



***Development of Computational Models
to Predict Boiler Tube Corrosion
in Advanced Combustion Systems***

Steven C. Kung

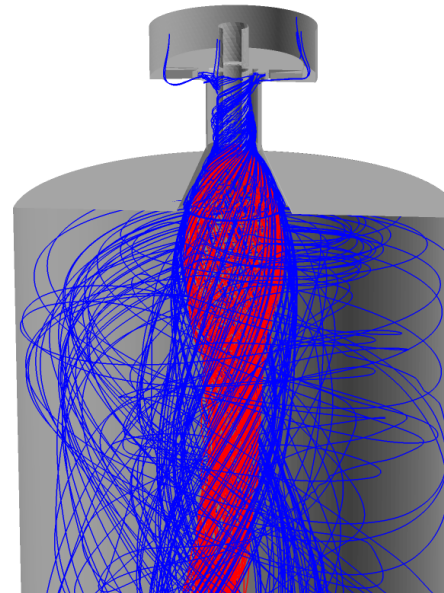
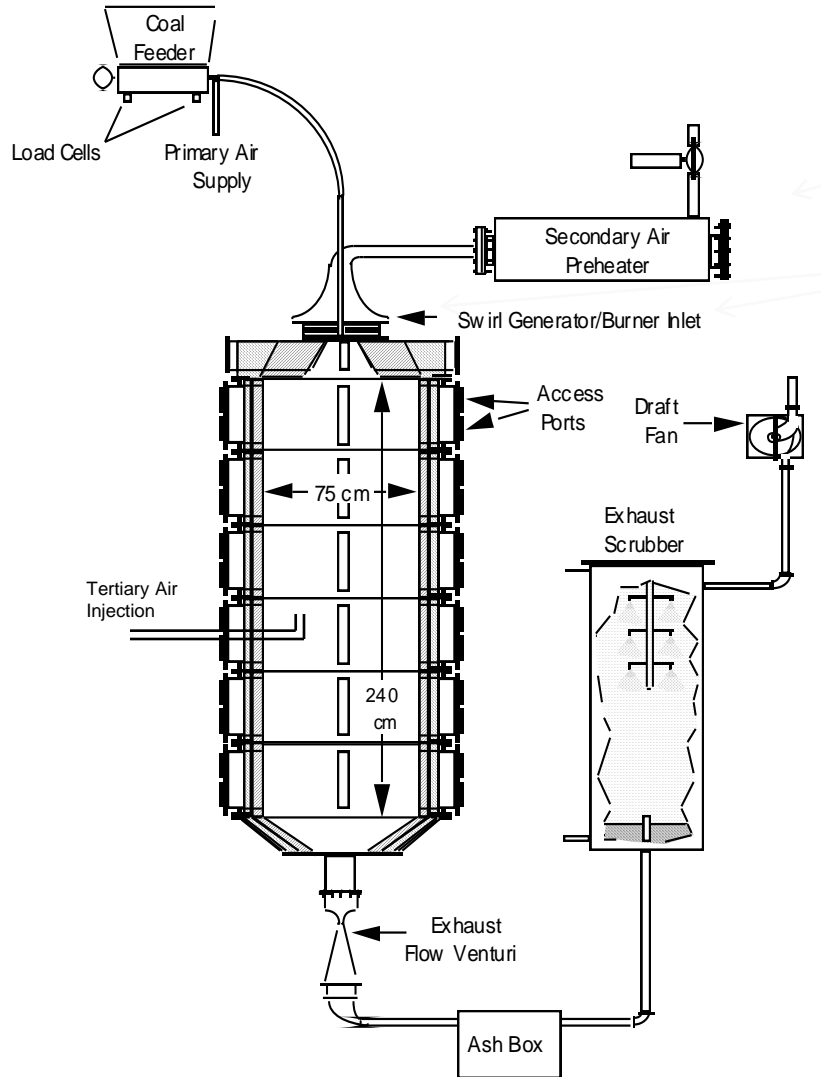
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Objectives

