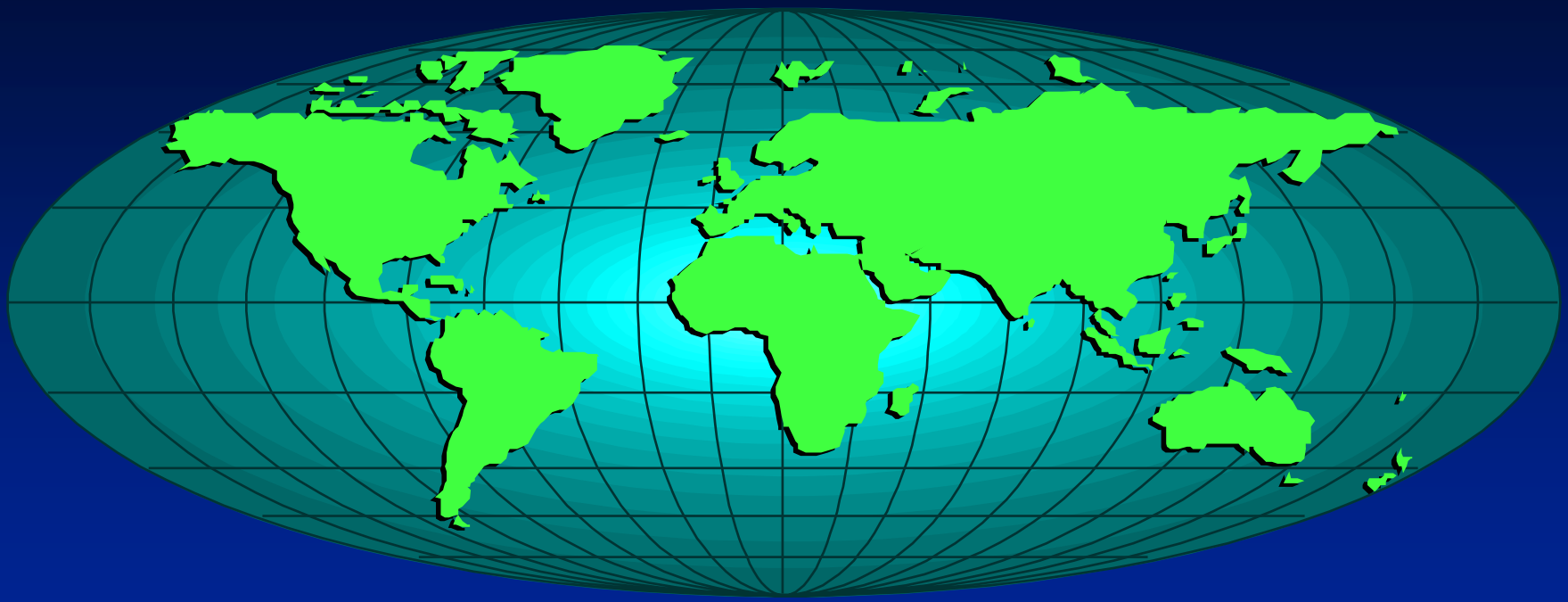
FTIR Monitoring of:

NO_x, SO_x, SO_3, & H_2SO_4



Environmental Controls Conference

Pittsburgh, PA

May 16-18, 2006

Attempts to Monitor SO_3/H_2SO_4 in Ducts

- An FTIR system was used to monitor NO, NO_2, SO_2, SO_3, H_2SO_4, H_2O, CO, CO_2, and HCl in SCR outputs
- The FTIR either extracted a sample from the duct at high temperature (>200C) or performed measurements in-situ
- Both approaches proved successful but the extractive measurements had many problems getting the sample to the analyzer

Attempts to Monitor SO_3/H_2SO_4 in Ducts

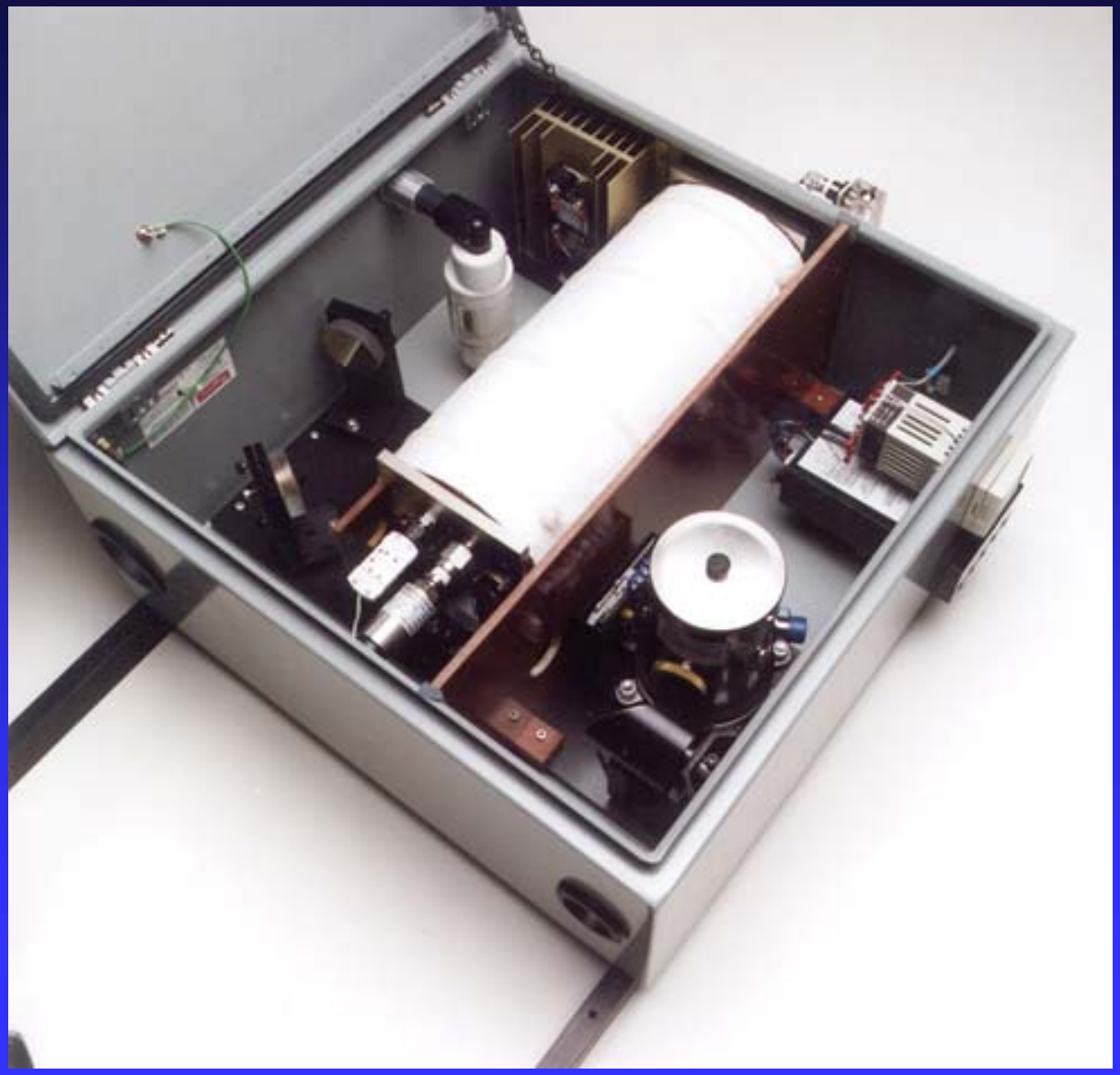
- Initial attempts used an extractive approach with high temperature (200C) lines and cell
- Lab tests showed both SO_3 and H_2SO_4 could be monitored using Teflon lines at this temperature
- Line effects were severe and limited length of line that could be used
- With sufficient line passivation this approach was ultimately successful

Extractive Monitoring
Lab Tests

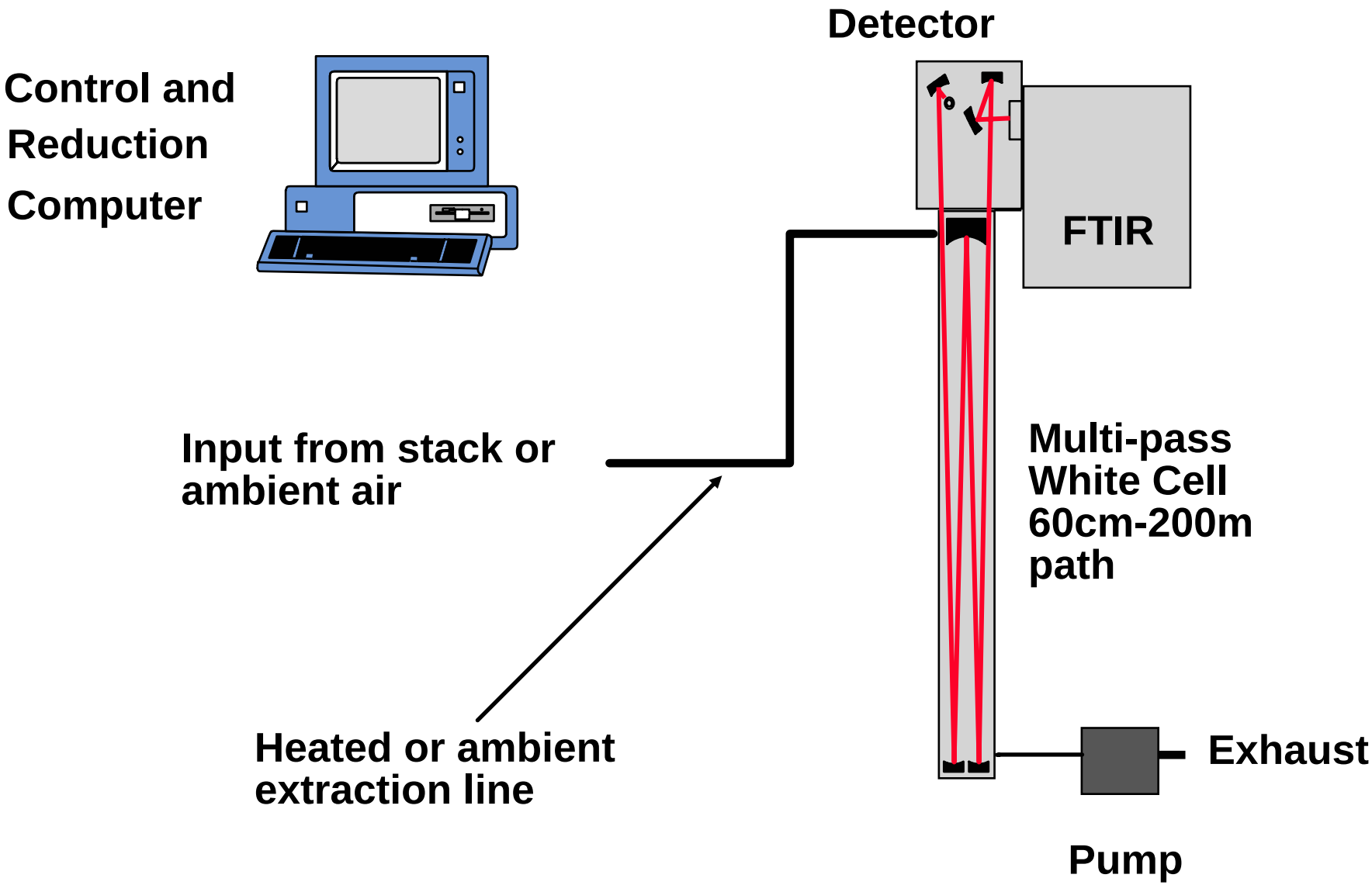
Imacc FTIR Base Unit with 10 meter cell Accessory

