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PROOF OF CONCEPT TESTING OF AN INTEGRATED DRY INJECTION SYSTEM FOR SO2/NOx CONTROL

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INTRODUCTION

The parametric test program was carried out in the time period covered by this report. Three coals and four sorbents were used in the testing. SO2 removal, NOx removal, and precipitator performance were all investigated. The test matrix is given in Table 1.

ACTIVITY

Testing in October concentrated on SO2 removal resulting from hydrate injection and precipitator baseline performance. Typical results for operation on October 30 are shown in Figure 1. Hydrate injection at 1030 deg F for various Ca/S mole ratios are shown. It is seen that increasing hydrate mole ratios yield decreasing outlet SO2 concentrations. Also shown is the precipitator exit opacity, and it can be seen that increasing hydrate injection rates lead to larger opacities.

Figure 2 reduces the data of Figure 1 to show SO2 removal as a function of Ca/S ratio. It should be pointed out that subsequent adjustments to the hydrate injection nozzles have improved utilization by about 5% over that shown in Figue 2. Maximum achievable hydrate utilization has been about 30% at a Ca/S of 2. This utilization has been reached with optimum placements of either the vertical pipe injector system, or the horizontal injector system, see Figures 3 & 4.

Testing in November concentrated on SO2 and NOx removal resulting from combined hydrate and bicarbonate injection and the subsequent electrostatic precipitator impacts. Typical results for operation on November 14 are shown in Figure 5. This Figure shows SO2 concentration at the precipitator exit as a function of operating time. It is seen that initial SO2 concentration without sorbent injection is 1800 ppm. The initiation of hydrate injection at 20 minutes into the test yields a drop of SO2 concentration to 700 ppm. An additional decrease in SO2 concentration to 200 ppm results with the initiation of bicarb injection at 40 minutes. The system response to sorbent injection shown in this figure is typical of that seen for all testing to date.

Figure 6 shows SO2 removal as a function of Na2/S ratio, based on the sulfur concentration at the bicarb injection point. It is seen that 60% removal is intially obtained with hydrate injection only, and increasing bicarb injection results in more SO2 removal, such that 90% removal is reached at a Na2/S ratio of 2.3.

Figure 7 shows the results of the November 14 testing over a 280 minute time period. These tests were performed in order to characterize the effects of lowering the precipitator inlet temperature by humidification on precipitator performance and on overall SO2 removal. The figure shows precipitator inlet temperature, SO2 and NOx removal percents, and precipitator exit opacity, all as functions of operating time. The temperature was decreased in steps from 300 deg F to 170 degrees. Hydrate injection at Ca/S=3 was started at 20 minutes and bicarb injection at Na2/S=2 was started at 40 minutes. There were four interruptions of the hydrate feed. These occurred at 80, 140, 180, and 230 minutes. The bicarb feed was continuous throughout the test. The viewpath of the opacity monitor was a longitudinal section of ductwork, and the opacity measurements are not calibrated to a stack but are taken for comparative purposes.

It can be seen that opacity increases significantly when the hydrate feed is initiated and drops to its original, fly ash only value when the hydrate feed is interrupted. This indicates that precipitator performance is adversely affected by the hydrate but not by the bicarb. It is also seen that near original opacity is recovered when the inlet precipitator temperature is reduced to 220 deg F, and further temperature lowering has no effect on opacity.

SO2 removal increases as the temperature is reduced below 200 degrees, and an additional 5% SO2 removal can be realized at 170 degrees. It is likely that SO2 removal would continue to improve as the gas temperature approaches adiabatic saturation.

Approximately 10% to 20% NOx removal is achieved, and it is interesting to observe peaks in NOx removal at those points were the hydrate injection was interrupted. This is because the NOx reaction with sodium bicarbonate requires the participation of SO2, and hence the higher SO2 concentrations resulting from no hydrate injection gave rise to enhanced NOx removal.

Other testing done in November includes the injection of a commercially available, relatively low surface area hydrate, and the injection of sodium sesquicarbonate.

Testing in December concentrated on examining the effects of alternate coals and sorbents. Typical results are shown in Figure 8, which gives SO2 removal while burning the program coal. This figure shows that 90% SO2 removal can be accomplished when Ca/S = 3 and Na2/S = 1. Both the Ca/S and the Na2/S mole ratios reported in Figure 8 are based on an inlet SO2 concentration of about 1900 ppm.

Figure 9 shows the relative effectiveness of sodium sesquicarbonate injection versus sodium bicarbonate injection. The mole ratios reported in this figure are based on the SO2 concentration at the point of sodium sorbent injection. It is seen that sodium bicarbonate is more effective than sesquicarbonate, with utilization about 8% higher.

Figure 10 shows how SO2 removal is affected by the SO2 inlet concentration supplied by the three different coals. As expected, higher SO2 removal is obtained at high SO2 concentration. The errant data point at 12% removal resulted from difficulty with the sorbent feed at the low feed rate.

CONCLUSIONS AND FORECAST

The test results have shown that 90% SO2 and 65% NOx removal is possible with the Integrated Dry Injection Concept, although higher than anticipated bicarb usage is required. It was also demonstrated that precipitator performance can be returned to pre-injection levels by evaporative cooling to 200 deg F. Other results have been:

- The optimum injection temperature is 1000 deg F.
- Optimization of the hydrate/gas mixing can lead to utilization improvements up to 10%.
- Some additional SO2 removal can be achieved by means of humidification.
- Sodium bicarbonate achieves approximately 20% higher incremental SO2 removal than sesquicarbonate.
- Hydrate utilization improves as SO2 concentration increases.