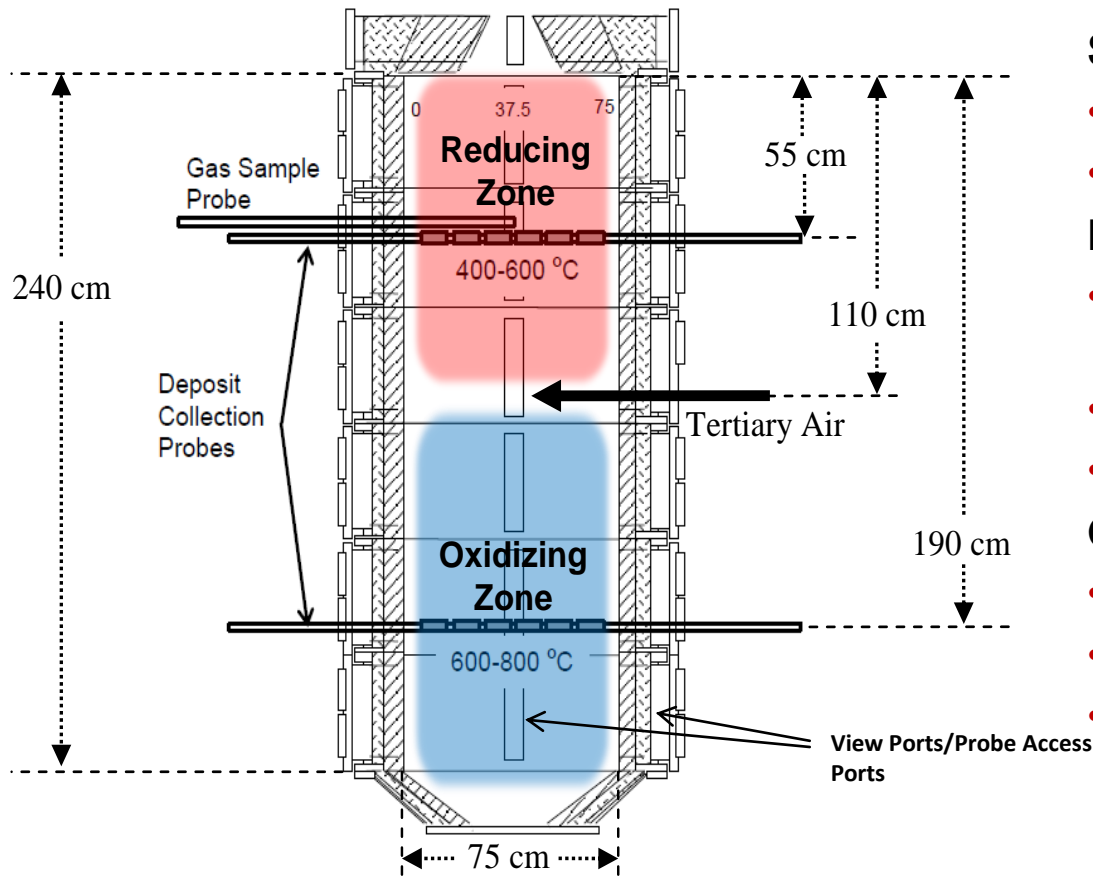
- To better understand corrosive environments in the lower and upper furnace of advanced coal-fired utility boilers.
 - Combustion of nine U.S. Coals in a pilot-scale testing facility under staged air combustion.
 - Online measurement of corrosive gaseous species and collection of ash deposits.
- To develop models and predictive equations for fireside corrosion on furnace walls and superheaters.
 - Perform laboratory corrosion tests under realistic conditions of staged coal combustion.
 - Analyze data and formulate corrosion models.

Pilot-Scale Combustion Facility with Variable Swirl Burner



- **Down-fired combustor**
- **Pulverized coal**
- **Variable swirl stabilized flame**
- **Staged air injection**

Gas and Deposit Sampling



Staged Combustion

- S.R. = 0.85 in burner zone
- S.R. = 1.15 in burnout zone

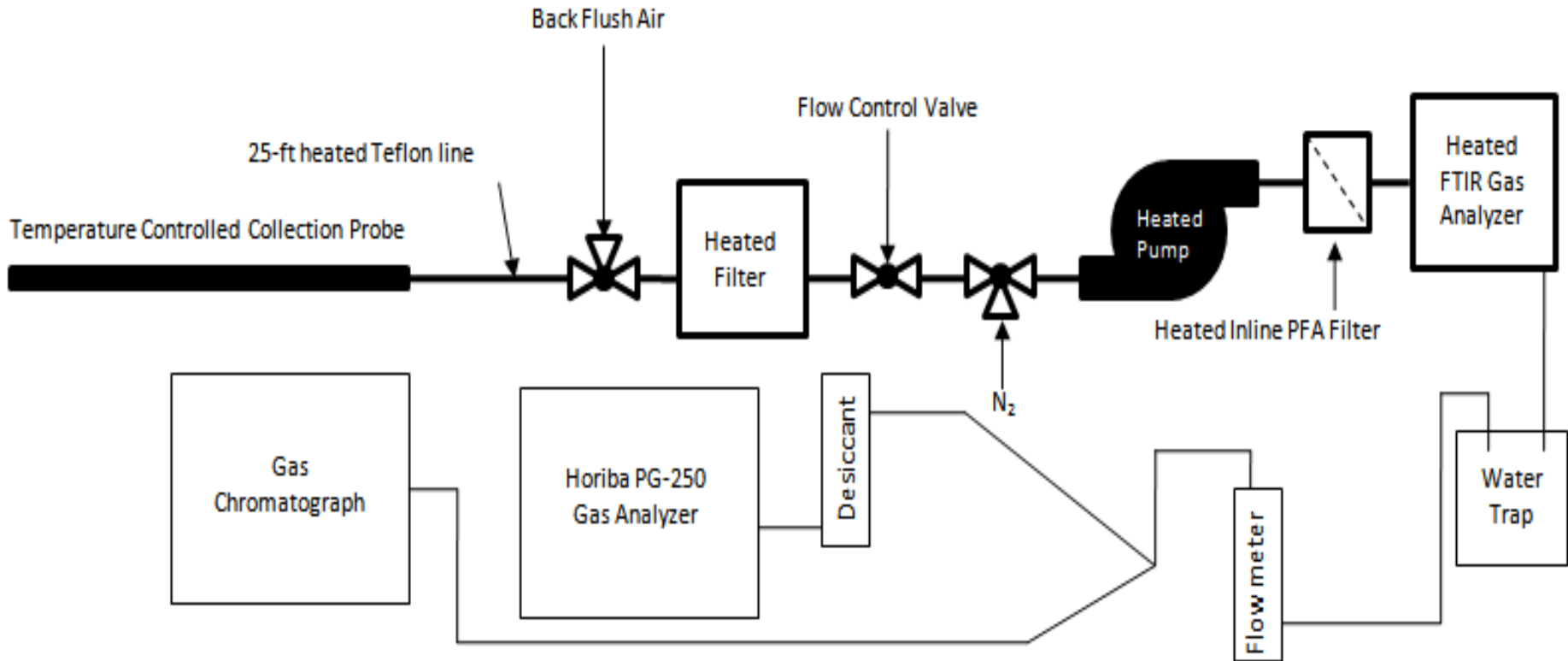
Deposit Sampling

- Water-cooled probe in burner zone
- Air-cooled probe in oxidizing zone
- Half-sleeves with TC's on probes

