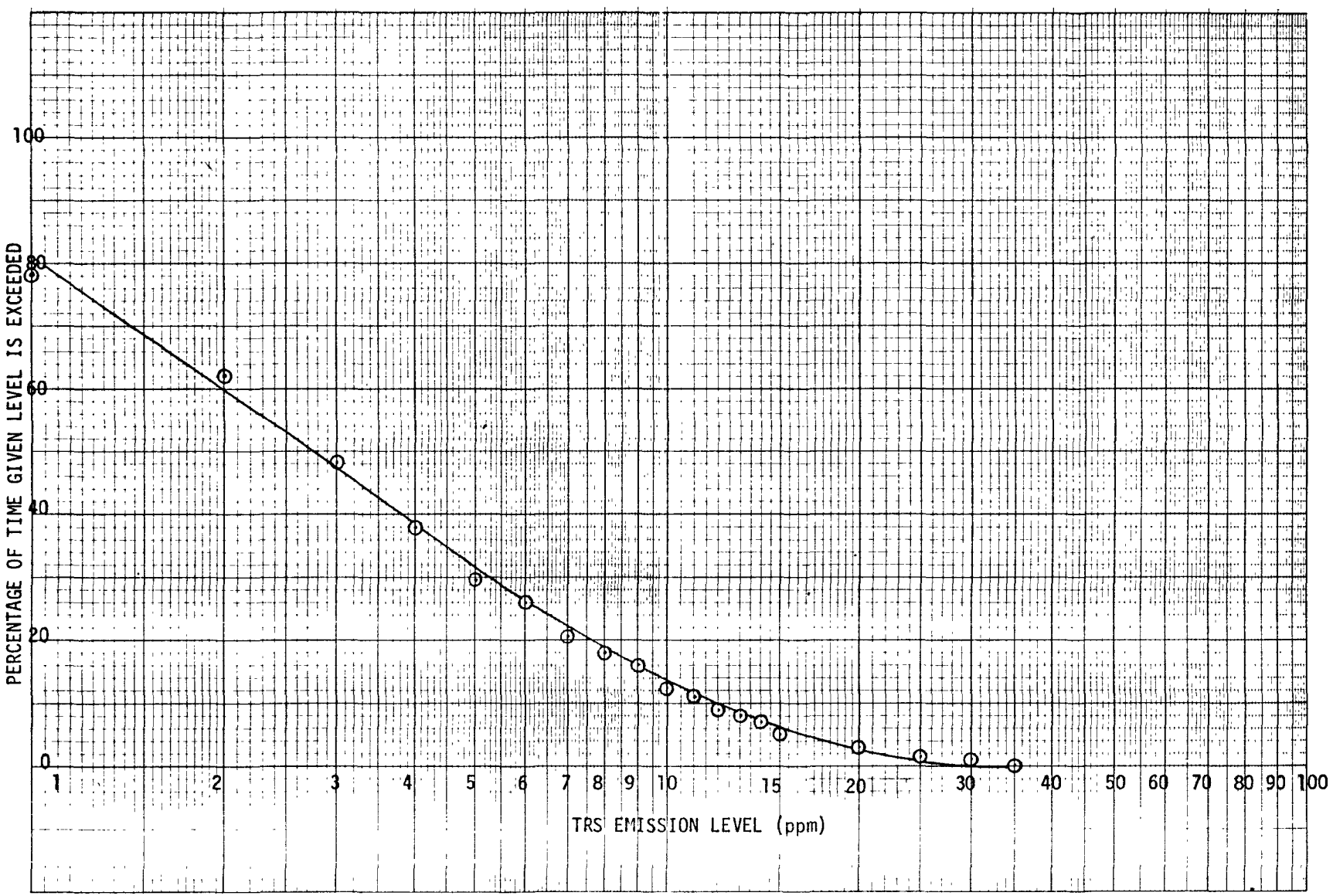

Figure 4 Analysis of all TRS Data Compiled

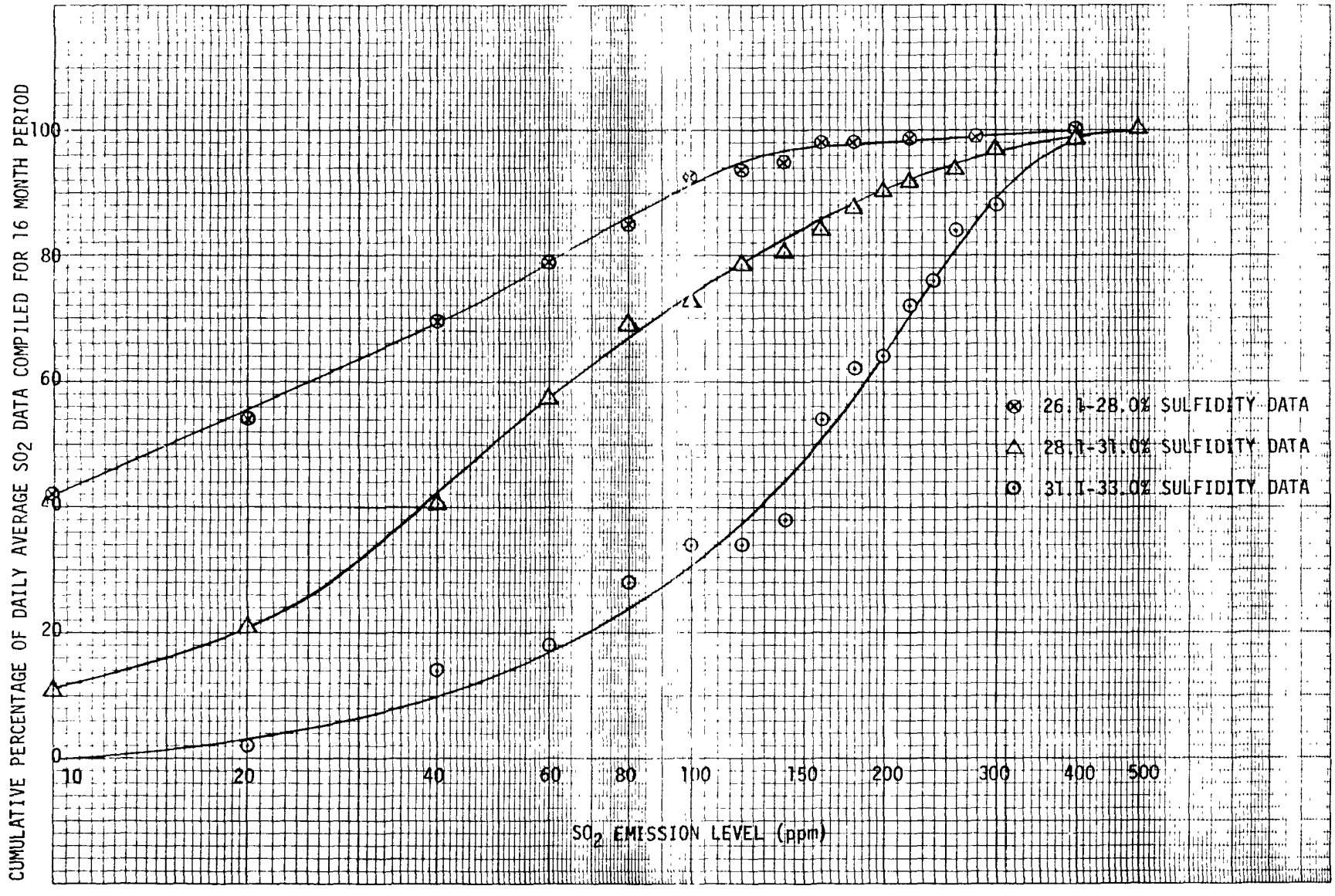

Figure 5 Analysis of SO_2 emission levels (cumulative percentage) for various sulfidity ranges

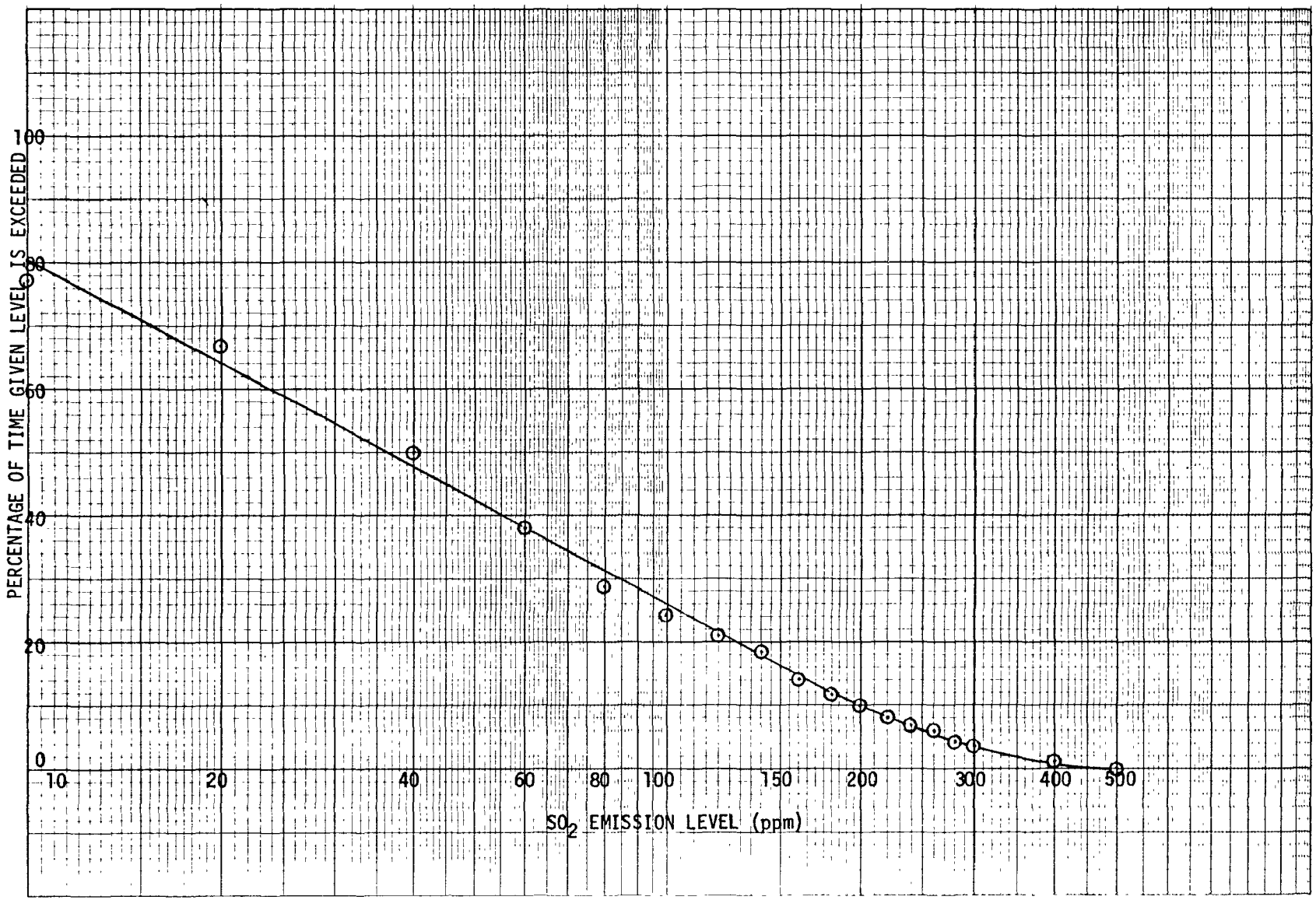

Figure 6 Analysis of all SO_2 Data Compiled

Instrument Design

The Model RM 4 instrument consists of an optical sensor which is attached to one side of the stack, with a reflector on the opposite side. The optical sensor contains the light source, light receiver, and the electronic signal processing unit. Both the sensor and reflector units are continually flushed with air to maintain dust-free equipment.

The data output from the transmissometer is continuously recorded on a strip chart recorder. The optical density readout is related to stack grain loading by means of a correlation curve that was developed from actual data points.

The transmissometer automatically re-zeros and calibrates at 45-minute intervals. These checks are accomplished by inserting into the light beam (on the optical sensor side of the unit) a reflector for the zero check and subsequently a filter which has a known opacity. The results of these checks are recorded on the strip chart so the operator can detect a malfunctioning instrument almost immediately.

Instrument Calibration

A preliminary least squares relationship between optical density and stack grain loading was calculated in mid-October 1973, using the results of seventeen stack tests and the corresponding Lear Siegler optical densities. This relationship was used until mid-February, 1974, when thirteen additional data points were added to the original date and a new least squares line calculated.

The Lear Siegler optical density calibration line presently used for monitoring the No. 4 recovery boiler stack is shown in Figure 7. This relationship was derived from all data collected from September 6, 1973, through June 12, 1974, exclusive of the February 22 - March 8, 1974 data, when the Lear Siegler zero point was not correct. The 95% confidence limits for the individual data points (73 in all) are also shown in Figure 7.

Utilization of Lear Siegler in Daily Operation

The Lear Siegler has become a valuable tool for operating personnel. This instrument has been installed on both No. 3 and No. 4 recovery stacks. An optical density value has been established as a guideline for both boiler and precipitator operators, which, if exceeded, would result in a violation of State particulate standards. The operators have been instructed to take steps to decrease the level of stack particulates if this optical density is reached. At 100% boiler loading, Lear Siegler readings exceeding 40% of scale usually indicate emissions exceeding State standards.

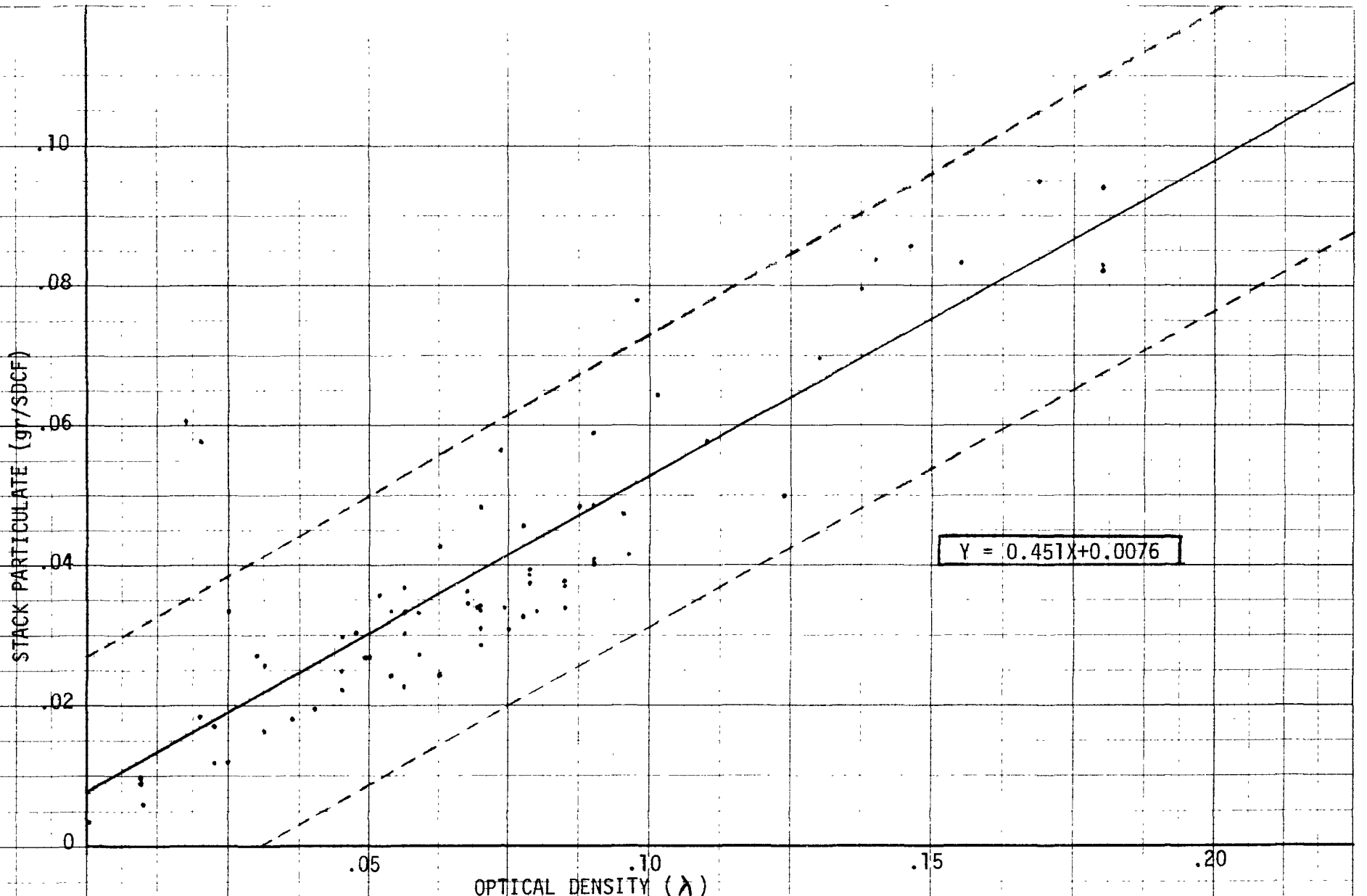

Figure 7 Lear Siegler Calibration Curve for No. 4 Recovery Stack, Particulate Emissions vs. Optical Density with 95% Confidence Limits for Individual Data Points

The Lear Siegler will also quickly identify a precipitator malfunction. Figure 8 shows a portion of a strip chart where a rapper malfunction occurred, resulting in an increase (from 40 to 100 lb/hr.) in particulates passing through the No. 3 precipitator. The Lear Siegler enabled operations to be aware of the problem and correct it much faster than normally would be possible.

