# REINHOLD ENVIRONMENTAL Ltd.

# 2011 NOx-Combustion Round Table & Expo Presentation

February 7-8, 2011, in Birmingham, AL / Hosted by Southern Company

SOUTHERN RESEARCH

Legendary Discoveries. Leading Innovation.

# MEASUREMENT AND MODELING OF $SO_3$ FORMATION IN COAL-FIRED POWER BOILERS

2011 $NO_x$-Combustion Round Table/PCUG Meeting

# MEASUREMENT AND MODELING OF $SO_3$ FORMATION IN COAL-FIRED POWER BOILERS

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# Outline

- Introduction
- Description of the SRI Model
- Descriptions of the Test Sites and Test Results
- Comparisons of Model and Test Results
- Results of Parametric Variations with Model
- Conclusions

# Introduction

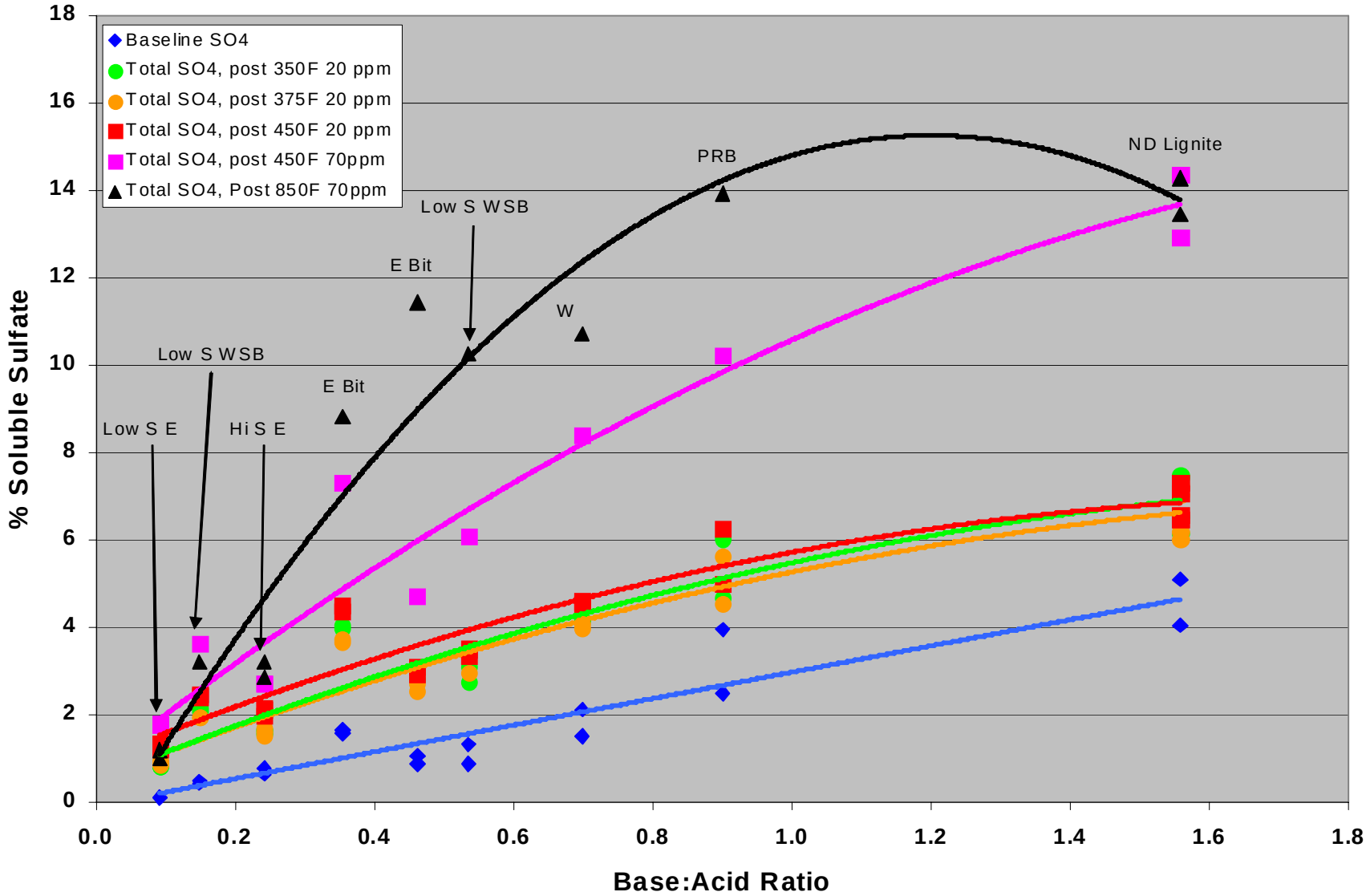
- As part of a then ongoing program related to the mitigation of $SO_3$ emissions SRI, in collaboration with UAB, refined a model of $SO_3$ formation in power boilers previously developed by Pete Walsh.
- EPRI independently contracted with Lehigh University to develop a model for the same purpose.
- Field data was needed for use in verification and refining of these models.

EPRI contracted with Southern Research to perform a series of measurement programs on full-scale coal-fired boilers.

- Tests have been conducted at three sites to date.
- Site 1 was a 1300 MW opposed-wall fired unit firing a moderate-sulfur eastern bituminous coal.
- Site 2 was a 450 MW tangentially-fired unit also firing a moderate sulfur eastern bituminous coal.
- Site 3 was a 250 MW wall-fired unit also firing a moderate sulfur eastern bituminous coal.
- $SO_3$ measurements were to be made using both the conventional controlled condensation method (CCM) and a CCM variant utilizing a nitrogen-dilution quench-probe designed specifically for this program.

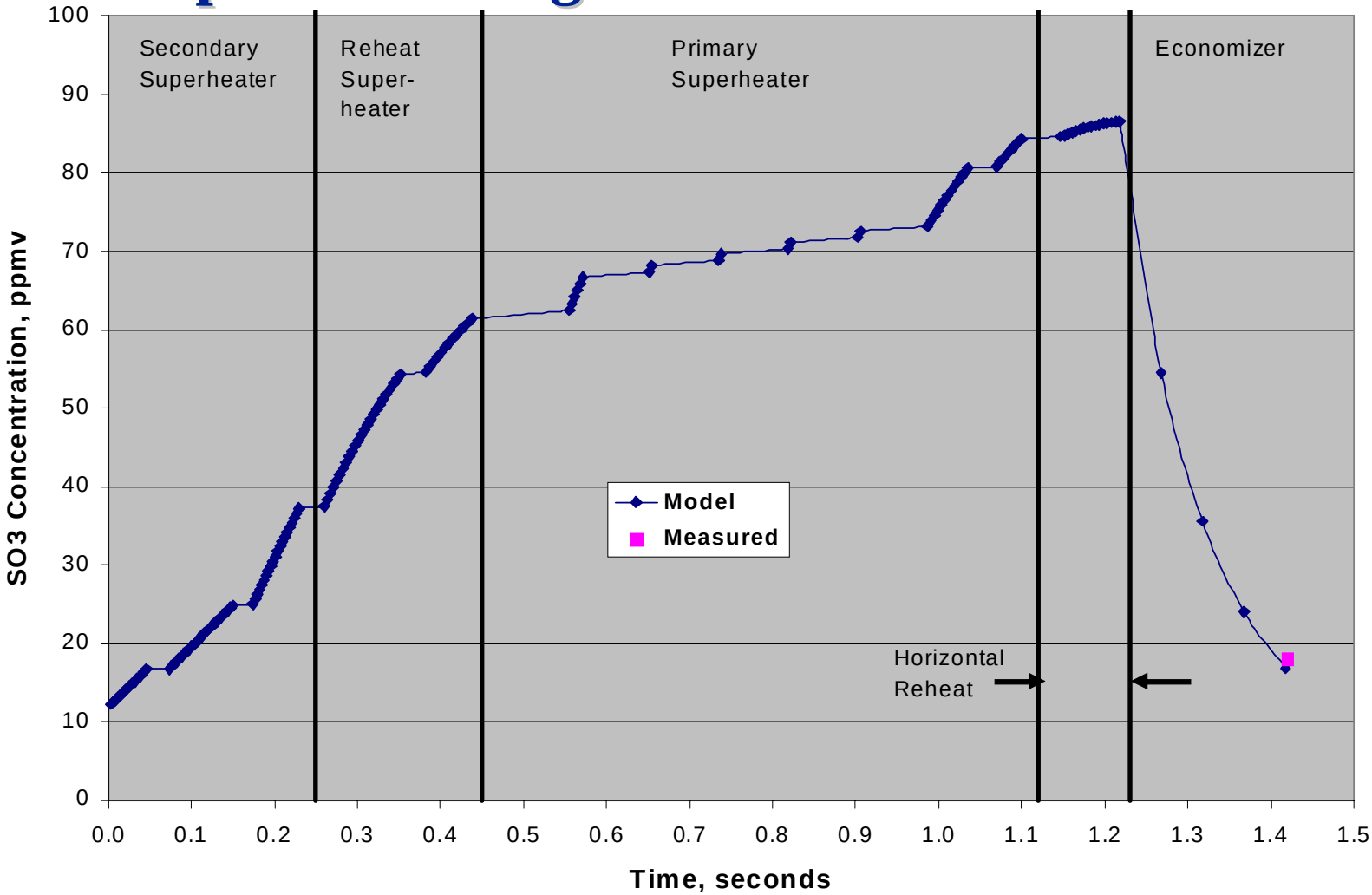
# Description of the SRI Model

- The Chemkin Homogeneous reaction model is used to predict the $SO_3$ concentration at the inlet to the convective section of the boiler. The concentration of $SO_3$ is taken to be the equilibrium concentration at that location.
- Catalytic formation with iron as the catalyst begins in the convective pass adding to $SO_3$ concentration.
- Uptake by ash reduces the $SO_3$ concentration and can proceed concurrently with formation.