Gas Sampling

- Water-cooled outer jacket
- Heated Inner tube (180 °C)
- Heated sampling line (180 °C) from furnace to analyzers

Online Sampling Train for In-Furnace Gas Measurement



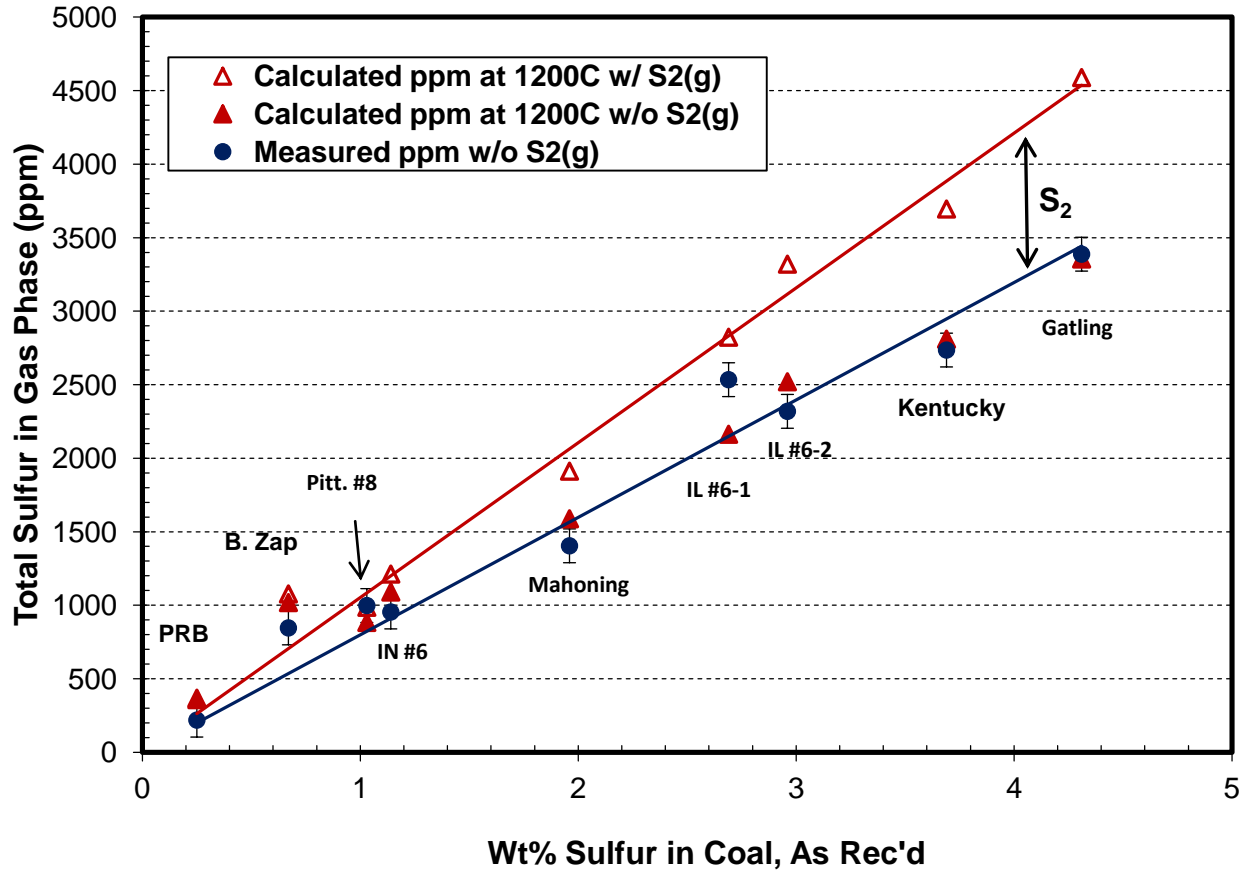
Chemistry of Nine U.S. Coals Studied

	ND B. Zap	WY PRB	IN #6 Gibson	OH Gating	IL#6-1 Galatia	IL #6-2 Galatia	KY #11	OH Mahoning	Pitt. #8
RANK	Lignite	Sub- Bit.	hvCb Bit	hvBb Bit	hvBb Bit	hvBb Bit	hvBb Bit	hvAb Bit	mvAb Bit
PROXIMATE ANALYSIS (ASTM D-5142), As Received (weight %)									
Moisture	27.33	24.59	7.25	3.77	5.40	3.68	3.39	2.22	1.05
Ash	8.66	5.14	7.20	11.34	8.65	10.45	8.46	9.92	10.45
Volatile Matter	33.77	37.00	30.87	40.73	35.68	33.70	36.97	40.79	18.61
Fixed Carbon	30.24	33.27	54.68	44.16	50.27	52.17	51.18	47.07	69.89
ULTIMATE ANALYSIS (ASTM D-5142 / 5373), As Received (weight %)									
Moisture	27.33	24.59	7.25	3.77	5.40	3.68	3.39	2.22	1.05
Hydrogen	2.03	2.55	4.02	4.07	3.74	3.14	4.34	4.18	3.86
Carbon	46.56	54.75	69.48	67.11	70.16	67.66	70.89	74.67	77.37
Nitrogen	0.86	0.83	1.36	0.94	1.04	0.95	1.23	0.93	1.44
Sulfur	0.67	0.25	1.14	4.31	2.69	2.96	3.64	1.96	1.03
Oxygen	13.89	11.89	9.55	8.46	8.32	11.16	8.05	6.12	4.80
Ash	8.66	5.14	7.20	11.34	8.65	10.45	8.46	9.92	10.45
Chloride*	0.001	0.001	0.212	0.039	0.389	0.283	0.206	0.199	0.0045
HEATING VALUE (ASTM D-5865), (Btu/lb)									
Heating Value	7,792	9,156	12,400	12,191	12,575	12,464	12,905	13,404	13,715