Imacc FTIR Base Unit with 10 meter cell Accessory

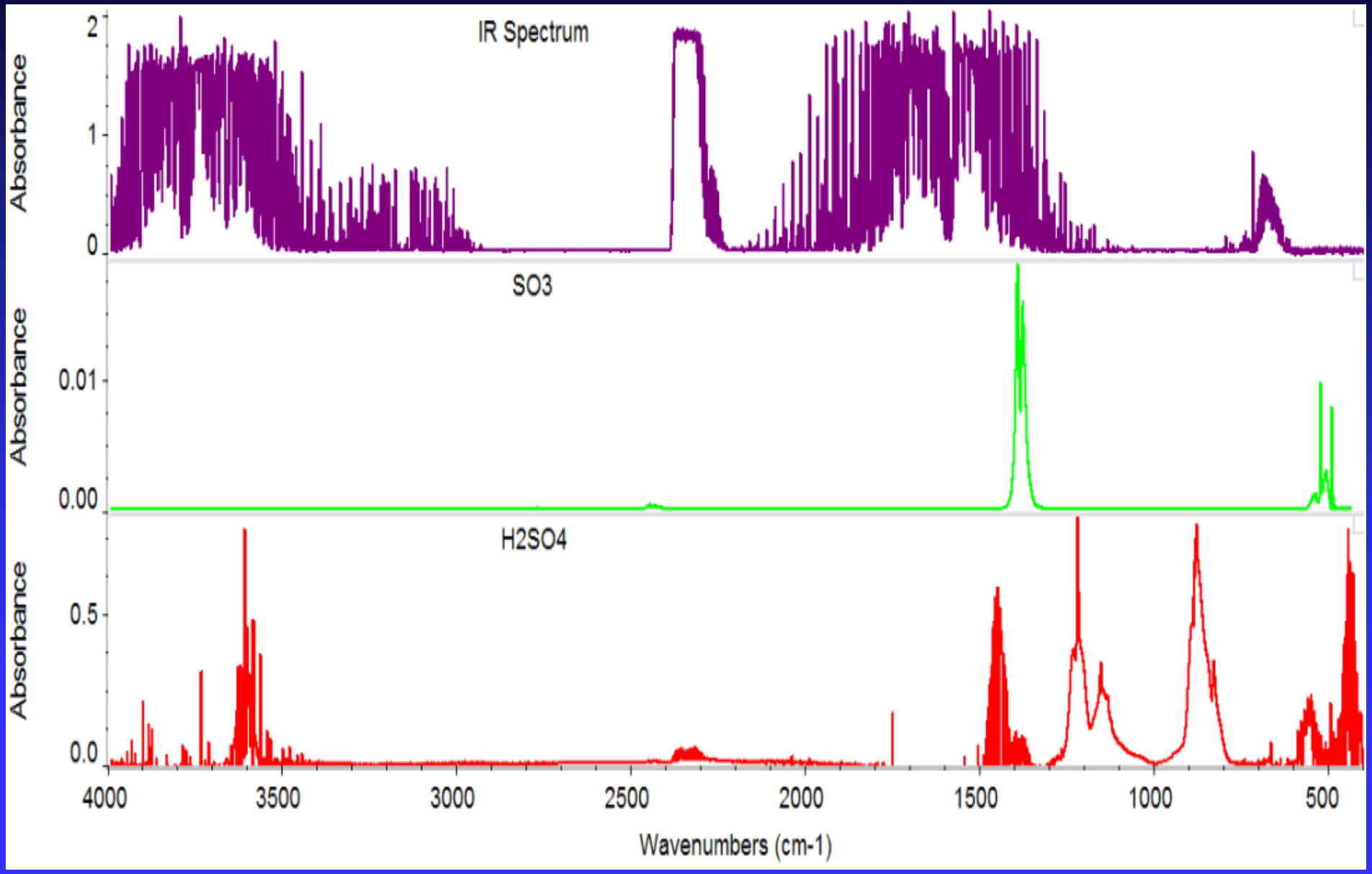
Imacc 10 meter cell Accessory



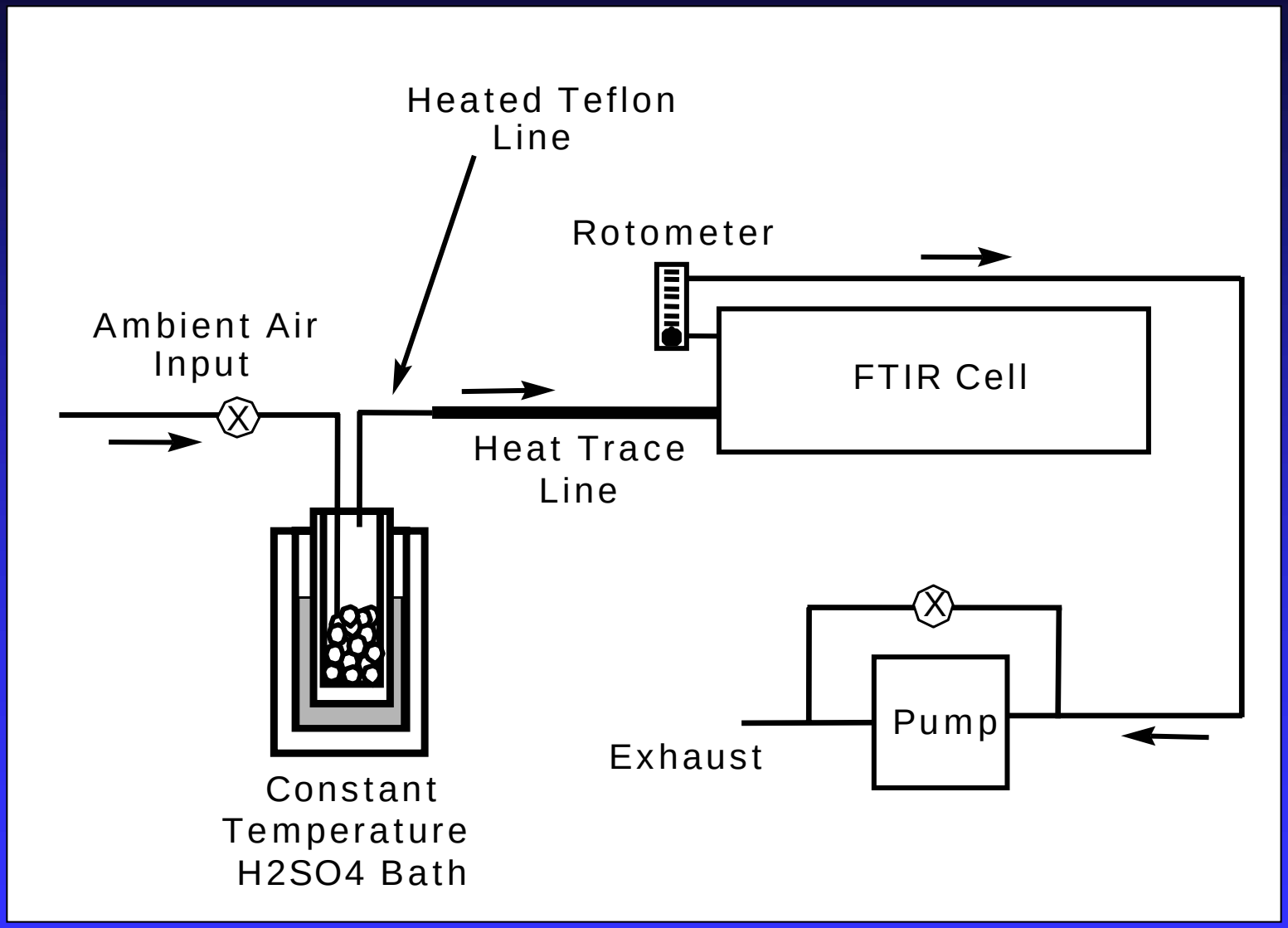
Typical Extractive FTIR System



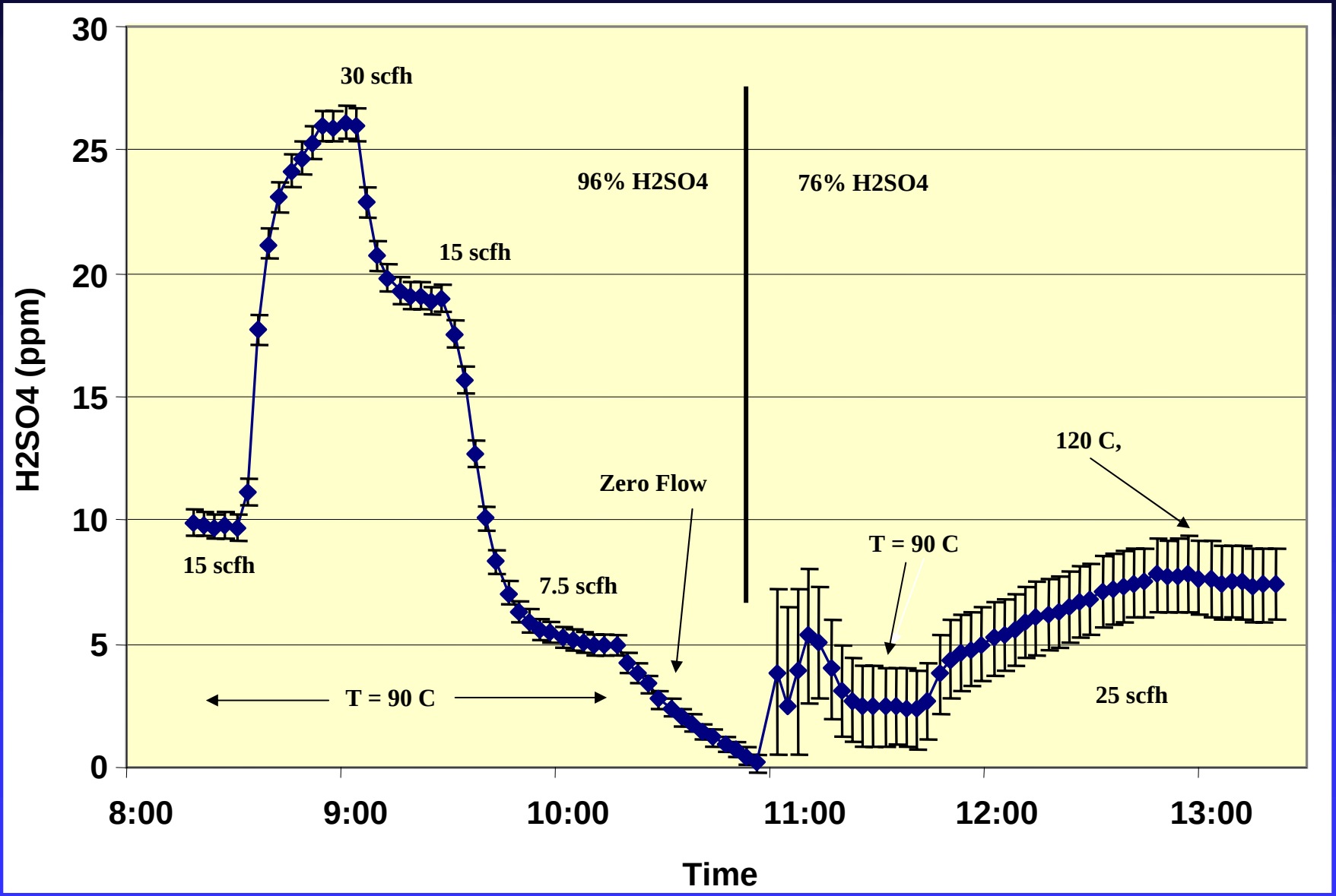
Spectra of H2SO4 and SO3



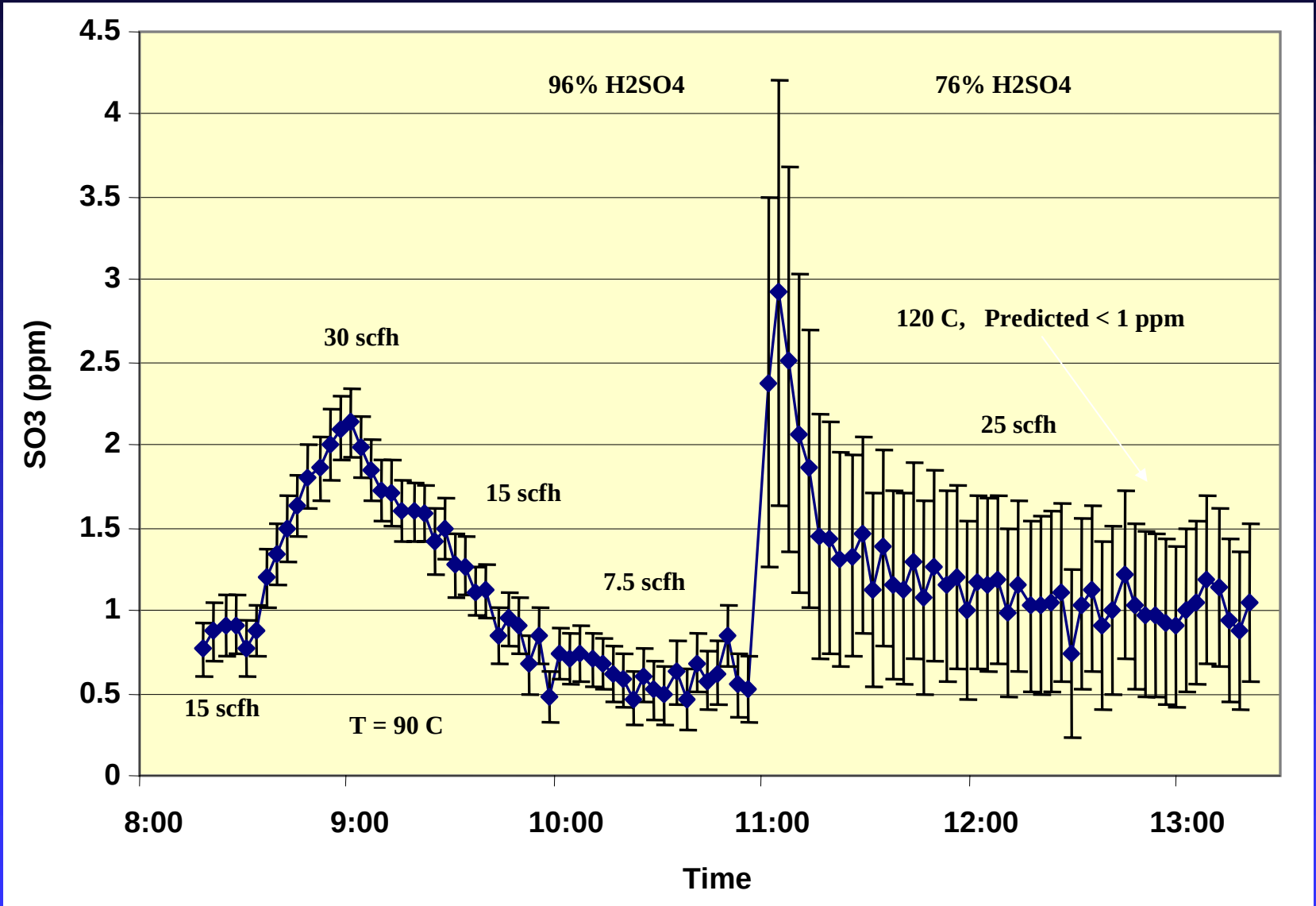