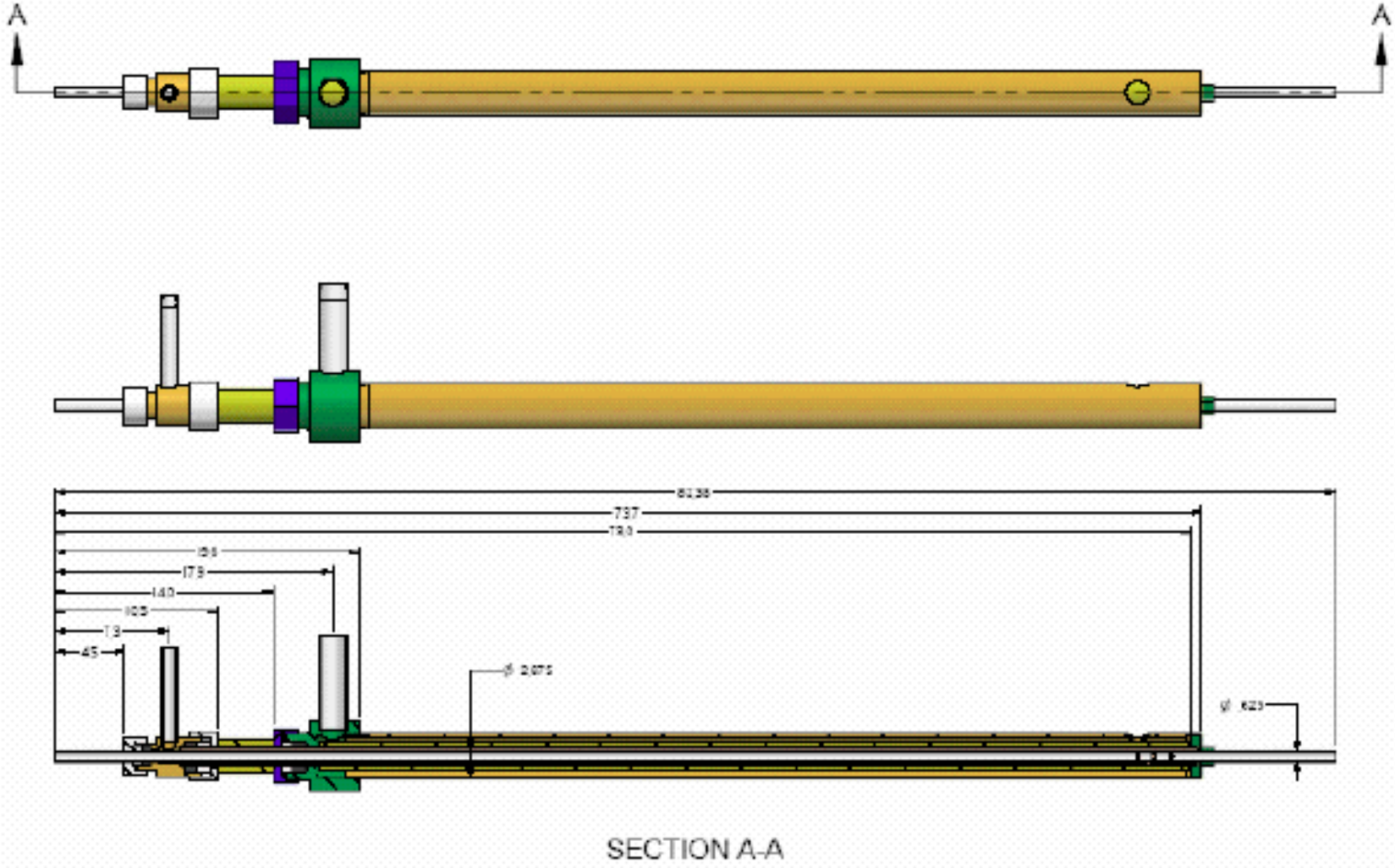


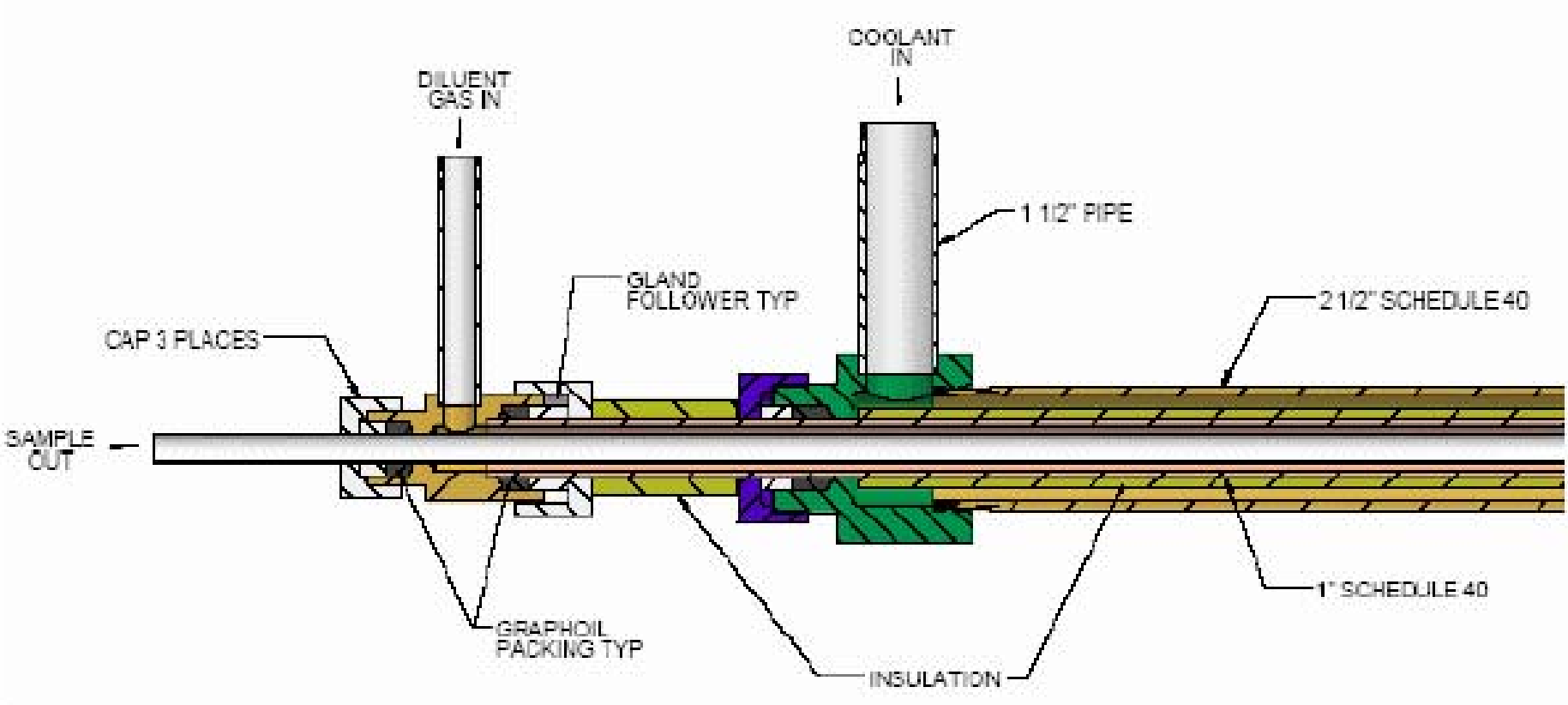

Measurements of $SO_3$ uptake by nine ashes at four temperatures.

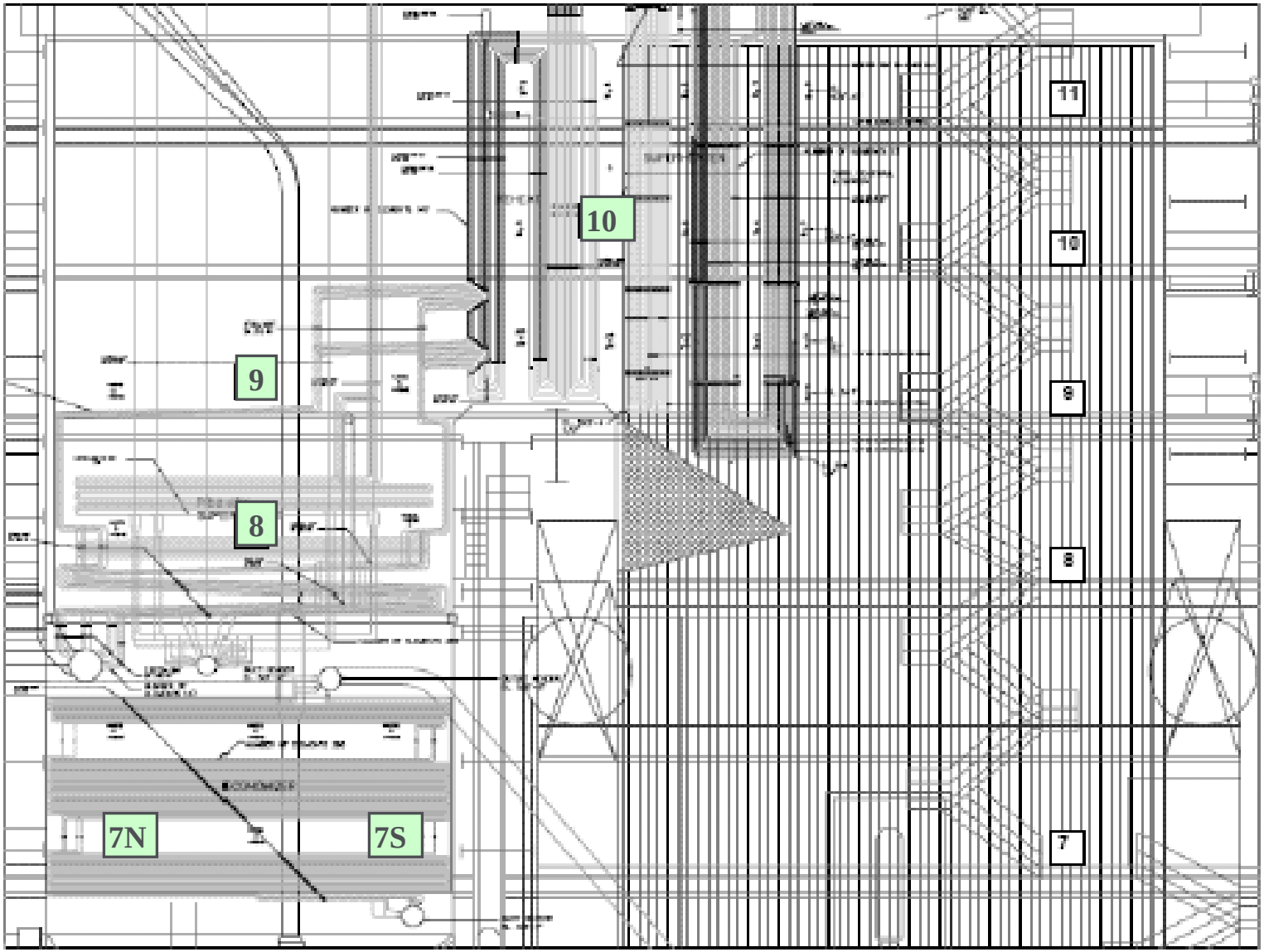
# Preliminary projection of the $SO_3$ concentration profile through a 1300 MW Boiler