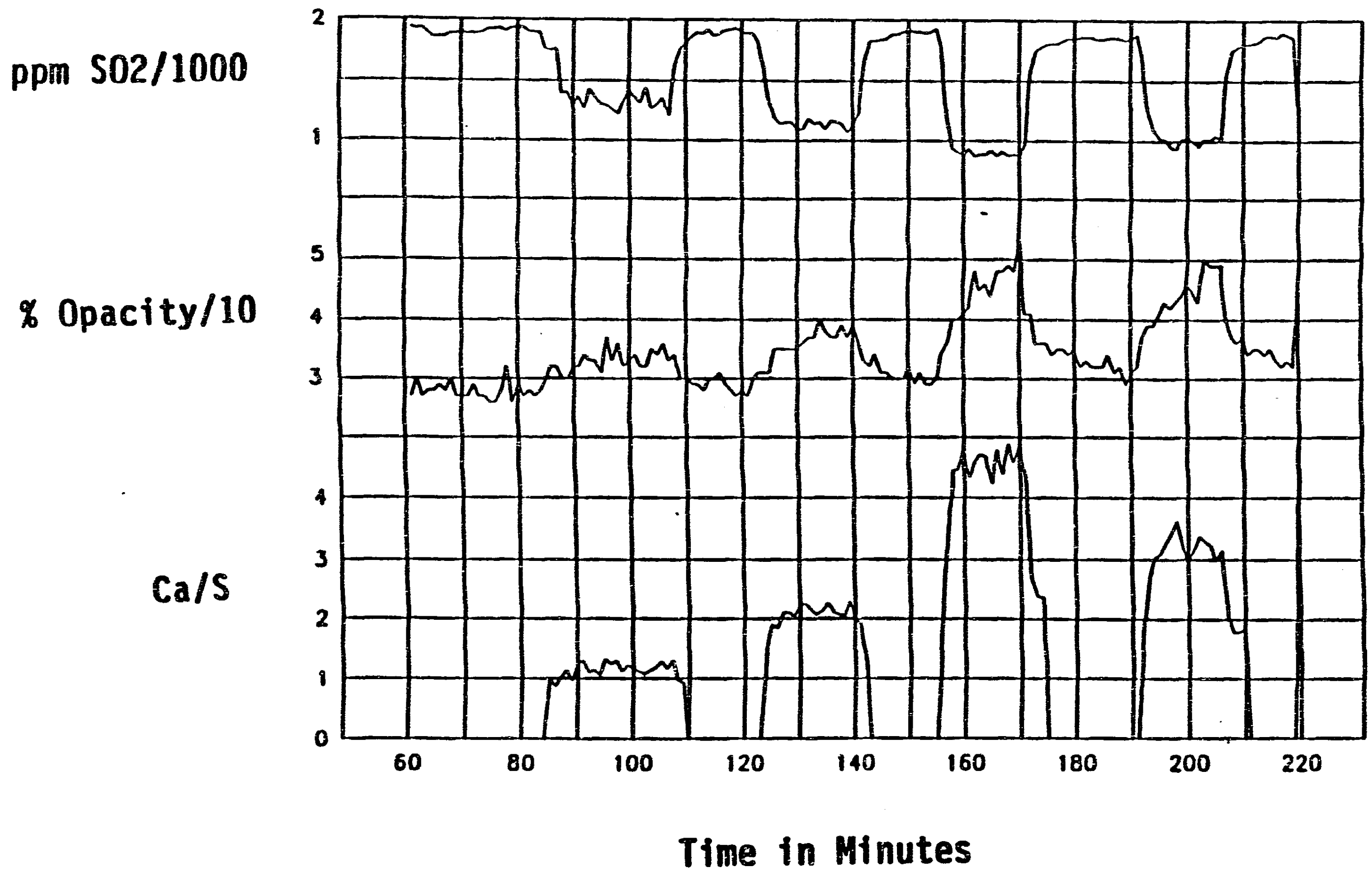
Activity in the next quarter will focus on a determination of the disposal options for the fly ash/sorbent waste material. A fixation technique will be evaluated. Also the data generated by the testing described here will be reduced and analyzed. Finally the test facility will be decommissioned for winter.