Figure 9 demonstrates that a decrease in liquor feed to both boilers had an immediate effect on stack particulate losses. In the case of No. 3 precipitator, emissions dropped from 45 to 30 lb/hr.

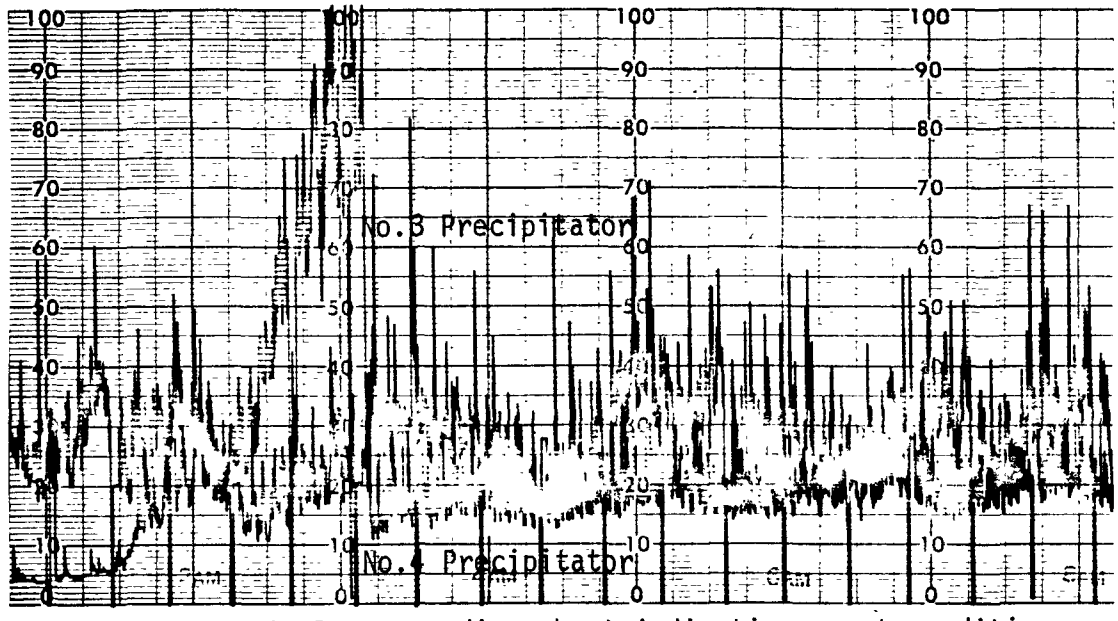

Figure 8 Lear Siegler recording chart indicating upset condition in No. 3 Precipitator due to rapper malfunction

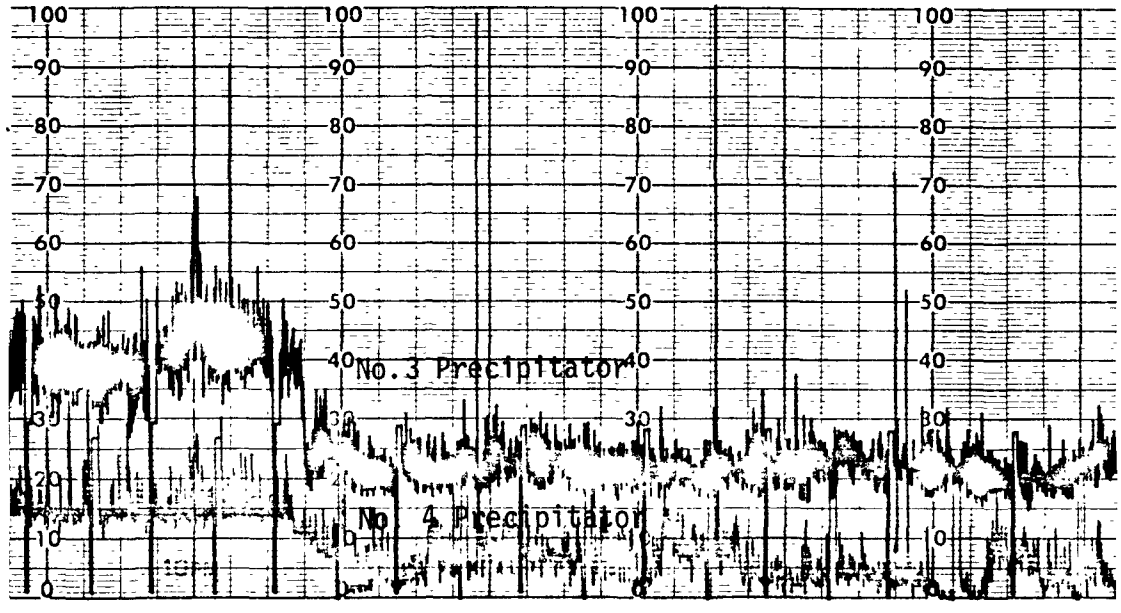

Figure 9 Lear Siegler recording chart indicating a reduction in stack particulate resulting from a decrease in boiler loading (liquor feed to recovery boiler)

SECTION VI

EPA TESTING PROGRAM FOR NO. 4 RECOVERY BOILER

INTRODUCTION

The testing program formulated for the No. 4 recovery boiler installed at the Missoula mill was intended to complement the earlier testing work carried out on the modified No. 3 recovery boiler, discussed in another EPA report.* The No. 4 testing program primarily investigated the effect of liquor distribution in the furnace on particulate and gaseous emissions. Sulfidity remained at a level of 26-28% throughout the entire testing period. Two different boiler loading levels were investigated, 70-75% and 90-100%.

Changes in air distribution and excess oxygen levels were planned but these efforts were not successful due to the tendency of the No. 4 recovery boiler to "black-out" under abnormal conditions (i.e., unable to support combustion). Approximately two months were devoted to this testing program (February-April, 1974).

MEASUREMENTS AND TESTS INCLUDED IN STUDY

Figure 10 shows the location of the various instruments used to indicate and record the pertinent information required for process control and data collection. Also shown are the locations of the sampling ports required for particulate collection.

Two particulate sampling stations were necessary to determine the concentration of dust in the flue gases both before and after the precipitator. The boiler exit sample ports were located on rectangular duct work where the straight run of duct available was conducive to meaningful flow measurements. The precipitator outlet sample ports were located on the main stack inside a completely enclosed testing station permanently attached to the periphery of the stack.

Table 5 summarizes the measurements and tests in the EPA test program.

TESTING PROCEDURES EMPLOYED

TRS and SO_2 Testing

Total reduced sulfur gases (TRS) and sulfur dioxide (SO_2) were continuously measured by means of two Model 400 Barton electrolytic titrators. TRS is expressed as equivalent hydrogen sulfide (H_2S). Both TRS and SO_2 results were reported as parts per million (ppm) by volume on a dry gas basis (SDCF).

* Improved Air Pollution Control for a Kraft Recovery Boiler: EPA report 650/2-74-071-a of August, 1974.

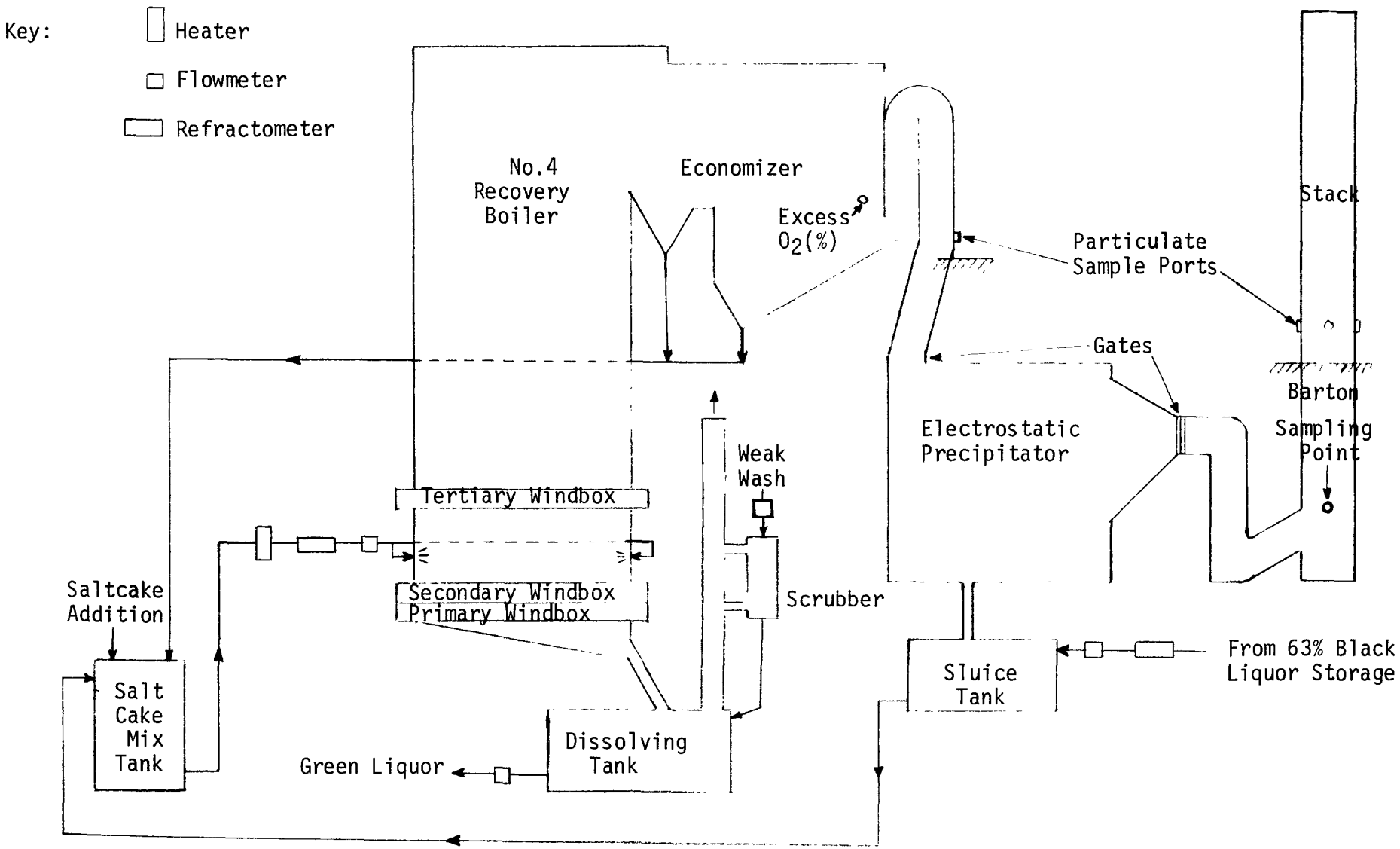

Figure 10 Instrumentation and sample points for No. 4 recovery system

Table 5

MEASUREMENTS AND TESTS INCLUDED IN EPA TEST PROGRAM

Item	Means of Data Collections
Black liquor flow to sluice tank	Magnetic flow meter, continuously recorded
Black liquor flow to nozzle	Magnetic flow meter, continuously recorded
Black liquor density	Measured once per test
Solids content of liquor	Refractometer, also check manually once per test
Salt cake makeup	Screw conveyor feed determined by rpm
Temperature of liquor at nozzle	Thermometer, continuously recorded
Nozzle pressure	Pressure gauge, manual readout
Primary, Secondary and Tertiary air flows	Pressure taps, continuously recorded
Temperature of incoming air	Thermocouple, continuously recorded
Excess oxygen	Analyzer, continuously recorded
Precipitator inlet flue gas temperature	Thermocouple, continously recorded
Steam flow	Orifice, continuously recorded
Green liquor flow	Magnetic flowmeter
Weak wash flow	Magnetic flowmeter
Sulfidity	Wet chemistry analysis
SO_2	Barton titrator
TRS	Barton titrator
Particulate	Sampled both at boiler exit and stack for each test

Titration is the addition of a measured amount of reagent to a sample until the reactive compounds in the sample have been satisfied (some identifiable end point has been reached). In the Barton titrator, the reagent is free bromine, generated by passing an electric current through the hydrobromic acid cell solution. A constant flow of sample gas passes through the cell and the sulfur compounds in the sample react with the bromine. The amount of current supplied to the cell is automatically adjusted by the circuit in the control module to produce just enough bromine to continuously maintain end-point conditions. The current flow is thus proportional to the reactive (sulfur) compounds in the sample. A calibration factor is used to convert current flow to parts per million of the measured compounds.

The gas flow through the reaction cell sweeps out a small amount of bromine. The current required to replace this bromine is the base line reading. The base line can be adjusted and represents the equilibrium concentration of free bromine. The exact value is not critical as long as it is known.

A small sample of flue gas is continuously drawn off at the sample port on the stack and is split into two sample lines going to two separate Barton titrators. One measures the total sulfur gases present in the stack sample. The second measures TRS after a citric acid batch scrubber has removed the SO_2. The SO_2 is calculated by difference. The gas stream then passes through the titration cell where the remaining sulfur compounds are oxidized by bromine. The current flow required to regenerate the consumed bromine from the hydrobromic acid electrolyte is proportional to the amount of sulfur gases present. The rest of the testing apparatus includes a rotometer, micrometering valve, and vacuum pump or water aspirator.

Figure 11 is a schematic flow diagram of the Barton titrator setup used for testing at No. 4 recovery boiler stack.

Probe - a teflon probe is used to extract the gas sample from the stack just above the I.D. fan. The sample stream is split to measure total sulfur compounds and reduced sulfur compounds (TRS).

Scrubber - To measure the reduced sulfur compounds, a scrubber is provided to remove SO_2. The scrubber is a gas washer bottle filled with a citric acid solution. The latter contains one (1) mole of potassium citrate to 0.2 mole of citric acid.

Surge Chamber - Each system contains a surge chamber to help level out the short term peaks and valleys. Condensed moisture is also removed at this point.

Cell - The cells are white plastic reaction chambers with an integral bubbler and electrode fitting.