H2SO4 Lab Test Setup



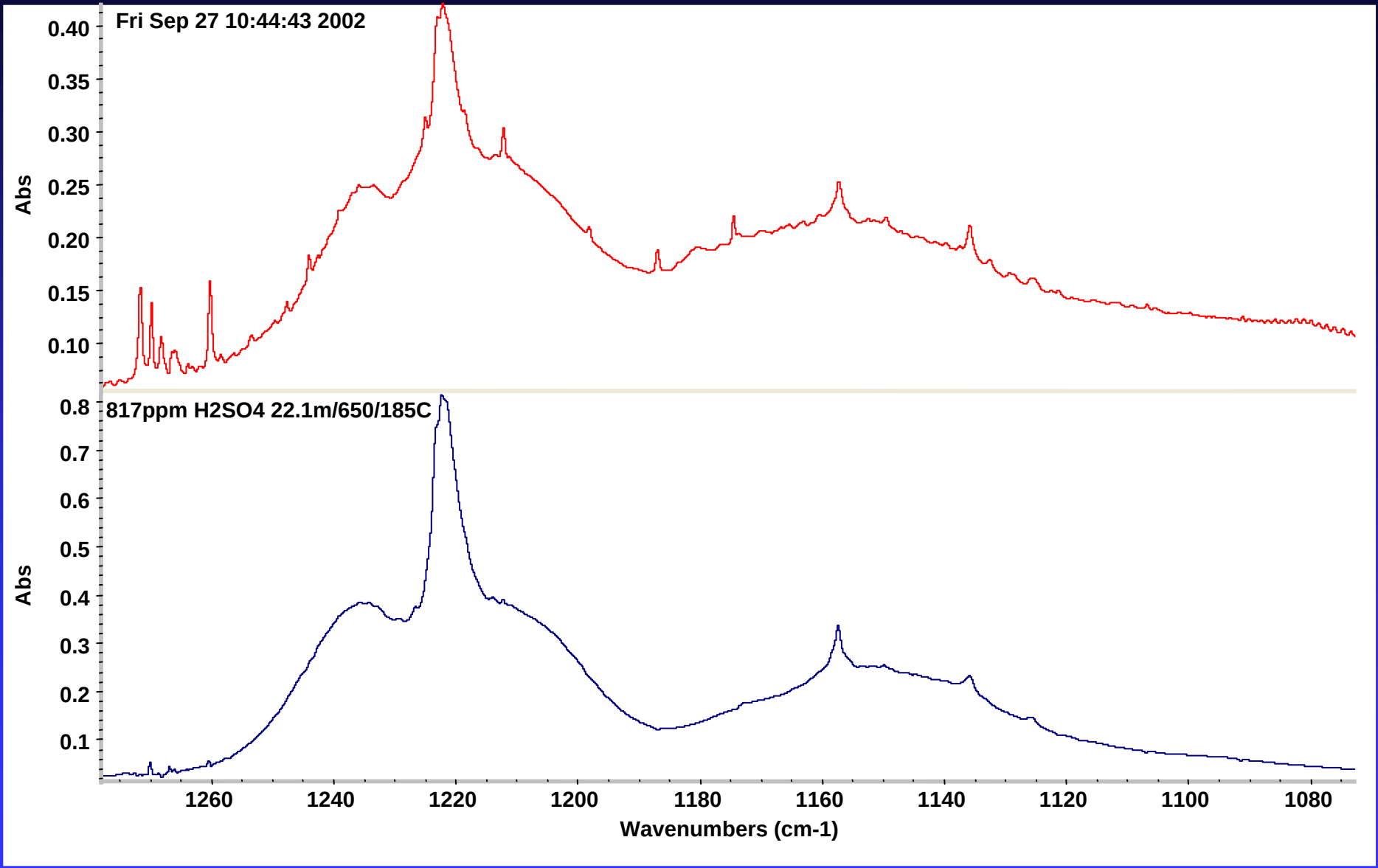
Flow & Temperature Effects: H_2SO_4 Bath, 80 ft. Line



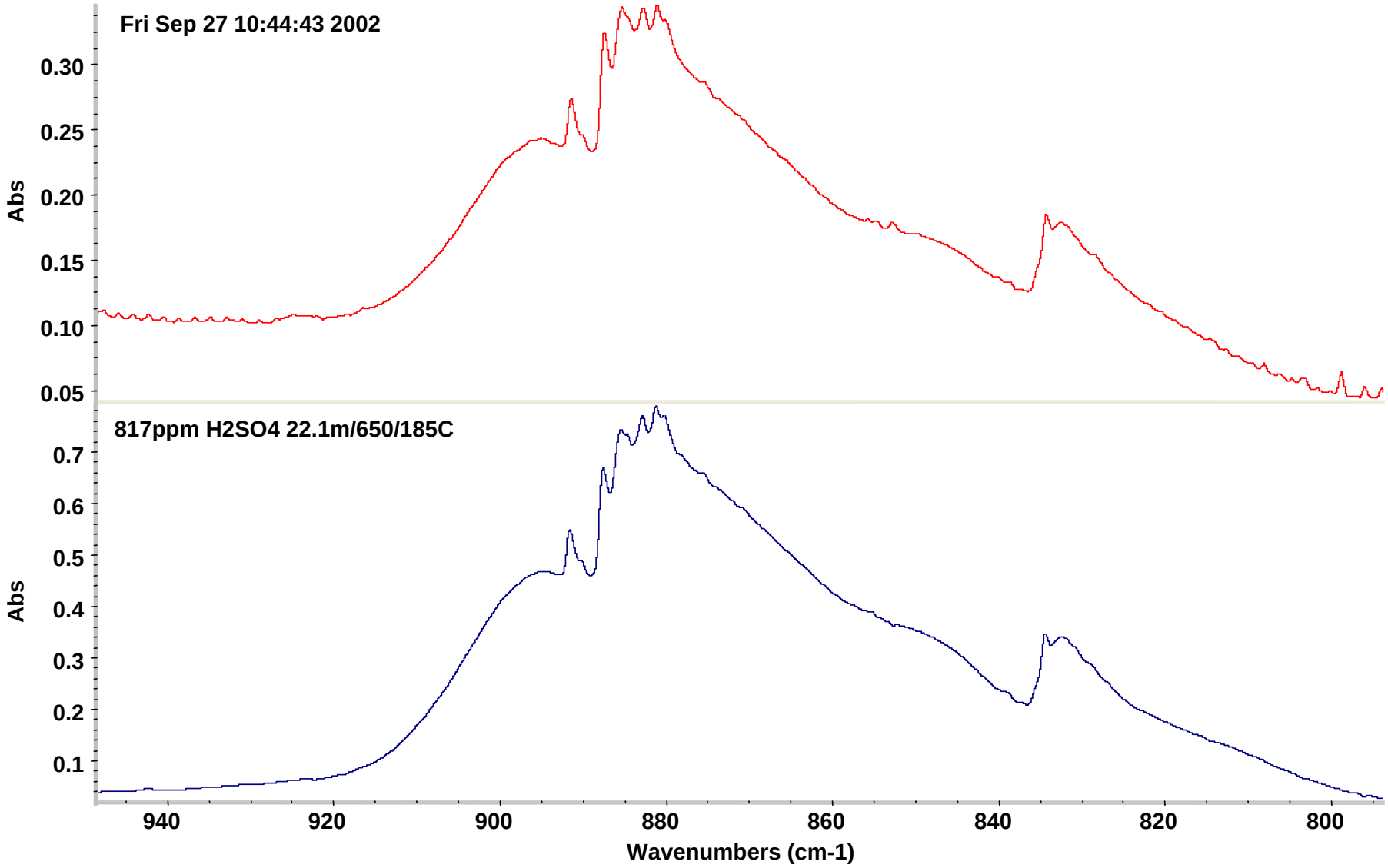
Flow & Temperature Effects: SO_3 Bath, 80 ft. Line



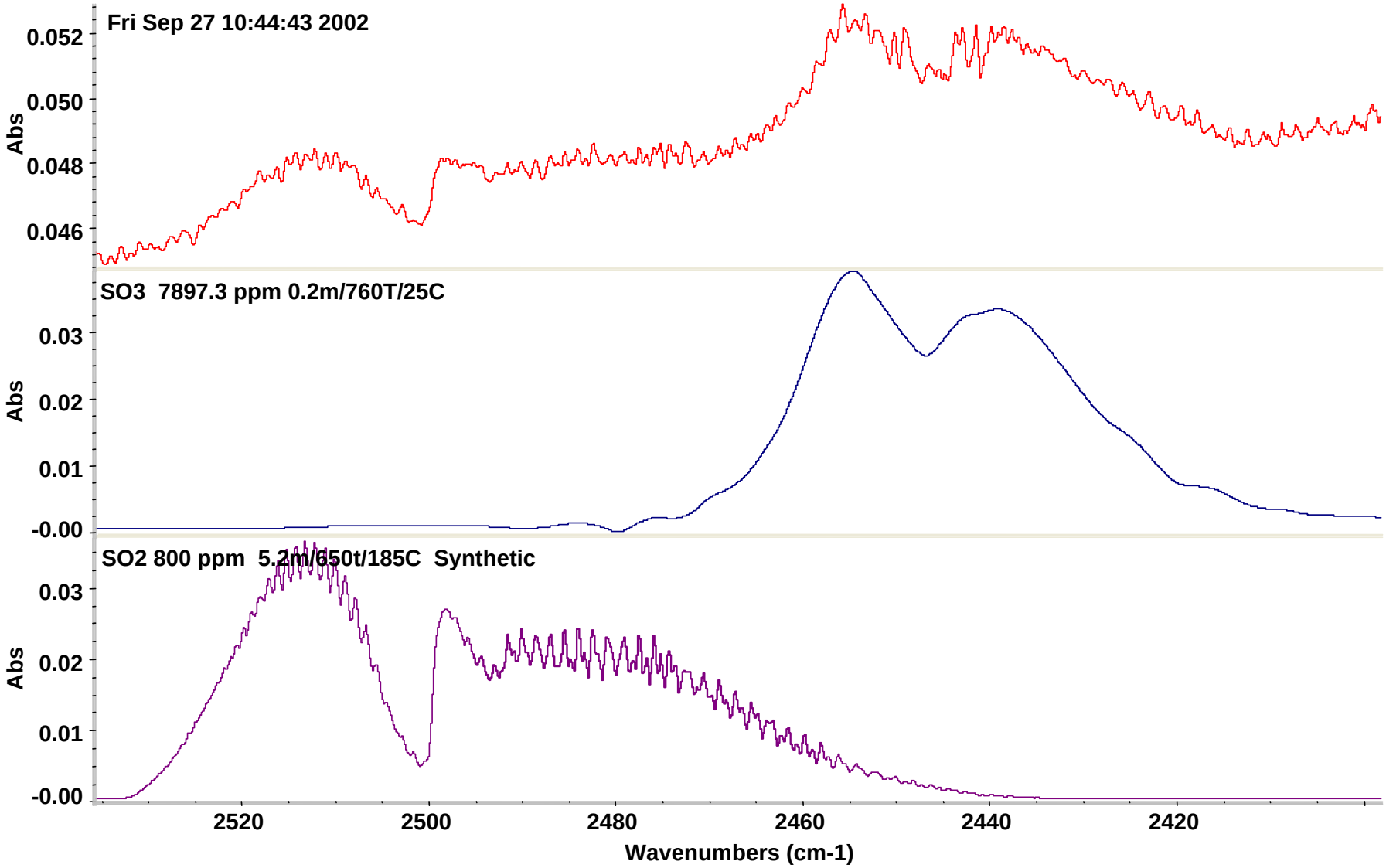
Comparison of H_2SO_4 Reference & Data Spectra