# Dilution Ouench Probe

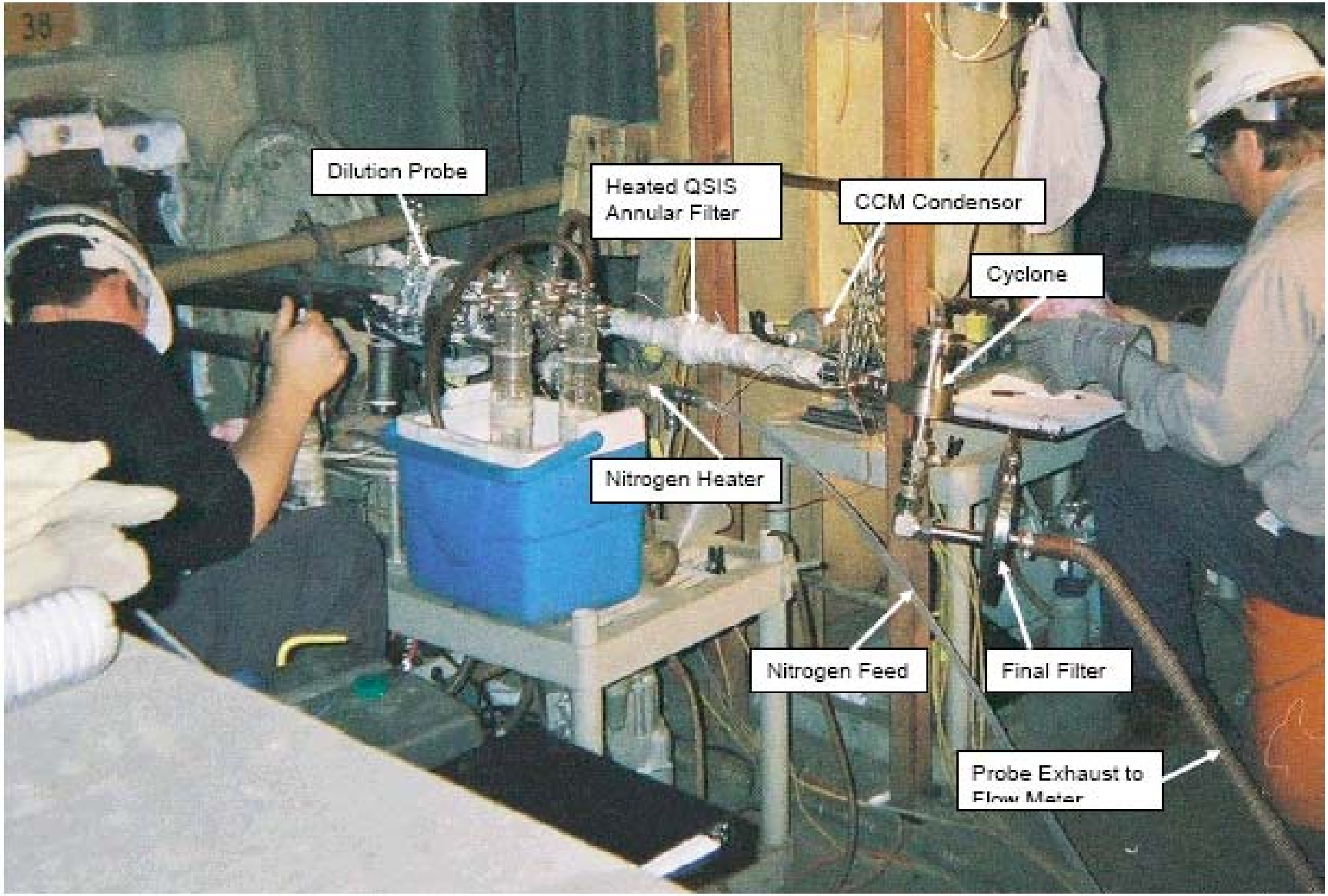



COOLANT
IN
DILUENT
GAS IN
1 1/2" PIPE
GLAND
FOLLOWER TYP
2 1/2" SCHEDULE 40
CAP 3 PLACES
SAMPLE
OUT
1" SCHEDULE 40
GRAPHOIL
PACKING TYP
INSULATION