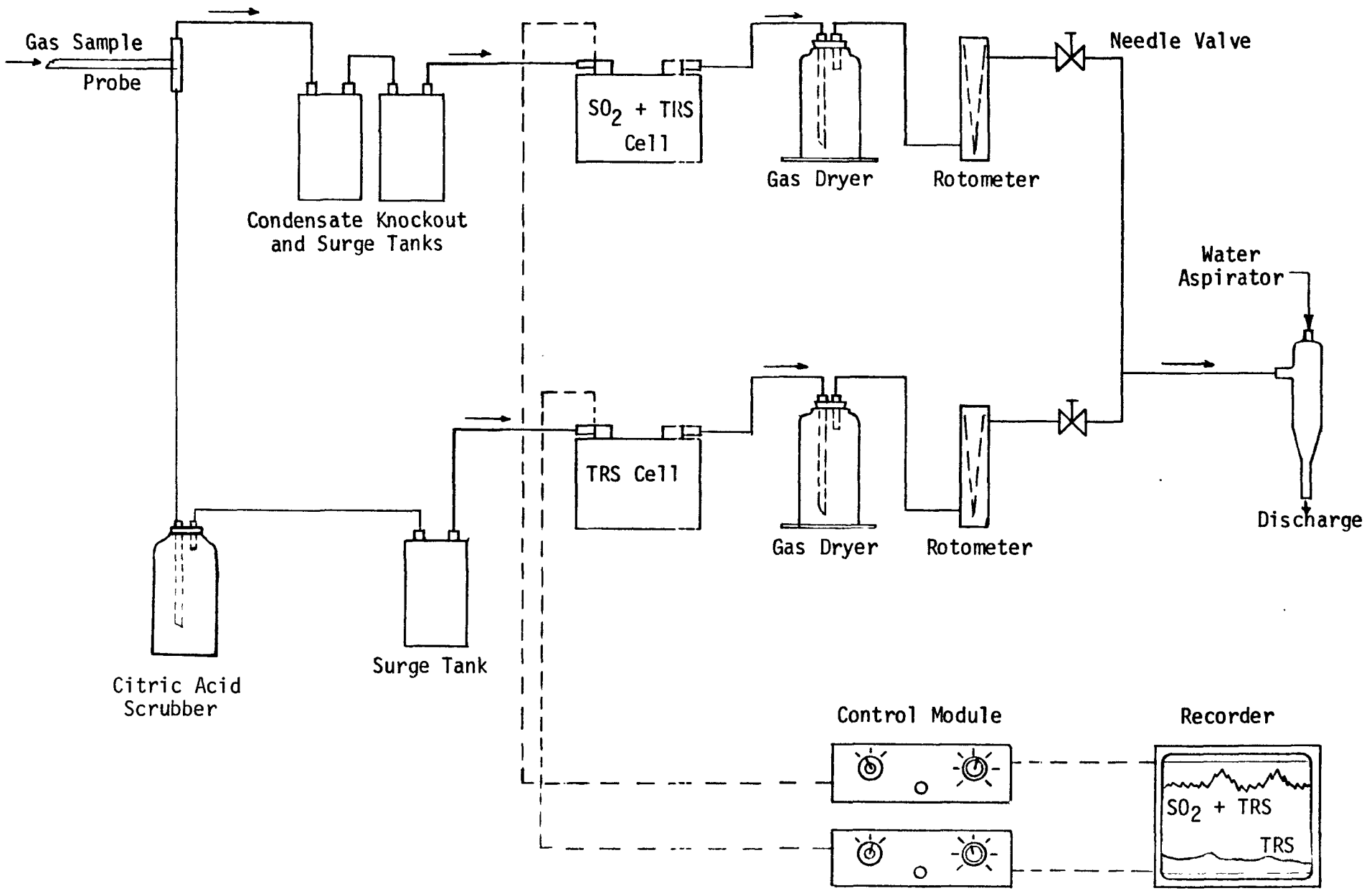

Figure 11 Barton titrator setup

Dryers - Gas washer bottles are filled with activated silica gel to dry the gas leaving the cell. The wet gas is very corrosive from the bromine swept out of the cell. The dryers protect the control valves.

Flowmeter - This is an indicator of the flow rate through the reaction cell. Ball float purge rotometers are used.

Control Valves - Stainless steel needle valves are used to control the flow.

Aspirator - A water aspirator is used to provide vacuum to draw the sample through the system.

The following items are located on the Operator's panel:

Control Module - This is the electronics package that controls the bromine level in the cell and provides a signal to the recorder. On the face of the module is a function switch, which turns the unit on and off, a recorder check button, and a range switch. The range switch selects the cell current which will give full scale deflection on the recorder. Ranges are from 0.1 to 100 millamps.

Recorder - A two-pen recorder with a 0-100 scale strip chart is used. This provides a continuous record of TRS and total sulfur emissions.

Integrators - Each pen trace is integrated with time and the total continuously displayed on a six wheel counter.

Particulate Testing

Particulate tests were run simultaneously on the boiler exit and the stack with the help of two 2-man testing teams. The majority of tests lasted 139 minutes, corresponding to one complete "soot-blowing cycle." The boiler itself is equipped with 40 IK sootblowers, and the economizer with 13 sootblowers. These are long retractable tubes with orifices at the sides of the tip. As the sootblowers spiral in and out of the boiler high pressure steam blasts salt cake from the outside of the furnace tubes. The IK's are blown on a time sequence, which repeats every 139 minutes.

Because of the high dust loading ahead of the precipitator, dry sampling methods could not be used at this point. A wet scrubbing train illustrated in Figure 1, Appendix B was finally selected for the EPA testing program. This is the same sampling unit Hoerner Waldorf has successfully employed at Missoula for particulate testing since 1969.

Particulate emissions at the stack were measured with an EPA train manufactured by Research Appliance Company. A stainless steel lined

"pitobe" was used. The EPA train is illustrated in Figure 2, Appendix B. Only the catch from the front half of the EPA train is used to measure particulate. The impinger train is used only as a condenser so that the moisture content of the gases sampled can be collected and measured. Spot checks of scrubber water showed no detectable sodium using a flame photometer. The justification for using only the front half catch of the EPA train is documented in Section C, pages 24-30 of NCASI Technical Bulletin No. 67, "Comparison of Source Particulate Emission Measurement Methods at Kraft Recovery Furnace Stacks." The details of the above two testing procedures for the collection of particulate matter from the flue gases are given in Appendix B. Miscellaneous facts of interest related to the particulate testing program are the following:

1. Plugging of the boiler exit probe sometimes occurred at the first bend above the nozzle. This was easily cleared by carefully cleaning the outside of the probe and tapping the probe at the suspected plug. The loosened dust is caught and added to the sample before making up the final volume. Other plugs were washed into the nearest scrubber with water reserved from the original measured 750 ml.

2. Testers could judge the difference between high and low particulate tests by the buildup of particulate on the outside of the probe.

3. For a normal 139 minute test (equivalent to one complete sootblowing cycle) about 500 ml of condensate is collected at the stack and 700 ml at the boiler exit. Volumes significantly different than this are an immediate flag that abnormal conditions exist in the boiler or that it is a bad test. Leaks, which occasionally developed in the train during a test run, resulted in a low water catch. Such difficulties were encountered only three or four times during the entire testing program period.

Black Liquor Solids Determination

Samples of liquor were taken during each particulate sampling period. "Sluice liquor" was taken at the discharge of the pump transferring liquor from the 63% storage tank to the precipitator sluice tank. The solids content was determined in the laboratory using a technique requiring in excess of 24 hours to complete.

PLAN OF INVESTIGATION

The testing program for the No. 4 recovery boiler was scheduled over a two-month period. At least three sets of data were obtained for each condition investigated.

The original testing program called for maintaining a low liquor sulfidity of 26-28% throughout. Air distribution, excess oxygen levels and two boiler loadings (normal and low) were to be varied to investigate the effect of each operating parameter on emissions. Half the testing program was planned to investigate the effect of liquor distribution on emissions by varying nozzle pressure, nozzle sidesweep and nozzle backsweep.

IMPLEMENTATION OF PROGRAM

All testing was carried out during the day shift (8-4). On most days one test was carried out in the morning and one in the afternoon. The rather lengthy and involved procedure for particulate sampling required three to four hours to complete each investigation. Minor changes in operating conditions were made three to four hours before resumption of testing to allow conditions to stablize.

Establishment of "Normal" Conditions

As a basis for comparison, "normal" conditions for the operation of the No. 4 recovery boiler were established with the help of Babcock and Wilcox personnel. The boiler manufacturer was called in to fine-tune the unit so that the average TRS emission would not exceed one ppm, the "guarantee" emission level for the boiler when operated under proper operating conditions. This work was accomplished during the last week of February, 1974.

The Babcock and Wilcox operating parameters established from these initial studies were somewhat different from those originally established by Hoerner Waldorf for the No. 4 recovery boiler. The old and new conditions were the following:

	HW before B&W	B&W Normal
Boiler Loading (%)	90-100	90-100
Excess Oxygen (%)	2.0-3.0	1.5-2.5
Nozzle Sizes	40/40	40/40
Nozzle Backsweep	-17° to -22°	-15° to -20°
Nozzle Sidesweep	5° L to 5° R	5° L to 5° R
Air Distribution (%)		
Primary	28	26
Secondary	52	50
Tertiary	20	24
Temperature of Primary Air (°F)	300	350

Operating Experiences and Observations at Different Conditions

Although it would have been desirable to investigate the magnitude of emissions from the No. 4 recovery system under overload conditions (i.e., higher boiler loading), the highest boiler loading attainable so as not to exceed State particulate standards was the 90-100% range.

Some variation in air distribution was intended during the course of the testing program on No. 4 recovery boiler. However, on two occasions when attempting to change the air distribution from 26/50/24 to 35/40/25, the furnace "blacked out." It was concluded that the new condition resulted in poor combustion due to improper air utilization. Consequently, air distribution changes were not attempted again.

An attempt was made to reduce the excess oxygen level below 1.5%, but this effort resulted in furnace blackouts or the presence of noncombustibles was detected before the level of 1.0% excess oxygen was reached. These conditions of testing were therefore eliminated from the program.

SECTION VII

DATA ANALYSIS AND DISCUSSION OF RESULTS

As the completion of the EPA testing program it was possible to analyze all the data (52 sets) and establish the relationship between particulate emissions and boiler loading. The relationship between steam production and boiler loading was also established. This analysis was accomplished statistically with the aid of an IBM System 370 (Model 135) computer.

The method of least squares was used to derive the several equations which best express the relationships developed from the extensive data available for analysis. This method of analysis minimizes the weighted sum of squares of deviations of the data from the function being fit.

Confidence limits of 95% were also calculated in order to show the range of the individual values for the dependent variable in each case. These confidence limits are summarized in Table 6 and are indicated by the dotted lines in Figures 12, 13, and 14. These dotted lines indicate the spread anticipated for 95% of all possible data points.

OVERALL ANALYSES

A summary of the results obtained from a cumputer analysis of all data sets is given in Table 7. Figures 12-14 illustrate the major relationships established from the data. The more comprehensive data analysis carried out in an earlier test program for No. 3 recovery boiler was most helpful to zero-in more quickly on the primary relationships that were most conducive to statistical analysis. Unfortunately, the relatively uniform conditions of liquor sulfidity and excess oxygen level in the exit gases prevented a meaningful overall analysis of TRS and SO_2 emissions, as they are affected by these other operating parameters.

Figure 12 gives the relationship between steam production and boiler loading. The regression analysis indicates that for 100% boiler loading the average net steam generated by the No. 4 recovery boiler is 436,000 lb/hr. Taking into account the fact that approximately 45,000 lb/hr. steam is utilized in the sootblowers to keep the economizer and boiler tubes clean, the total gross steam production is about 481,000 lb/hr. This is very close to the 485,000 lb/hr. rating for the boiler at design load. At 75% boiler loading the net steam availability is 322,000 lb/hr.

Figure 13 gives the relationship between Boiler Exit Dust Load and Boiler Loading. The average dust load at 100% boiler loading is 9777 lb/hr. The maximum dust load emission from the No. 4 recovery boiler at design load indicated by Babcock and Wilcox is 9600 lb/hr. (8.0 gr/SDCF).

Table 6

95% CONFIDENCE LIMITS FOR INDIVIDUAL VALUES ABOUT A REGRESSION LINE

Figure 12

Steam Production (Y) vs. Boiler Loading (X)

$Y = 4.53X - 16.06$; $\overline{Y} = 395$, $\overline{X} = 91$

X Value (%)	Y Lower Limit $\left[\frac{M\ lb.}{hr.}\right]$	Y Upper Limit $\left[\frac{M\ lb.}{hr.}\right]$
70	269	333
80	315	377
90	360	422
90.86	364	426
100	405	468
110	450	514

Figure 13

Boiler Exit Dust Load (Y) vs. Boiler Loading (X)

$Y = 166.75X - 6898$; $\overline{Y} = 8254$, $\overline{X} = 91$

X Value (%)	Y Lower Limit(lb/hr.)	Y Upper Limit (lb/hr.)
70	2190	7,360
80	3921	8,964
90	5612	10,608
90.86	5757	10,752
100	7263	12,292
110	8874	14,016

Figure 14

Precipitator Outlet Dust Load (Y) vs. Boiler Loading (X)

$Y = 1.176X - 61.5$; $\overline{Y} = 45.4$, $\overline{X} = 91$

X Value (%)	Y Lower Limit (lb/hr.)	Y Upper Limit (lb/hr.)
70	-35.4	77.1
80	-22.3	87.5
90	-10.0	98.7
90.86	-9.0	99.7
100	1.4	110.8
110	11.9	123.8