Comparison of H_2SO_4 Reference & Data Spectra

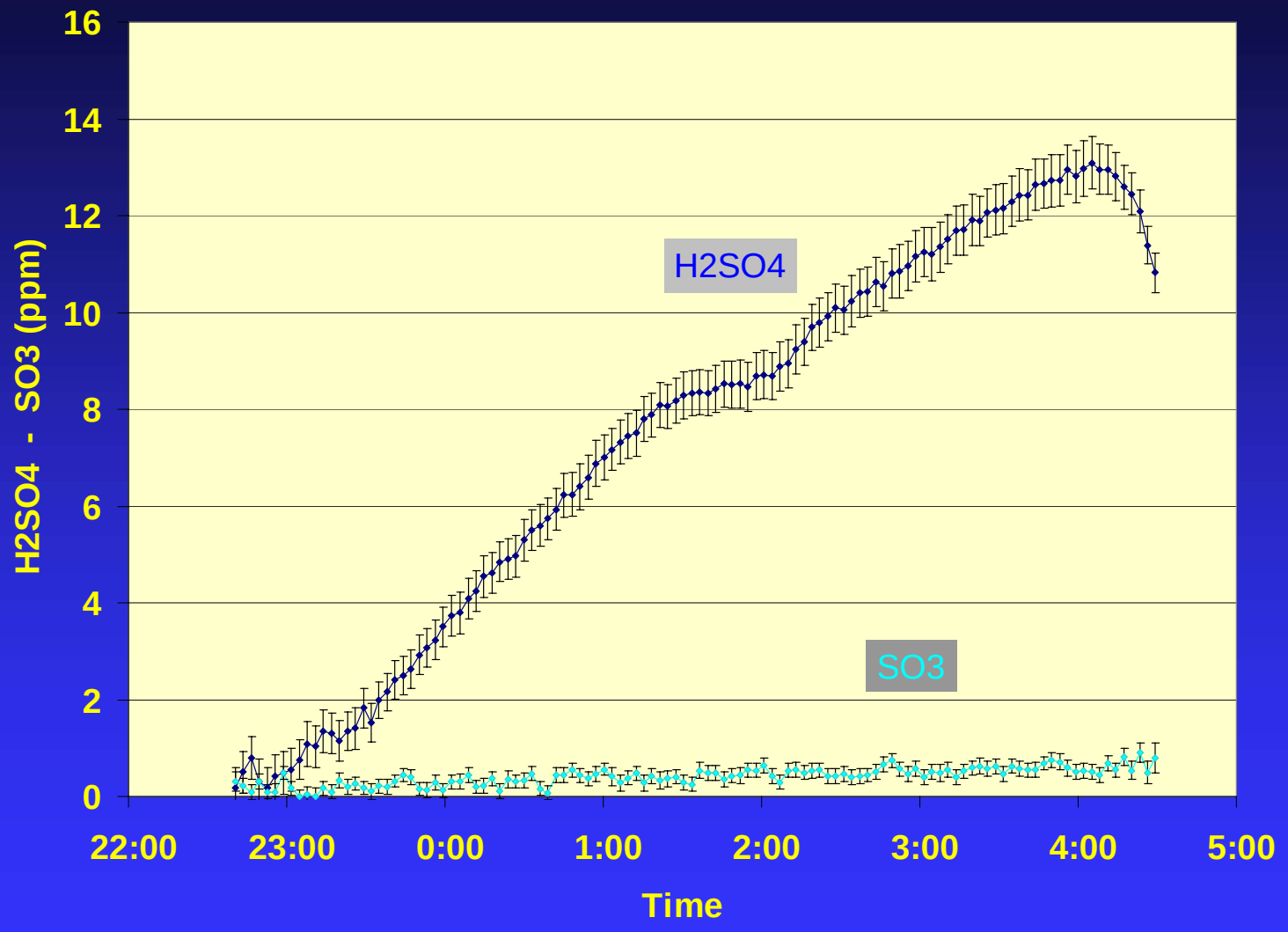


Comparison of SO_2 & SO_3 Reference & Data Spectra



Extractive Monitoring in SCR Outputs

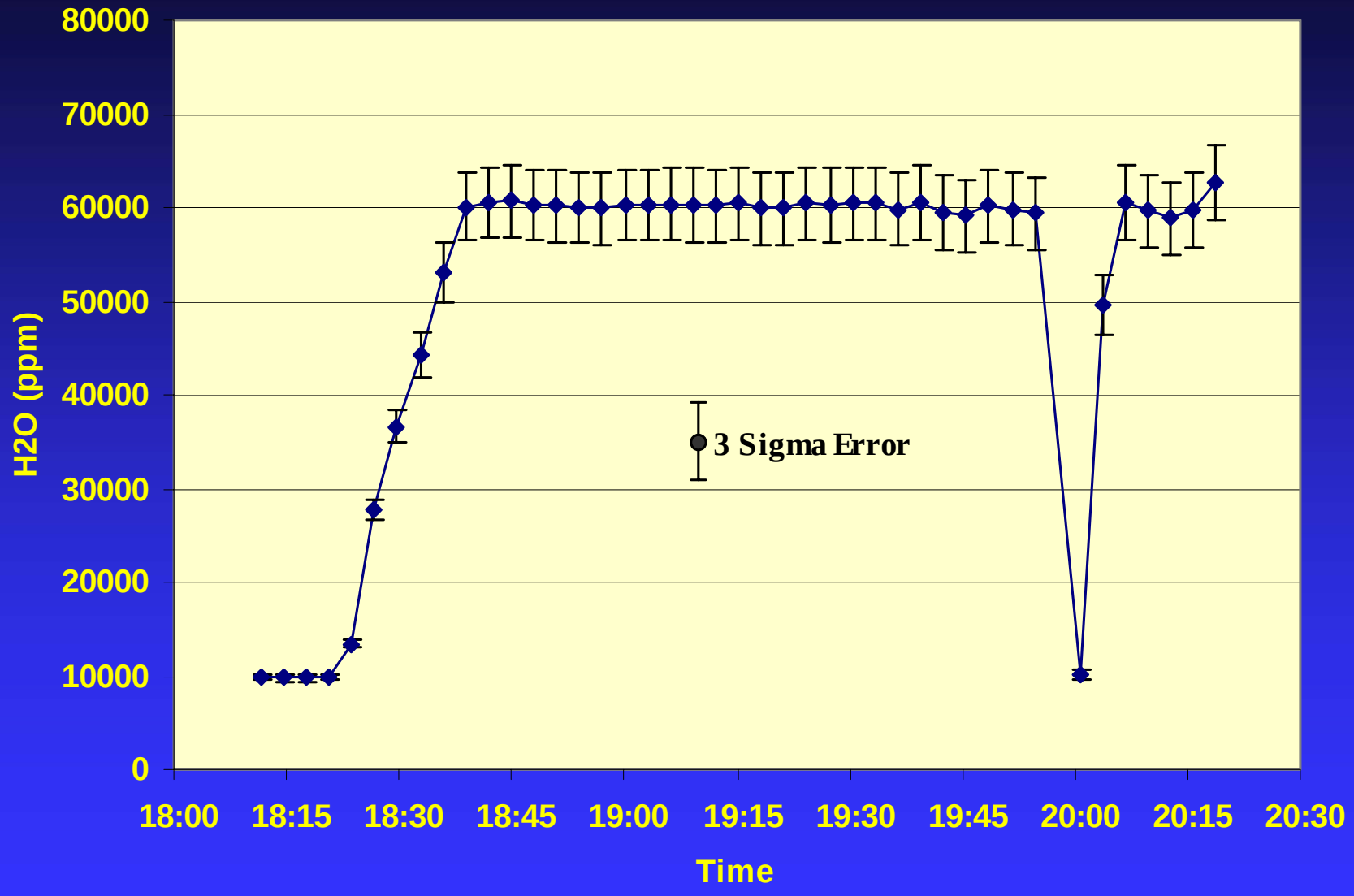
H_2SO_4 & SO_3 Line Equilibration With Overnight Run



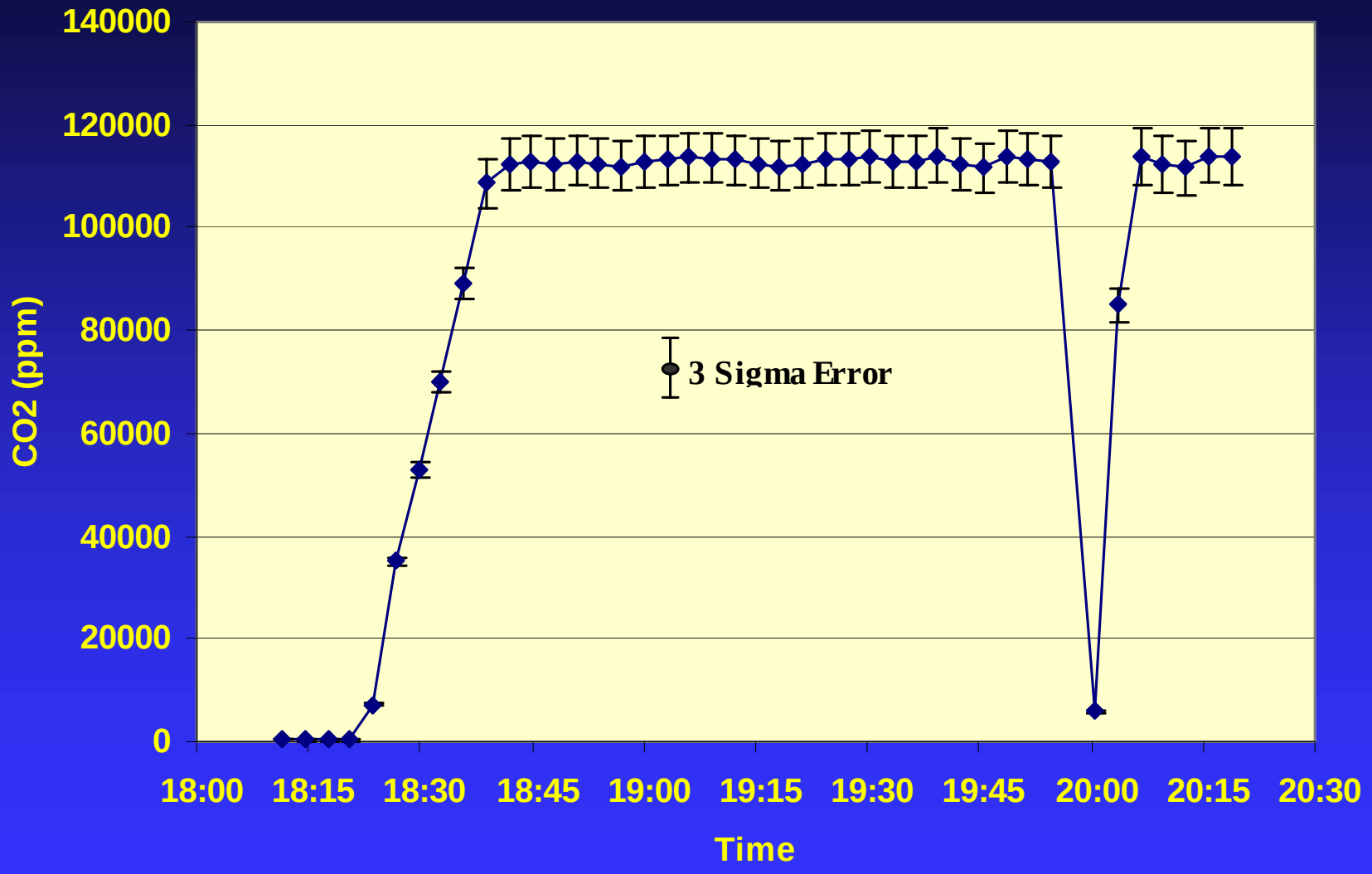
Observed Concentrations in SCR Output

Compound	Concentration (ppm)
Water	60,000
Carbon Dioxide	114,000
Carbon Monoxide	2.1 to 2.4
Nitric Oxide	330 to 350
Nitrogen Dioxide	1.7 to 1.9
Sulfur Dioxide	2330 to 2370
Sulfuric Acid	36.3 to 37.5
Hydrochloric Acid	31.1 to 32.2

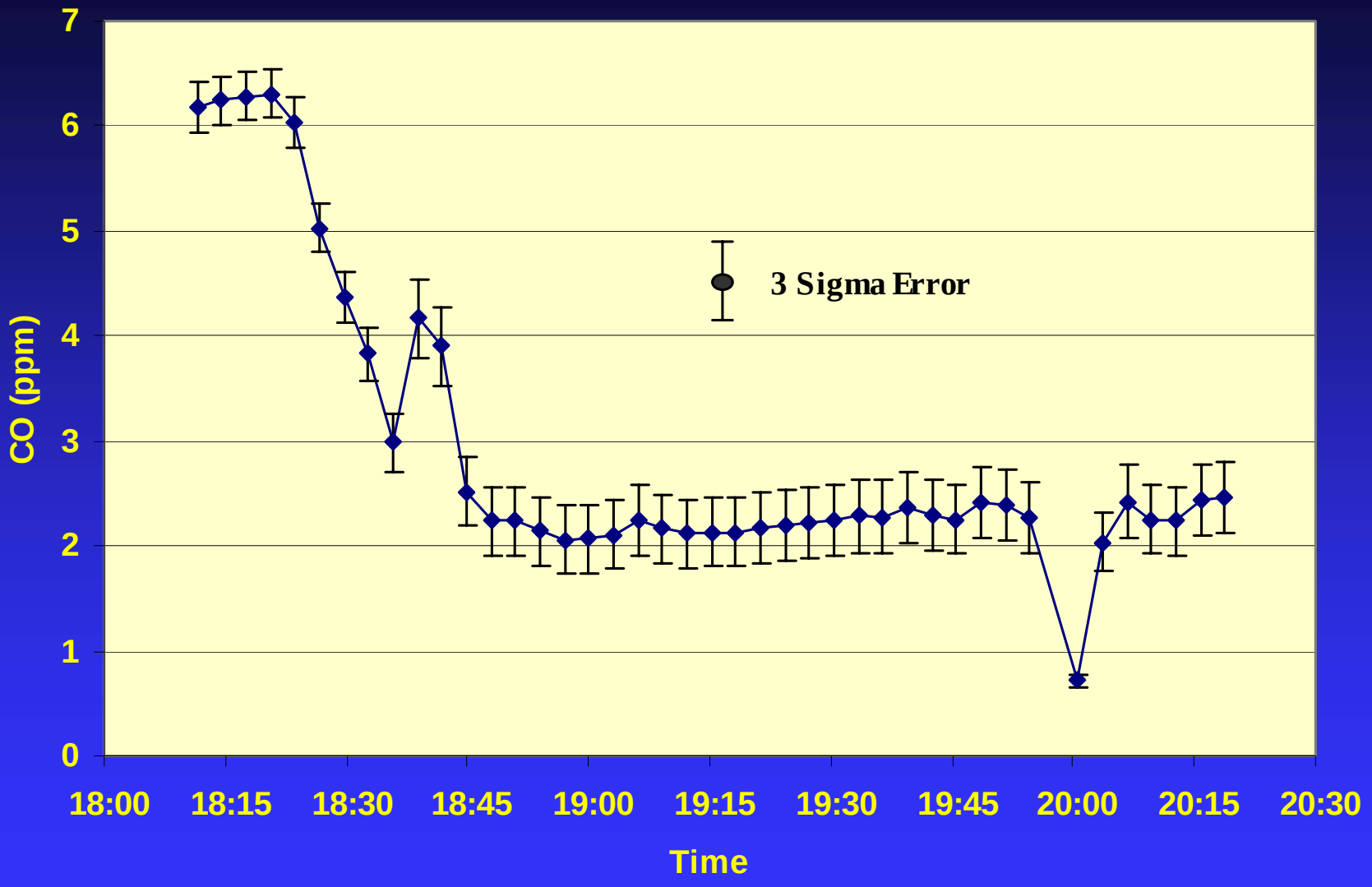
Observed H_2O Concentrations in SCR Output



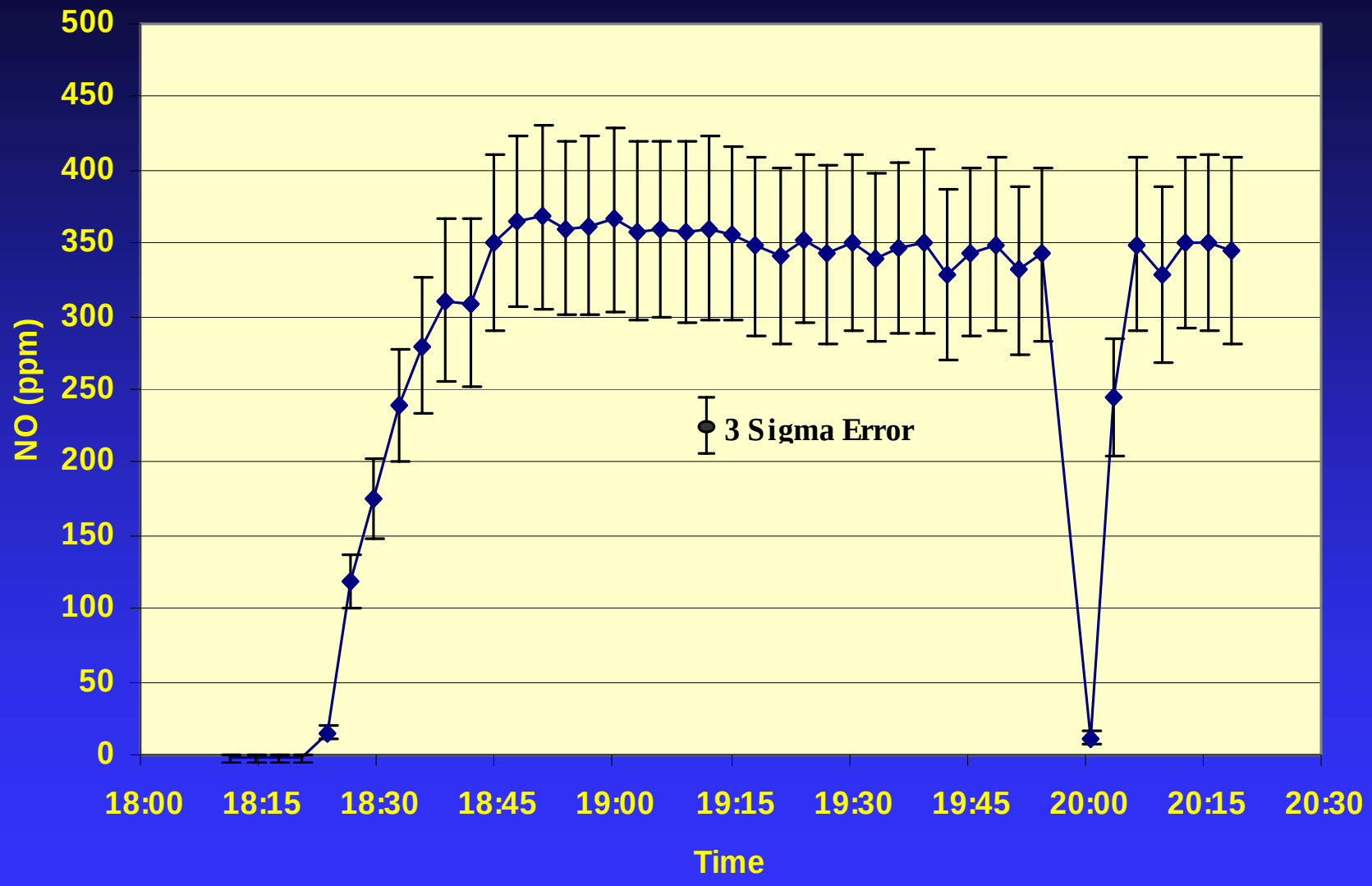
Observed CO_2 Concentrations in SCR Output