TABLE 1

PROPOSED INTEGRATED DRY INJECTION TEST MATRIX

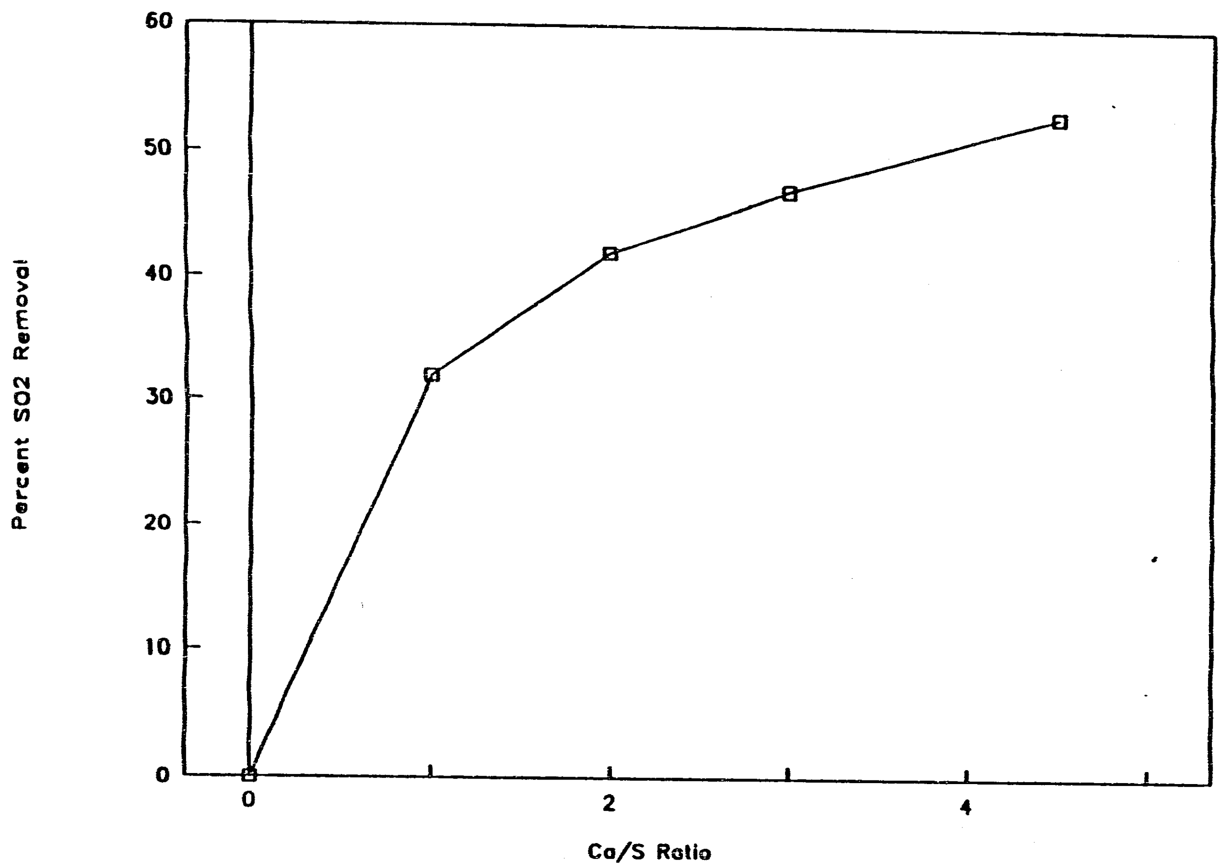
RUN NO.	CONDITIONS	ECON TEMP	Ca/S	AH TEMP	2Na/(S+2NO)	HUMID TEMP
1	PROGRAM	1000	0	300	0	300
2	HYDRATE,	"	2	"	0	300
3	BICARB,	"	"	"	1	300
4	COAL &	"	"	"	"	200
5	LOW NOX	"	"	"	"	250
6	BURNER,	"	"	"	"	BEST
7	UNLESS	1100	"	"	"	"
8	OTHERWISE	900	"	"	"	"
9	INDICATED	BEST	"	"	"	"
10	"	"	2.5	"	"	"
11	"	"	1.5	"	"	"
12	"	"	2	"	"	"
13	"	"	"	270	"	"
14	"	"	"	350	"	"
15	"	"	"	300	"	"
16	"	"	"	"	1.5	"
17	"	"	"	"	.5	"
18	"	"	"	"	1	200
19	"	"	"	"	"	160
20	"	"	"	"	"	180
21	"	"	"	"	"	BEST(RUN 6)
22	HYDRATE 2	"	"	"	"	"
23	"	1100	"	"	"	"
24	"	900	"	"	"	"
25	"	BEST	"	"	"	"
26	"	"	2.5	"	"	"
27	"	"	1.5	"	"	"
28	BICARB 2	BEST(RUN 9)	2	"	"	"
29	"	"	"	270	"	"
30	"	"	"	350	"	"
31	"	"	"	300	"	"
32	"	"	"	"	1.5	"
33	"	"	"	"	.5	"
34	COAL 2	"	"	"	1	"
35	"	"	2.5	"	"	"
36	"	"	1.5	"	"	"
37	COAL 3	"	2	"	"	"
38	"	"	2.5	"	"	"
39	"	"	1.5	"	"	"
40	PROG COAL	"	2	"	"	"
41	MEDIUM NOX	"	"	"	"	"
42	"	"	"	"	1.5	"
43	"	"	"	"	.5	"
44	HIGH NOX	"	"	"	1	"
45	"	"	"	"	1.5	"
46	"	"	"	"	.5	"

Figure 1



ppm SO2/1000
% Opacity/10
Ca/S
2
1
5
4
3
4
3
2
1
0
60
80
100
120
140
160
180
200
220
Time in Minutes