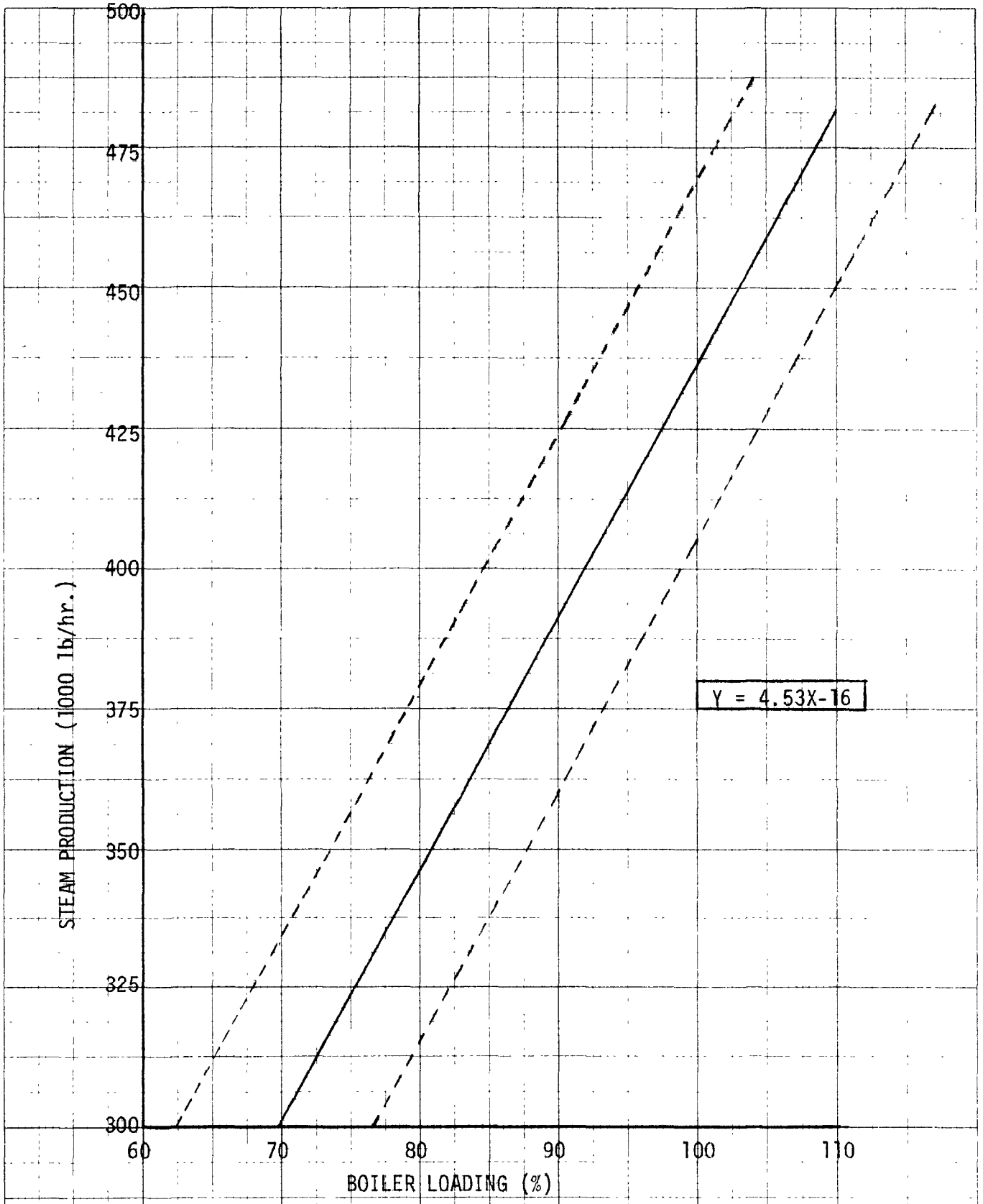

Figure 12 Steam Production vs. Boiler Loading

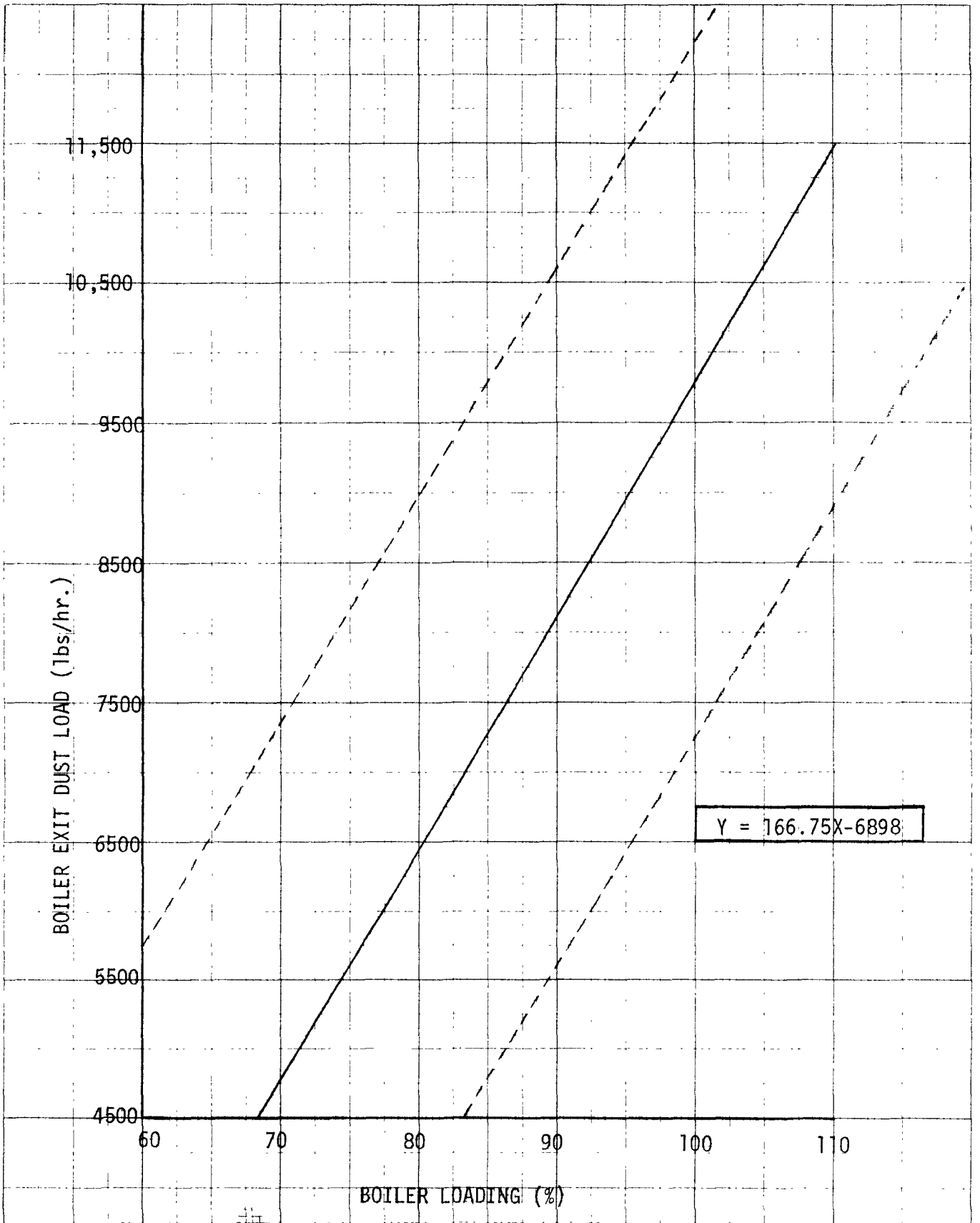

Figure 13 Boiler Exit Dust Load vs. Boiler Loading with 95% Confidence Limits for Individual Data Points

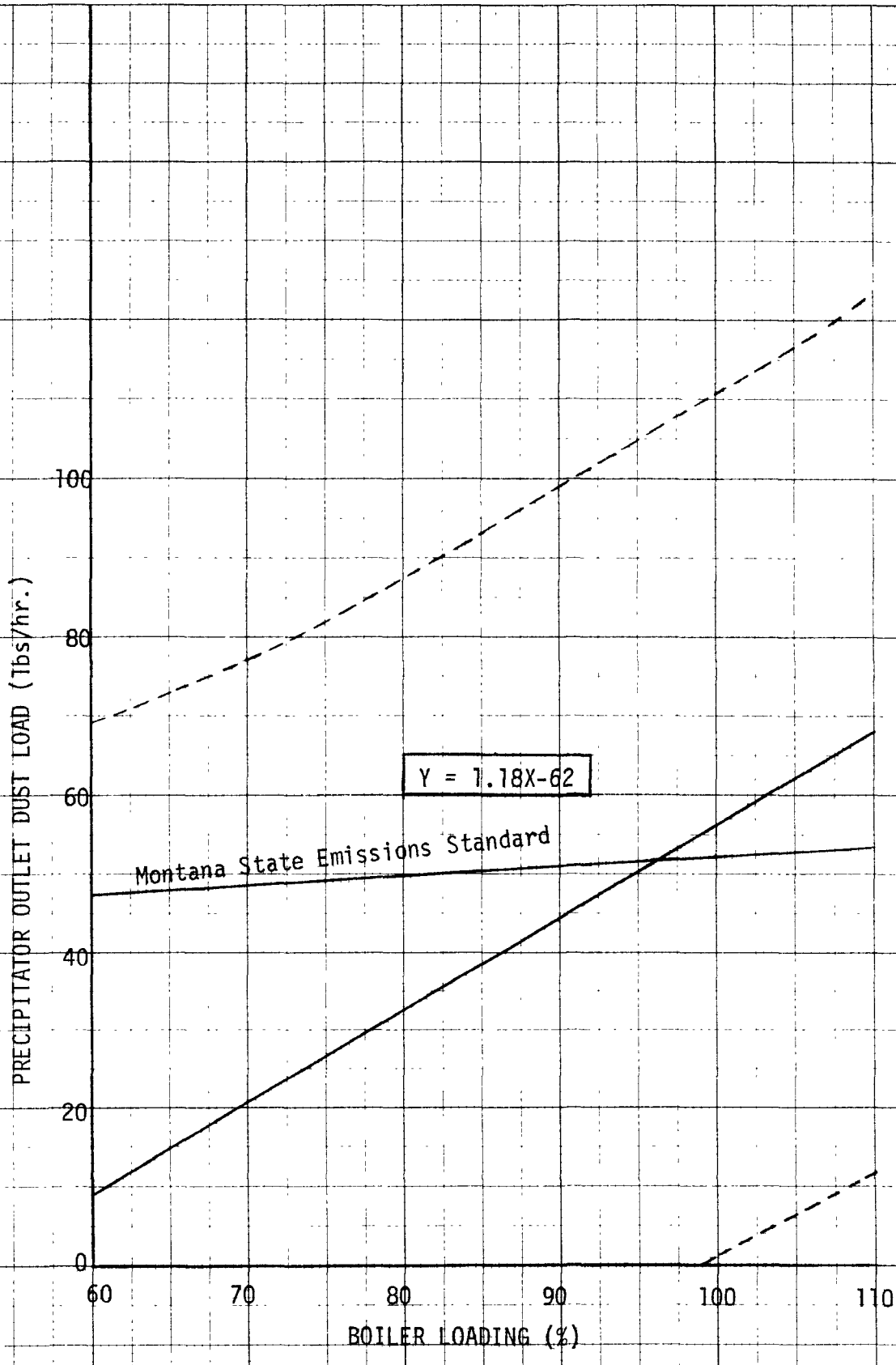

Figure 14 Precipitator Outlet (Stack) Dust Load vs. Boiler Loading with 95% Confidence Limits for Individual Data Points

Table 7

SUMMARY OF COMPUTER ANALYSIS RESULTS
(Observation Dates: February - April 1974)

Variables	No.of Points	Mean	Standard Deviation
1. Boiler Loading (%)	52	90.87	
2. Steam Flow (M lb/hr.)	52	395.10	50.95
3. Boiler Exit Dust Load (lb/hr.)	52	8254.23	2167.36
4. Precipitator Outlet Dust Load (lb/hr.) (All efficiencies)	52	45.37	29.38
5. Precipitator Outlet Dust Load (lb/hr.) (Efficiencies at least 99%)	49	40.59	20.47

Relationships	Regression Equation
a. 1 vs. 2	SF = 4.525 BL - 16.056
b. 1 vs. 3	BEDL = 166.750 BL - 6897.59
c. 1 vs. 4	PODL(1) = 1.176 BL - 61.509
d. 1 vs. 5	PODL(2) = 1.173 BL - 66.146

Figure 14 gives the relationship between Precipitator Outlet Dust Load and Boiler Loading. The regression equation developed was based on all the data sets compiled. At design boiler loading (100%), the average particulate emissions from the precipitator are 56 lb/hr., just slightly above the Montana State Emission Standard of 52 lb/hr. for No. 4 recovery. If the three suspect sets of data having precipitator efficiencies less than 99% are omitted from the regression analysis, another equation is obtained (see Table 7) having a similar slope but with a Y value approximately 5 units below the one obtained from the regression equation. At design boiler loading, the modified regression line then gives an average particulate emission of 51 lb/hr. which does fall below the maximum allowable State standard.

VARIOUS LIQUOR DISTRIBUTION CONDITIONS

Much of the testing program for No. 4 recovery boiler was devoted to investigating the effect of different liquor distribution conditions on emissions. Nozzle pressure, nozzle sidesweep, and nozzle backsweep were varied individually and collectively to evaluate such changes. A smaller nozzle size was used to obtain a higher liquor feed pressure under full load conditions. A summary of various operating conditions investigated are given in Table 8. For low boiler loading conditions (69-76%), only the first four conditions were employed.

Tables 9 and 10 summarize the results obtained from this part of the testing program. Full boiler loading data is summarized in Table 9 and low boiler loading data in Table 10. As a general observation, it does not appear from the limited data collected that any particular combination of operating parameters result in a significant higher or lower level of emissions than the others. It might possibly be significant in Table 9 that conditions four and eight result in the highest level of particulate emissions from the boiler. However, these averages are still below the design dust load of 8.0 gr/SDCF. Both conditions include high backsweep and wide sidesweep.

A comparison of the two tables indicates that the general level of SO_2 emissions under low boiler loading conditions (Table 10) is higher than the level of SO_2 emissions encountered under full boiler loading conditions (Table 9). The complete test data for No. 4 recovery will be found in APPENDIX C.

Table 8

VARIOUS LIQUOR DISTRIBUTION CONDITIONS EVALUATED

1. All Conditions Normal: Nozzle Pressure, 30-35 psig; Backsweep, -15° to -20°; Sidesweep, 5°L to 5°R

2. All Conditions Normal except High Backsweep (-10° to -14°)

3. All Conditions Normal except Wide Sidesweep (10°L to 10°R)

4. All Conditions Normal except High Backsweep and Wide Sidesweep

5. All Conditions Normal except High Nozzle Pressure (44 psig)

6. All Conditions Normal except High Nozzle Pressure and High Backsweep (-10° to -14°)

7. All Conditions Normal except High Nozzle Pressure and Wide Sidesweep (10°L to 10°R)

8. All Conditions Normal except High Nozzle Pressure, High Backsweep and Wide Sidesweep

Table 9

FULL BOILER LOADING DATA SUMMARY

Condition	Test Data	No.of Data Sets	Boiler Loading (%)	Excess Oxygen (%)	Particulate Emissions Boiler Exit (gr/SDCF)	Particulate Emissions Stack Loss (lb/hr.)	Precipitator Efficiency (%)	TRS (ppm)	SO_2 (ppm)
1	3/6-8, 3/25-26	6	101	1.8	7.14	74	99.2	4.7	6.2
2	3/28-29, 4/30	3	87	2.2	7.36	38	99.5	3.7	12.6
3	4/3-4	3	99	2.3	6.66	38	99.5	1.5	5.3
4	4/1-2	3	95	2.1	7.80	38	99.6	7.5	20.5
5	4/5,9	3	97	2.1	6.55	26	99.7	1.7	47
6	4/19-20	3	92	2.1	7.10	65	99.2	3.2	14.5
7	4/15-16	3	94	2.1	6.88	38	99.5	2.8	27
8	4/17-18	3	93	2.4	7.81	36	99.6	1.9	3.3

Table 10

LOW BOILER LOADING DATA SUMMARY

Condition	Test Data	No.of Data Sets	Boiler Loading (%)	Excess Oxygen (%)	Particulate Emissions Boiler Exit (gr/SDCF)	Particulate Emissions Stack Loss (lb/hr.)	Precipitator Efficiency (%)	TRS (ppm)	SO_2 (ppm)
1	3/18,22, 5/23	4	76	2.5	5.65	8	99.8	1.2	35
2	4/22-23	3	69	2.3	5.85	27	99.5	6.3	133
3	4/29, 5/2,6	4	74	2.4	5.76	51	99.0	4.7	93
4	4/24-25	3	71	2.3	5.68	8	99.8	8.0	149

APPENDIX A

DESIGN PARAMETERS FOR THE MAJOR COMPONENTS OF THE SYSTEM

1. No. 4 Recovery Boiler (Babcock and Wilcox unit erected in 1972)

   Nominal Capacity - 1000 TPD (based on 3000 lb dry solids per pulp ton)

   Design Loading - 3,000,000 lbs of black liquor solids per day at 6600 BTU/lb (equivalent to 3,040,000 lbs of solids at Missoula with average liquor BTU content of 6515 BTU/lb)

   Dust Load (max.) from Boiler at Design Load = 8.0 gr/SDCF

   Steam Production (max) - 485,000 lb/hr at 750°F and 600 psi based on feedwater temperature of 275°F entering economizer

   Total Heating Surface in Boiler - 60,483 sq.ft.
   Heating Surface of Superheater - 15,052 sq.ft.
   Heating Surface of Economizer - 66,750 sq.ft.

2. Evaporator Concentrator (Unitech unit)

   Evaporation Capacity 177,000 lb/hr.

   Total Heating Surface 49,000 sq.ft.

   Feed Liquor - 459,000 lb/hr at 190°F and 40% TS

   Product Liquor - 282,000 lb/hr at 215°F and 65% TS

3. Electrostatic Precipitator (Western Precipitation unit)

   a. Performance Data

      Maximum gas flow 470,000 ACFM

      Maximum gas temperature 440 °F

      Particulate to the Precipitator 10 grains/SDCF

      Particulate outlet loading 0.01 grains/SCF (wet)

      Guaranteed Efficiency 99.7%

      Density of Salt Cake Collected 8 lb/cu.ft.

      Net Gas Velocity at Rated Volume 3.80 FPS

      Gas Treatment Time at Rated Volume 7.9 Sec.

      Collecting area/volume rate flow 0.357

b. Typical Gas Conditions

H_2O by Volume	31%
H_2O by Weight	21%
Specific Density of Gas	0.037

c. Physical Characteristics of Precipitator

Walls	Steel
Roof	Steel
Gas Inlet	Top
Gas Outlet	Horizontal
Dust Removal System	Drag bottom Conveyor (5 drag chains per chamber,90° to gas flow, center discharge) Screw Conveyor (18" dia.x 18" pitch)
Number of chambers (units)	2(parallel units)
Number of Electrical Sections in series per chamber	4
Number of collecting plates per section	41
Number of ducts (gas passages) per unit	42
Size of each duct	9" x 30'5" x 30'
Collecting Electrodes	Solid Steel Plates
Total Collecting Area	158,760 sq.ft.
Total Electrode Length	102,480 feet
Discharge Electrodes	Vertical wires 0.1055" - steel

Electrical Field Designation	A	B	C	D
Collecting Surface Size Feet	6x31	9x31	9x31	6x31
Transformer-Rectifier Units				
Silicone, full wave - KV	50	50	50	50
MA	800	1200	1600	1200
Inductor Ratings - MH(2 each)	1.5	2.5	3.0	3.5
Power Supply	480V, 60 Hz , 3 phase			
Voltage Control	Thyristor			
Rapping Systems				
Collecting Surfaces	AUP - 300 Eriez pneumatic (total of 88)			
Discharge Electrodes	AUP - 300 Eriez pneumatic (total of 32)			
Inlet Distribution Plate	Martin Vibrolator (total of 8) AUP - 300 Eriez pneumatic (total of 8)			
Rapping Intensity	Variable			
Rapping Duration	Variable			

APPENDIX B

PARTICULATE SAMPLING

Particulate sampling was carried out once or twice a day during the EPA testing problem. Concurrent sampling both at the boiler exit duct and at the stack was accomplished by two testing teams in order to get meaningful data for the determination of precipitator collection efficiencies.