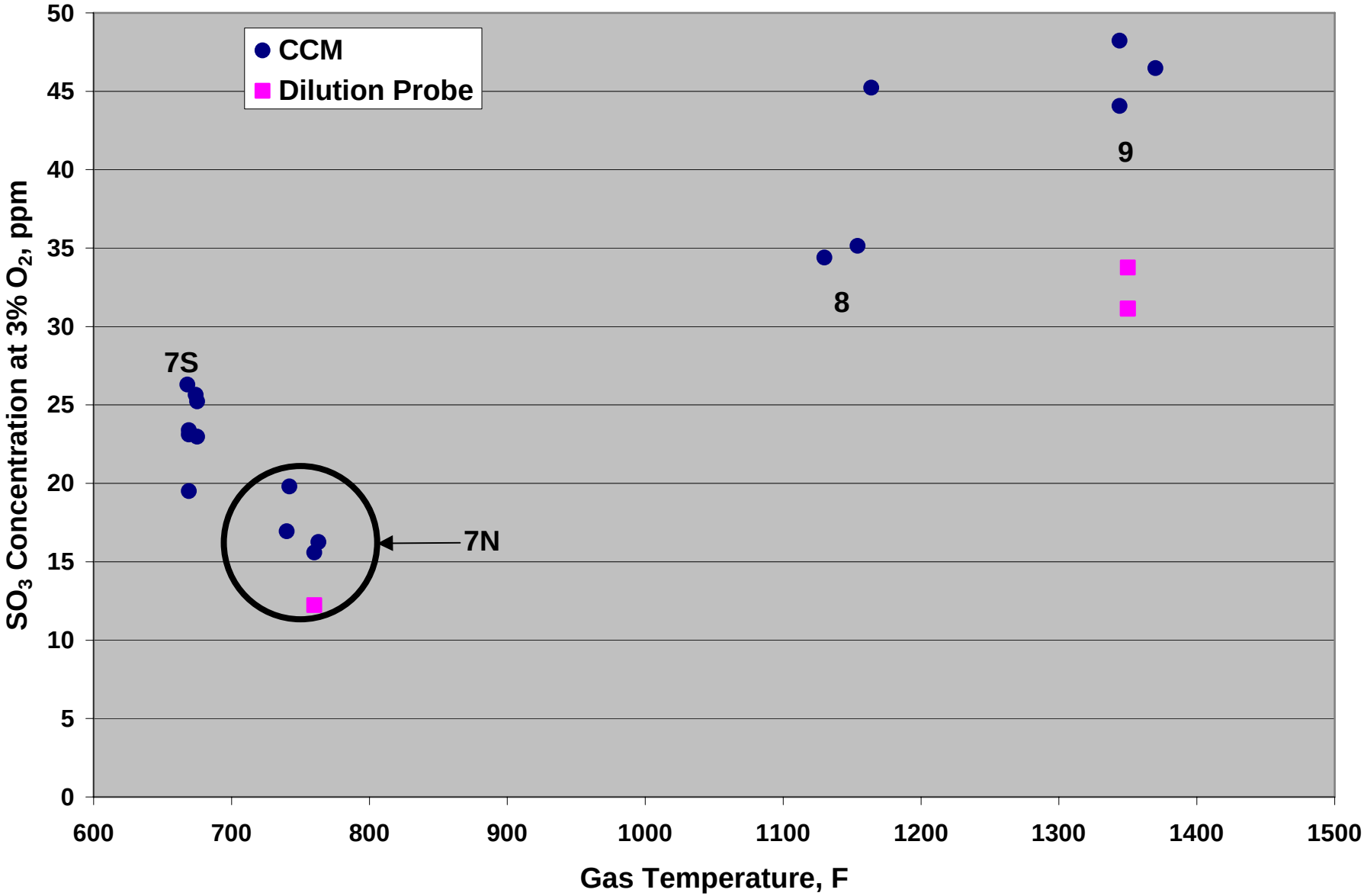



**Side View of Test Site 1 Boiler Showing Sampling Locations**

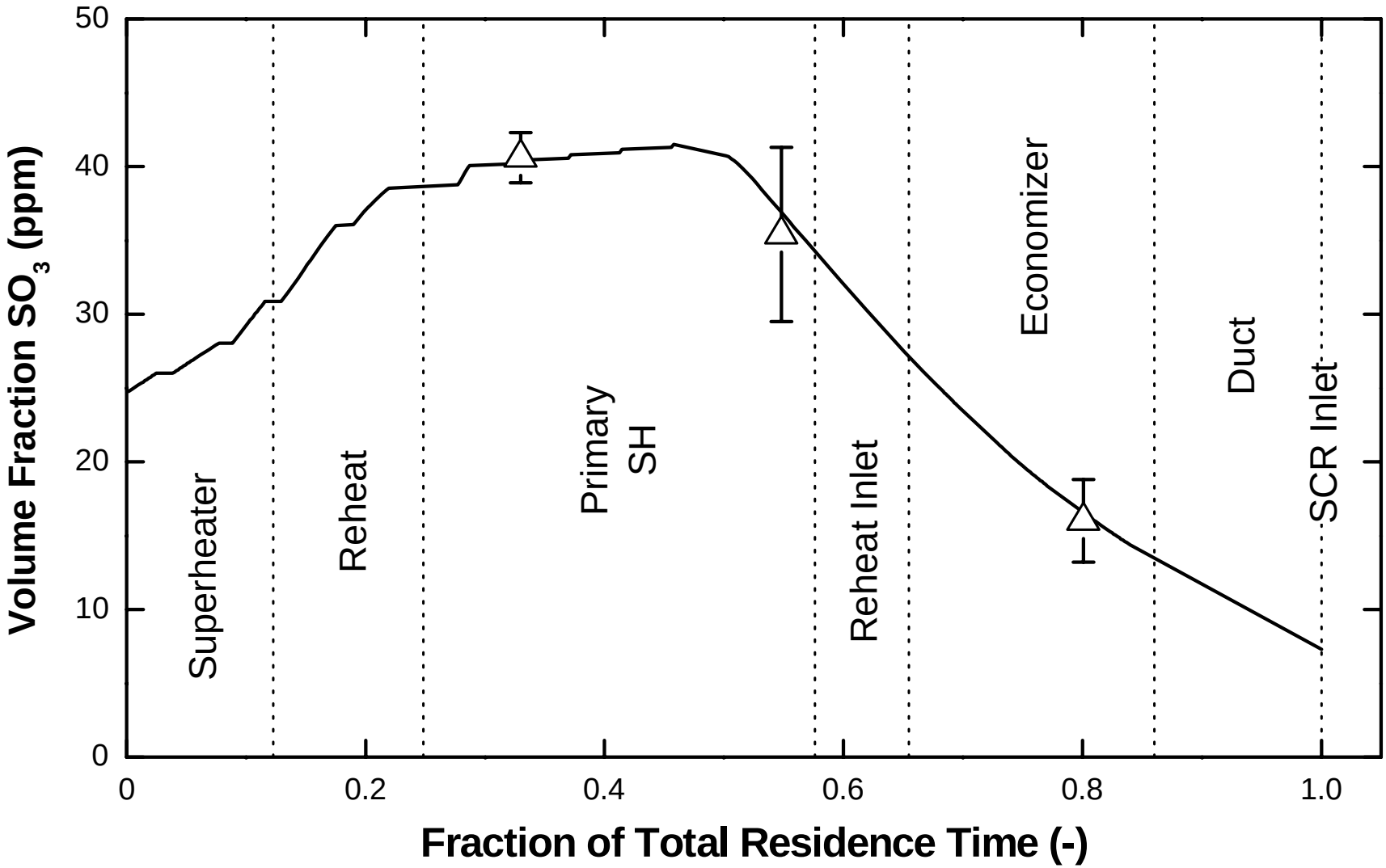

Typical access point to Site 1boiler



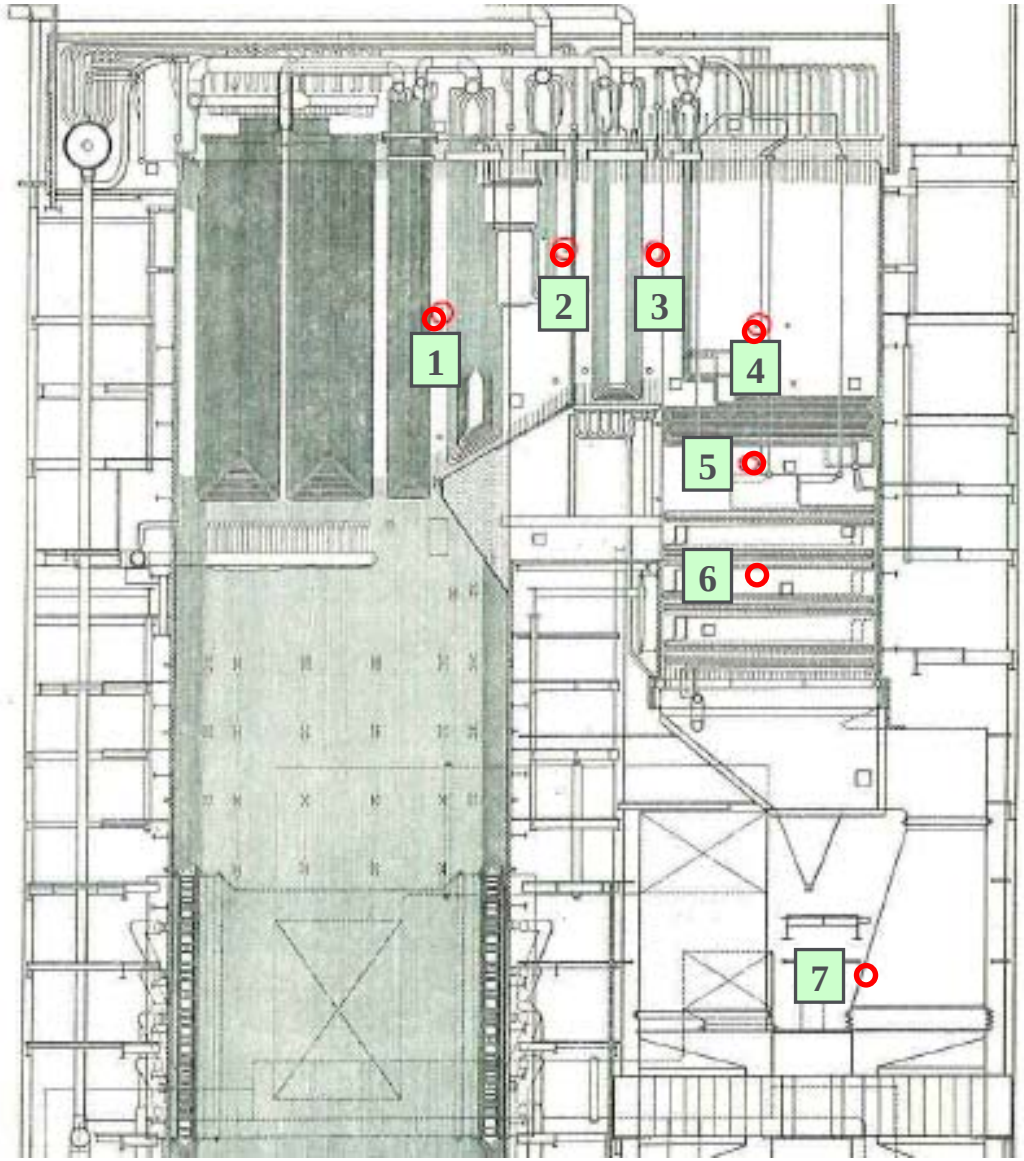

Sampling in progress at Site 1



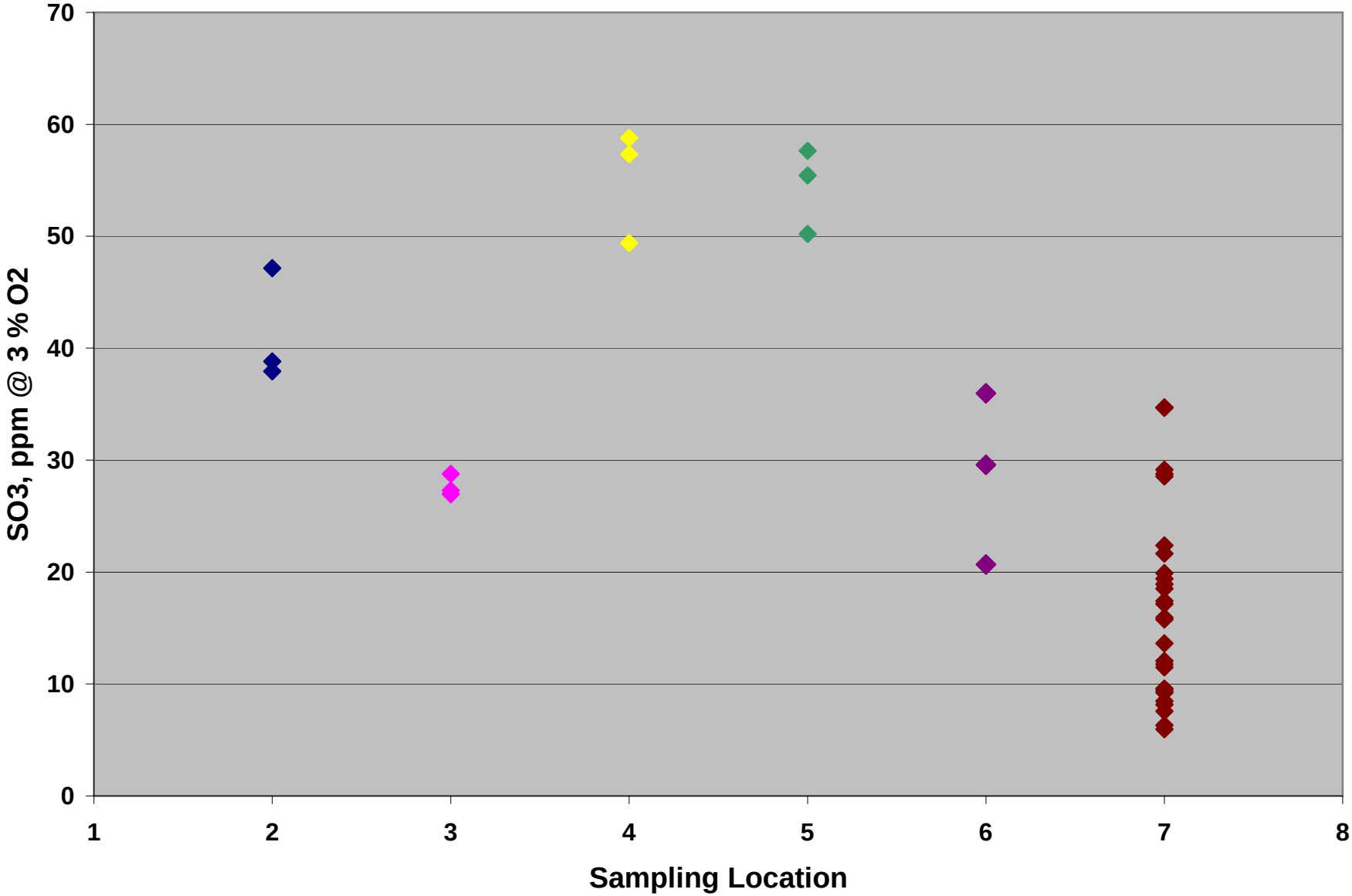

# Results of measurements at Site 1.



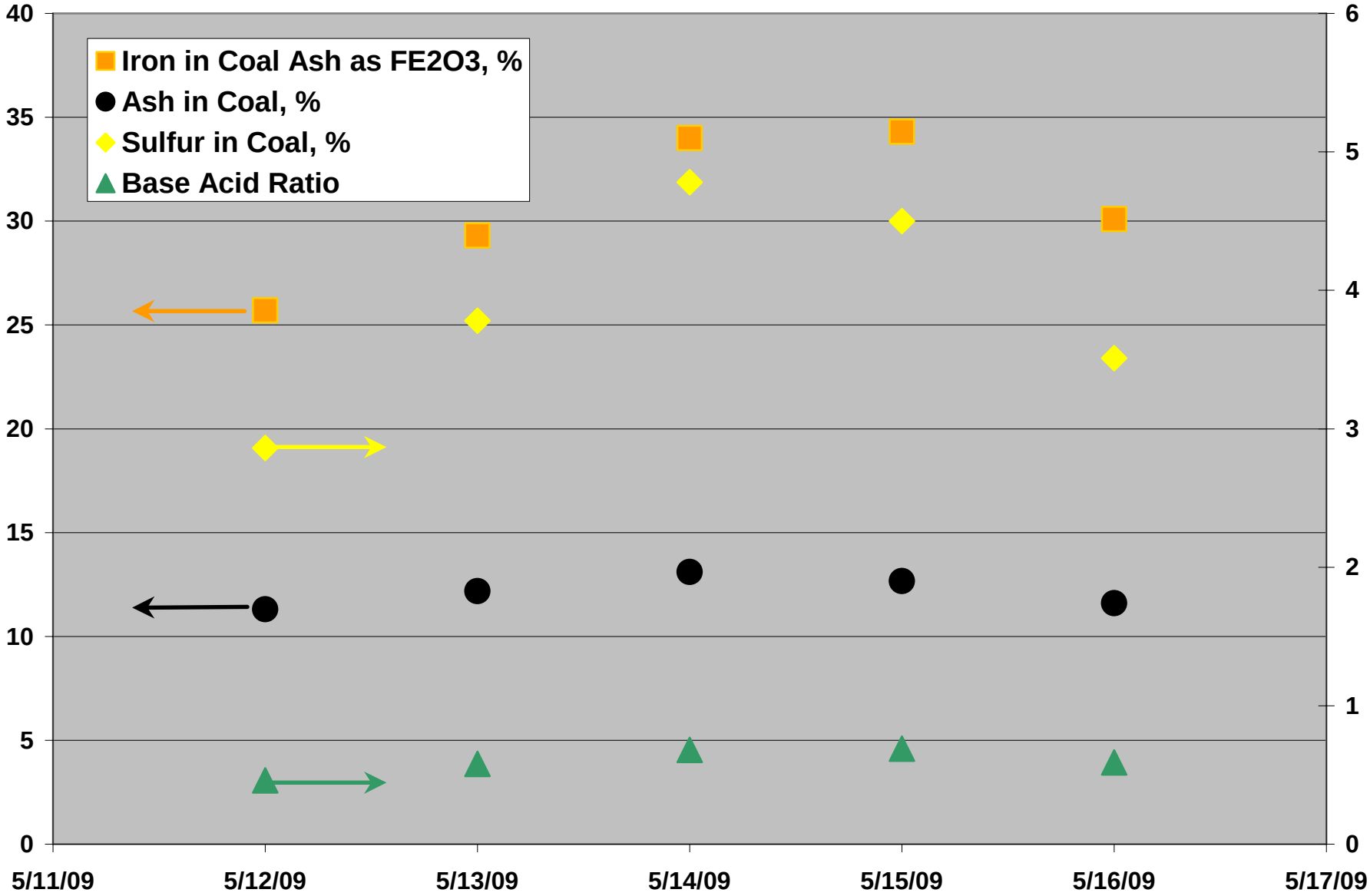