Figure 2



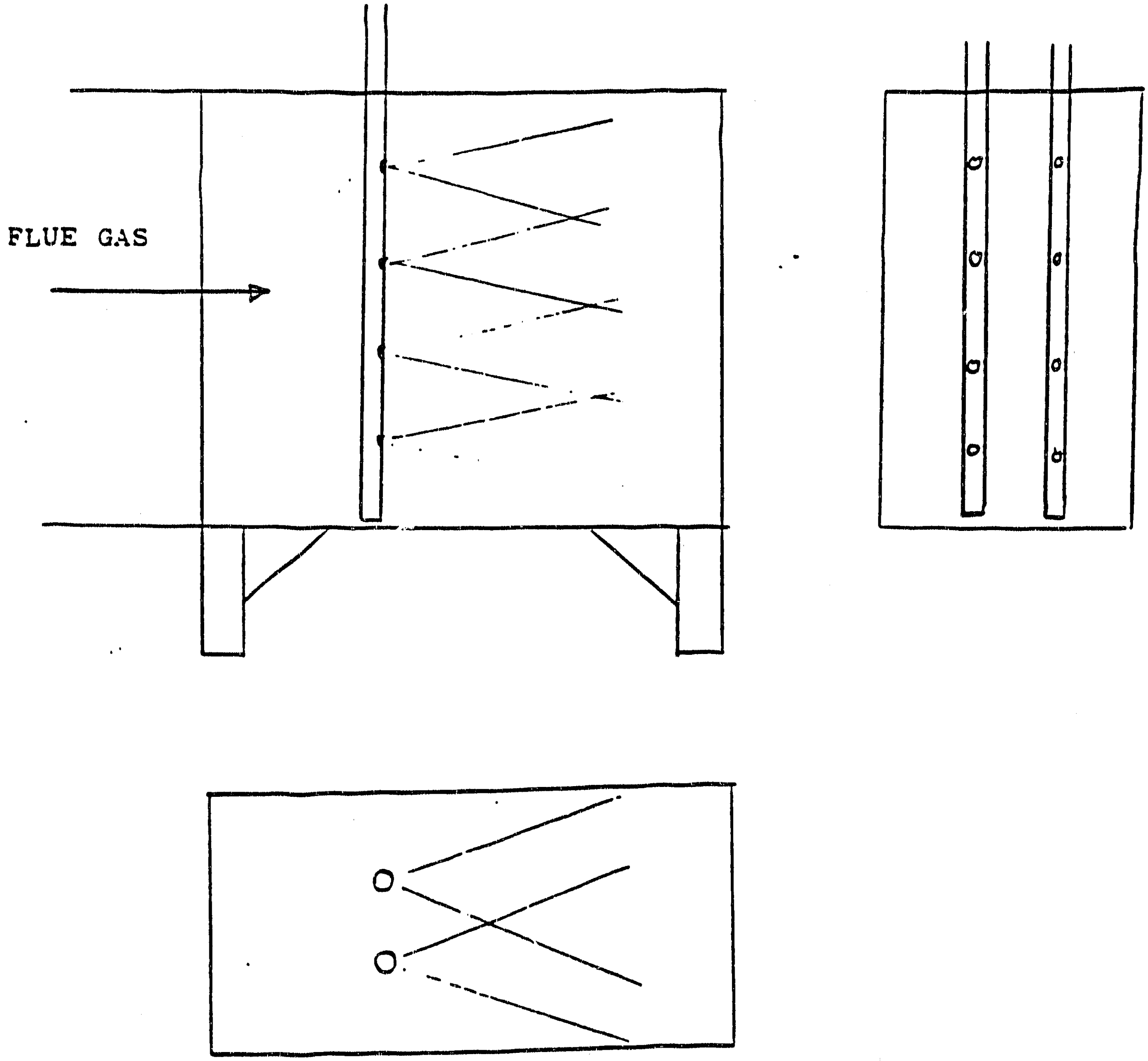


Figure 3

Injection System 1 Design

Two 2.5" pipes with four 3/4" holes

Pipes can be rotated for co or countercurrent injection