The details of the testing procedure employed at each sampling location are given in the following sections.

PARTICULATE SAMPLING PROCEDURE AT RECOVERY BOILER EXIT

Equipment

The sample train used for particulate testing at the boiler exit is illustrated in Figure 1. The probe is 1/2" stainless steel tubing, with an inside diameter of 3/8". The first scrubber-condenser is a 2 liter Florence flask, fitted with a glass bubble tube. The bubble tube is drawn out to a nozzle tip and positioned within 1/4 inch of the flask bottom to take advantage of impingement separation. The second and third scrubbers are commercial Greenburg-Smith impingers, the first with a standard impinger tip and the second with a straight tube. The mist trap consists of moist fiberglass wool, packed in a Gooch crucible to remove any carryover from the scrubbers and to act as a final filter in the system.

The meter is a Sprague dry gas meter, with totalizing dials to 99.99 cubic feet. Calibration is checked periodically with a fixed orifice calibrator. The vacuum pump has a free air capacity of 7 CFM. The flow through the sample train is adjusted by regulating the bleed valve at the pump inlet.

Rubber vacuum tubing is used to connect the various pieces of equipment.

Procedure

750 ml of distilled water are measured out and distributed to the three scrubbers, reserving about 100 ml for washing the probe into the condensate jar if any plugging occurs. A wad of fiberglass is placed in the crucible of the mist trap and the vacuum hoses connected.

The system is checked for leaks by sealing the nozzle tip, drawing a vacuum of at least 10 inches of Mercury and pinching off the hose between the gas meter and vacuum pump. The system is leak free when no bubbles are seen in the scrubber, the gas meter does not move, and the vacuum does not drop perceptibly in one minute.

A velocity traverse is made with a calibrated "S" type pitot tube and inclined manometer. Velocities are read off the calibration chart and

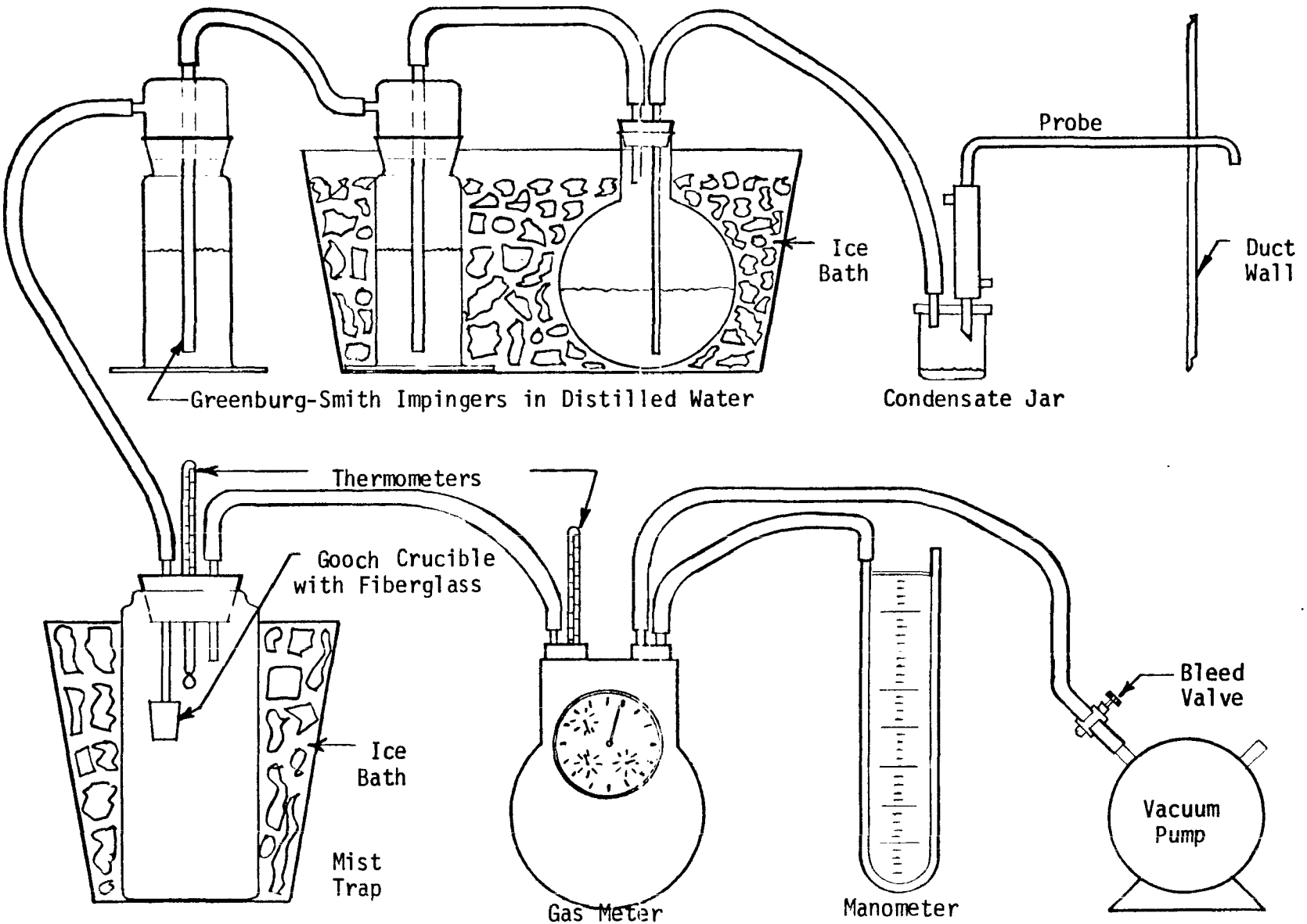

Figure 1 Hoerner Waldorf particulate sampling train used for boiler exit sampling

corrected for actual gas density. Stack temperature and pressure are measured, but for the preliminary figures, the moisture and gas analysis are assumed from previous tests. From the point velocities, metering rates are calculated to give isokinetic flow at the nozzle tip.

The probe is inserted into the stack with the nozzle located at the first point, and turned to face upstream. At the same time, the vacuum pump is turned on and the meter flow adjusted to establish isokinetic flow at the nozzle. Each point is sampled for the same length of time (4.5 minutes). The probe is moved from point to point at each port, without stopping the sample flow. Sampling is stopped when changing ports. During each test, the temperature and vacuum at the meter and the temperature at the mist trap are recorded periodically.

When sampling is complete, the probe is first rinsed with any remaining water previously reserved from the measured liter. All water in the system is combined and measured. Subtracting the original 750 ml gives the amount of collected condensate. The sample train is washed three times with distilled water. The washings are added to the sample liquid and the whole made up to volume in a volumetric flask (2000 ml).

The liquid is analyzed on the Coleman flame photometer for sodium and the concentration multiplied by the total volume gives the total weight of sodium sulfate collected.

The total gas volume measured at the gas meter is corrected to dry standard conditions of 70°F and 29.92 inches of Mercury. The total catch divided by the corrected gas flow sampled gives the dust loading. This is reported as grains of dust per dry standard cubic foot of gas.

The amount of collected condensate is used to determine the moisture in the flue gas and the gas density is corrected for temperature, pressure and moisture. The stack velocity is then corrected for actual gas density at stack conditions and the total gas flow calculated.

The total flow is corrected to dry standard conditions, and by multiplying by the dust loading, the total weight of dust lost is calculated.

PARTICULATE SAMPLING PROCEDURE AT THE STACK

Equipment

An R.A.C. Train Stack Sampler, manufactured by Research Appliance Company, was used for stack sampling in the testing program for No. 4 recovery system at Missoula. The unit conforms to specifications given in Volume 36, No. 247, of the Federal Register "Standards of Performance for New Stationary Samples - Method 5 Particulate Sampling." For ease of moving from port to port in the course of sampling, the sampling case was supported on a wheeled car in place of the factory supplied Duorail support. This sample train is illustrated in Figure 2.

Procedure

A new filter (Whatman GF/C) is oven dried, desicated and weighed. The sample train is assembled according to the manufacturer's instructions, with 100 ml of distilled water in each of the first two impingers; the third impinger is empty and approximately 200 grams of weighed dry silica gell is in the fourth.

The system is checked for leaks by plugging the nozzle tip. With the coarse-adjustment valve closed, the pump is turned on and the fine-adjustment valve regulated to maintain 10 inches of Mercury vacuum. At 10 inches of Mercury gage vacuum, the flow through the dry gas meter must not exceed 0.02 cu.ft. per minute, or the leaks must be found and corrected.

The stack is dividied into six equal areas with the sampling along two diameters located 90° apart for a total of 24 sample points. Factory supplied nomographs were used to establish isokinetic sampling at each point.

A velocity traverse is made with a calibrated "S" type pitot tube and inclined manometer. The indicated velocity is read off of the calibration chart and corrected for actual gas density. The average velocity multiplied by the stack area gives the total gas flow.

The probe heater and filter oven are turned on for 15 minutes to warm up to 250°F. The impinger section of the sample case is filled with ice.

The probe is inserted into the stack with the nozzle located at the first position facing upstream. At the same time the vacuum pump is started and isokinetic flow established. The required sampling flow is obtained by nothing the pitot tube manometer reading (ΔP), setting this value on the operating nomograph, reading the corresponding ΔH and with first the coarse and then fine control valves, making adjustments until this ΔH is indicated on the orifice manometer. Each point is sampled for the same length of time with adjustments made as needed for isokinetic sampling. The pump is not turned off when moving from point to point, but only when changing ports. The time, gas meter reading ΔP, ΔH readings, temperature in and out of the gas meter, scrubber train outlet temperature and vacuum at the gas meter are recorded at the beginning,

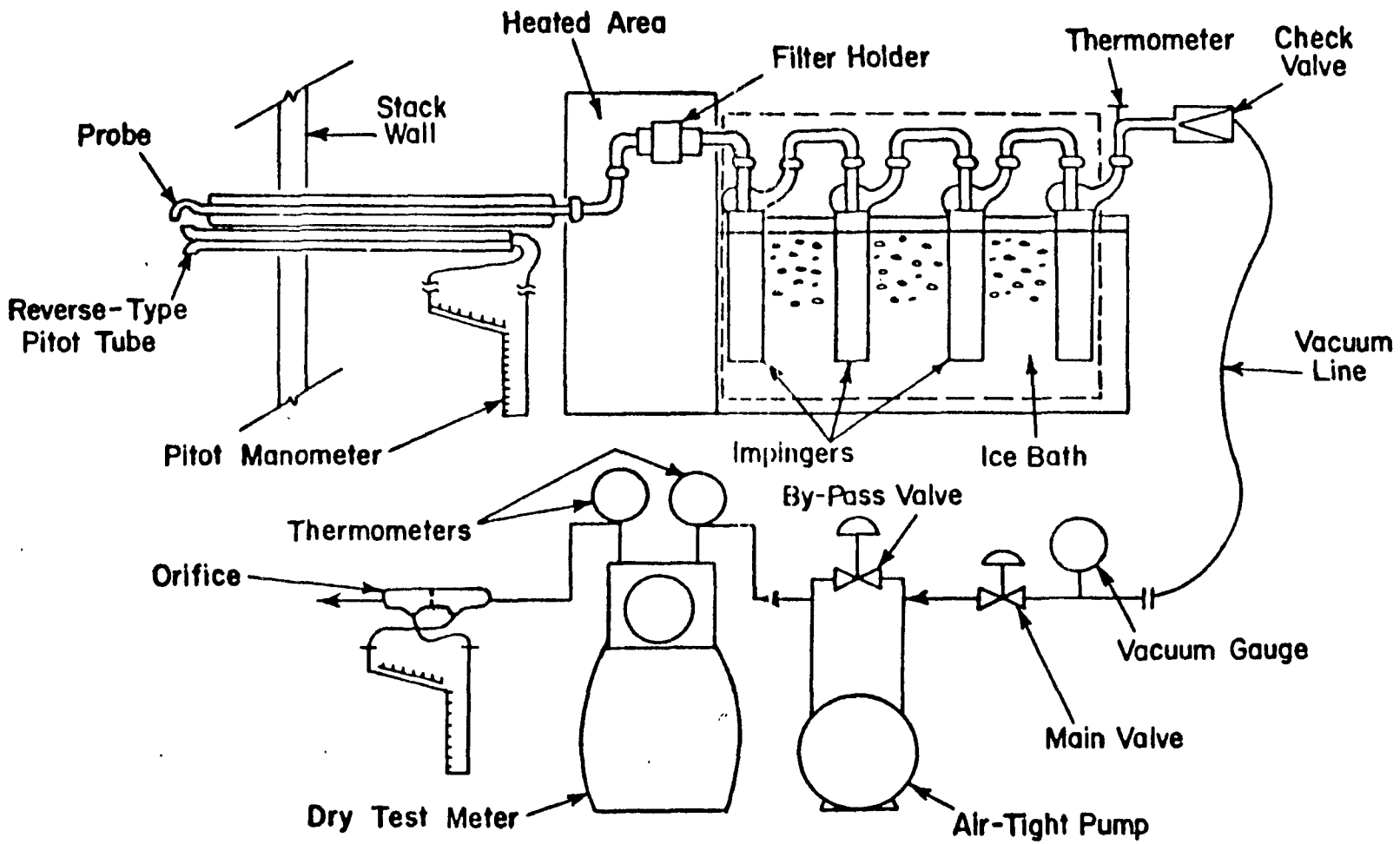

Figure 2 EPA particulate sampling train used for stack sampling

the end, and at each change of position during the test.

When the test is complete, the train is dismantled and the sample removed to the lab for analysis. As much loose dust as possible is brushed from the inside of the nozzle, probe and cyclone and added to the filter catch. The filter is carefully removed, dried and weighed. The entire probe and train from the nozzle through the filter holder is washed with distilled water. The wash water is collected, evaporated in tared breakers and the net increase in weight added to the weight collected on the filter. The total liquid in the impinger train is measured. The wet silica gel is weighed and the increased weight of water is converted to volume (1 gram = 1 milliliter), and added to the total water. Subtracting the original 200 ml gives the volume of collected condensate.

The total gas volume measured at the gas meter is corrected to dry standard conditions of 70°F and 29.92 inches of Mercury. The total weight of dust collected, divided by the corrected gas volume, gives the grain loading. This is reported as grains of dust per dry standard cubic foot of gas.

The amount of collected condensate is used to calculate the stack gas moisture. The gas density is corrected for temperature, pressure, and moisture. The indicated stack velocity is corrected for gas density and the actual total gas flow calculated from the average velocity and stack area.

The total flow is corrected to dry standard conditions. By multiplying the flow by the dust loading, the total weight of dust lost is obtained.

Precipitator efficiency is then calculated by subtracting the total weight of dust lost up the stack from the total weight of dust at the boiler exit (precipitator inlet) to determine the weight of dust removed by the precipitator. Dividing the dust removed by the dust to the precipitator and multiplying by 100 gives the percent efficiency.

APPENDIX C

COMPLETE EPA TEST DATA FOR BASIC PROGRAM

GLOSSARY FOR DATA SHEETS

Liquor flows - measured with a magnetic flow meter and continuously recorded on a strip chart in gallons per minute.

Liquor densities - an average of two actual measurements during each test period.

Liquor solids - an average of two black liquor samples collected during each test period with solids being determined by oven drying a 12-18 gram sample of black liquor for 24 hours at 105°C.

Boiler loading - actual true black liquor solids throughput divided by design solids throughput, corrected for the BTU value in use at that time.

EXAMPLE: No. 4 recovery design - 3,000,000 lbs true black liquor solids per day at 6600 BTU/lb

Hoerner Waldorf black liquor contains 6,515 BTU's/lb

Therefore, corrected design solids throughput is:

$$3{,}000{,}000 \times \frac{6600}{6515} = 3{,}039{,}140 \text{ lbs/day}$$

Given:	Sluice flow	300 gal/min.
	% solids	62.0%
	B.L. density	11.0 lb/gal

Boiler loading would then be:

$$\frac{300 \text{ gal/min} \times .62 \times 11 \text{ lb/gal} \times 1440 \text{ min/day}}{3{,}039{,}140 \text{ lb/day}} \times 100 = 96.9\%$$

Salt cake - is added via a calibrated screw conveyor. Salt cake is the basic makeup chemical for the Kraft process and controls the sulfidity level.