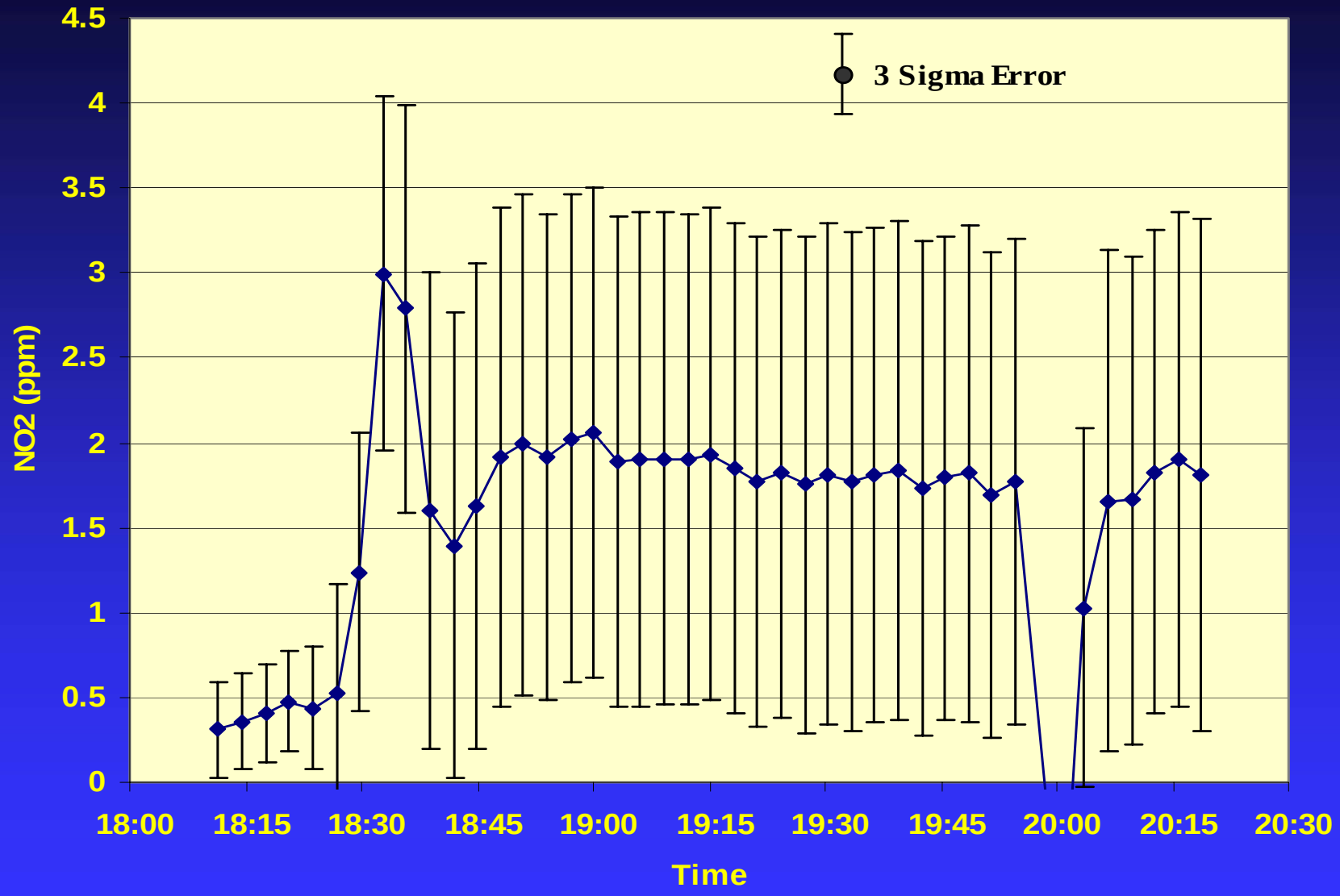
Observed CO Concentrations in SCR Output



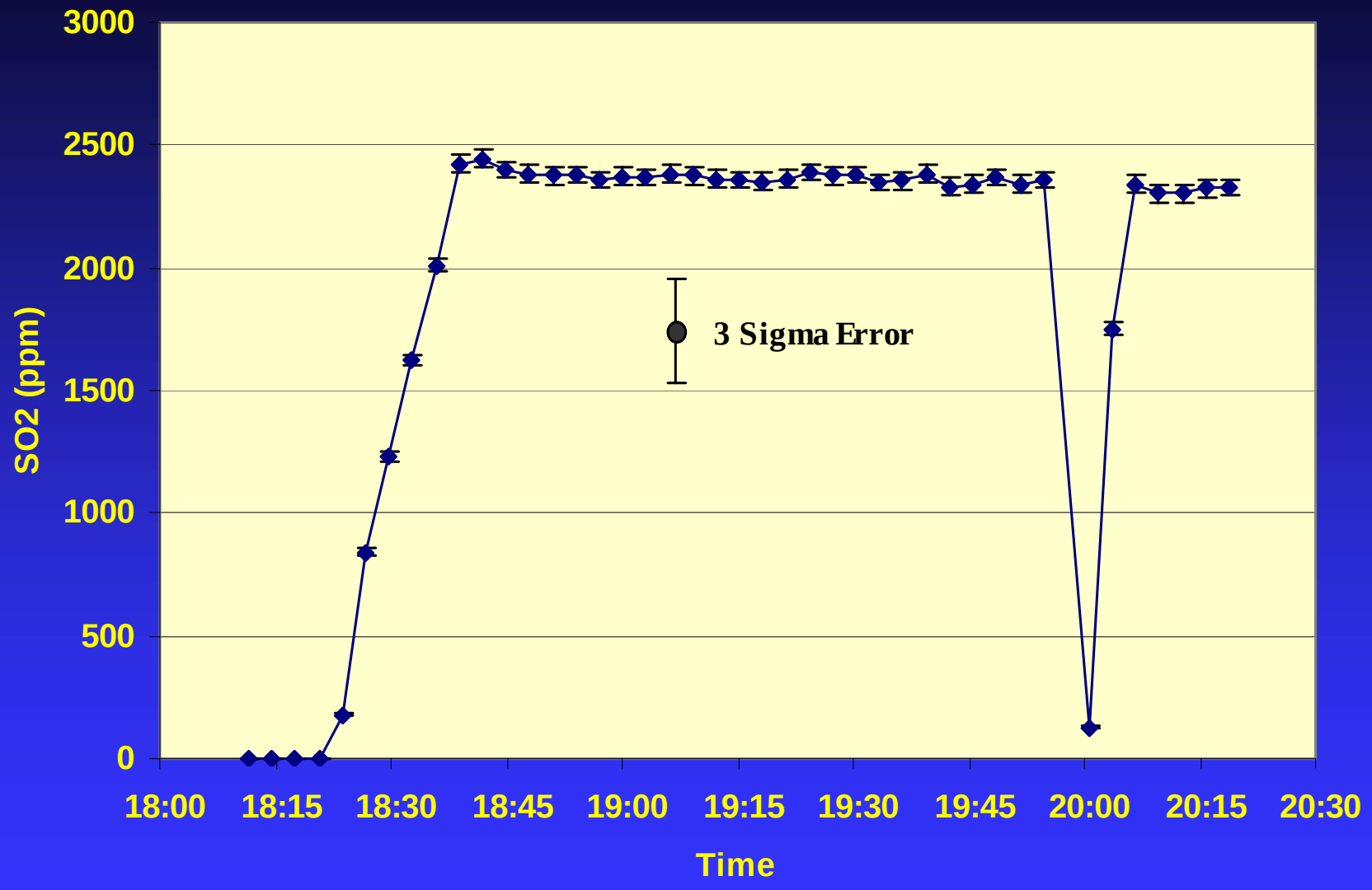
Observed NO Concentrations in SCR Output