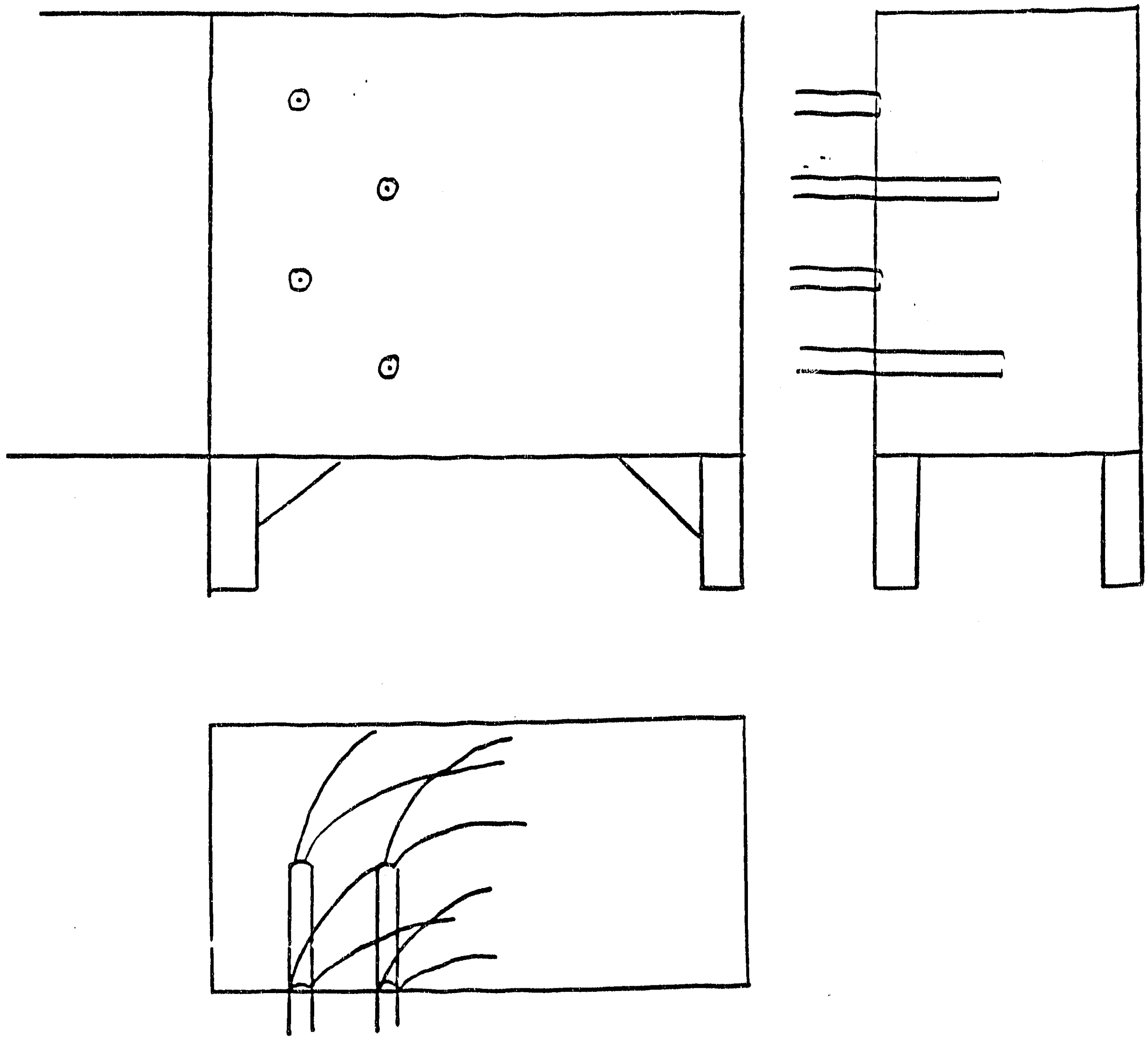


Figure 4

Injection System 2 Design

Four 2" pipes with 1 1/4" nozzles

Depth of insertion adjustable for each injector