Nozzle size - the diameter of the nozzle in 32nds of an inch. e.g., a size 40 nozzle is 3.175 cm (1.25 inches) in diameter.

Nozzle Pressure - the liquor line pressure (psig).

Nozzle backsweep - the vertical upper and lower limits of nozzle movement expressed in degrees with 0 degrees at the horizontal position.

Nozzle sidesweep - the rotation of the nozzle expressed in degrees with 0 degrees at the vertical position.

Air flows - the amount of air entering the furnace at the primary, secondary, or tertiary air ports. It is measured by pressure differential in the duct and recorded continuously on a strip chart.

Total air - the summation of the individual primary, secondary, and tertiary air flows.

Combustion air temperature - the temperature of the combustion air after it has been heated by a gas air heater and before it enters the recovery boiler. It is measured and recorded continuously on a strip chart.

Excess O_2 - the percentage of oxygen leaving the furnace. Measurement based upon a paramagnetic principle. It is calibrated weekly, using 1.0 and 9.0% oxygen standards and recorded continuously on a strip chart.

TRS and SO_2 Averages - the amount of TRS and SO_2 as ppm (dry gas basis) leaving the recovery boiler stack during the test period as measured with a Barton titrator. Accuracies and calibration frequencies are discussed in the section of this report entitled testing procedures.

Sulfidity - the percentage ratio of sodium sulfide to total alkali ($NaOH$, Na_2S, and Na_2CO_3), all expressed as Na_2O. The daily sulfidity is an average of six white and three green liquor titrations run by lab personnel.

Steam flow - the amount of 600 psig, 750°F steam produced in lbs/hr from the recovery boiler. The Hoerner Waldorf No. 4 recovery boiler will produce 485,000 lbs/hr of steam at design solids loading.

Boiler exit and precipitator outlet conditions - ACFM, DSCFM, temperatures, particulate loadings, and precipitator efficiencies are either directly measured or calculated from data collected during each test period.

TABLE OF CONVERSION FACTORS
(English to Metric Units)

Multiply	by	to obtain
cubic feet	0.02832	cubic meters
degrees Fahrenheit (°F)	(-32) x 5/9	degrees centigrade(°C)
gallons	3.785	liters
pounds	0.454	kilograms
pounds per gallon	0.1195	kilograms per liter
pressure (PSI)	760/14.7	pressure(mm.of mercury)

NO. 4 RECOVERY EPA DATA

	INITIAL	"NORMAL"	CONDITIONS ESTABLISHED BY	
TARGET CONDITIONS				
Boiler Loading (% of Design)	100	100	100	
Air Distribution (1°/2°/3°-%)	28/52/20	28/52/20	28/52/20	
Excess O_2 (%)	2.0-3.0	2.0-3.0	2.0-3.0	
TEST DATE	2/18/74	2/18/74	2/19/74	
SLUICE TANK LIQUOR				
Flow (gpm)	301	302	293	
Density (lbs/gal)	11.4	11.4	11.5	
Solids (%)	62.2	62.6	64.9	
BOILER LOADING (%)	100	102	104	
SALT CAKE (lbs/min)	30	30	30	
SULFIDITY - (DAILY AVG.%)	27.5	27.5	27.5	
NOZZLE CONDITIONS				
Size	40	40	40	
Pressure (PSI)	39	39	39	
Liquor Temp. (°F)	225	225	225	
Backsweep (°)	-17 to -22	-17 to -22	-16 to -21	
Sidesweep (°)	5L to 5R	5L to 5R	5L to 5R	
COMBUSTION AIR TEMP (°F) 1°/2°	300/300	300/300	300/300	
AIR FLOW				
Primary (M lbs/hr)	148	148	148	
(% of Total)	28	28	28	
Secondary (M lbs/hr)	272	272	272	
(% of Total)	52	52	52	
Tertiary (M lbs/hr)	108	105	105	
(% of Total)	20	20	20	
Total (M lbs/hr)	528	525	525	
EXCESS O_2 (%)	2.5	2.5	2.3	
TRS AVG. (ppm)	2	2	2	
SO_2 AVG (ppm)	0	0	0	
STEAM FLOW (M lbs/hr)	429	429	442	
BOILER EXIT CONDITIONS				
Temp (°F)	410	420	420	
ACFM (1000 cu.ft./min)	465	485	506	
DSCFM(1000 cu.ft./min)	165	167	178	
Grain Loading(gr/DSCF)	8.20	8.71	8.14	
Particulate Load(lbs/hr)	11,576	12,500	12,445	
PRECIPITATOR INLET COND.				
Temp (°F)	405	405	405	
ACFM(1000 cu.ft./min)	462	477	497	
Volume @ 400°F	460	474	494	
PRECIPITATOR OUTLET COND.				
Temp (°F)	420	410	415	
ACFM (1000 cu.ft./min)	406	403	419	
DSCF (1000 cu.ft./min)	147	147	143	
Grain Loading(gr/DSCF)	0.0350	0.0434	0.0463	
Particulate Loading(lbs/hr)	44.0	54.7	60.8	
PRECIPITATOR EFFICIENCY(%)	99.6	99.5	99.4	

NO. 4 RECOVERY EPA DATA

TARGET CONDITIONS	BABCOCK AND WILCOX "TUNE-UP" EFFORT TO MINIMIZE TRS EMISSIONS				
Boiler Loading (% of Design)					
Air Distribution (1°/2°/3°-%)					
Excess O_2 (%)					
TEST DATE	2/20/74	2/22/74	2/26/74	2/26/74	2/27/
SLUICE TANK LIQUOR					
Flow (gpm)	294	268	256	241	248
Density (lbs/gal)	11.4	11.4	11.5	11.5	11.5
Solids (%)	64.5	63.7	65.4	66.0	NA
BOILER LOADING (%)	103	93	91	87	NA
SALT CAKE (lbs/min)	30	30	50	50	35
SULFIDITY - (DAILY AVG.%)	28.3	27.9	26.8	26.8	26.9
NOZZLE CONDITIONS					
Size	40	40	40	40	40
Pressure (PSI)	35	34	30	28	27
Liquor Temp. (°F)	220	213	225	225	225
Backsweep (°)	-18 to -21	-18 to -21	-19 to -22	-19 to -22	-15 to
Sidesweep (°)	5L to 5R	5L to 5R	5L to 5R	5L to 5R	5L to
COMBUSTION AIR TEMP (°F) 1°/2°	300/300	300/300	300/300	300/300	300/30
AIR FLOW					
Primary (M lbs/hr)	146	126	134	162	129
(% of Total)	26	24	24	28	23
Secondary (M lbs/hr)	232	266	260	234	260
(% of Total)	45	50	46	41	46
Tertiary (M lbs/hr)	142	142	174	174	177
(% of Total)	27	26	30	31	31
Total (M lbs/hr)	520	534	568	570	566
EXCESS O_2 (%)	2.9	3.7	2.2	2.5	2.4
TRS AVG. (ppm)	1	1	1	1	1
SO_2 AVG (ppm)	2	1	0	1	1
STEAM FLOW (M lbs/hr)	458	424	421	392	385
BOILER EXIT CONDITIONS					
Temp (°F)	410	405	410	417	417
ACFM (1000 cu.ft./min)	422	504	508	499	498
DSCFM(1000 cu.ft./min)	157	209	194	183	187
Grain Loading(gr/DSCF)	7.13	7.57	6.80	7.63	7.18
Particulate Load(lbs/hr)	9,598	8,916	8,516	10,148	10,016
PRECIPITATOR INLET COND.					
Temp (°F)	400	400	400	400	400
ACFM(1000 cu.ft./min)	417	546	502	494	488
Volume @ 400°F	417	546	502	494	488
PRECIPITATOR OUTLET COND.					
Temp (°F)	410	410	410	410	410
ACFM (1000 cu.ft./min)	405	366	380	395	418
DSCF (1000 cu.ft./min)	158	137	146	155	163
Grain Loading(gr/DSCF)	0.0358	0.0507	0.0538	0.0524	0.0796
Particulate Loading(lbs/hr)	48.6	59.7	67.4	69.8	111.2
PRECIPITATOR EFFICIENCY(%)	99.5	99.3	99.2	99.3	98.9

NO. 4 RECOVERY EPA DATA

TARGET CONDITIONS	BABCOCK AND WILCOX "TUNE-UP" EFFORT TO MINIMIZE TRS EMISSIONS			
Boiler Loading (% of Design)				
Air Distribution (1°/2°/3°-%)				
Excess O_2 (%)				
TEST DATE	2/28/74	3/4/74	3/5/74	3/5/74
SLUICE TANK LIQUOR				
Flow (gpm)	272	276	285	284
Density (lbs/gal)	11.5	11.5	11.3	11.5
Solids (%)	63.9	65.4	64.0	65.7
BOILER LOADING (%)	94	98	98	102
SALT CAKE (lbs/min)	35	15	30	30
SULFIDITY - (DAILY AVG.%)	26.8	27.6	27.2	27.2
NOZZLE CONDITIONS				
Size	40	40	40	40
Pressure (PSI)	26	32	32	32
Liquor Temp. (°F)	225	225	225	225
Backsweep (°)	-15 to -19	-12 to -18	-12 to -18	-12 to -18
Sidesweep (°)	3L to 7R	5L to 5R	5L to 5R	5L to 5R
COMBUSTION AIR TEMP (°F) 1°/2°	350/300	350/300	350/300	350/300
AIR FLOW				
Primary (M lbs/hr)	140	140	140	140
(% of Total)	28	26	26	26
Secondary (M lbs/hr)	263	266	266	266
(% of Total)	52	50	50	50
Tertiary (M lbs/hr)	101	126	126	126
(% of Total)	20	24	24	24
Total (M lbs/hr)	504	532	532	532
EXCESS O_2 (%)	1.9	1.4	1.8	1.2
TRS AVG. (ppm)	1	0.1	1	1
SO_2 AVG (ppm)	3	2	1	2
STEAM FLOW (M lbs/hr)	379	419	422	438
BOILER EXIT CONDITIONS				
Temp (°F)	395	407	415	412
ACFM (1000 cu.ft./min)	485	479	390	424
DSCFM(1000 cu.ft./min)	178	176	139	152
Grain Loading(gr/DSCF)	7.56	6.86	7.53	7.69
Particulate Load(lbs/hr)	11,538	10,346	8,960	10,049
PRECIPITATOR INLET COND.				
Temp (°F)	390	405	395	400
ACFM(1000 cu.ft./min)	482	478	381	418
Volume @ 400°F	486	475	383	418
PRECIPITATOR OUTLET COND.				
Temp (°F)	400	410	407	408
ACFM (1000 cu.ft./min)	391	394	408	410
DSCF (1000 cu.ft./min)	146	150	152	142
Grain Loading(gr/DSCF)	0.0494	0.0373	0.0374	0.0473
Particulate Loading(lbs/hr)	62.0	47.9	48.7	57.4
PRECIPITATOR EFFICIENCY(%)	99.3	99.5	99.5	99.4

NO. 4 RECOVERY EPA DATA

TARGET CONDITIONS	"NORMAL" CONDITIONS ESTABLISHED BY B & W			
Boiler Loading (% of Design)	100	100	100	100
Air Distribution (1°/2°/3°-%)	26/50/24	26/50/24	26/50/24	26/50/24
Excess O_2 (%)	1.5-2.5	1.5-2.5	1.5-2.5	1.5-2.5
TEST DATE	3/6/74	3/6/74	3/7/74	3/8/74
SLUICE TANK LIQUOR				
Flow (gpm)	293	302	284	276
Density (lbs/gal)	11.5	11.5	11.5	11.5
Solids (%)	64.5	65.2	65.8	66.2
BOILER LOADING (%)	103	107	102	100
SALT CAKE (lbs/min)	15	15	30	30
SULFIDITY - (DAILY AVG.%)	27.4	27.4	27.3	27.2
NOZZLE CONDITIONS				
Size	40	40	40	40
Pressure (PSI)	32	32	35	31
Liquor Temp. (°F)	215	215	225	225
Backsweep (°)	-20 to -25	-20 to -25	-15 to -21	-15 to -21
Sidesweep (°)	5L to 5R	5L to 5R	5L to 5R	5L to 5R
COMBUSTION AIR TEMP (°F) 1°/2°	350/300	350/300	350/300	350/300
AIR FLOW				
Primary (M lbs/hr)	140	140	154	134
(% of Total)	25	25	28	25
Secondary (M lbs/hr)	266	266	266	266
(% of Total)	48	48	48	49
Tertiary (M lbs/hr)	148	148	136	142
(% of Total)	27	27	24	26
Total (M lbs/hr)	554	554	556	542
EXCESS O_2 (%)	1.8	1.8	1.5	2.0
TRS AVG. (ppm)	0.3	0	1.2	1.0
SO2 AVG (ppm)	3.8	4.7	1.7	2.3
STEAM FLOW (M lbs/hr)	435	435	440	415
BOILER EXIT CONDITIONS				
Temp (°F)	421	410	413	395
ACFM (1000 cu.ft./min)	480	467	456	440
DSCFM(1000 cu.ft./min)	174	172	165	157
Grain Loading(gr/DSCF)	7.46	7.46	7.17	6.37
Particulate Load(lbs/hr)	10,168	10,175	9,442	8,408
PRECIPITATOR INLET COND.				
Temp (°F)				
ACFM(1000 cu.ft./min)	NA	NA	NA	NA
Volume @ 400°F				
PRECIPITATOR OUTLET COND.				
Temp (°F)	410	415	415	405
ACFM (1000 cu.ft./min)	420	423	413	404
DSCF (1000 cu.ft./min)	159	159	154	154
Grain Loading(gr/DSCF)	0.0410	0.0510	0.0620	0.0540
Particulate Loading(lbs/hr)	56	70	82	71
PRECIPITATOR EFFICIENCY(%)	99.4	99.3	99.1	99.2

NO. 4 RECOVERY EPA DATA

TARGET CONDITIONS	NORMAL LOAD, LOW EXCESS OXYGEN		
Boiler Loading (% of Design)	90-100	90-100	90-100
Air Distribution (1°/2°/3°-%)	26/50/24	26/50/24	26/50/24
Excess O_2 (%)	0.5-1.0	0.5-1.0	0.5-1.0
TEST DATE	3/26/74	3/25/74	3/25/74
SLUICE TANK LIQUOR			
Flow (gpm)	268	277	281
Density (lbs/gal)	11.1	11.2	11.1
Solids (%)	65.6	66.6	66.2
BOILER LOADING (%)	92	98	98
SALT CAKE (lbs/min)	30	30	30
SULFIDITY - (DAILY AVG.%)	28.3	27.5	27.5
NOZZLE CONDITIONS			
Size	40	40	40
Pressure (PSI)	35	37	37
Liquor Temp. (°F)	235	225	225
Backsweep (°)	-15 to -20	-15 to -20	-15 to -20
Sidesweep (°)	5L to 5R	5L to 5R	5L to 5R
COMBUSTION AIR TEMP (°F) 1°/2°	350/300	350/300	350/300
AIR FLOW			
Primary (M lbs/hr)	140	140	149
(% of Total)	29	28	28
Secondary (M lbs/hr)	244	266	266
(% of Total)	49	53	50
Tertiary (M lbs/hr)	111	101	111
(% of Total)	22	20	22
Total (M lbs/hr)	495	507	526
EXCESS O_2 (%)	2.1	1.8	1.6
TRS AVG. (ppm)	4.2	13.5	21.0
SO2 AVG (ppm)	3.3	4.3	29.6
STEAM FLOW (M lbs/hr)	414	450	450
BOILER EXIT CONDITIONS			
Temp (°F)	402	400	400
ACFM (1000 cu.ft./min)	421	448	501
DSCFM(1000 cu.ft./min)	158	169	154
Grain Loading(gr/DSCF)	7.86	7.38	6.34
Particulate Load(lbs/hr)	9,684	9,092	7,235
PRECIPITATOR INLET COND.			
Temp (°F)			
ACFM(1000 cu.ft./min)	NA	NA	NA
Volume @ 400°F			
PRECIPITATOR OUTLET COND.			
Temp (°F)	390	392	392
ACFM (1000 cu.ft./min)	368	372	343
DSCF (1000 cu.ft./min)	144	144	133
Grain Loading(gr/DSCF)	0.0226	.1448	.0335
Particulate Loading(lbs/hr)	27.8	178.4	38.2
PRECIPITATOR EFFICIENCY(%)	99.7	98.0	99.5