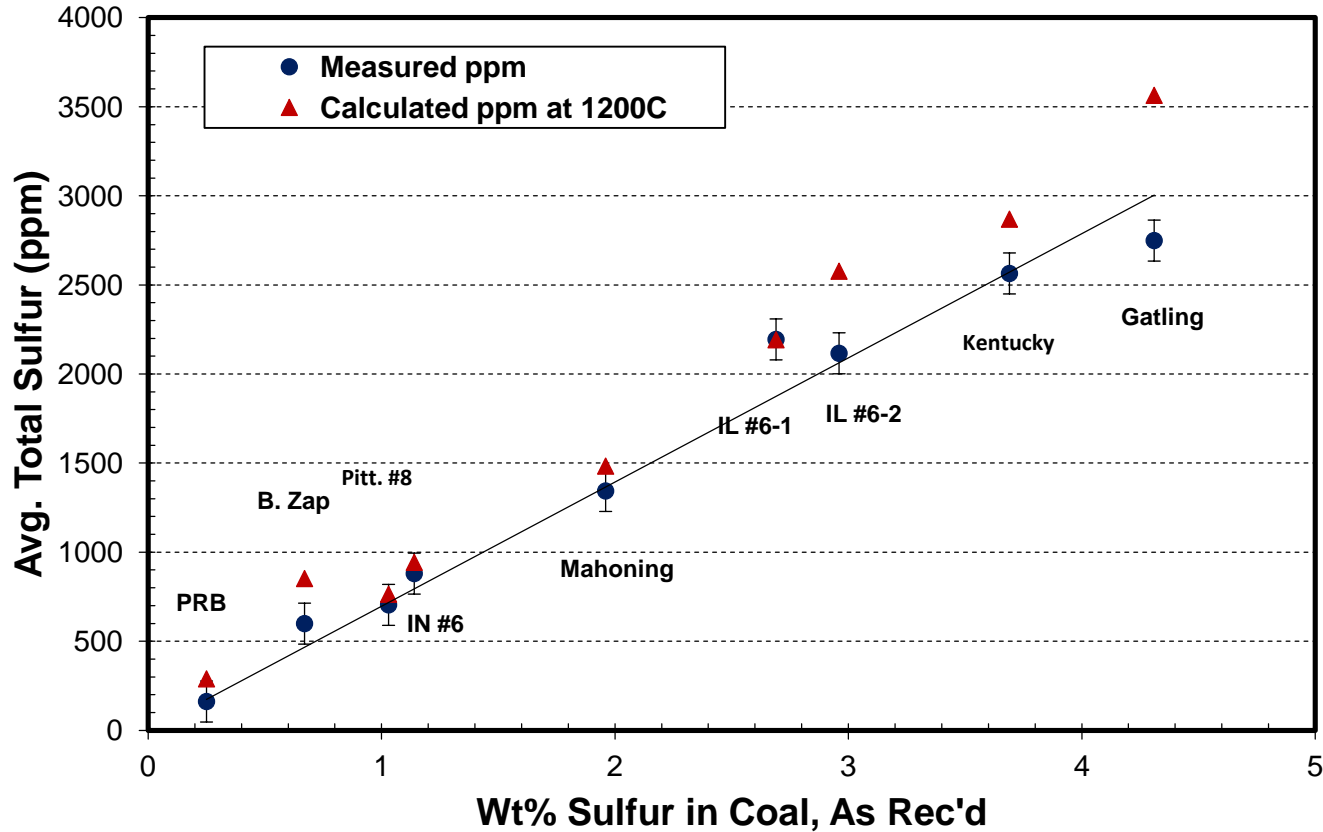
babcock & wilcox power generation group



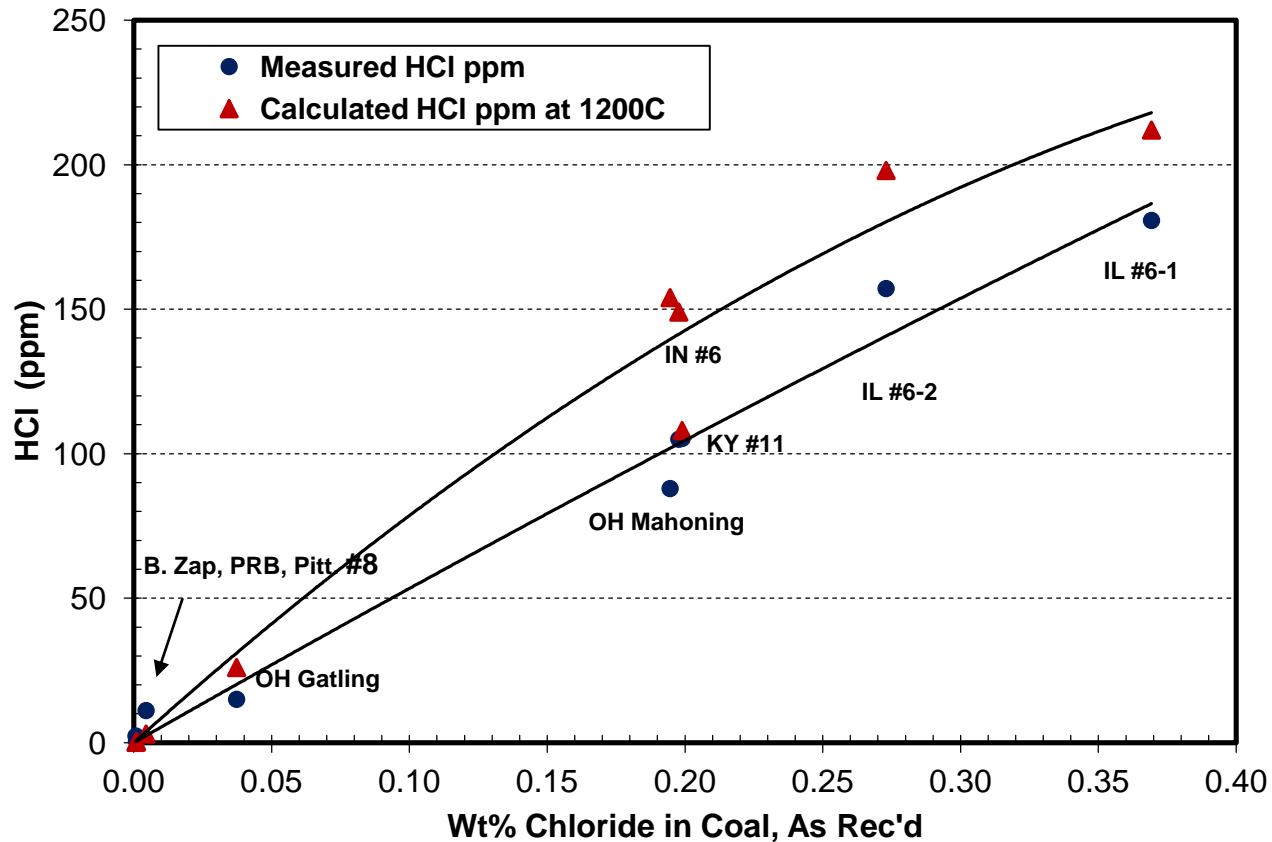
Measured and Calculated Total Sulfur-Bearing Gases in Reducing (Burner) Zone