FIGURE 5

SO2 Removal

Ca/S=3, Na/S=2

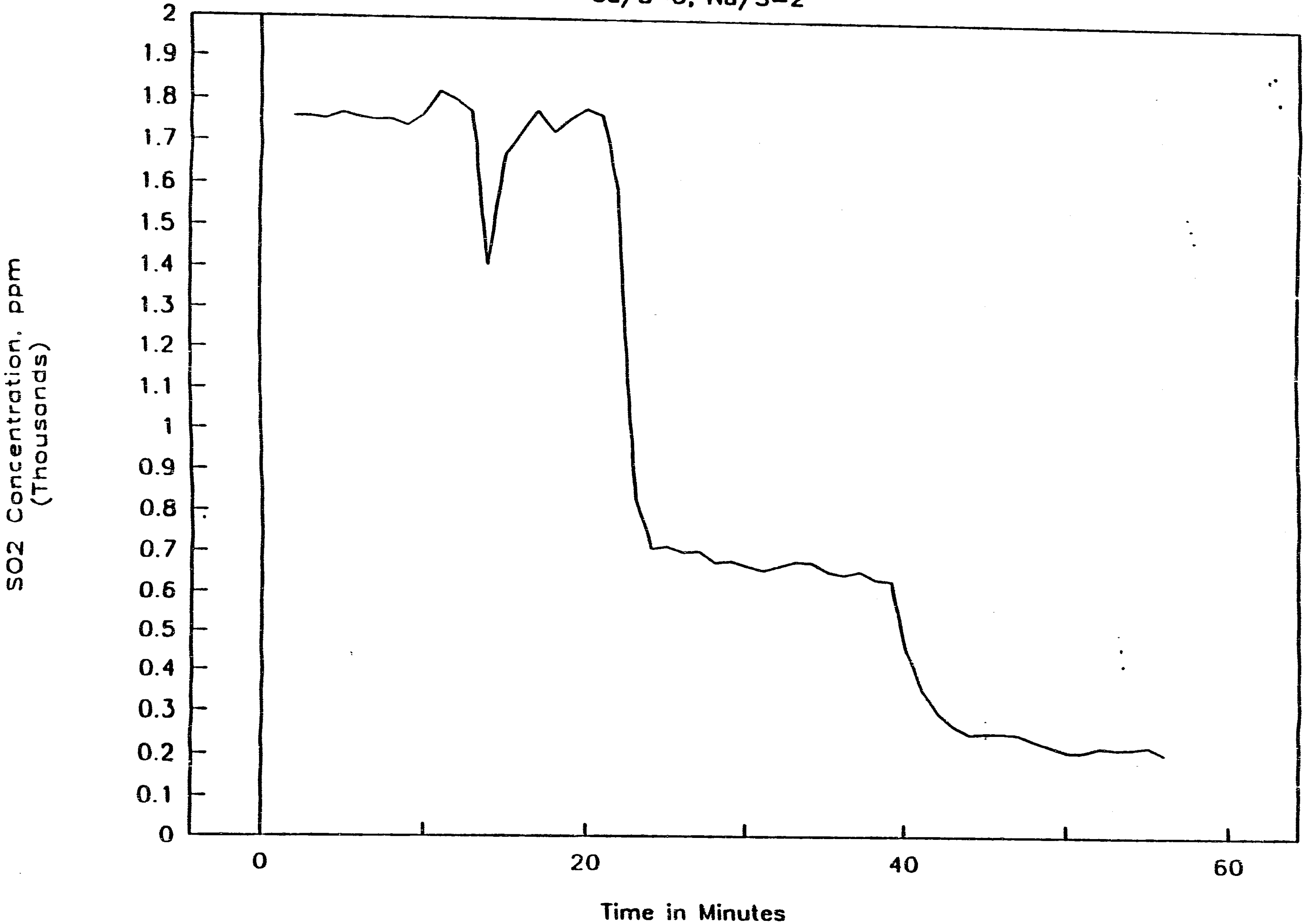
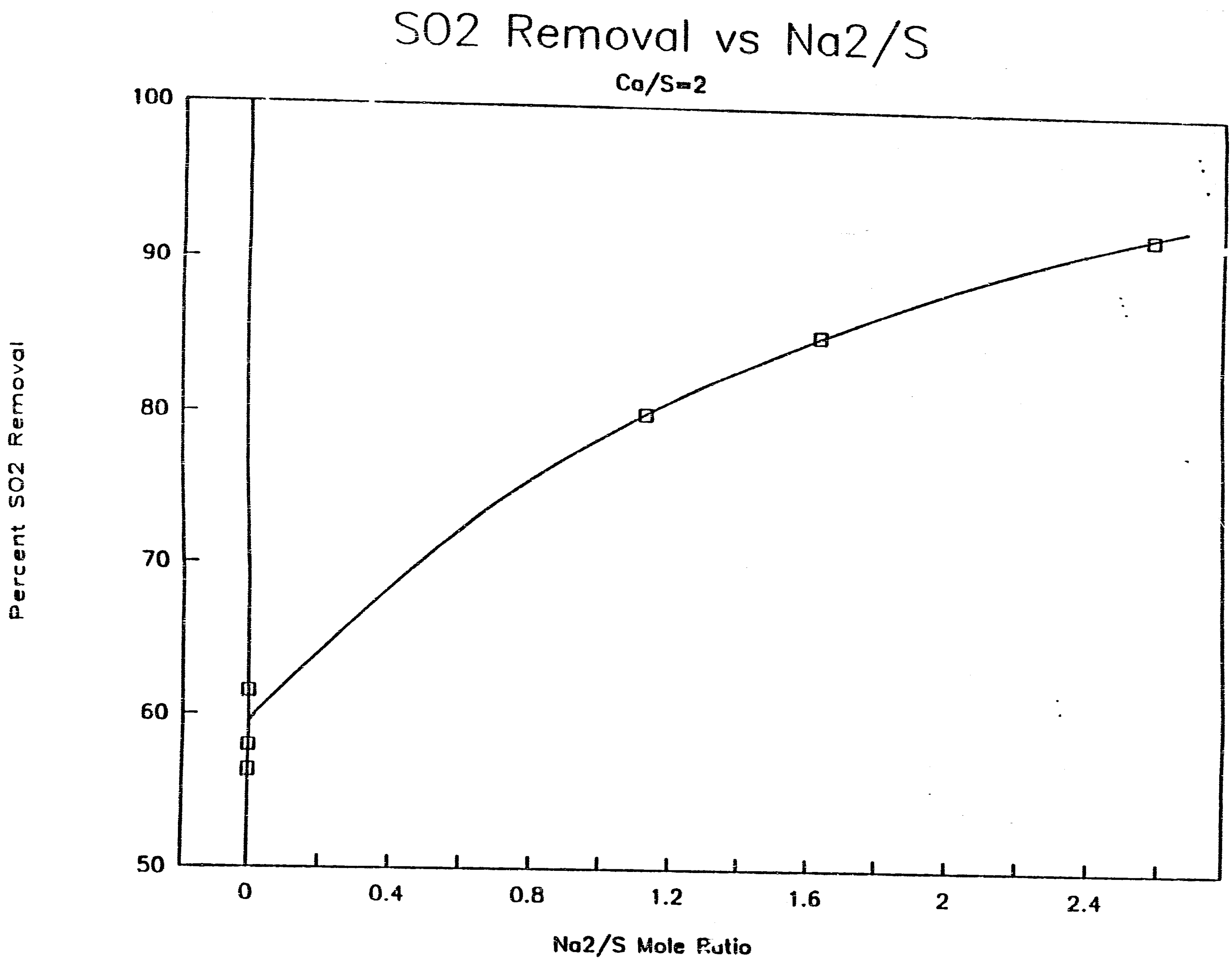
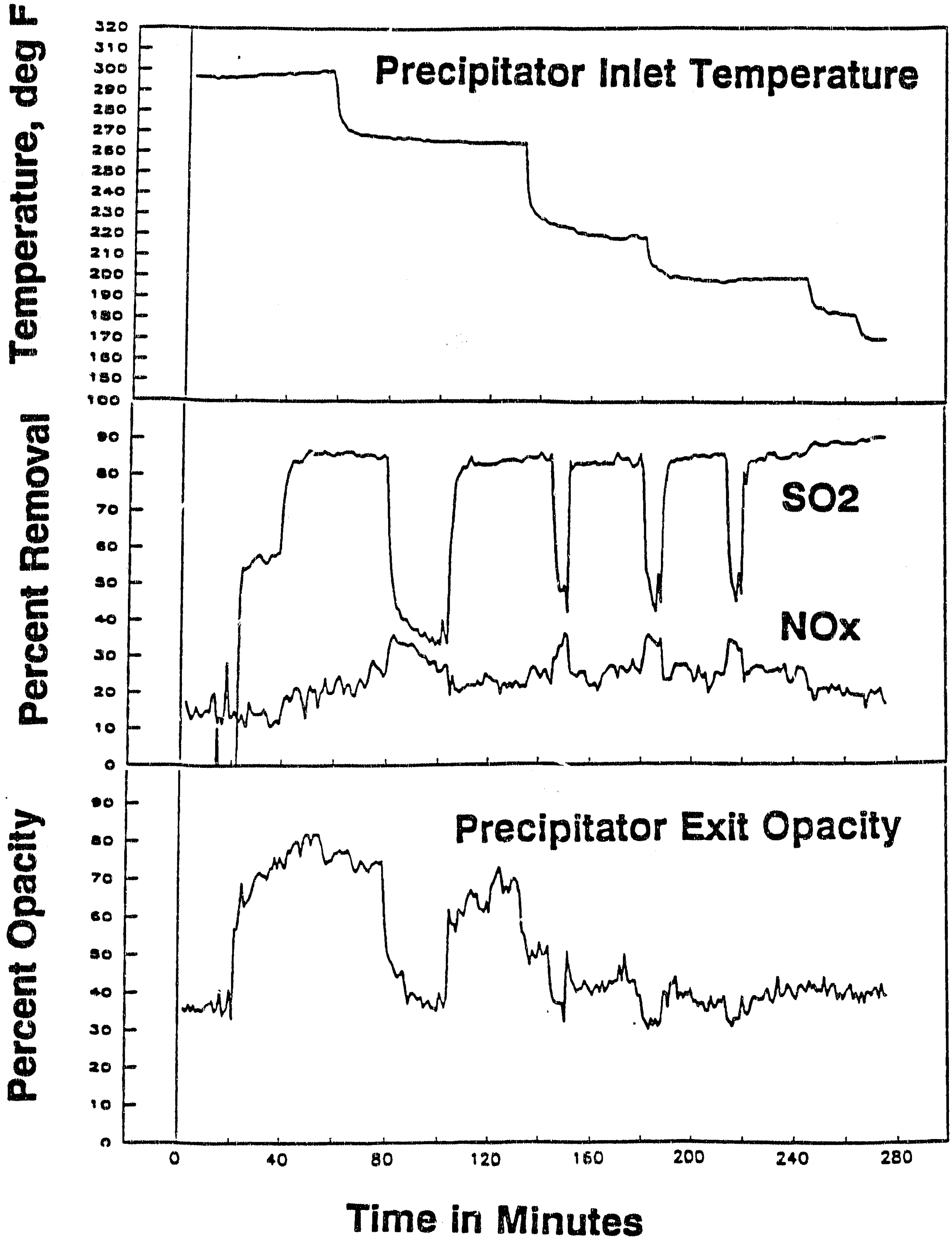