# Plant No. 1 Test Results



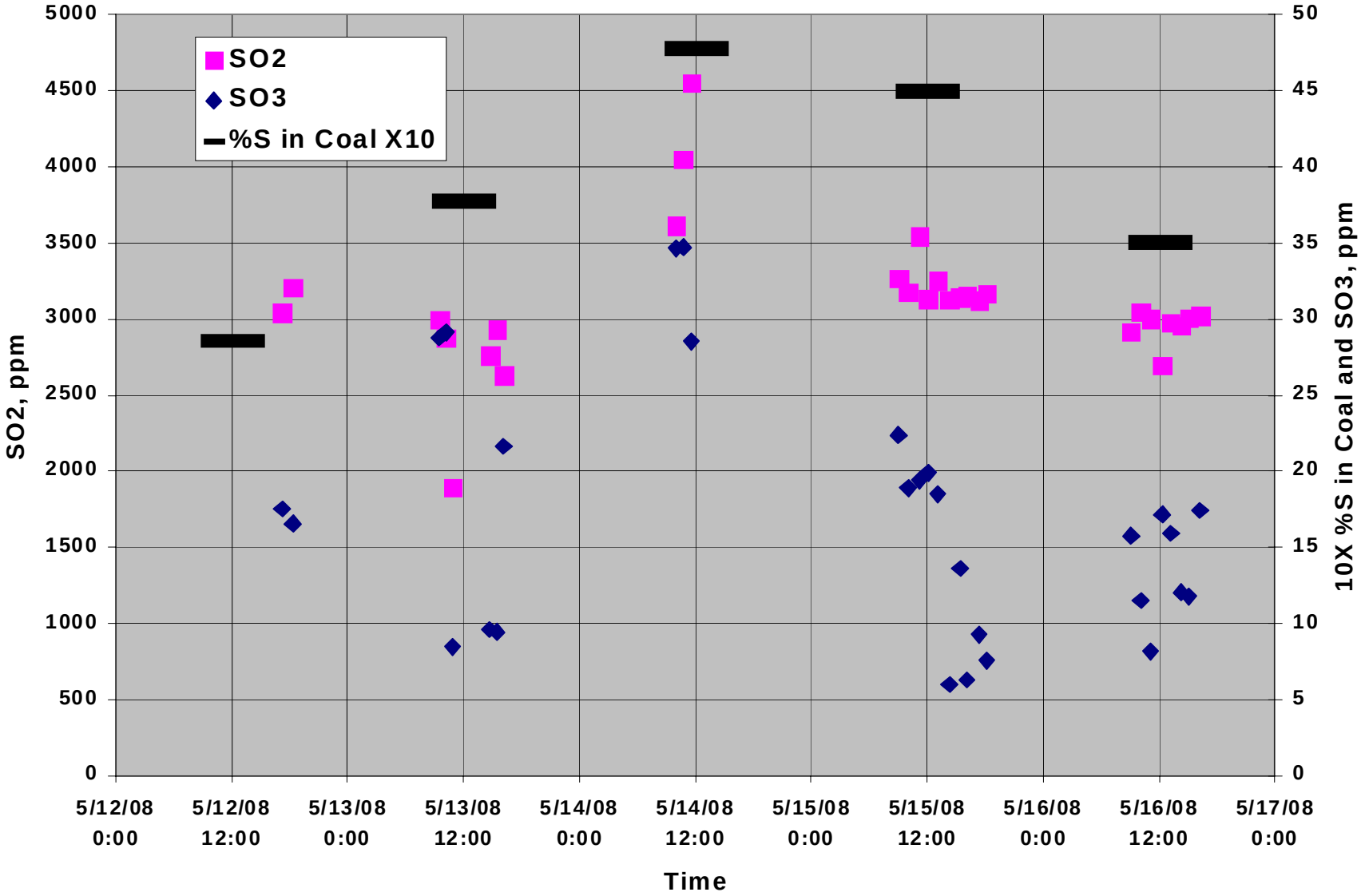

# Side View of Test Site 2 Boiler Showing Sampling Locations



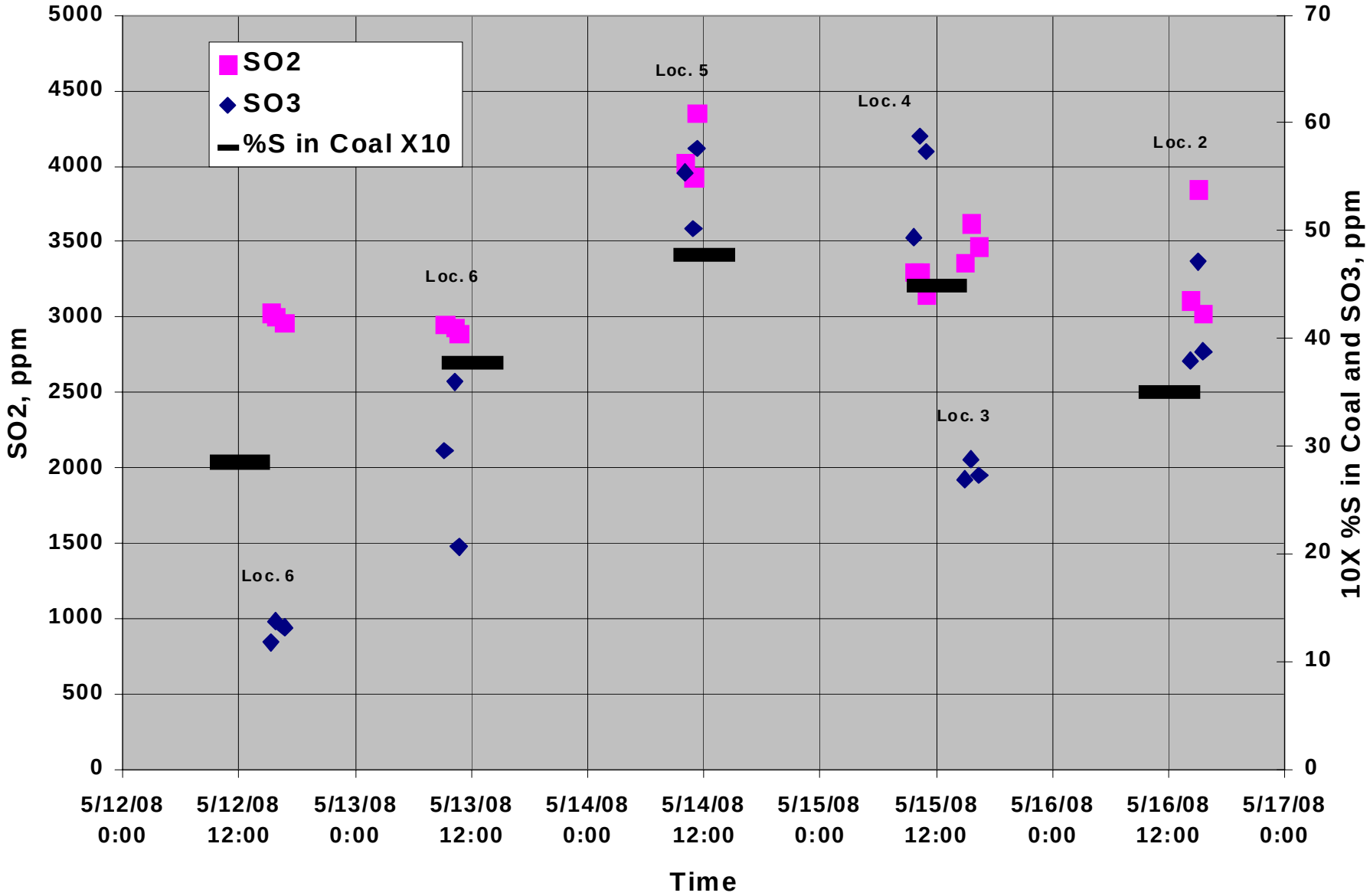

# Results of measurements at Site 2.



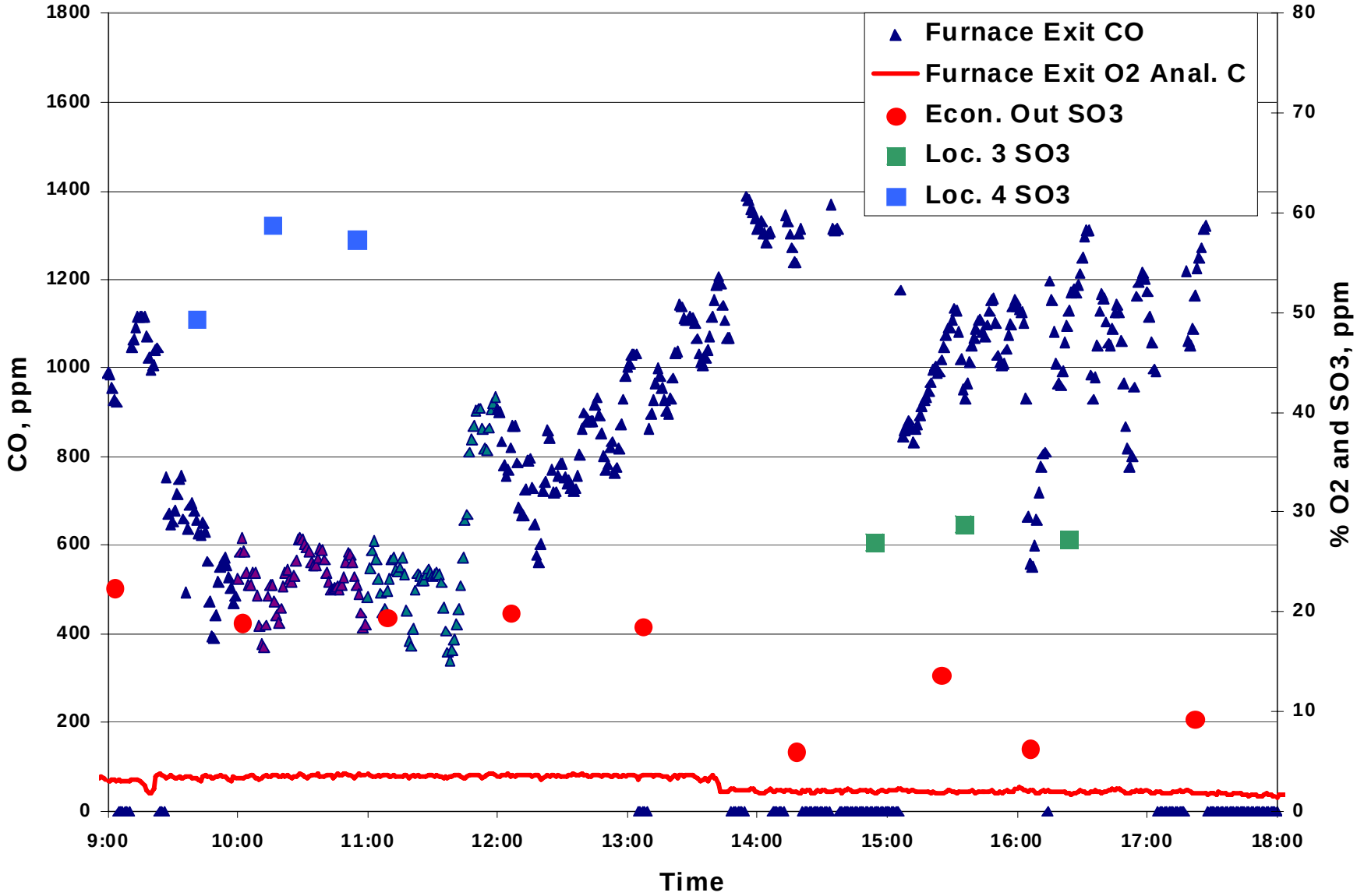

# Daily Values of Key Coal Properties




# Plant No. 2 Daily $SO_2$ and $SO_3$ at Air Heater Inlet and Daily Coal Sulfur Contents




# Plant No. 