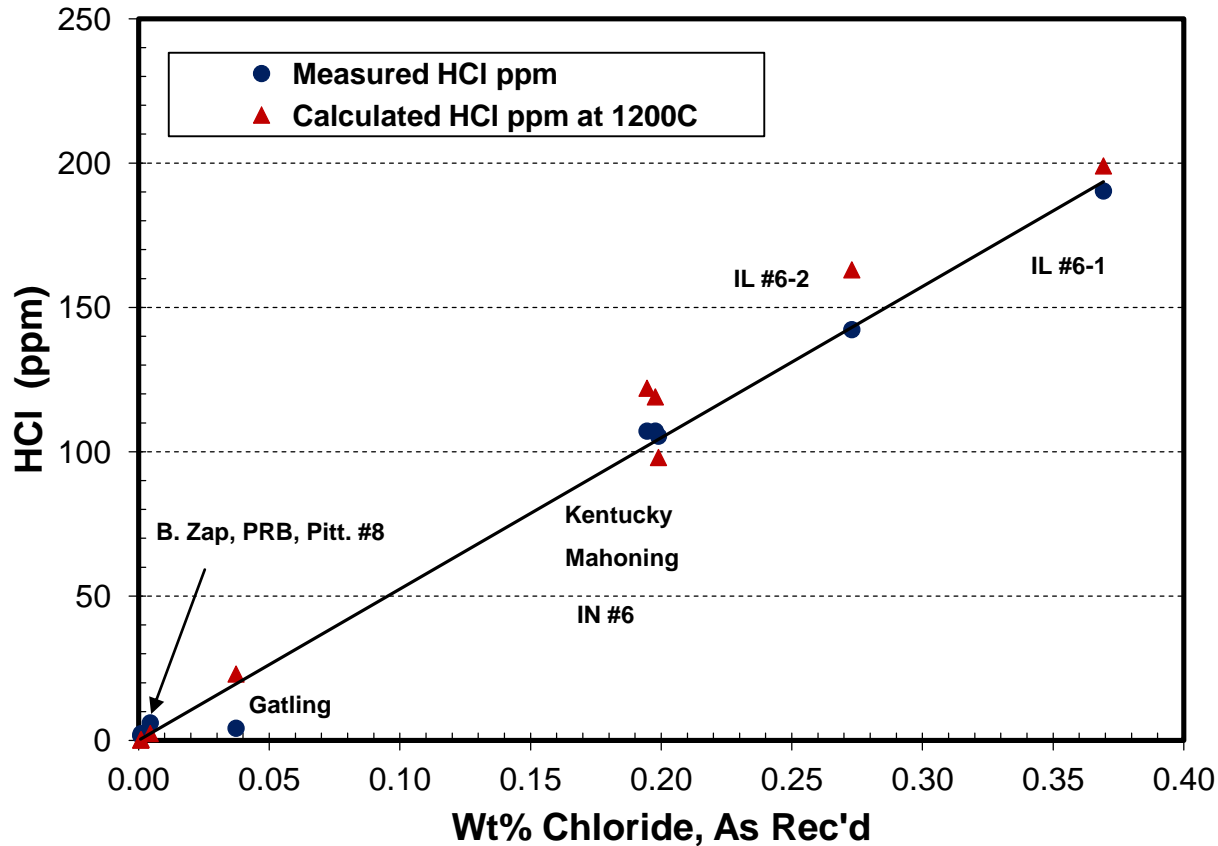
Measured and Calculated Total Sulfur-Bearing Gases in Oxidizing Zone



Measured and Calculated HCl in Reducing (Burner) Zone



Measured and Calculated HCl in Oxidizing Zone



- Chlorine is fully released to form HCl in oxidizing zone.