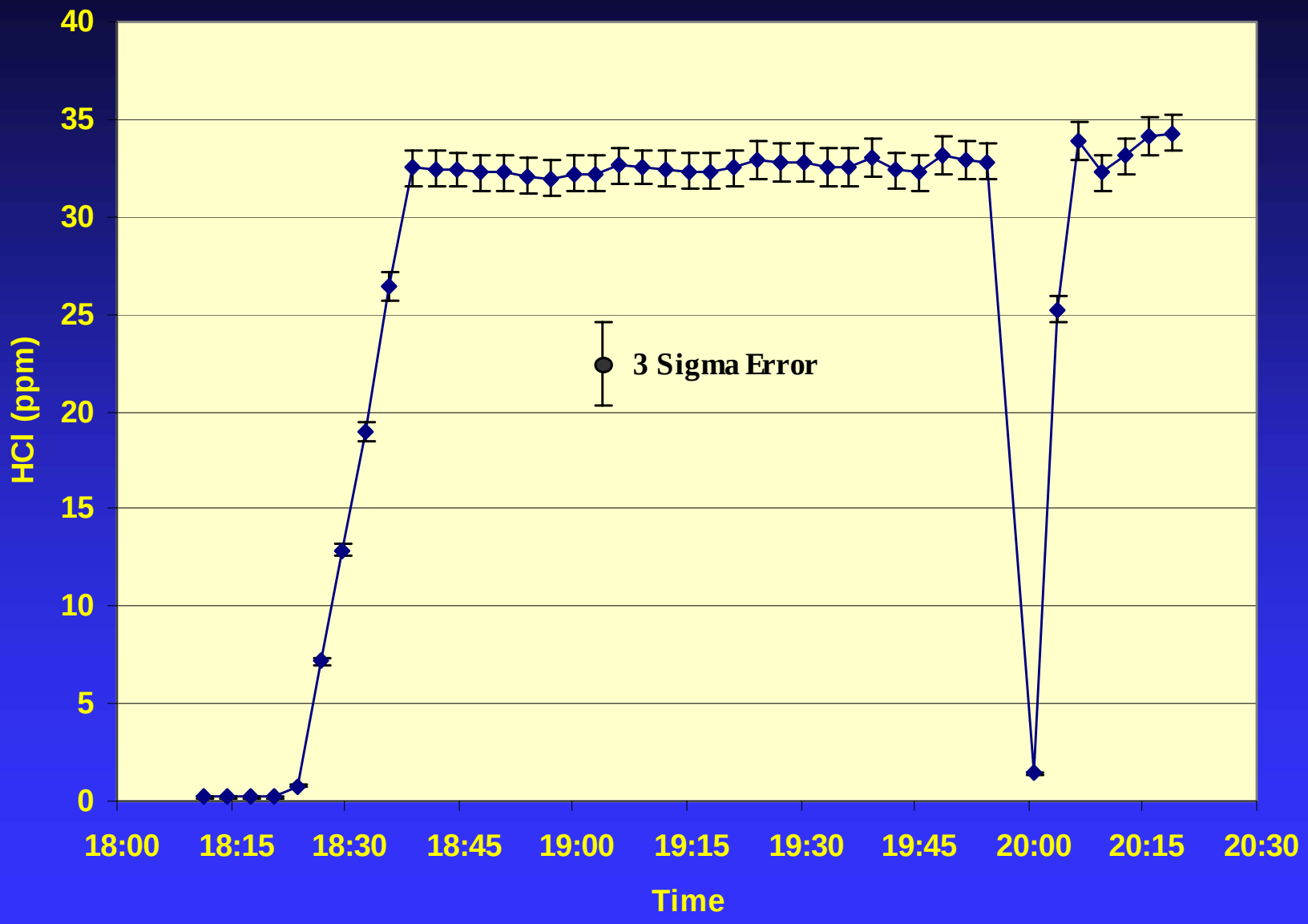
Observed Concentrations in SCR Output



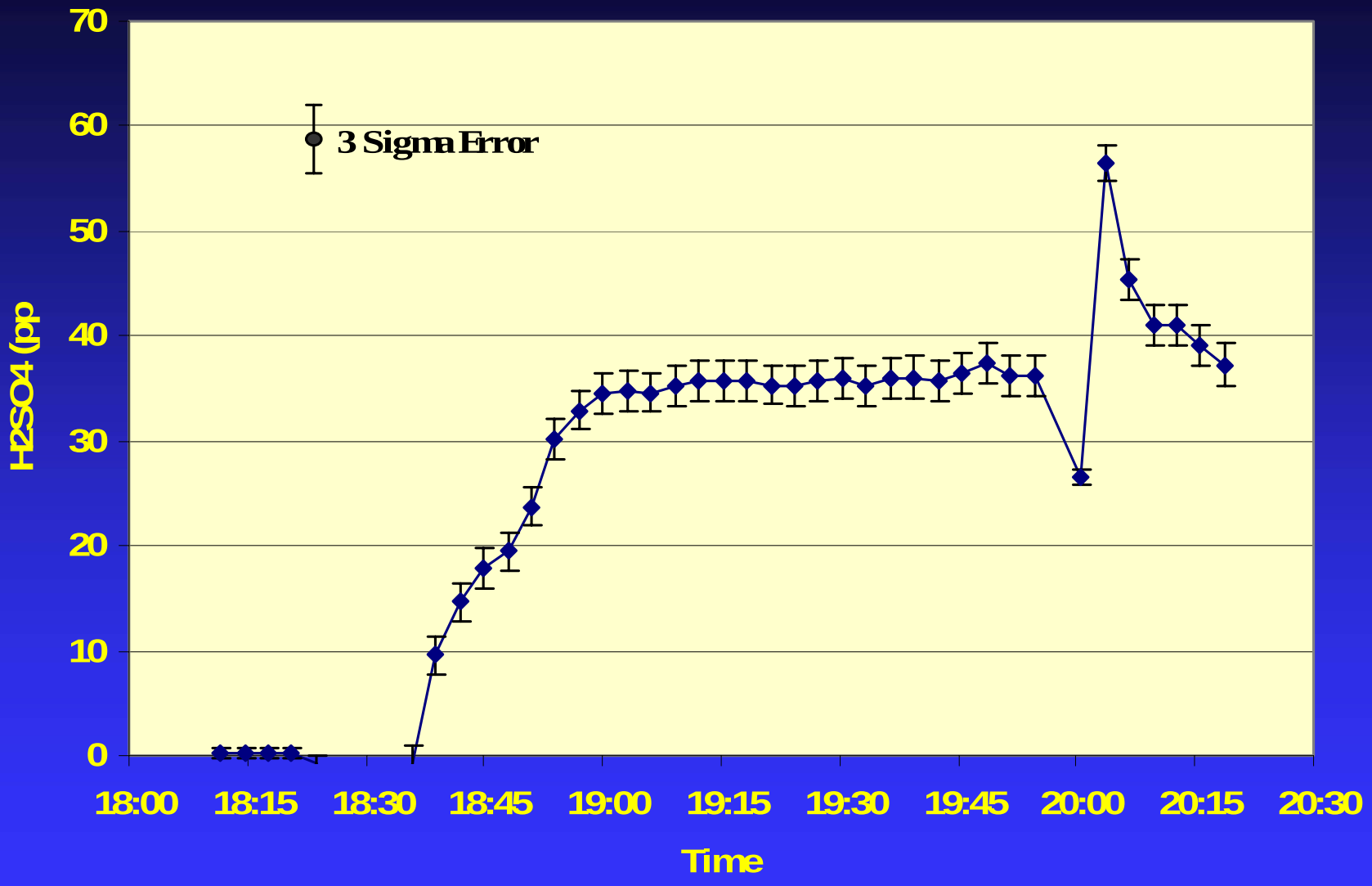
Observed SO_2 Concentrations in SCR Output



Observed HCl Concentrations in SCR Output



Observed H_2SO_4 Concentrations in SCR Output



EPRI Program
In-situ Monitoring

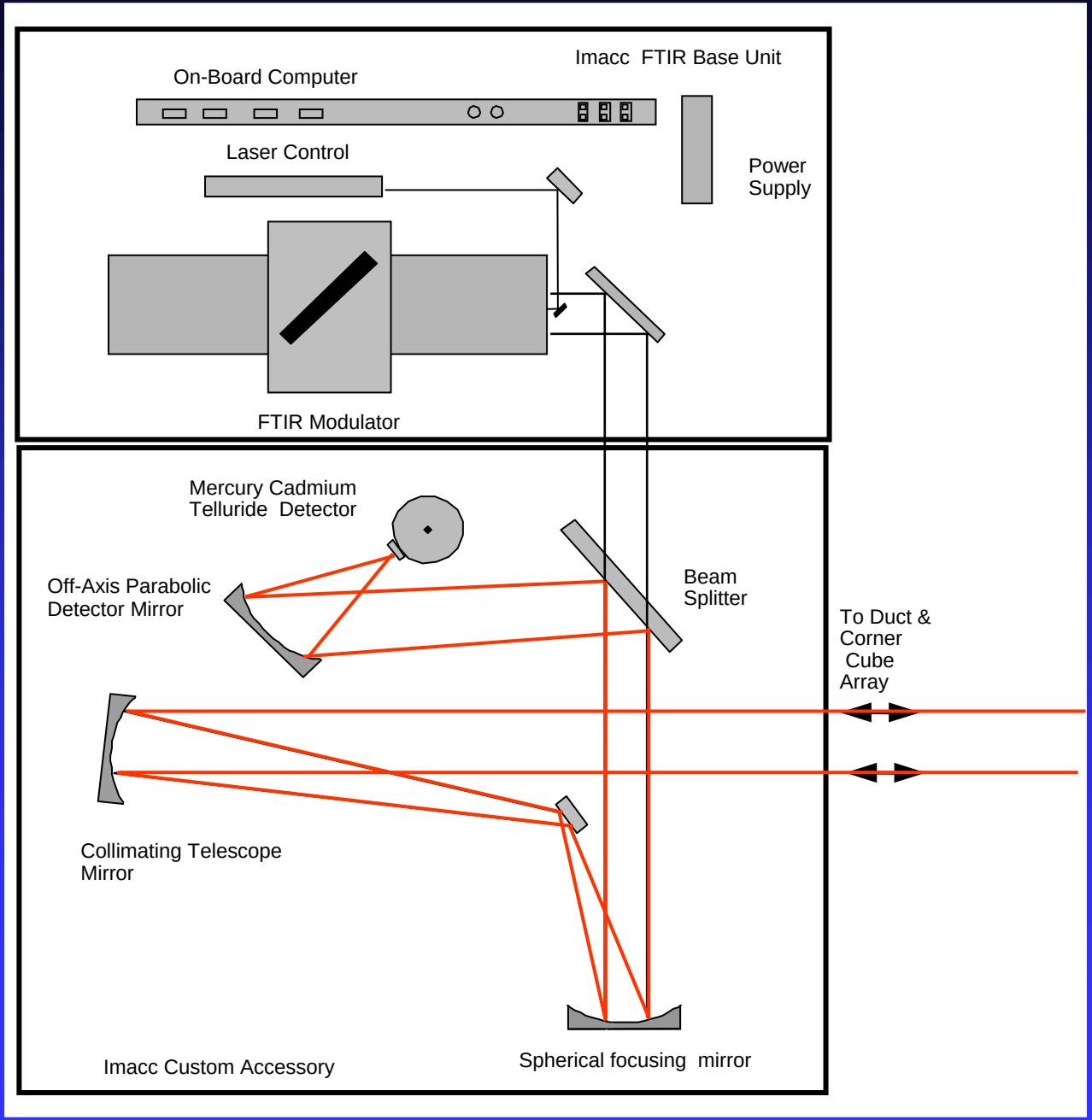
EPRI In-situ Measurement Program

- In-situ measurements are preferred for SO_3/H_2SO_4 because no contact with the sample is required
- However, particulate loading in ducts is very high limiting optical paths possible to a few inches
- EPRI contracted with Univ. of California at Riverside to develop an in-situ probe which would discriminate against particulates
- Tests to date indicate the probe can reduce particulate loading by 80% or more
- This allowed for measurements over 30 to 60 ft. in ducts - path lengths that are normally impossible

EPRI In-situ Measurement Configuration

- Configuration
  - Imacc Cross-stack unit coupled to in-situ probe
  - FTIR spectra analyzed for: SO_3, H_2SO_4, SO_2, HCl, NH_3, CO, CO_2, NO, NO_2, and H_2O
  - System initially set up for monostatic transmission measurements doubling the available path