NO. 4 RECOVERY EPA DATA

TARGET CONDITIONS	HIGH BACKSWEEP(-10 to -13) NORMAL SIDESWEEP(5L to 5R)			
Boiler Loading (% of Design)	90-100	90-100	90-100	90-100
Air Distribution (1°/2°/3°-%)	26/50/24	26/50/24	26/50/24	26/50/24
Excess O_2 (%)	1.5-2.5	1.5-2.5	1.5-2.5	1.5-2.5
TEST DATE	3/28/74	3/29/74	3/29/74	4/30/74
SLUICE TANK LIQUOR				
Flow (gpm)	267	268	266	275
Density (lbs/gal)	11.2	11.3	11.3	11.2
Solids (%)	63.7	64.4	65.3	63.7
BOILER LOADING (%)	90	93	92	93
SALT CAKE (lbs/min)	15	20	20	40
SULFIDITY - (DAILY AVG.%)	27.3	27.7	27.7	27.5
NOZZLE CONDITIONS				
Size	40	40	40	40
Pressure (PSI)	32	32	32	35
Liquor Temp. (°F)	248	235	223	225
Backsweep (°)	-10 to -15	-10 to -14	-10 to -15	-10 to -13
Sidesweep (°)	5L to 5R	5L to 5R	5L to 5R	5L to 5R
COMBUSTION AIR TEMP (°F) 1°/2°	350/300	350/300	350/300	350/300
AIR FLOW				
Primary (M lbs/hr)	132	135	150	134
(% of Total)	25	28	29	26
Secondary (M lbs/hr)	249	233	247	252
(% of Total)	47	48	48	49
Tertiary (M lbs/hr)	152	120	120	132
(% of Total)	28	24	23	25
Total (M lbs/hr)	533	488	517	518
EXCESS O_2 (%)	2.3	2.1	2.3	2.2
TRS AVG. (ppm)	0	6.0	5.1	2.4
SO2 AVG (ppm)	9.0	19.2	9.7	1.4
STEAM FLOW (M lbs/hr)	410	402	414	404
BOILER EXIT CONDITIONS				
Temp (°F)	405	410	410	435
ACFM (1000 cu.ft./min)	371	443	497	483
DSCFM(1000 cu.ft./min)	141	168	181	182
Grain Loading(gr/DSCF)	5.40	8.30	8.39	7.49
Particulate Load(lbs/hr)	6,739	9,433	10,337	9,179
PRECIPITATOR INLET COND.				
Temp (°F)				
ACFM(1000 cu.ft./min)	NA	NA	NA	NA
Volume @ 400°F				
PRECIPITATOR OUTLET COND.				
Temp (°F)	390	395	403	400
ACFM (1000 cu.ft./min)	362	343	377	380
DSCF (1000 cu.ft./min)	146	133	144	143
Grain Loading(gr/DSCF)	0.0365	0.0278	0.0294	0.0777
Particulate Loading(lbs/hr)	45.5	31.6	36.1	95.2
PRECIPITATOR EFFICIENCY(%)	99.3	99.7	99.7	99.0

NO. 4 RECOVERY EPA DATA

TARGET CONDITIONS	NORMAL BACKSWEEP (-15 to -20) WIDE SIDESWEEP (10L			
Boiler Loading (% of Design)	90-100	90-100	90-100	
Air Distribution (1°/2°/3°-%)	26/50/24	26/50/24	26/50/24	
Excess O_2 (%)	1.5-2.5	1.5-2.5	1.5-2.5	
TEST DATE	4/3/74	4/4/74	4/4/74	
SLUICE TANK LIQUOR				
Flow (gpm)	275	280	277	
Density (lbs/gal)	11.3	11.4	11.5	
Solids (%)	65.6	66.3	66.3	
BOILER LOADING (%)	97	100	100	
SALT CAKE (lbs/min)	20	20	20	
SULFIDITY - (DAILY AVG.%)	27.1	27.0	27.0	
NOZZLE CONDITIONS				
Size	40	40	40	
Pressure (PSI)	35	35	35	
Liquor Temp. (°F)	225	225	225	
Backsweep (°)	-15 to -20	-15 to -20	-15 to -20	
Sidesweep (°)	10L to 10R	10L to 10R	10L to 10R	
COMBUSTION AIR TEMP (°F) 1°/2°	350/300	350/300	350/300	
AIR FLOW				
Primary (M lbs/hr)	135	137	137	
(% of Total)	26	26	26	
Secondary (M lbs/hr)	261	263	261	
(% of Total)	50	50	50	
Tertiary (M lbs/hr)	126	126	129	
(% of Total)	24	24	24	
Total (M lbs/hr)	522	526	527	
EXCESS O_2 (%)	2.0	2.5	2.5	
TRS AVG. (ppm)	1.5	1.2	1.7	
SO2 AVG (ppm)	6.0	7.7	2.3	
STEAM FLOW (M lbs/hr)	439	440	430	
BOILER EXIT CONDITIONS				
Temp (°F)	410	400	400	
ACFM (1000 cu.ft./min)	453	445	469	
DSCFM(1000 cu.ft./min)	172	171	183	
Grain Loading(gr/DSCF)	6.81	6.45	6.71	
Particulate Load(lbs/hr)	8,306	8,125	8,976	
PRECIPITATOR INLET COND.				
Temp (°F)				
ACFM(1000 cu.ft./min)	NA	NA	NA	
Volume @ 400°F				
PRECIPITATOR OUTLET COND.				
Temp (°F)	395	392	400	
ACFM (1000 cu.ft./min)	362	367	379	
DSCF (1000 cu.ft./min)	132	147	156	
Grain Loading(gr/DSCF)	0.0308	0.0342	0.0254	
Particulate Loading(lbs/hr)	37.5	43.1	34.0	
PRECIPITATOR EFFICIENCY(%)	99.5	99.5	99.6	

NO. 4 RECOVERY EPA DATA

TARGET CONDITIONS	HIGH BACKSWEEP (-10 to -13) WIDE SIDESWEEP (10L to 10R)				
Boiler Loading (% of Design)	90-100	90-100	90-100		
Air Distribution (1°/2°/3°-%)	26/50/24	26/50/24	26/50/24		
Excess O_2 (%)	1.5-2.5	1.5-2.5	1.5-2.5		
TEST DATE	4/1/74	4/1/74	4/2/74		
SLUICE TANK LIQUOR					
Flow (gpm)	280	278	268		
Density (lbs/gal)	11.4	11.4	11.4		
Solids (%)	63.5	64.5	64.0		
BOILER LOADING (%)	96	97	93		
SALT CAKE (lbs/min)	20	20	20		
SULFIDITY - (DAILY AVG.%)	27.5	27.5	27.2		
NOZZLE CONDITIONS					
Size	40	40	40		
Pressure (PSI)	35	35	34		
Liquor Temp. (°F)	225	225	225		
Backsweep (°)	-10 to -14	-10 to -14	-10 to -14		
Sidesweep (°)	10L to 10R	10L to 10R	10L to 10R		
COMBUSTION AIR TEMP (°F) 1°/2°	350/300	350/300	350/300		
AIR FLOW					
Primary (M lbs/hr)	132	132	135		
(% of Total)	27	27	26		
Secondary (M lbs/hr)	246	249	258		
(% of Total)	50	50	49		
Tertiary (M lbs/hr)	117	117	129		
(% of Total)	23	23	25		
Total (M lbs/hr)	495	498	522		
EXCESS O_2 (%)	1.5	1.3	2.6		
TRS AVG. (ppm)	13.6	7.3	1.6		
SO2 AVG (ppm)	34.8	24.7	2.0		
STEAM FLOW (M lbs/hr)	392	412	414		
BOILER EXIT CONDITIONS					
Temp (°F)	420	410	410		
ACFM (1000 cu.ft./min)	542	463	524		
DSCFM(1000 cu.ft./min)	208	166	194		
Grain Loading(gr/DSCF)	7.53	7.60	8.28		
Particulate Load(lbs/hr)	8,866	9,075	9,945		
PRECIPITATOR INLET COND.					
Temp (°F)					
ACFM(1000 cu.ft./min)	NA	NA	NA		
Volume @ 400°F					
PRECIPITATOR OUTLET COND.					
Temp (°F)	395	390	400		
ACFM (1000 cu.ft./min)	367	369	365		
DSCF (1000 cu.ft./min)	137	139	140		
Grain Loading(gr/DSCF)	0.0331	0.0337	0.0346		
Particulate Loading(lbs/hr)	36.2	37.4	41.6		
PRECIPITATOR EFFICIENCY(%)	99.6	99.6	99.6		

NO. 4 RECOVERY EPA DATA

TARGET CONDITIONS	HIGH LIQUOR PRESSURE, SMALLER NOZZLE SIZE				
Boiler Loading (% of Design)	90-100	90-100	90-100		
Air Distribution (1°/2°/3°-%)	26/50/24	26/50/24	26/50/24		
Excess O_2 (%)	1.5-2.5	1.5-2.5	1.5-2.5		
TEST DATE	4/5/74	4/5/74	4/9/74		
SLUICE TANK LIQUOR					
Flow (gpm)	272	272	276		
Density (lbs/gal)	11.4	11.4	11.3		
Solids (%)	67.2	64.4	65.1		
BOILER LOADING (%)	99	95	96		
SALT CAKE (lbs/min)	20	20	30		
SULFIDITY - (DAILY AVG.%)	27.3	27.3	27.5		
NOZZLE CONDITIONS					
Size	34	34	34		
Pressure (PSI)	44	44	44		
Liquor Temp. (°F)	225	225	225		
Backsweep (°)	-15 to -21	-15 to -21	-15 to -21		
Sidesweep (°)	5L to 5R	5L to 5R	5L to 5R		
COMBUSTION AIR TEMP (°F) 1°/2°	350/300	350/300	350/300		
AIR FLOW					
Primary (M lbs/hr)	150	135	137		
(% of Total)	29	27	28		
Secondary (M lbs/hr)	256	258	258		
(% of Total)	49	51	52		
Tertiary (M lbs/hr)	114	111	101		
(% of Total)	22	22	20		
Total (M lbs/hr)	520	504	496		
EXCESS O_2 (%)	2.0	2.1	2.3		
TRS AVG. (ppm)	1.4	1.4	2.3		
SO_2 AVG (ppm)	16.6	8.8	116		
STEAM FLOW (M lbs/hr)	433	428	407		
BOILER EXIT CONDITIONS					
Temp (°F)	405	395	410		
ACFM (1000 cu.ft./min)	501	499	478		
DSCFM(1000 cu.ft./min)	189	188	142		
Grain Loading(gr/DSCF)	6.45	6.97	6.23		
Particulate Load(lbs/hr)	7,640	8,251	7,369		
PRECIPITATOR INLET COND.					
Temp (°F)					
ACFM(1000 cu.ft./min)	NA	NA	NA		
Volume @ 400°F					
PRECIPITATOR OUTLET COND.					
Temp (°F)	395	390	383		
ACFM (1000 cu.ft./min)	356	353	354		
DSCF (1000 cu.ft./min)	138	138	138		
Grain Loading(gr/DSCF)	0.0250	0.0231	0.0182		
Particulate Loading(lbs/hr)	29.7	27.4	21.4		
PRECIPITATOR EFFICIENCY(%)	99.6	99.7	99.7		

NO. 4 RECOVERY EPA DATA

TARGET CONDITIONS	HIGH LIQUOR PRESSURE, NORMAL SIDESWEEP, HIGH BACKSWEEP				
Boiler Loading (% of Design)	90-100	90-100	90-100		
Air Distribution (1°/2°/3°-%)	26/50/24	26/50/24	26/50/24		
Excess O_2 (%)	1.5-2.5	1.5-2.5	1.5-2.5		
TEST DATE	4/19/74	4/19/74	4/20/74		
SLUICE TANK LIQUOR					
Flow (gpm)	275	274	274		
Density (lbs/gal)	11.3	11.3	11.2		
Solids (%)	63.5	63.1	62.2		
BOILER LOADING (%)	94	92	90		
SALT CAKE (lbs/min)	25	25	25		
SULFIDITY - (DAILY AVG.%)	28.4	28.4	26.8		
NOZZLE CONDITIONS					
Size	34	34	34		
Pressure (PSI)	45	45	44		
Liquor Temp. (°F)	225	220	225		
Backsweep (°)	-10 to -13	-10 to -13	-10 to -15		
Sidesweep (°)	5L to 5R	5L to 5R	5L to 5R		
COMBUSTION AIR TEMP (°F) 1°/2°	350/300	350/300	350/300		
AIR FLOW					
Primary (M lbs/hr)	133	135	133		
(% of Total)	26	26	26		
Secondary (M lbs/hr)	255	255	252		
(% of Total)	49	49	49		
Tertiary (M lbs/hr)	129	130	131		
(% of Total)	25	25	25		
Total (M lbs/hr)	517	520	516		
EXCESS O_2 (%)	2.2	2.0	2.0		
TRS AVG. (ppm)	2.0	3.0	4.6		
SO_2 AVG (ppm)	5.9	2.4	35.3		
STEAM FLOW (M lbs/hr)	413	416	410		
BOILER EXIT CONDITIONS					
Temp (°F)	400	395	410		
ACFM (1000 cu.ft./min)	513	451	496		
DSCFM(1000 cu.ft./min)	190	164	182		
Grain Loading(gr/DSCF)	7.23	7.43	6.64		
Particulate Load(lbs/hr)	9,439	9,878	7,955		
PRECIPITATOR INLET COND.					
Temp (°F)					
ACFM(1000 cu.ft./min)	NA	NA	NA		
Volume @ 400°F					
PRECIPITATOR OUTLET COND.					
Temp (°F)	390	400	390		
ACFM (1000 cu.ft./min)	315	363	362		
DSCF (1000 cu.ft./min)	141	144	130		
Grain Loading(gr/DSCF)	0.0383	0.0450	0.0772		
Particulate Loading(lbs/hr)	46.4	55.6	92.5		
PRECIPITATOR EFFICIENCY(%)	99.5	99.4	98.8		

NO. 4 RECOVERY EPA DATA

TARGET CONDITIONS	HIGH LIQUOR PRESSURE, WIDE SIDESWEEP, NORMAL BACKSW				
Boiler Loading (% of Design)	90-100	90-100	90-100		
Air Distribution (1°/2°/3°-%)	26/50/24	26/50/24	26/50/24		
Excess O_2 (%)	1.5-2.5	1.5-2.5	1.5-2.5		
TEST DATE	4/15/74	4/16/74	4/16/74		
SLUICE TANK LIQUOR					
Flow (gpm)	279	280	277		
Density (lbs/gal)	11.2	11.2	11.2		
Solids (%)	63.3	63.1	63.3		
BOILER LOADING (%)	94	94	93		
SALT CAKE (lbs/min)	20	20	20		
SULFIDITY - (DAILY AVG.%)	28.8	28.6	28.6		
NOZZLE CONDITIONS					
Size	34	34	34		
Pressure (PSI)	45	45	45		
Liquor Temp. (°F)	210	210	210		
Backsweep (°)	-16 to -22	-16 to -22	-16 to -22		
Sidesweep (°)	10L to 10R	10L to 10R	10L to 10R		
COMBUSTION AIR TEMP (°F) 1°/2°	350/300	350/300	350/300		
AIR FLOW					
Primary (M lbs/hr)	137	132	137		
(% of Total)	26	26	26		
Secondary (M lbs/hr)	258	249	252		
(% of Total)	49	49	49		
Tertiary (M lbs/hr)	129	126	129		
(% of Total)	25	25	25		
Total (M lbs/hr)	524	507	518		
EXCESS O_2 (%)	2.2	2.0	2.0		
TRS AVG. (ppm)	2.3	3.5	2.5		
SO_2 AVG (ppm)	14.4	46.8	19.8		
STEAM FLOW (M lbs/hr)	415	417	418		
BOILER EXIT CONDITIONS					
Temp (°F)	410	400	400		
ACFM (1000 cu.ft./min)	505	460	482		
DSCFM(1000 cu.ft./min)	187	158	179		
Grain Loading(gr/DSCF)	6.80	7.04	6.79		
Particulate Load(lbs/hr)	8,258	8,115	7,950		
PRECIPITATOR INLET COND.					
Temp (°F)					
ACFM(1000 cu.ft./min)	NA	NA	NA		
Volume @ 400°F					
PRECIPITATOR OUTLET COND.					
Temp (°F)	405	400	395		
ACFM (1000 cu.ft./min)	365	354	357		
DSCF (1000 cu.ft./min)	142	135	137		
Grain Loading(gr/DSCF)	0.0398	0.0266	0.0319		
Particulate Loading(lbs/hr)	48.3	30.7	34.6		
PRECIPITATOR EFFICIENCY(%)	99.4	99.6	99.6		