Laboratory Fireside Corrosion Testing (1000 hours each)



Materials Evaluated in Laboratory Corrosion Tests

Oxidizing Conditions

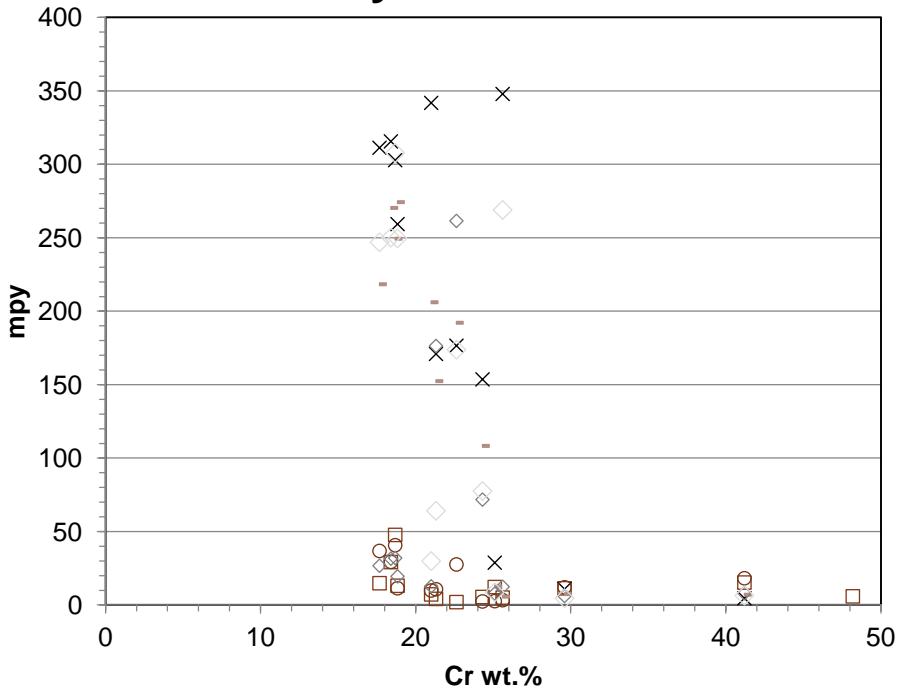
	304H	S304H	310HCbN	230	347HFG	347H	WO72	WO52	671	740	617	120	800H
Ni	11	8.73	19.97	59.5	11.98	10.42	47.2	56.3	50.7	49.45	53.2	37.3	32.7
Cr	18.83	18.68	25.61	21.31	18.4	17.67	>41.2	29.6	48.19	24.31	22.63	25.1	21.0
Fe	Bal	67.6	Bal	1.25	Bal	68.4	10.6	12.2	0.078	1.02	0.76	34.7	Bal.

Reducing Conditions

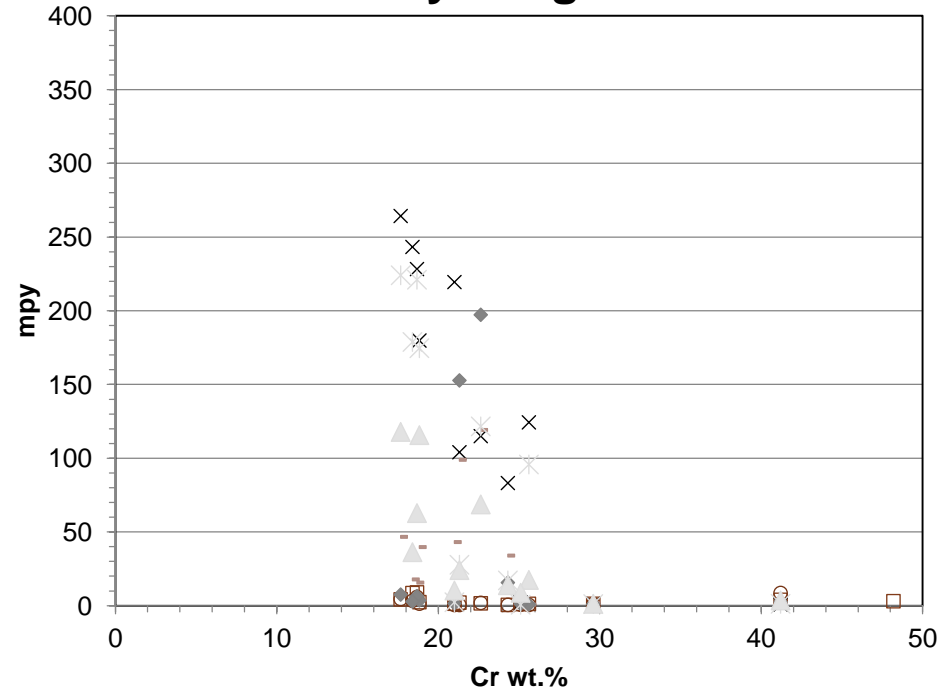
	T2	304H	T11	T22	T23	F9	F91	WO52	WO72	309	310	CS
Ni		11	0.04	0.13		0.14	0.14	56.3	47.2	12.48	19.37	0.02
Cr	0.56	18.83	1.29	2.41	2.18	2.30	8.15	29.6	>41.2	22.34	25.45	0.03
Fe	Bal	Bal	BAL	Bal	Bal	Bal	Bal	12.2	10.6	Bal	Bal	Bal

Conditions for Laboratory Tests Performed Oxidizing (Superheaters/Reheaters), 1300°F