FIGURE 6



SO2 Removal vs Na2/S
Ca/S=2
Percent SO2 Removal
100
90
80
70
60
50
0
0.4
0.8
1.2
1.6
2
2.4
Na2/S Mole Ratio

FIGURE 7



Temperature, deg F
Precipitator Inlet Temperature
320
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
100
Percent Removal
90
80
70
60
50
40
30
20
10
0
SO2
NOx
Percent Opacity
Precipitator Exit Opacity
90
80
70
60
50
40
30
20
10
0
0
40
80
120
160
200
240
280
Time in Minutes

FIGURE 8

EFFECT OF SORBENT MOLE RATIOS ON SO2 REMOVAL

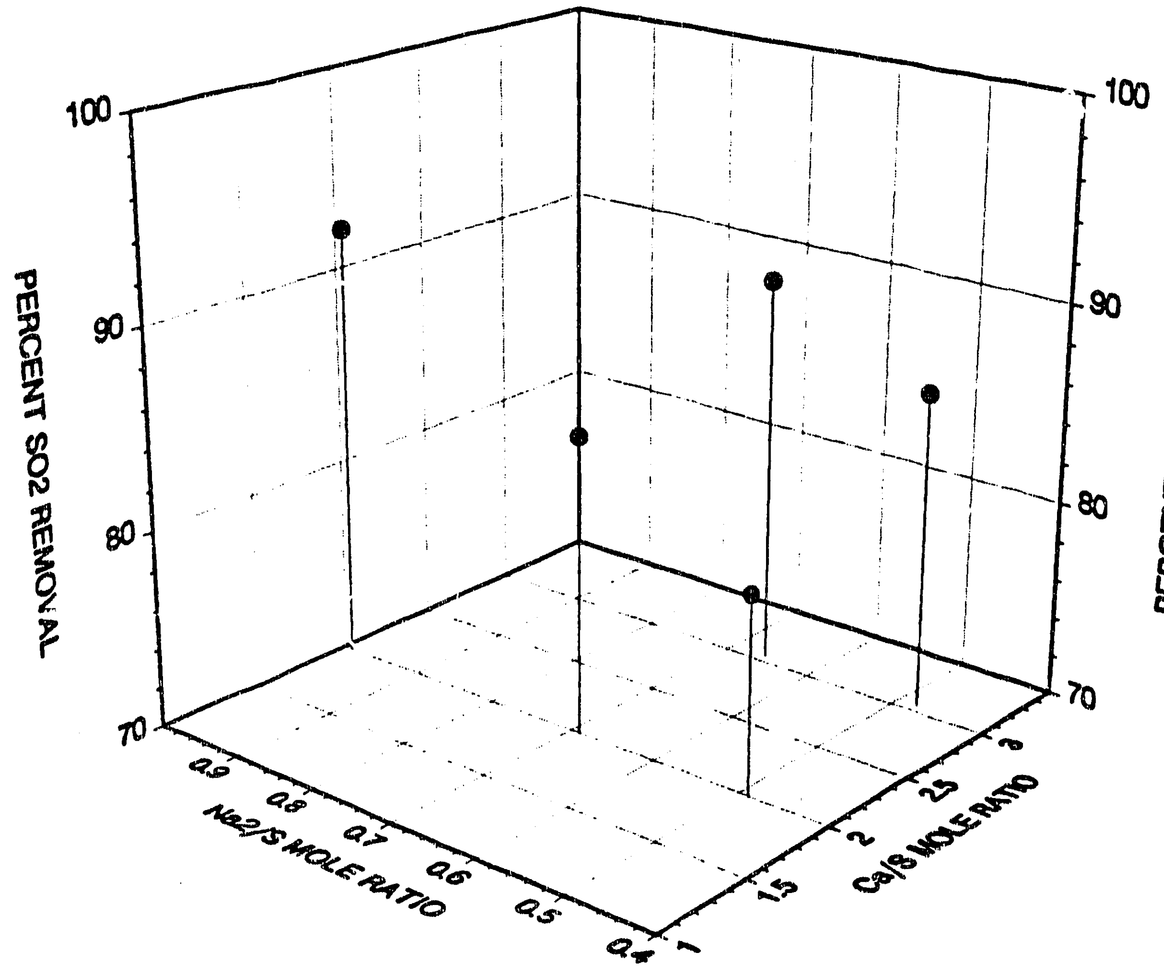


FIGURE 9

EFFECTIVENESS OF SODIUM SORBENTS

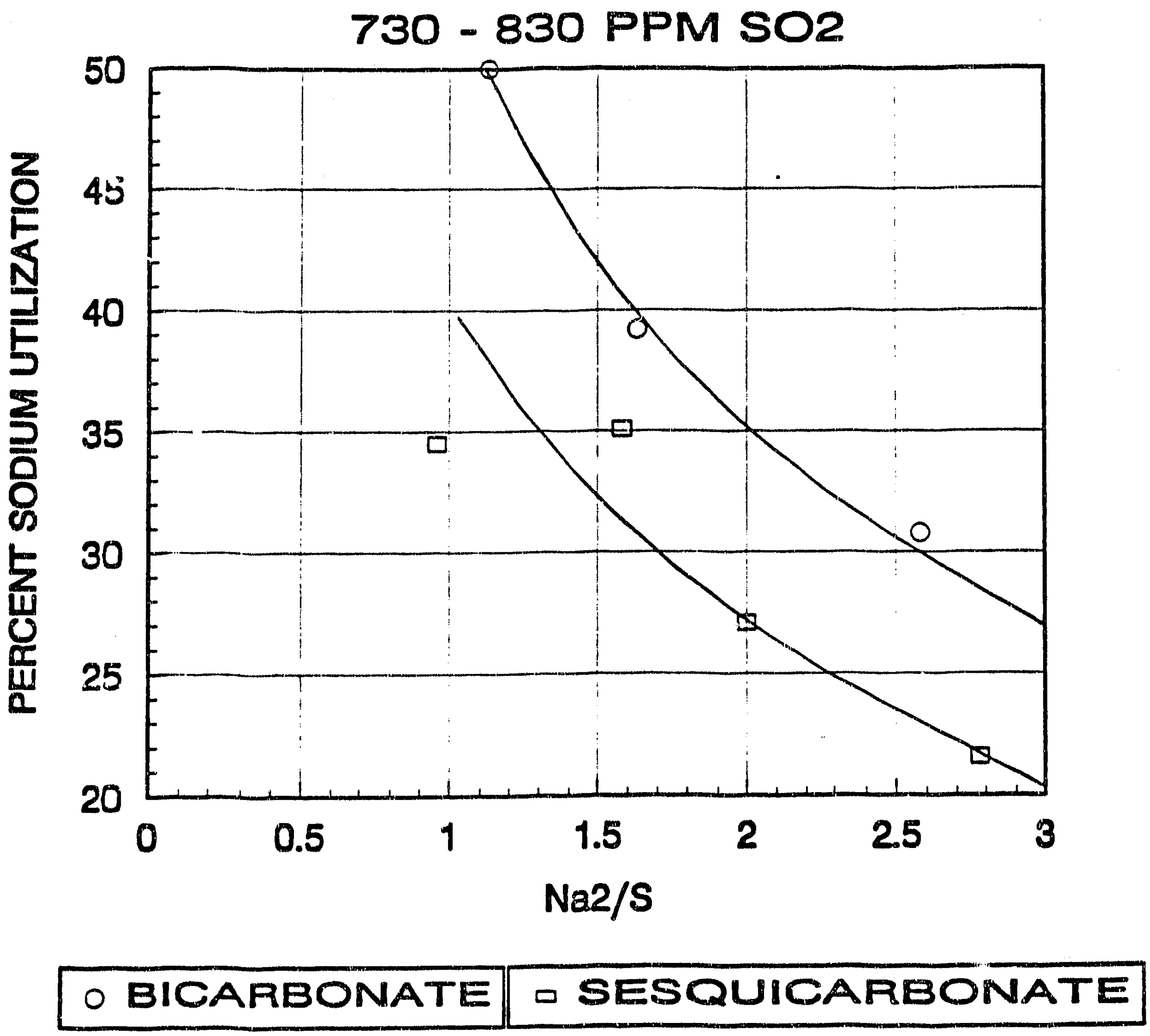
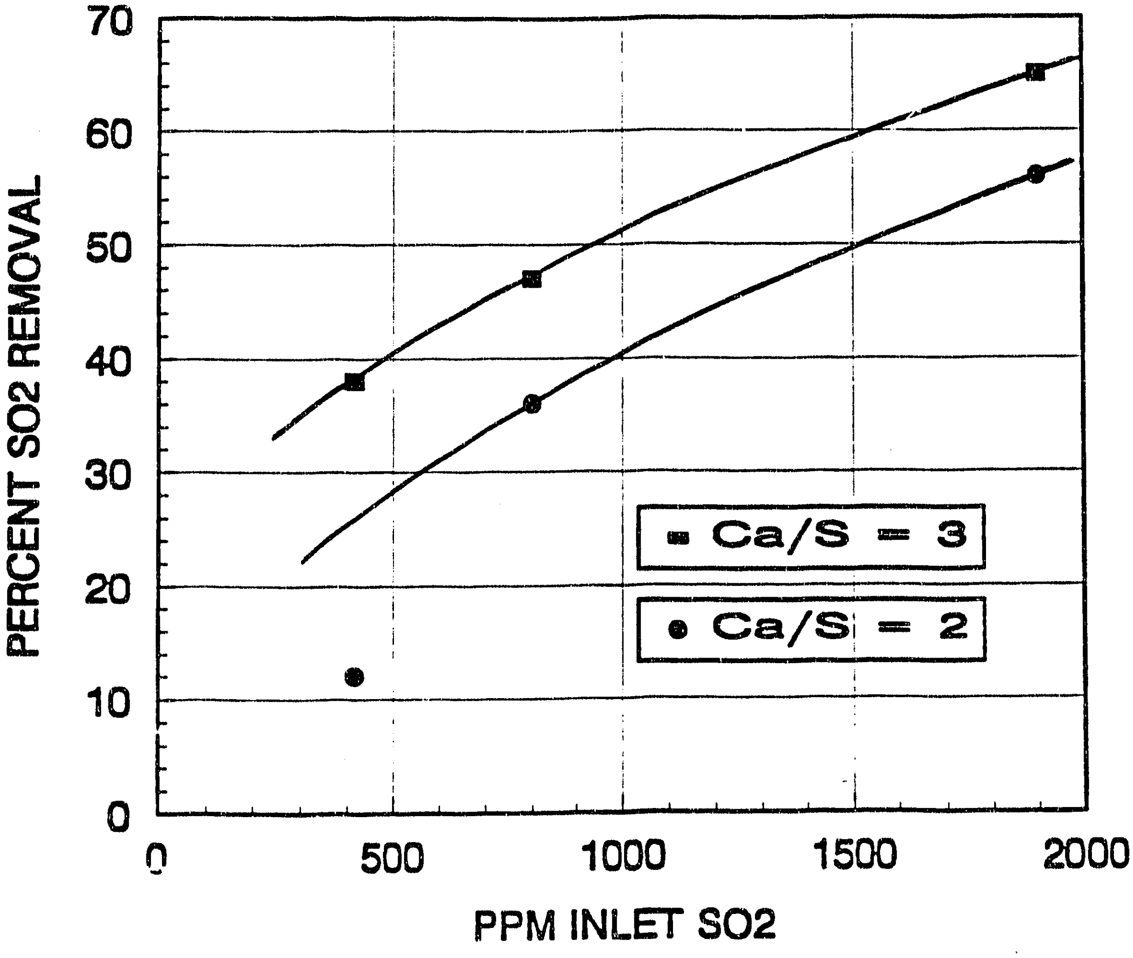


FIGURE 10

EFFECT OF INLET SO2 CONCENTRATION ON SO2 REMOVAL BY HYDRATE INJECTION



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