NO. 4 RECOVERY EPA DATA

TARGET CONDITIONS	HIGH LIQUOR PRESSURE, WIDE SIDESWEEP, HIGH BACKSWEEP				
Boiler Loading (% of Design)	90-100	90-100	90-100		
Air Distribution (1°/2°/3°-%)	26/50/24	26/50/24	26/50/24		
Excess O_2 (%)	1.5-2.5	1.5-2.5	1.5-2.5		
TEST DATE	4/17/74	4/17/74	4/18/74		
SLUICE TANK LIQUOR					
Flow (gpm)	274	272	271		
Density (lbs/gal)	11.3	11.3	11.2		
Solids (%)	63.8	64.0	63.4		
BOILER LOADING (%)	94	93	91		
SALT CAKE (lbs/min)	20	20	25		
SULFIDITY - (DAILY AVG.%)	28.6	28.6	27.8		
NOZZLE CONDITIONS					
Size	34	34	34		
Pressure (PSI)	45	45	45		
Liquor Temp. (°F)	220	225	225		
Backsweep (°)	-11 to -14	-11 to -14	-10 to -14		
Sidesweep (°)	10L to 10R	10L to 10R	10L to 10R		
COMBUSTION AIR TEMP (°F) 1°/2°	350/300	350/300	350/300		
AIR FLOW					
Primary (M lbs/hr)	133	135	133		
(% of Total)	26	26	25		
Secondary (M lbs/hr)	252	252	257		
(% of Total)	49	49	50		
Tertiary (M lbs/hr)	134	134	132		
(% of Total)	25	25	25		
Total (M lbs/hr)	519	521	522		
EXCESS O_2 (%)	2.3	2.4	2.6		
TRS AVG. (ppm)	2.3	2.1	1.3		
SO_2 AVG (ppm)	3.0	1.0	5.9		
STEAM FLOW (M lbs/hr)	411	415	403		
BOILER EXIT CONDITIONS					
Temp (°F)	405	415	400		
ACFM (1000 cu.ft./min)	476	491	496		
DSCFM(1000 cu.ft./min)	177	180	184		
Grain Loading(gr/DSCF)	7.58	7.45	8.41		
Particulate Load(lbs/hr)	8,956	8,241	9,799		
PRECIPITATOR INLET COND.					
Temp (°F)					
ACFM(1000 cu.ft./min)	NA	NA	NA		
Volume @ 400°F					
PRECIPITATOR OUTLET COND.					
Temp (°F)	400	400	395		
ACFM (1000 cu.ft./min)	358	335	356		
DSCF (1000 cu.ft./min)	138	129	136		
Grain Loading(gr/DSCF)	0.0314	0.0321	0.0329		
Particulate Loading(lbs/hr)	37.1	35.4	35.3		
PRECIPITATOR EFFICIENCY(%)	99.6	99.6	99.6		

NO. 4 RECOVERY EPA DATA

TARGET CONDITIONS	NORMAL LOW LOAD CONDITIONS			
Boiler Loading (% of Design)	70-75	70-75	70-75	70-75
Air Distribution (1°/2°/3°-%)	26/50/24	26/50/24	26/50/24	26/50/24
Excess O_2 (%)	1.5-2.5	1.5-2.5	1.5-2.5	1.5-2.5
TEST DATE	3/18/74	3/22/74	3/22/74	5/23/74
SLUICE TANK LIQUOR				
Flow (gpm)	212	216	224	220
Density (lbs/gal)	11.4	11.2	11.1	11.3
Solids (%)	65.0	66.1	66.5	64.4
BOILER LOADING (%)	74	76	78	76
SALT CAKE (lbs/min)	30	10	30	20
SULFIDITY - (DAILY AVG.%)	26.7	26.7	26.7	26.6
NOZZLE CONDITIONS				
Size	32	32	32	32
Pressure (PSI)	28	33	33	28
Liquor Temp. (°F)	235	223	223	225
Backsweep (°)	-15 to -20	-15 to -20	-15 to -20	-16 to -21
Sidesweep (°)	5R to 5R	5L to 5R	5L to 5R	5L to 5R
COMBUSTION AIR TEMP (°F) 1°/2°	350/300	350/300	350/300	350/300
AIR FLOW				
Primary (M lbs/hr)	104	107	115	112
(% of Total)	25	26	28	28
Secondary (M lbs/hr)	213	205	210	207
(% of Total)	52	50	50	52
Tertiary (M lbs/hr)	95	98	92	82
(% of Total)	23	24	22	20
Total (M lbs/hr)	412	410	417	401
EXCESS O_2 (%)	2.7	2.3	2.5	2.5
TRS AVG. (ppm)	1.2	1.4	1.1	1.3
SO_2 AVG (ppm)	12.9	23.5	25.4	76.9
STEAM FLOW (M lbs/hr)	305	343	360	330
BOILER EXIT CONDITIONS				
Temp (°F)	370	365	360	375
ACFM (1000 cu.ft./min)	355	295	383	389
DSCFM(1000 cu.ft./min)	139	115	154	145
Grain Loading(gr/DSCF)	5.79	6.35	4.82	5.61
Particulate Load(lbs/hr)	5,741	3,830	4,453	5,719
PRECIPITATOR INLET COND.				
Temp (°F)				
ACFM(1000 cu.ft./min)	NA	NA	NA	NA
Volume @ 400°F				
PRECIPITATOR OUTLET COND.				
Temp (°F)	355	350	350	355
ACFM (1000 cu.ft./min)	287	219	293	283
DSCF (1000 cu.ft./min)	116	70.4	94.7	120
Grain Loading(gr/DSCF)	.0030	.0180	.0037	0.0118
Particulate Loading(lbs/hr)	3.4	10.8	3.0	12.2
PRECIPITATOR EFFICIENCY(%)	99.9	99.7	99.9	99.8

NO. 4 RECOVERY EPA DATA

TARGET CONDITIONS	LOW LOAD, NORMAL SIDESWEEP, HIGH BACKSWEEP				
Boiler Loading (% of Design)	70-75	70-75	70-75		
Air Distribution (1°/2°/3°-%)	26/50/24	26/50/24	26/50/24		
Excess O_2 (%)	1.5-2.5	1.5-2.5	1.5-2.5		
TEST DATE	4/22/74	4/23/74	4/23/74		
SLUICE TANK LIQUOR					
Flow (gpm)	205	207	205		
Density (lbs/gal)	11.3	11.2	11.2		
Solids (%)	63.4	63.0	63.1		
BOILER LOADING (%)	70	69	68		
SALT CAKE (lbs/min)	25	20	20		
SULFIDITY - (DAILY AVG.%)	26.9	26.5	26.5		
NOZZLE CONDITIONS					
Size	32	32	32		
Pressure (PSI)	29	29	29		
Liquor Temp. (°F)	225	225	225		
Backsweep (°)	-10 to -13	-10 to -13	-10 to -13		
Sidesweep (°)	5L to 5R	5L to 5R	5L to 5R		
COMBUSTION AIR TEMP (°F) 1°/2°	350/300	350/300	350/300		
AIR FLOW					
Primary (M lbs/hr)	98	98	95		
(% of Total)	26	26	25		
Secondary (M lbs/hr)	196	193	193		
(% of Total)	52	52	52		
Tertiary (M lbs/hr)	79	82	82		
(% of Total)	22	22	22		
Total (M lbs/hr)	373	373	370		
EXCESS O_2 (%)	2.3	2.1	2.5		
TRS AVG. (ppm)	5.7	5.9	7.2		
SO2 AVG (ppm)	130	119	150		
STEAM FLOW (M lbs/hr)	289	298	293		
BOILER EXIT CONDITIONS					
Temp (°F)	365	375	375		
ACFM (1000 cu.ft./min)	450	356	405		
DSCFM(1000 cu.ft./min)	171	132	148		
Grain Loading(gr/DSCF)	6.03	5.71	5.80		
Particulate Load(lbs/hr)	5,408	4,782	5,139		
PRECIPITATOR INLET COND.					
Temp (°F)					
ACFM(1000 cu.ft./min)	NA	NA	NA		
Volume @ 400°F					
PRECIPITATOR OUTLET COND.					
Temp (°F)	360	350	350		
ACFM (1000 cu.ft./min)	269	251	271		
DSCF (1000 cu.ft./min)	105	98	103		
Grain Loading(gr/DSCF)	0.0372	0.0310	0.0240		
Particulate Loading(lbs/hr)	33.3	26.0	21.3		
PRECIPITATOR EFFICIENCY(%)	99.4	99.5	99.6		

NO. 4 RECOVERY EPA DATA

TARGET CONDITIONS	LOW LOAD, WIDE SIDESWEEP, NORMAL BACKSWEEP			
Boiler Loading (% of Design)	70-75	70-75	70-75	70-75
Air Distribution (1°/2°/3°-%)	26/50/24	26/50/24	26/50/24	26/50/24
Excess O_2 (%)	1.5-2.5	1.5-2.5	1.5-2.5	1.5-2.5
TEST DATE	4/29/74	4/29/74	5/2/74	5/6/74
SLUICE TANK LIQUOR				
Flow (gpm)	210	208	222	218
Density (lbs/gal)	11.2	11.2	11.3	11.5
Solids (%)	62.8	63.1	63.4	66.7
BOILER LOADING (%)	70	70	75	79
SALT CAKE (lbs/min)	40	40	40	25
SULFIDITY - (DAILY AVG.%)	27.6	27.6	26.4	27.7
NOZZLE CONDITIONS				
Size	32	32	32	32
Pressure (PSI)	30	30	33	34
Liquor Temp. (°F)	225	225	225	223
Backsweep (°)	-17 to -21	-16 to -21	-16 to -20	-16 to -21
Sidesweep (°)	10L to 10R	10L to 10R	10L to 10R	10L to 10R
COMBUSTION AIR TEMP (°F) 1°/2°	350/300	350/300	350/300	350/300
AIR FLOW				
Primary (M lbs/hr)	98	98	101	101
(% of Total)	27	27	27	26
Secondary (M lbs/hr)	193	190	196	202
(% of Total)	52	53	52	52
Tertiary (M lbs/hr)	76	72	82	85
(% of Total)	21	20	21	22
Total (M lbs/hr)	367	360	379	388
EXCESS O_2 (%)	2.4	2.4	2.5	2.2
TRS AVG. (ppm)	5.6	6.7	4.4	2.1
SO_2 AVG (ppm)	122	132	97	21.7
STEAM FLOW (M lbs/hr)	274	278	297	318
BOILER EXIT CONDITIONS				
Temp (°F)	385	385	360	345
ACFM (1000 cu.ft./min)	474	428	330	372
DSCFM(1000 cu.ft./min)	171	156	132	152
Grain Loading(gr/DSCF)	6.30	6.14	5.71	4.89
Particulate Load(lbs/hr)	5,393	5,524	5,150	4,608
PRECIPITATOR INLET COND.				
Temp (°F)				
ACFM(1000 cu.ft./min)	NA	NA	NA	NA
Volume @ 400°F				
PRECIPITATOR OUTLET COND.				
Temp (°F)	350	355	345	355
ACFM (1000 cu.ft./min)	261	273	267	277
DSCF (1000 cu.ft./min)	100	105	105	110
Grain Loading(gr/DSCF)	Data	Data	0.0536	0.0563
Particulate Loading(lbs/hr)	Missing	Missing	48.3	53.0
PRECIPITATOR EFFICIENCY(%)	-	-	99.1	98.9

NO. 4 RECOVERY EPA DATA

TARGET CONDITIONS	LOW LOAD, WIDE SIDESWEEP, HIGH BACKSWEEP				
Boiler Loading (% of Design)	70-75	70-75	70-75		
Air Distribution (1°/2°/3°-%)	26/50/24	26/50/24	26/50/24		
Excess O_2 (%)	1.5-2.5	1.5-2.5	1.5-2.5		
TEST DATE	4/24/74	4/24/74	4/25/74		
SLUICE TANK LIQUOR					
Flow (gpm)	207	210	209		
Density (lbs/gal)	11.3	11.3	11.3		
Solids (%)	63.6	63.9	63.2		
BOILER LOADING (%)	70	72	70		
SALT CAKE (lbs/min)	40	40	40		
SULFIDITY - (DAILY AVG.%)	26.7	26.7	26.9		
NOZZLE CONDITIONS					
Size	32	32	32		
Pressure (PSI)	31	31	30		
Liquor Temp. (°F)	225	225	225		
Backsweep (°)	-10 to -13	-10 to -13	-10 to -13		
Sidesweep (°)	10L to 10R	10L to 10R	10L to 10R		
COMBUSTION AIR TEMP (°F).1°/2°	350/300	350/300	350/300		
AIR FLOW					
Primary (M lbs/hr)	98	98	93		
(% of Total)	27	27	26		
Secondary (M lbs/hr)	189	189	189		
(% of Total)	52	52	53		
Tertiary (M lbs/hr)	76	76	71		
(% of Total)	21	21	21		
Total (M lbs/hr)	363	363	353		
EXCESS O_2 (%)	2.4	2.5	2.0		
TRS AVG. (ppm)	6.9	5.1	12.0		
SO_2 AVG (ppm)	103	102	243		
STEAM FLOW (M lbs/hr)	288	300	289		
BOILER EXIT CONDITIONS					
Temp (°F)	375	380	355		
ACFM (1000 cu.ft./min)	356	328	387		
DSCFM(1000 cu.ft./min)	130	119	147		
Grain Loading(gr/DSCF)	6.08	6.25	4.71		
Particulate Load(lbs/hr)	5,297	5,396	4,069		
PRECIPITATOR INLET COND.					
Temp (°F)					
ACFM(1000 cu.ft./min)	NA	NA	NA		
Volume @ 400°F					
PRECIPITATOR OUTLET COND.					
Temp (°F)	350	345	345		
ACFM (1000 cu.ft./min)	262	256	260		
DSCF (1000 cu.ft./min)	102	101	101		
Grain Loading(gr/DSCF)	0.0109	0.0090	0.0084		
Particulate Loading(lbs/hr)	9.5	7.8	7.3		
PRECIPITATOR EFFICIENCY(%)	99.8	99.9	99.8		

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

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4. TITLE AND SUBTITLE Improved Air Pollution Control for a Kraft Recovery Boiler: Recovery Boiler No. 4		5. REPORT DATE December 1974
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) K. Henning, W. Andreson, and J. Ryan		8. PERFORMING ORGANIZATION REPORT NO.
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16. ABSTRACT The report gives results of intensive tests to establish the level of both gaseous and particulate air pollutants discharged from a controlled-odor kraft recovery boiler. It documents both the cost and emission control capability of such a boiler, designed and erected without direct contact evaporation of the feed liquor. Also investigated were major process variables that affect kraft recovery boiler operation and the emissions resulting therefrom in order to establish boiler operating conditions that minimize emissions. Investigated were boiler loading, liquor sulfidity, and liquor distribution within the furnace. Test data was analyzed statistically by computer, using the multiple regression analysis technique. Particulate emissions were primarily affected by and directly proportional to the amount of black liquor solids burned in the recovery furnace (boiler loading). Both SO_2 and total reduced sulfur (TRS) emissions were affected by liquor sulfidity: emissions increased as sulfidity levels increased. This new kraft recovery boiler incorporates the most recent technology for air pollution control, enabling it to meet the Montana state emission standards for both TRS and particulates.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution	Air Pollution Control	13B
Sulfate Pulping	Stationary Sources	13H, 07A
Boilers	Kraft Recovery Boiler	13A
Process Variables	Particulates	
Sulfur Oxides	Montana	07B

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