By Thickness

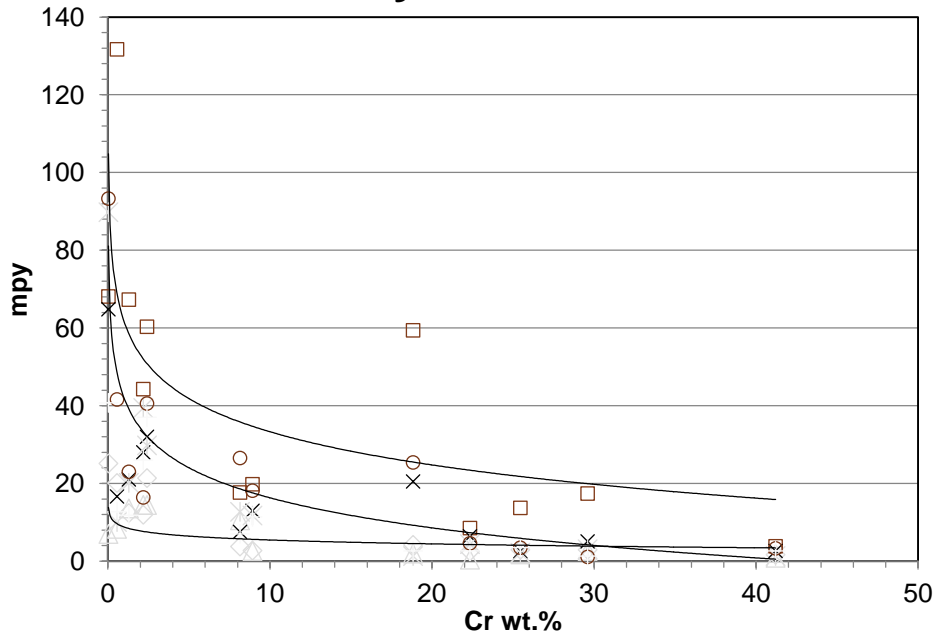


By Weight

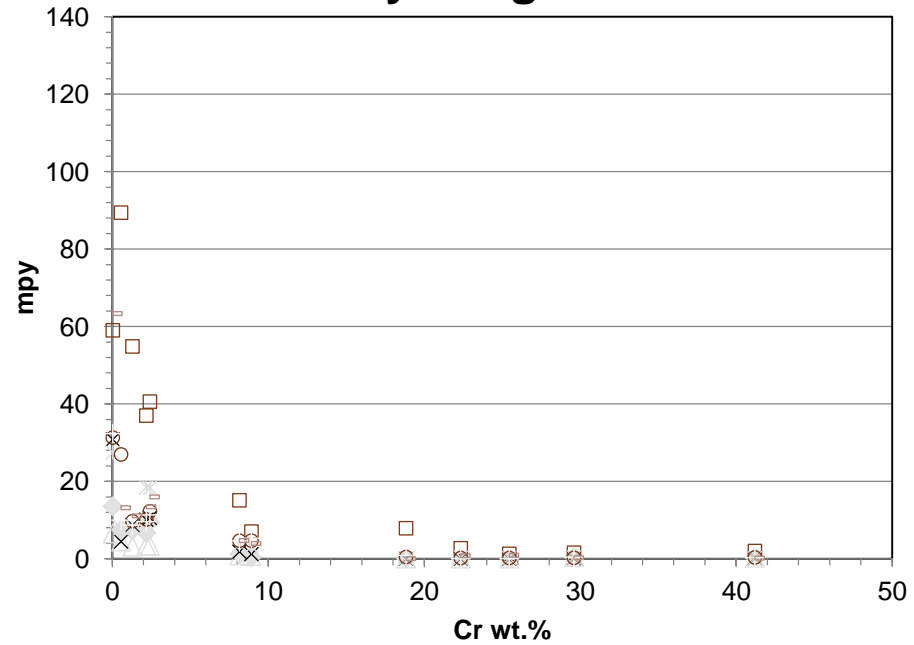


Conditions for Laboratory Tests Performed Reducing (Lower Furnace Walls), 850°F

By Thickness

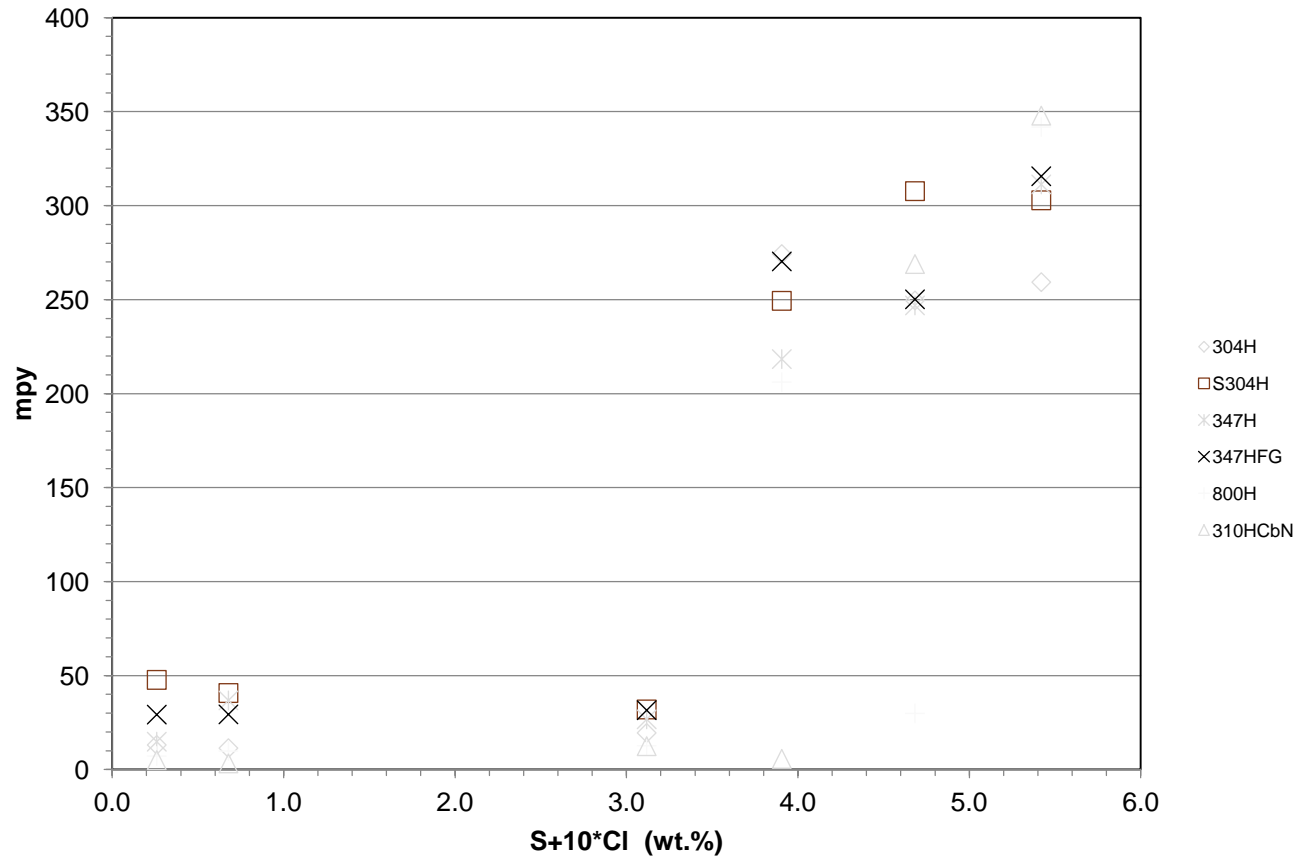


By Weight

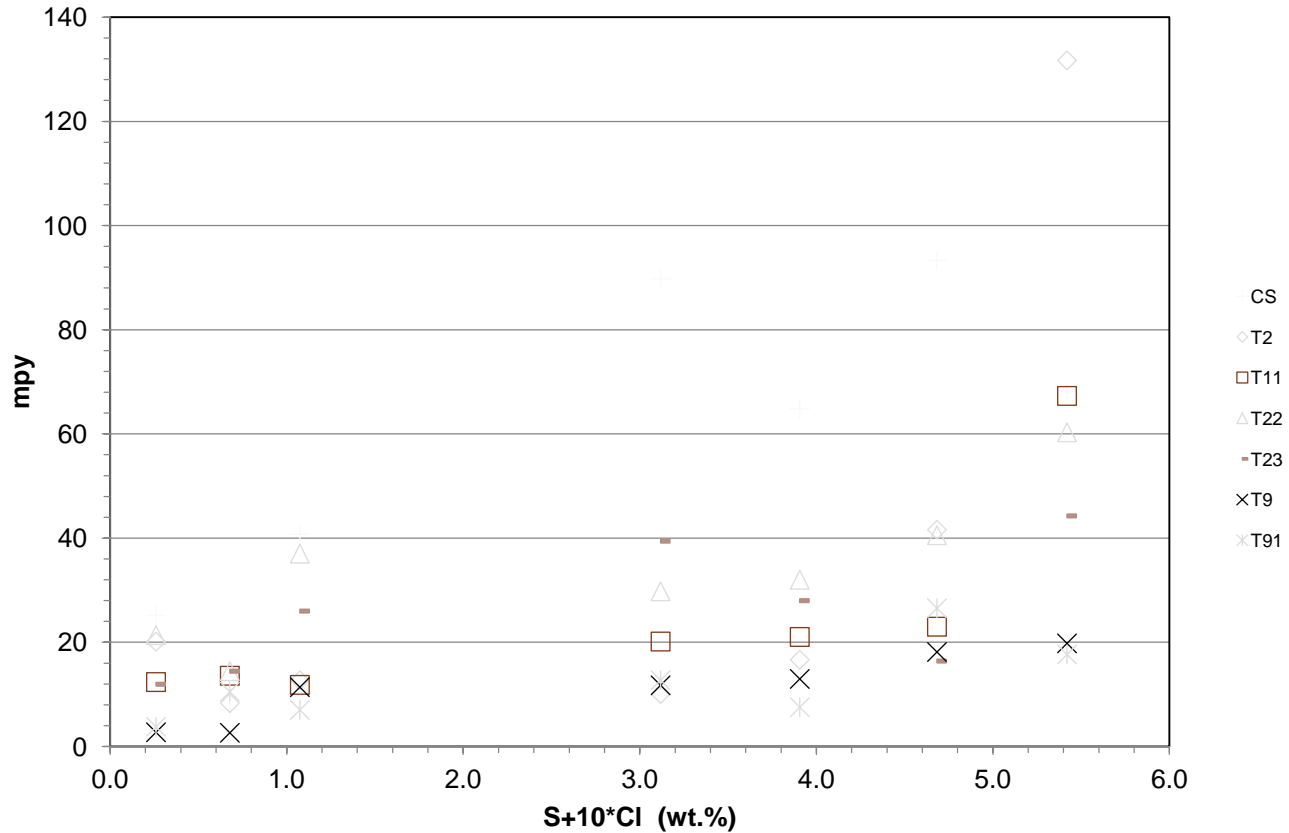


Laboratory Test Results

Oxidizing (Superheaters/Reheaters), 1300°F



Laboratory Test Results Reducing (Lower Furnace Walls), 850°F



Summary

- Pilot-scale combustion tests and gas/deposit analyses completed; extensive new knowledge gained:
 - Coexistence of reducing and oxidizing gaseous species → **non-equilibrium confirmed.**
 - Coal sulfur released quickly to form gases → **independent of sulfur forms in coal.**
 - Coal chlorine also released quickly but slightly behind sulfur.
 - Formation of iron sulfide and iron sulfate from iron oxides via gas-solid reactions.
- Majority of laboratory tests completed:
 - Results agree with expectation.
 - Sulfur, chlorine, deposit, and alloy all play important roles in fireside corrosion but via different mechanisms.
- Intensive modeling effort underway.

Acknowledgement

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- NETL project managers: Vito Cedro