2 Daily $SO_2$ and $SO_3$ at Locations 2 through 6 and Daily Coal Sulfur Contents

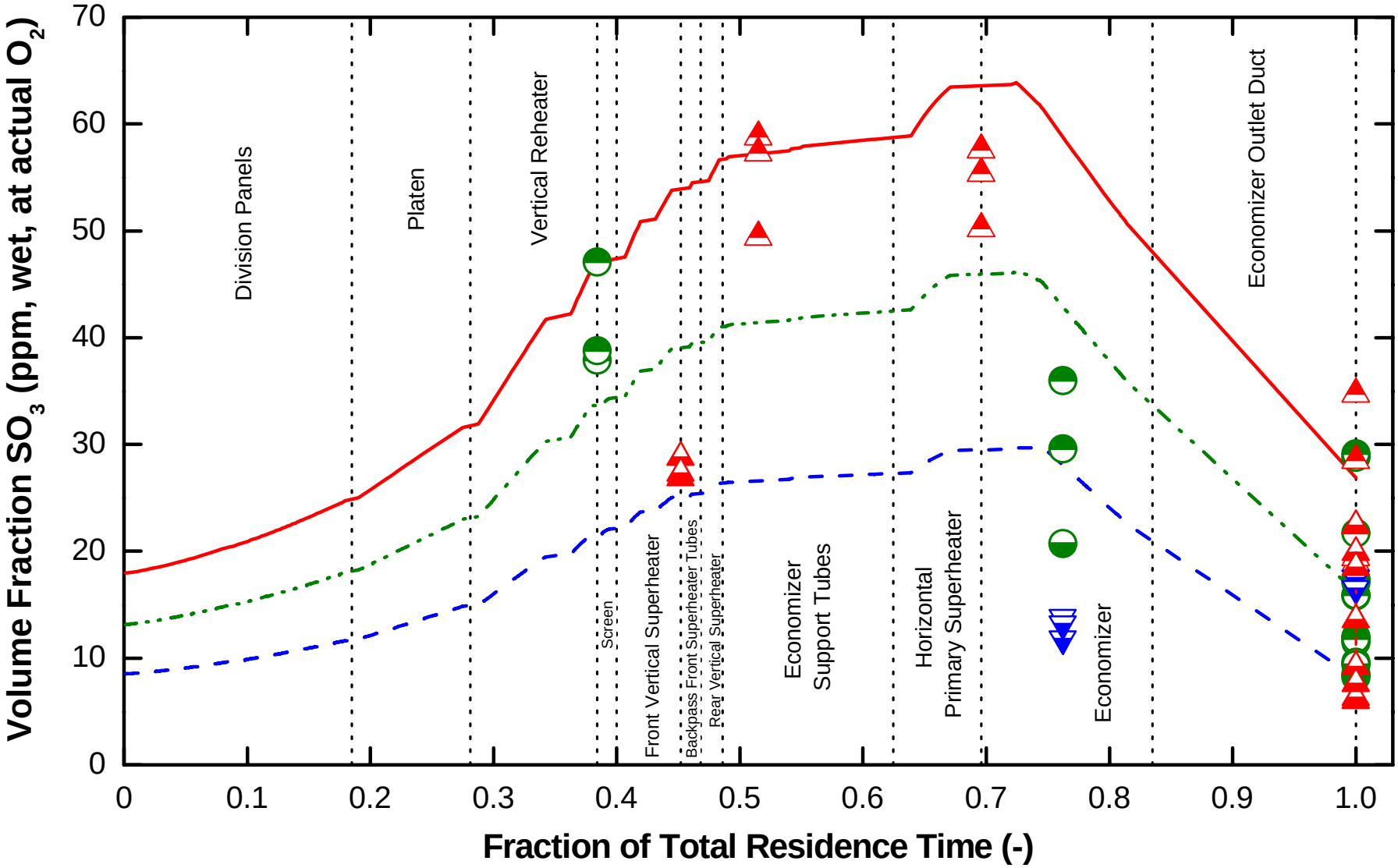



# Plant No. 2 $SO_3$ Concentrations and Furnace Exit $O_2$ and CO Concentrations on 5/15/08

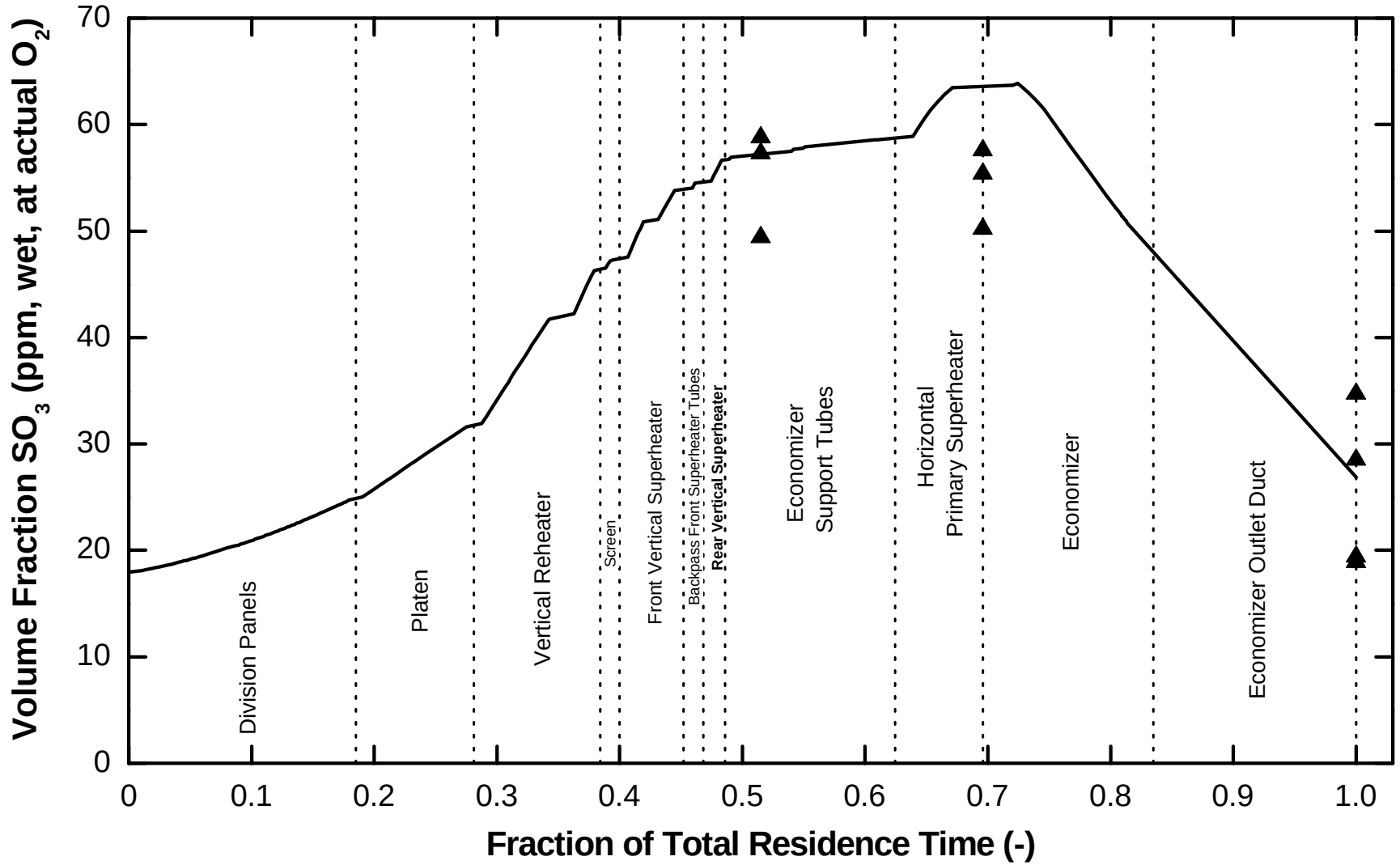
# Plant No. 2 Test Results

**Coal Analyses and Levels of $O_2$ and CO in Flue Gas Associated with the Ranges of $SO_3$ Formation Observed at Site 2.**

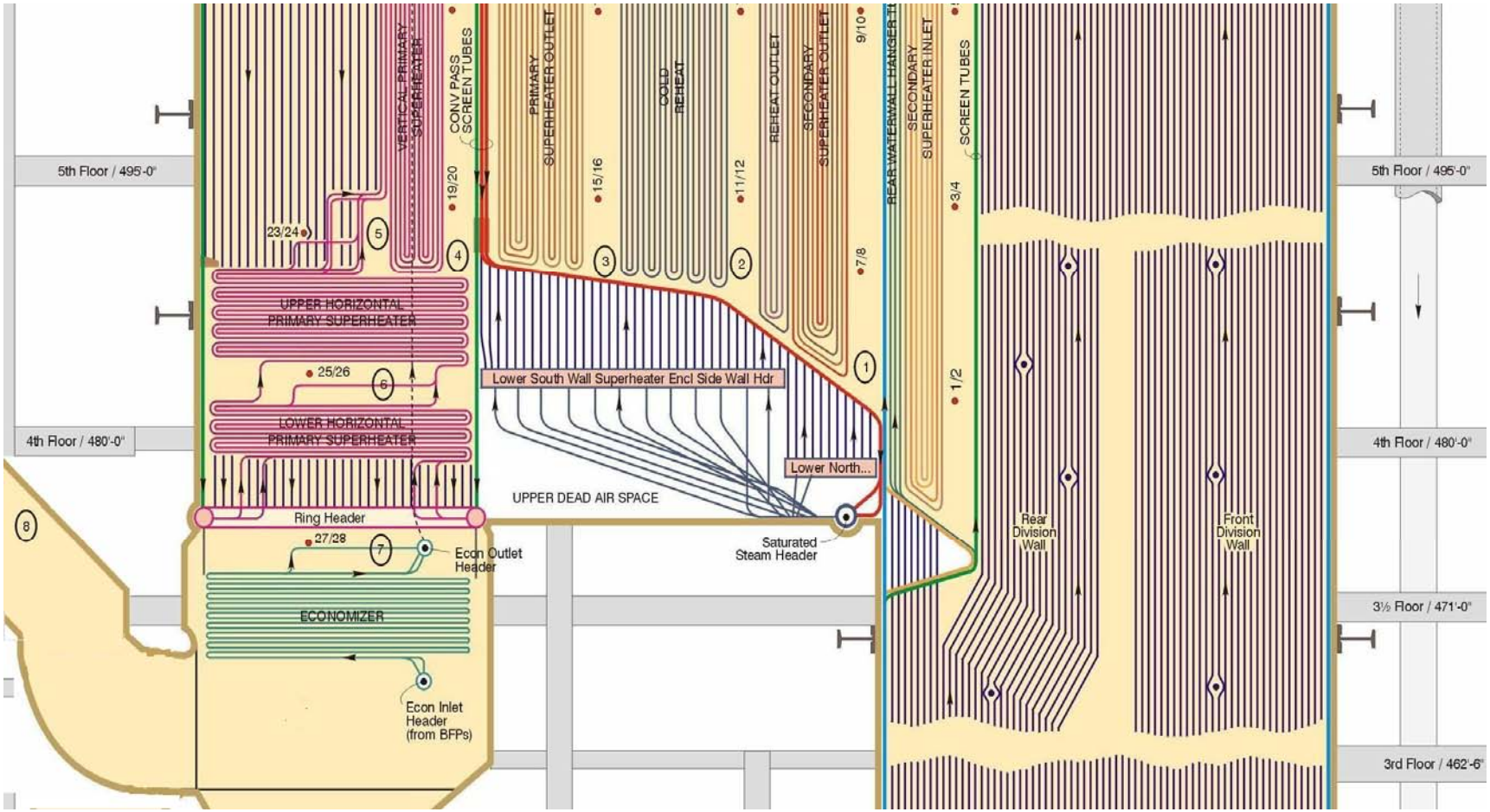
| | Effect on $SO_3$ | | |
|---|---|---|---|
| Parameter | Low $SO_3$ | Med. $SO_3$ | High $SO_3$ |
| Coal sulfur (wt%, dry) | 2.8 | 3.8 | 4.8 |
| Coal ash (wt%, dry) | 11.3 | 12.2 | 13.1 |
| Iron oxides in ash (wt%, $SO_3$-free) | 26 | 30 | 34 |
| Flue gas $O_2$ (vol%, wet) | 2.1 | 3 | 3.9 |
| Flue gas CO (ppmv, dry) | > 600 | | < 600 |