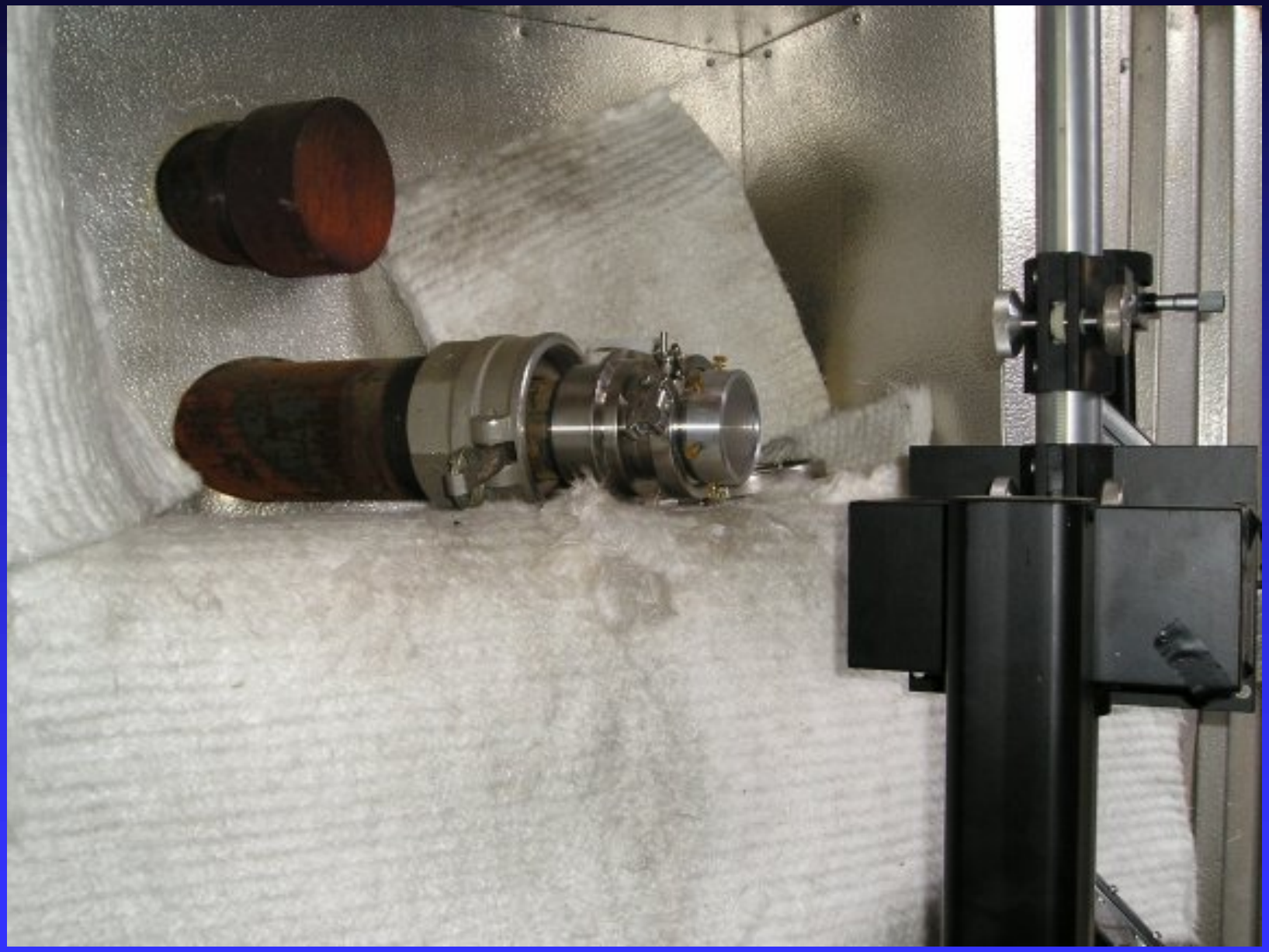
Imacc Monostatic Cross-Stack Unit



2.5” Corner Cube Mirror < 5 arc second accuracy

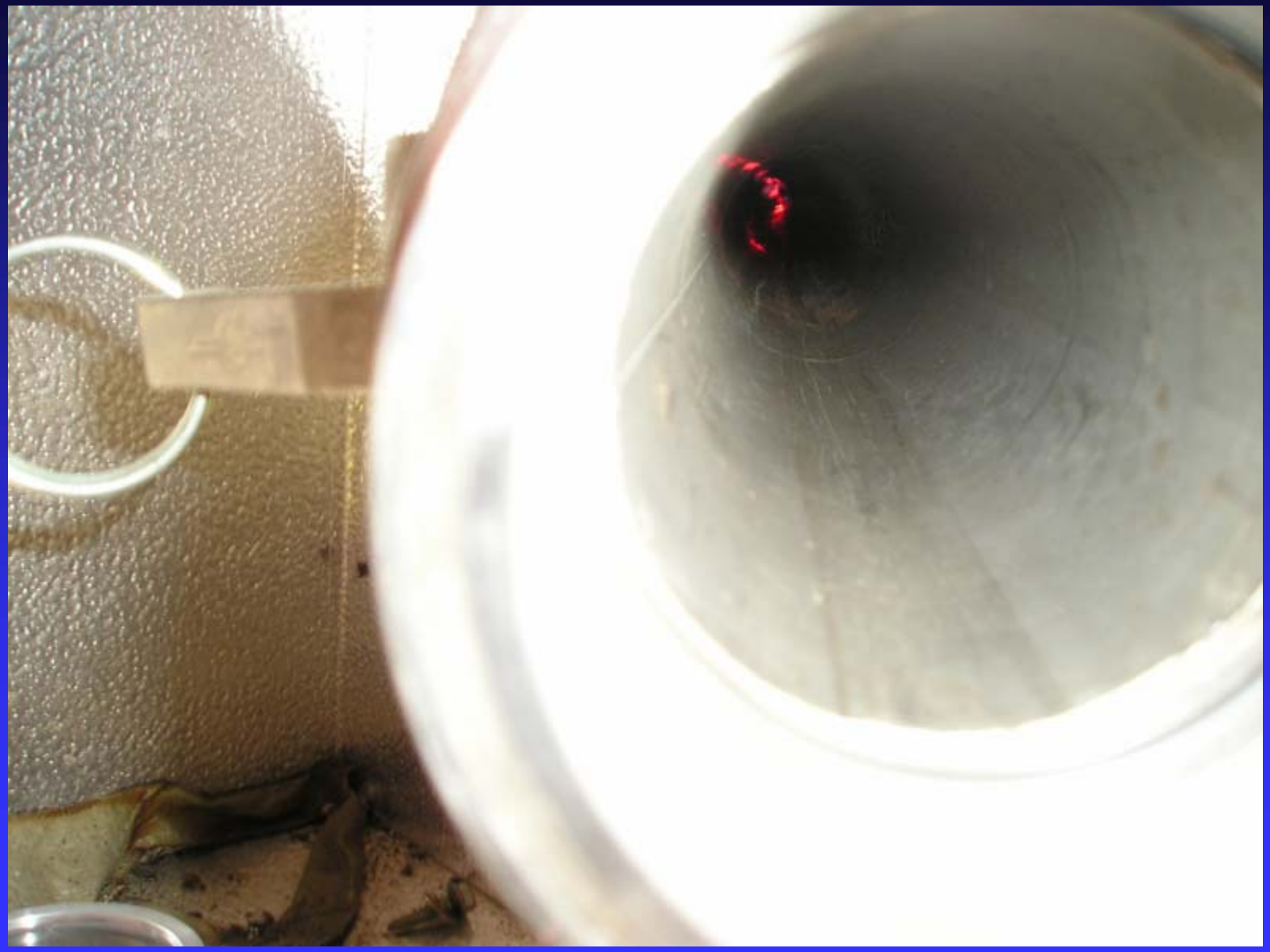
FTIR, Periscope, and Probe

Periscope, and Probe

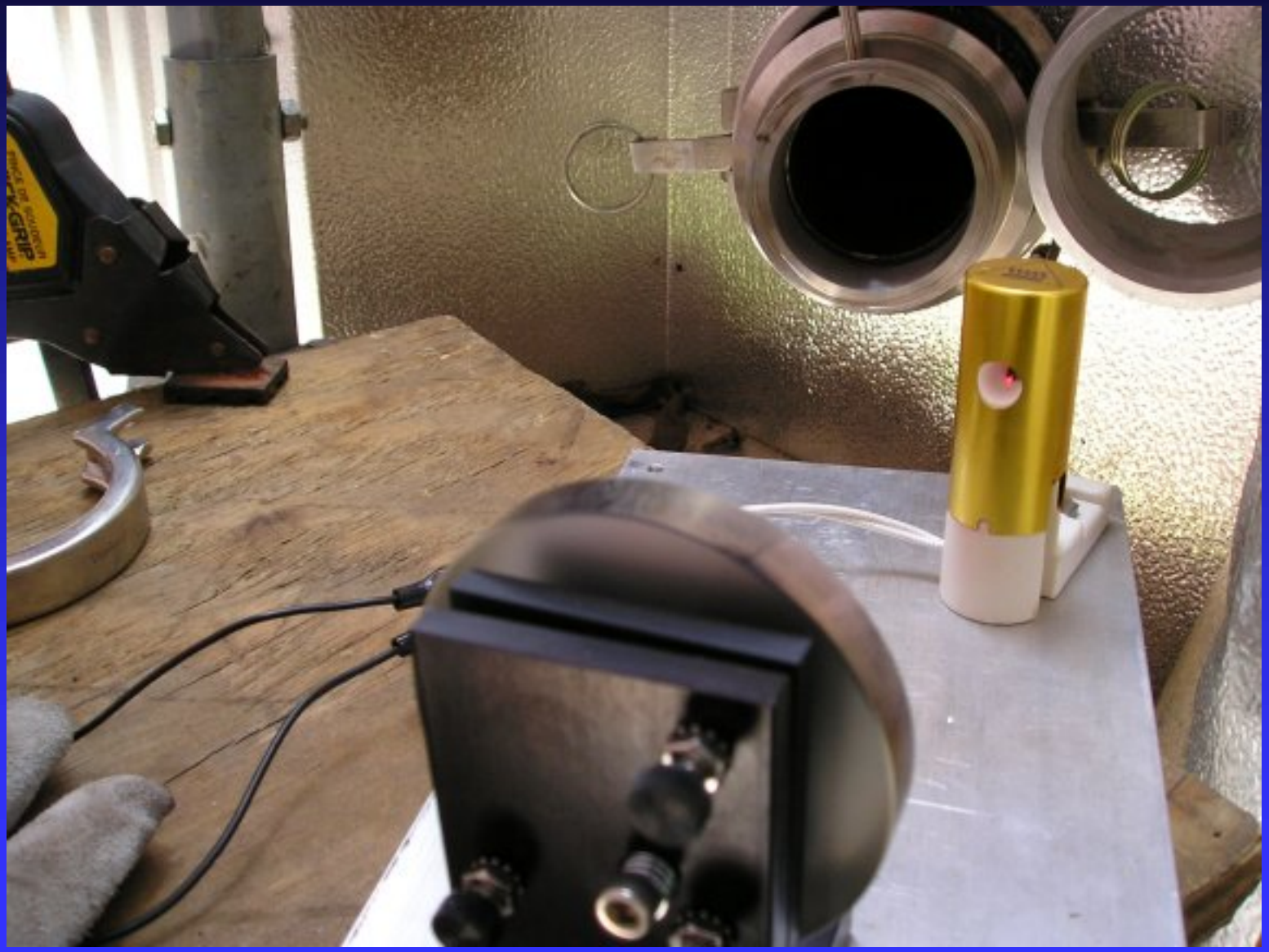


Cross-stack Probe Installation

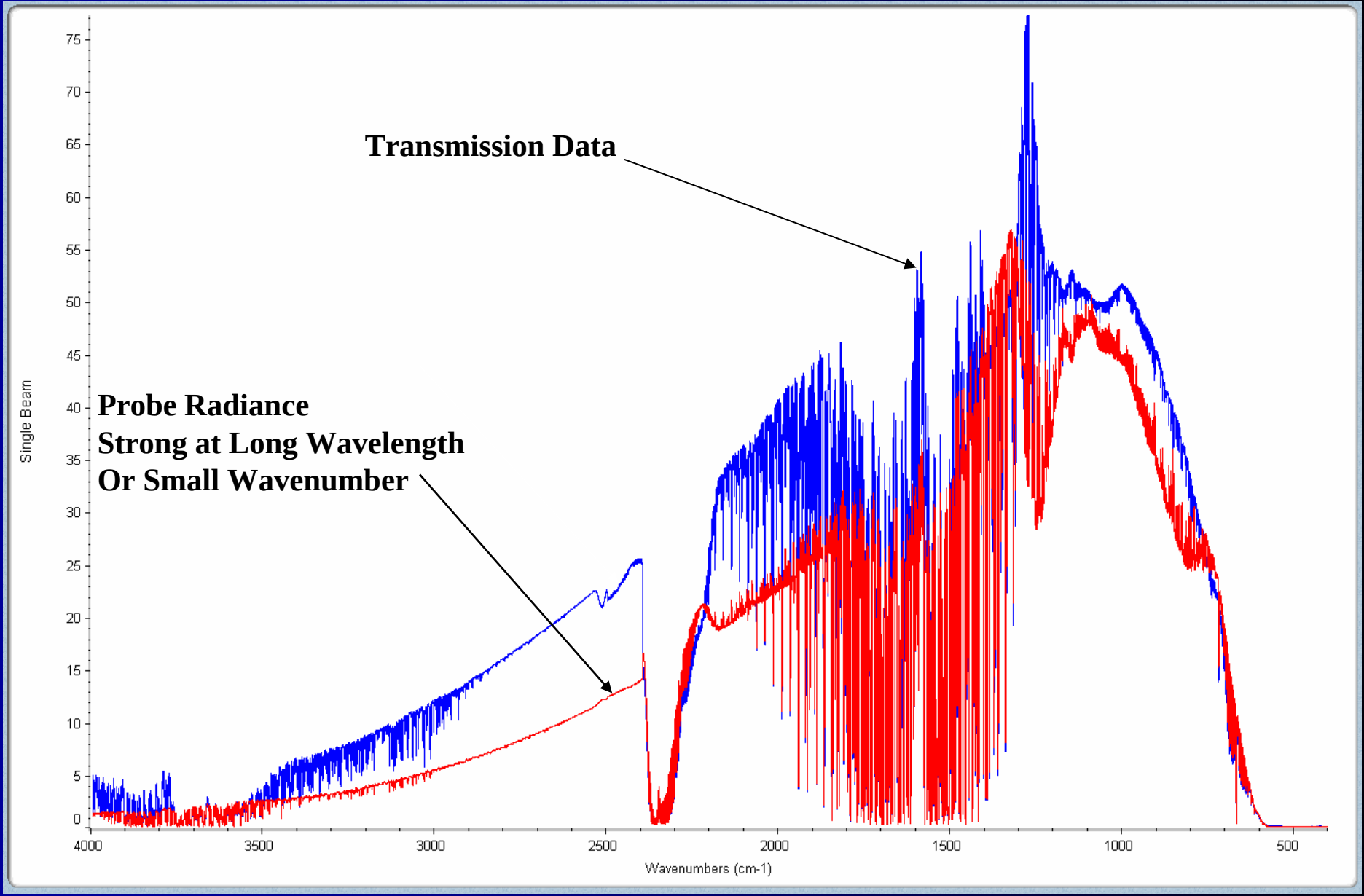
Curvature of Probe



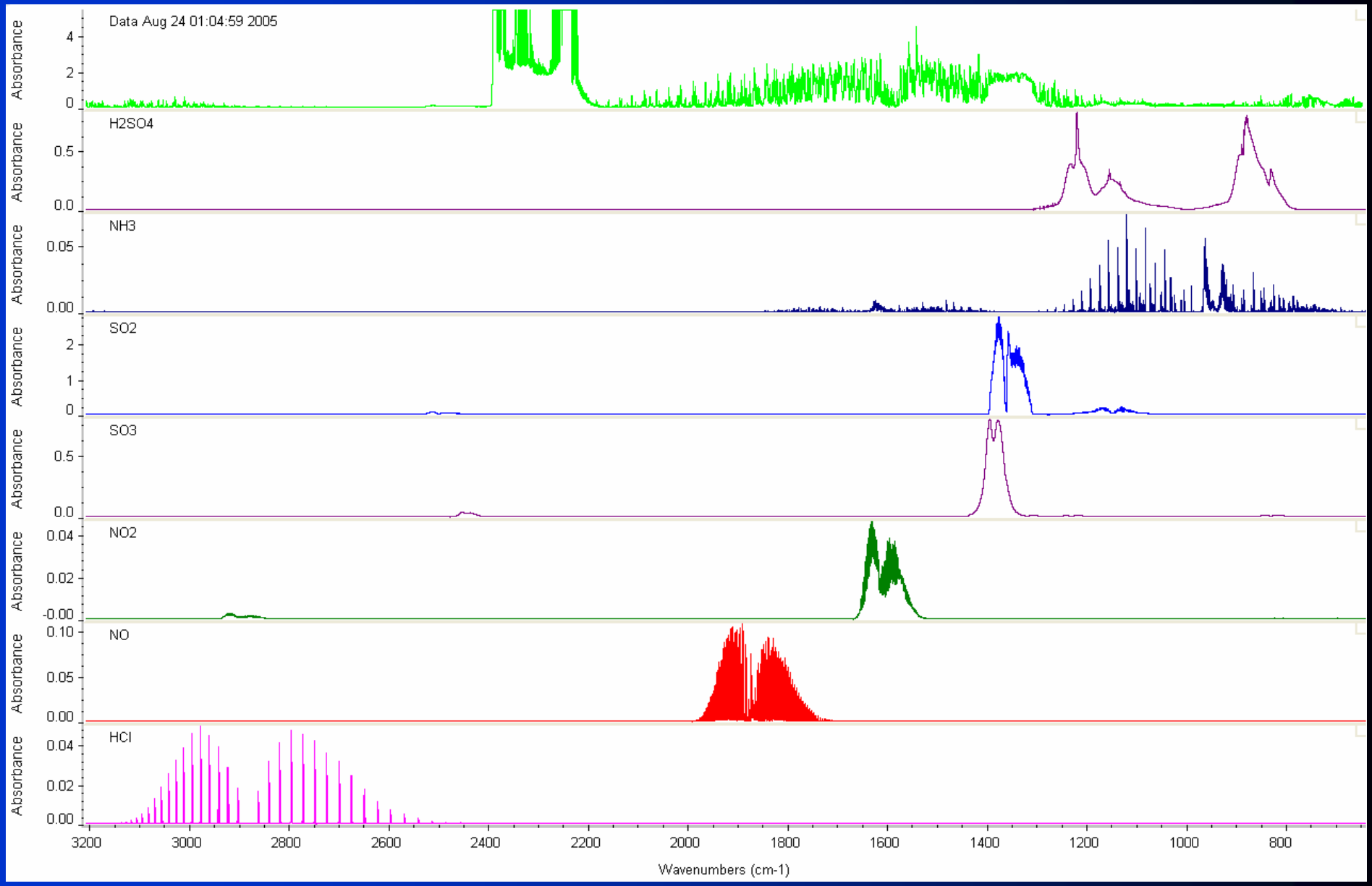
Source Used for Bistatic Configuration



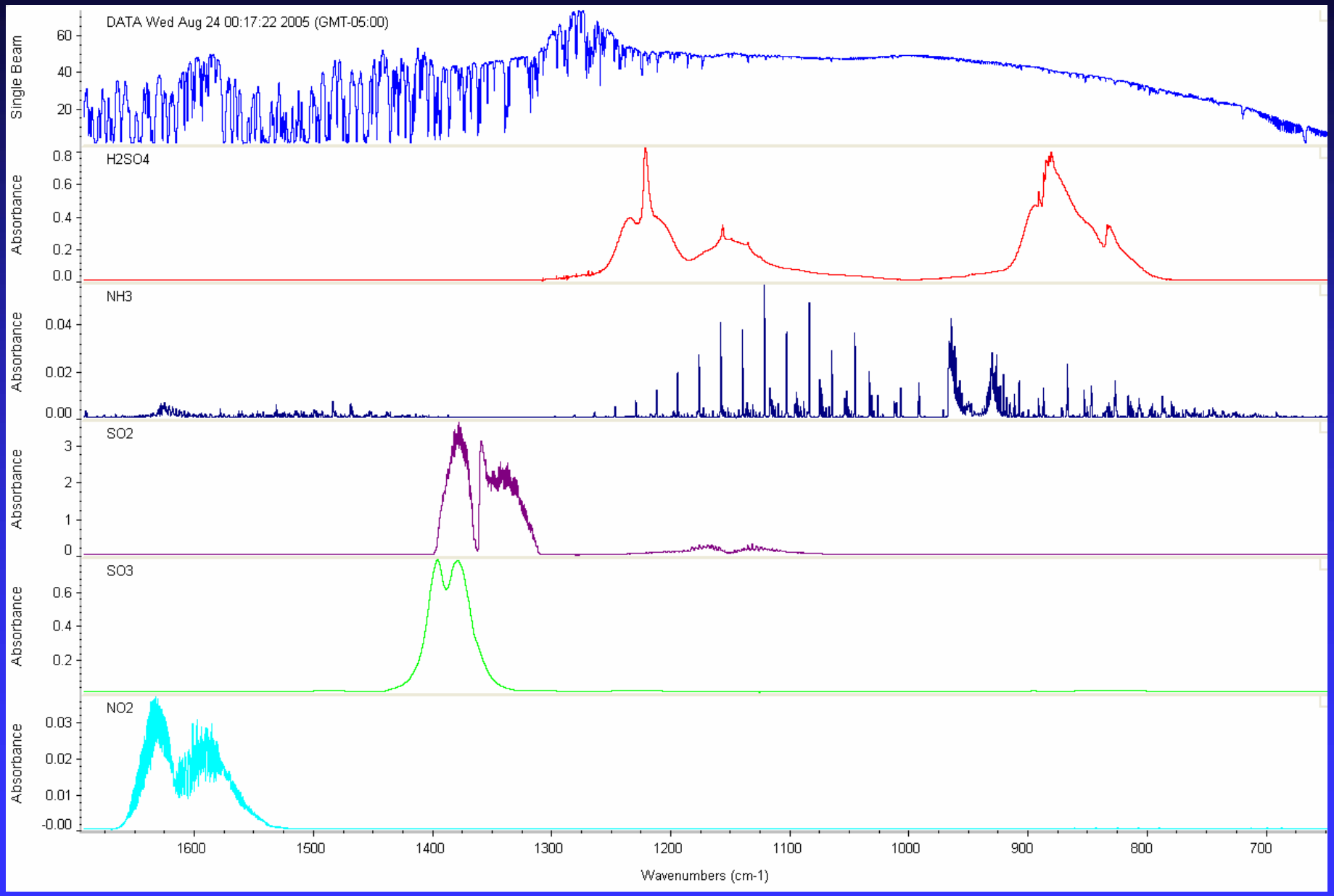
Spectra of Transmitted Infrared Source (Blue) Compared to The Background Radiance from The Probe Wall (Red)



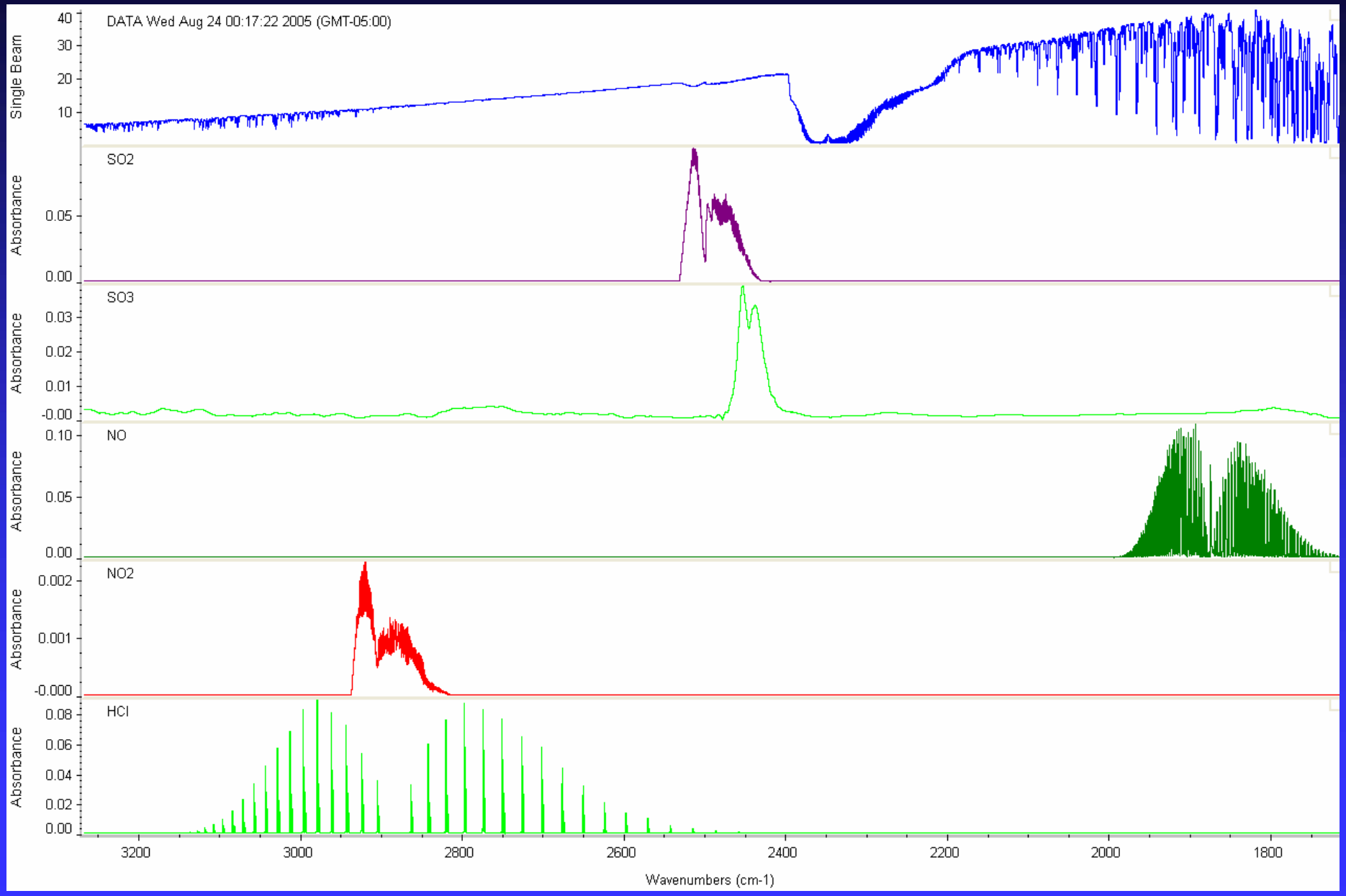
EPRI Program - Measured FTIR Data and References



EPRI Program - Measured FTIR Data and References



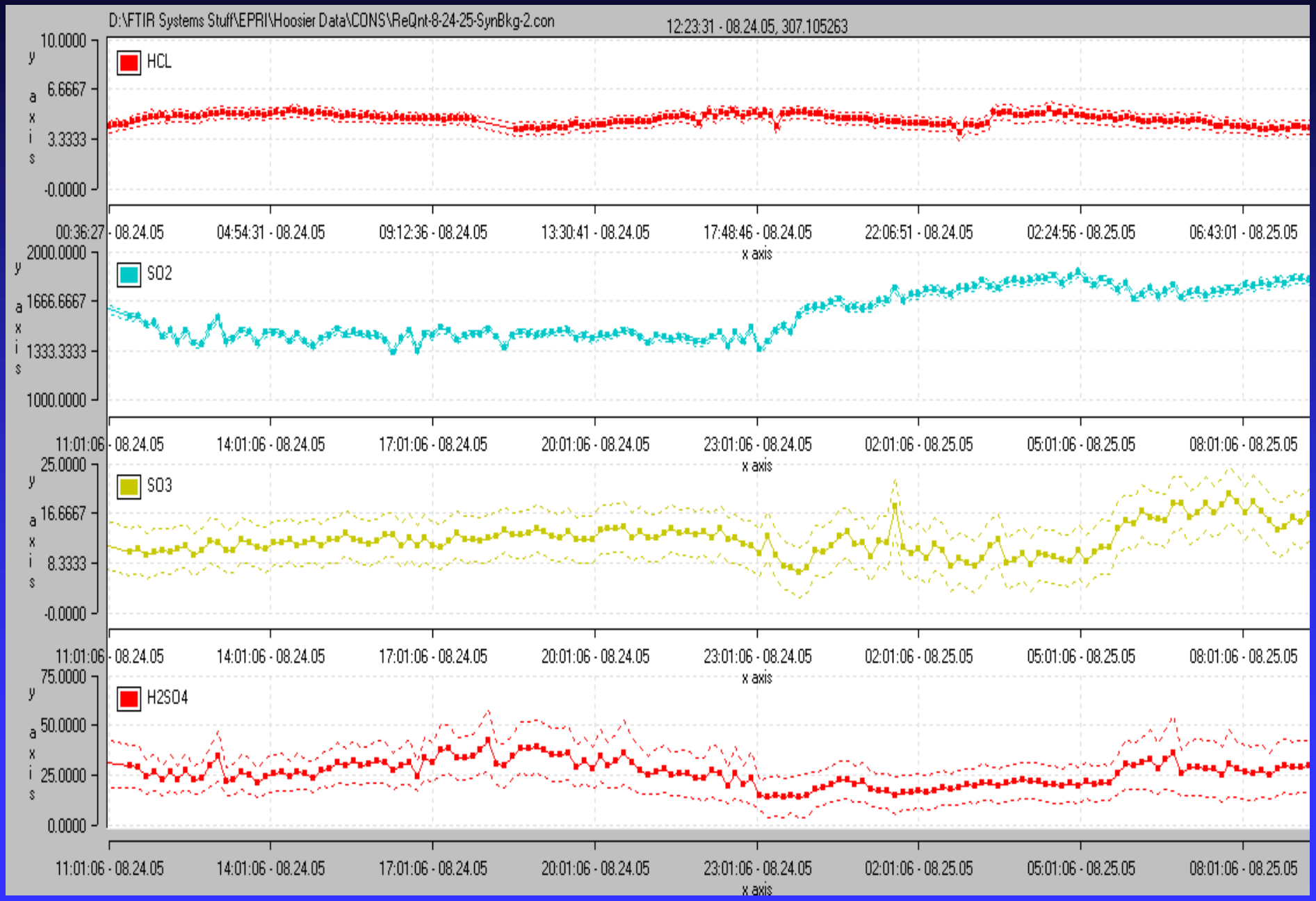
EPRI Program - Measured FTIR Data and References



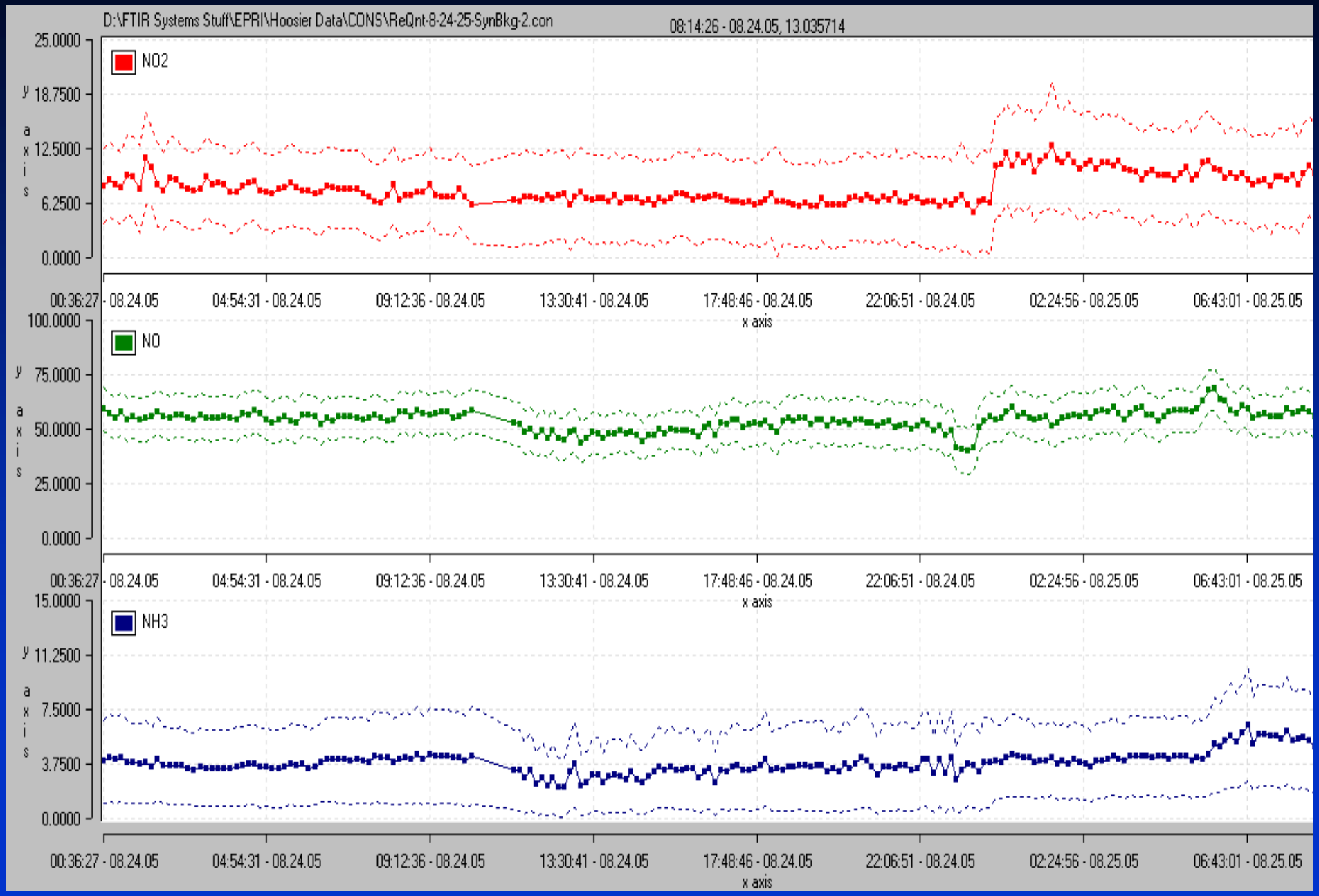
EPRI Program - Gas Concentration Data

Species	Measurement (ppmv)	Std Dev of Concentrations (ppmv)	Detection Limits Single Traverse (ppmv)
SO_3	16.9	4.0	~ 3
H_2SO_4	22.2	5.0	~ 4
NH_3	2.9	0.6	< 1
NO	65.8	4.3	~ 5
NO_2	7.7	0.9	~ 2
HCl	4.1	0.4	< 1

EPRI Program - Gas Concentration Data



EPRI Program - Gas Concentration Data



Controlled Condensate Data

EPRI Program - Intercomparison Data

		FTIR		
	Controlled Condensate	H2SO4	SO3	Total
10/25/05				
Concentration	33.61	25.98	11.35	37.33
St. Dev.	3.15	5.7	2.3	6.2
10/26/05				
Concentration	32.00	24.30	13.36	37.66
St. Dev.	3.4	5.4	3.5	6.4

EPRI Phase II Program

EPRI Program – Phase II

- Next phase to be conducted at Ameren's Sioux Station near St. Louis
- Probe now supported in slip fittings allowing for free expansion but no horizontal movement
- Duct width 32 ft. should provide an optical path of 64 ft (19.5 m).
- Primary objective: long term unmanned operation for assessment of maintenance issues
- Test to be 1 month long with option for a second month

EPRI Program – Phase II

"That's all Folks!"