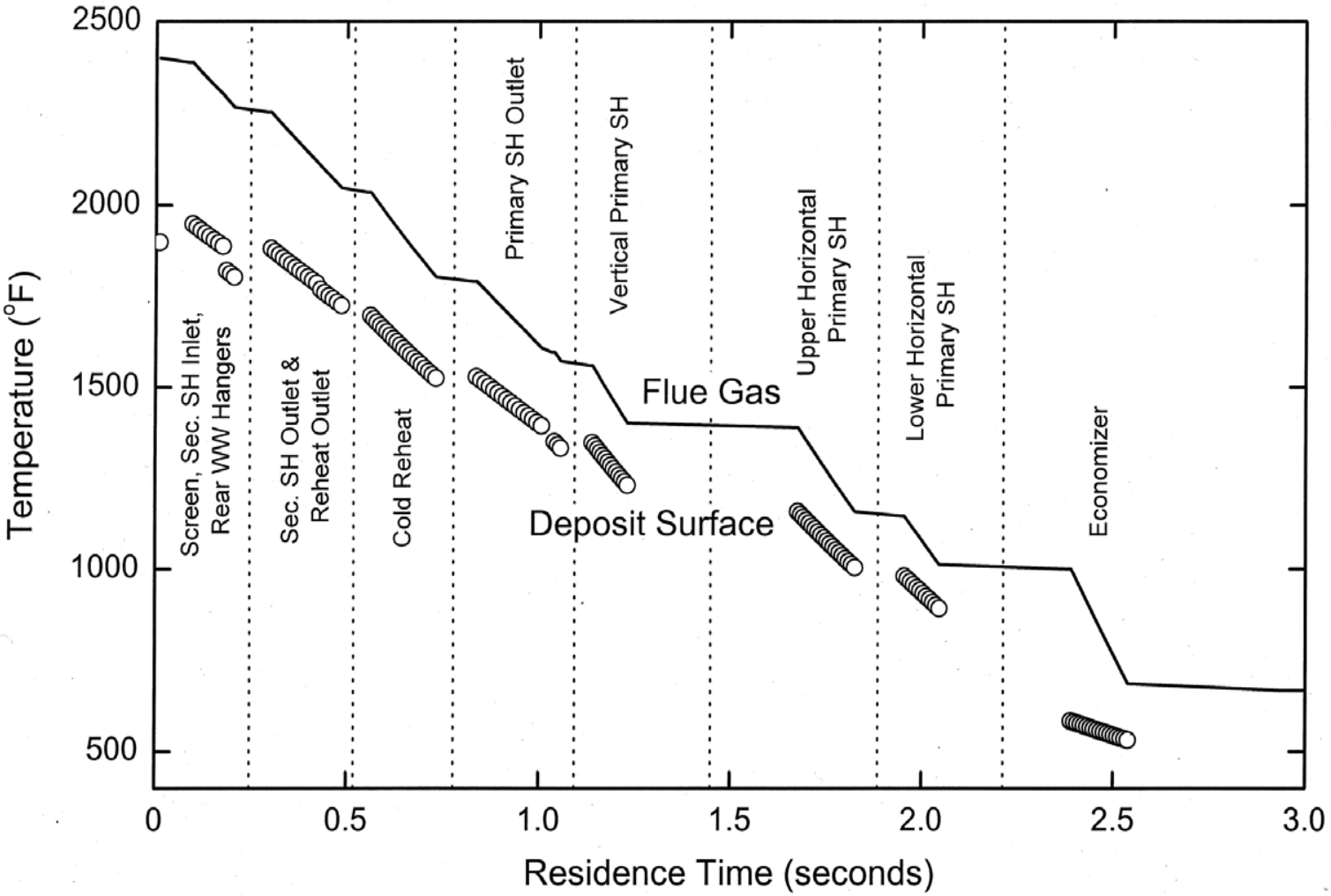

# Plant No. 2 Test Results Compared to Model Predictions

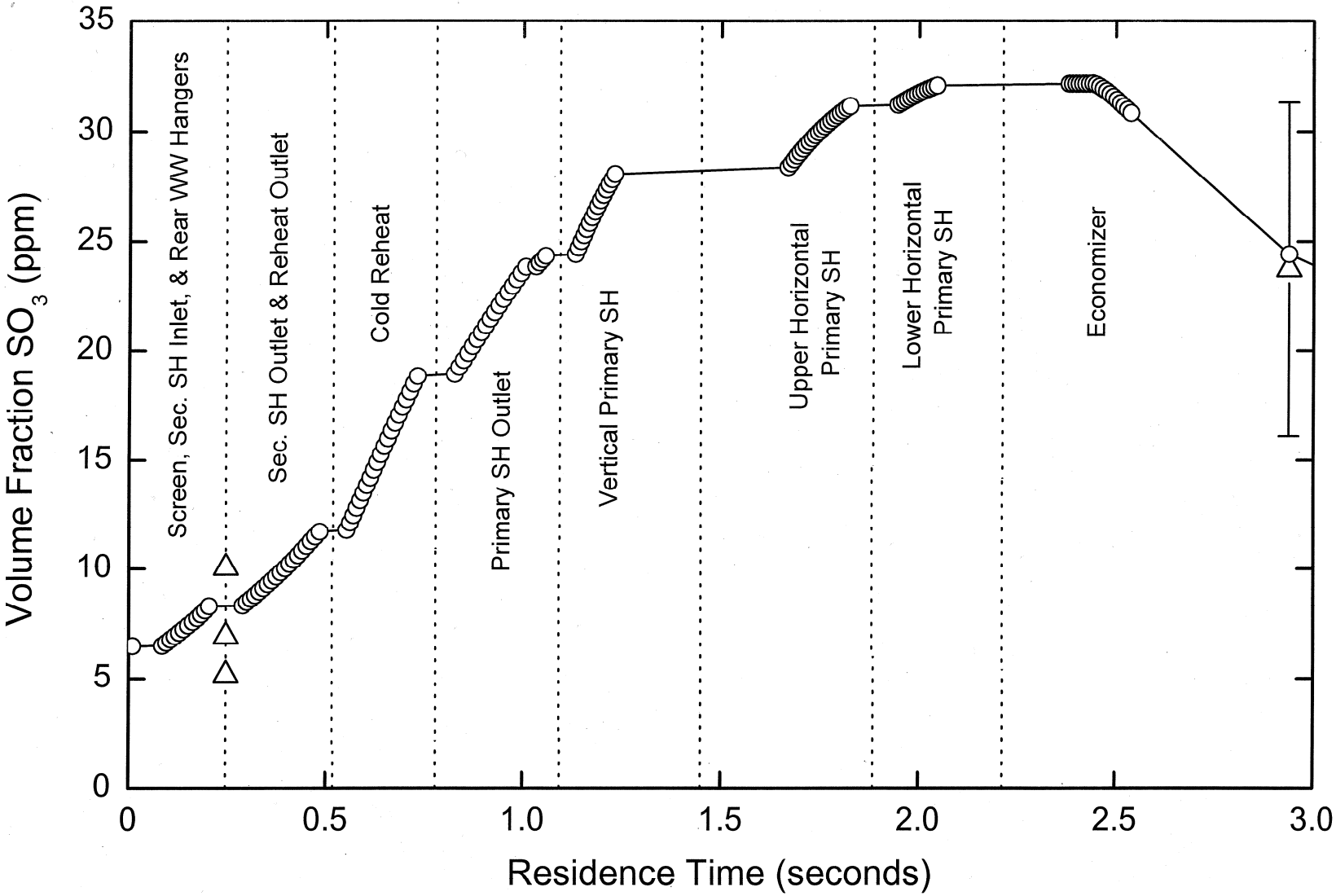



# Plant No. 2 SRI Model compared toTest Results for the High $SO_3$ Formation Condition

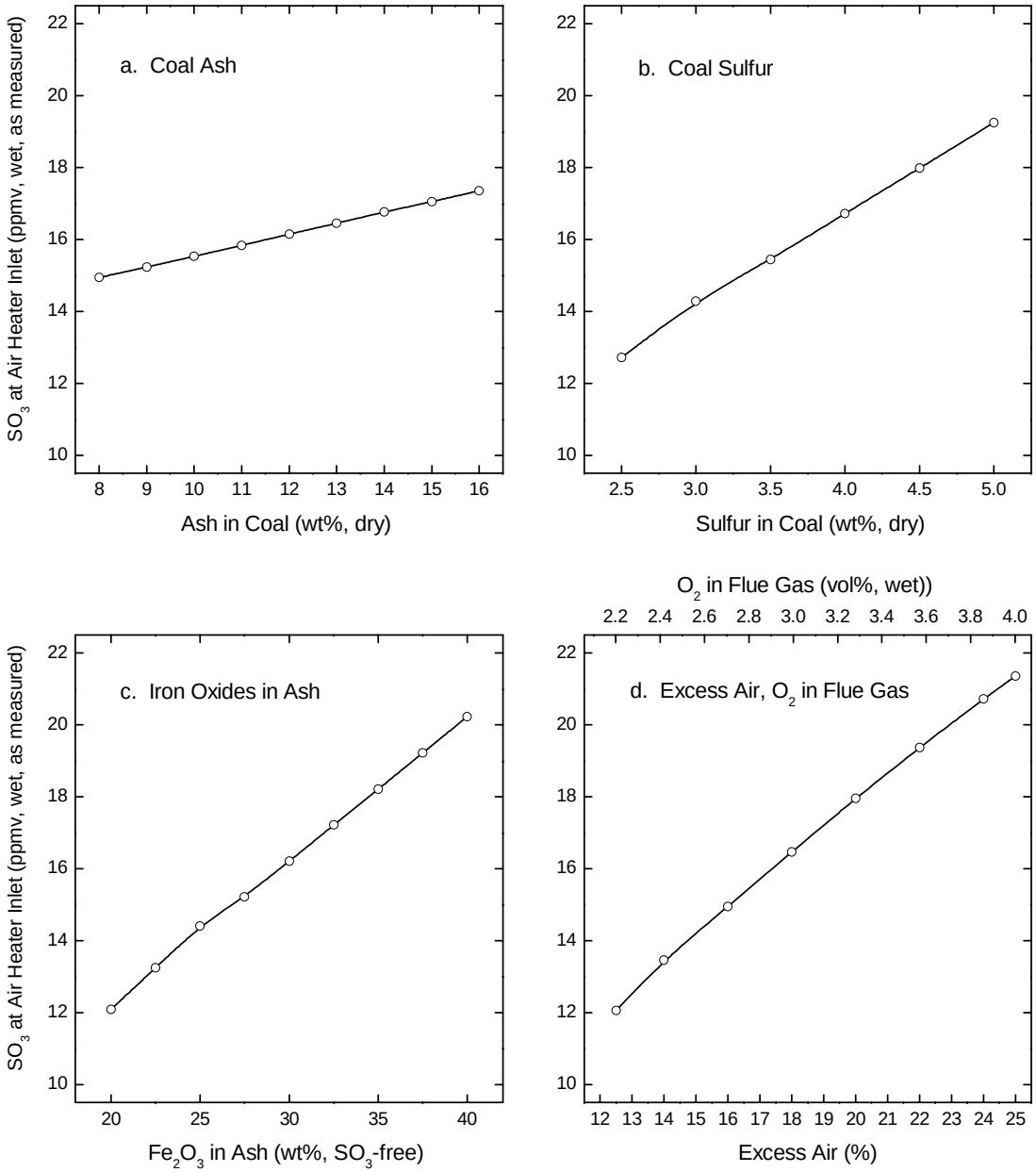



# Side View of Test Site 3 Boiler Showing Sampling Locations


2500
2000
1500
1000
500
Temperature (°F)
0
0.5
1.0
1.5
2.0
2.5
3.0
Residence Time (seconds)
Screen, Sec. SH Inlet, Rear WW Hangers
Sec. SH Outlet & Reheat Outlet
Cold Reheat
Primary SH Outlet
Vertical Primary SH
Upper Horizontal Primary SH
Lower Horizontal Primary SH
Economizer
Flue Gas
Deposit Surface




# Plant No. 3 Test Results




# Results of Parametric Variations of Key Inputs to Model

# Conclusions

- Based upon the present data and analysis, if additional control of $SO_3$ formation were needed, the most effective strategy is expected to be placing upper limits on coal sulfur and iron oxides in ash. The two properties often go hand-in-hand, through the association of iron and sulfur in iron pyrite, $FeS_2$, so a reduction in either one might be amplified by the associated reduction in the other.

- There is a great benefit, from the point of view of minimizing uncertainty in the values of the reaction rate and equilibrium parameters derived from the measurements, of having measurements at as many streamwise locations in the convection section as possible.

Questions?