Infrared Emission Based Temperature Sensor

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Infrared Emission Based Temperature Sensor

- In natural gas flames, infrared emission originates from CO_2, H_2O, CO, and CH_4 molecules

- Infrared emission can be used to sense the temperature and concentrations of the emitting species

- Effects of turbulence and inhomogeneous paths must be considered.

P U R D U E

Accomplishments Laboratory Study

- Infrared (IR) radiation model to find inverse temperatures within 20 K and species concentrations within 15% was established

- IR temperatures were within 20 K of thin filament pyrometer temperatures for laminar flames

- IR temperatures were within 100 K of thin filament temperatures for turbulent flames.

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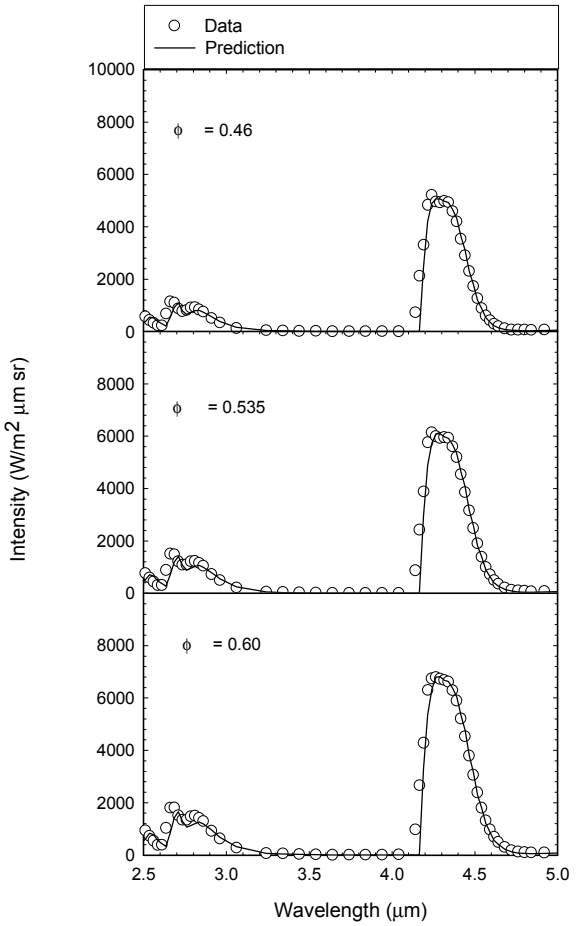
Emission Spectroscopy Data



1. Predictions using RADCAL are in excellent agreement with measurements

2. Temperature and CO_2 and H_2O concentrations can be inferred from radiation intensity data

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Comparison of ES and TFP

ϕ	0.46	0.535	0.60
ϕ_{ES}	0.48	0.533	0.59
T_{TFP} (K)	1388	1503	1596
T_{ES} (K)	1395	1498	1558
T_{ADB} (K)	1402	1499	1600

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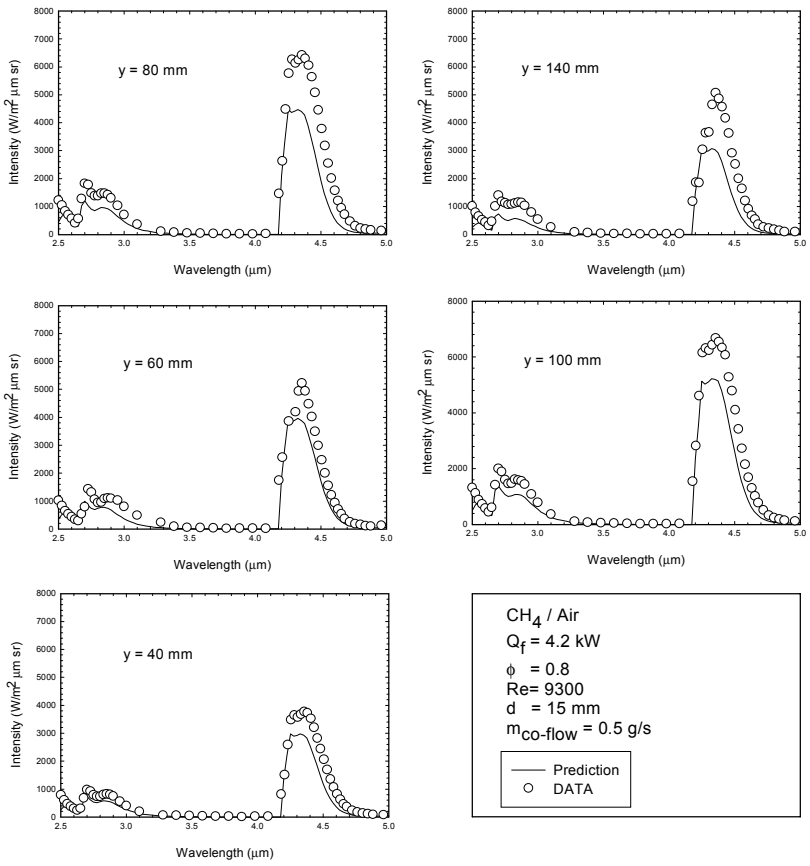
Turbulent Premixed Flame ES



Predictions using RADCAL and spatially uncorrelated T, H_2O, CO_2 data

Maurice J. Zucrow Laboratories : Combustion Laboratory
School of Mechanical Engineering

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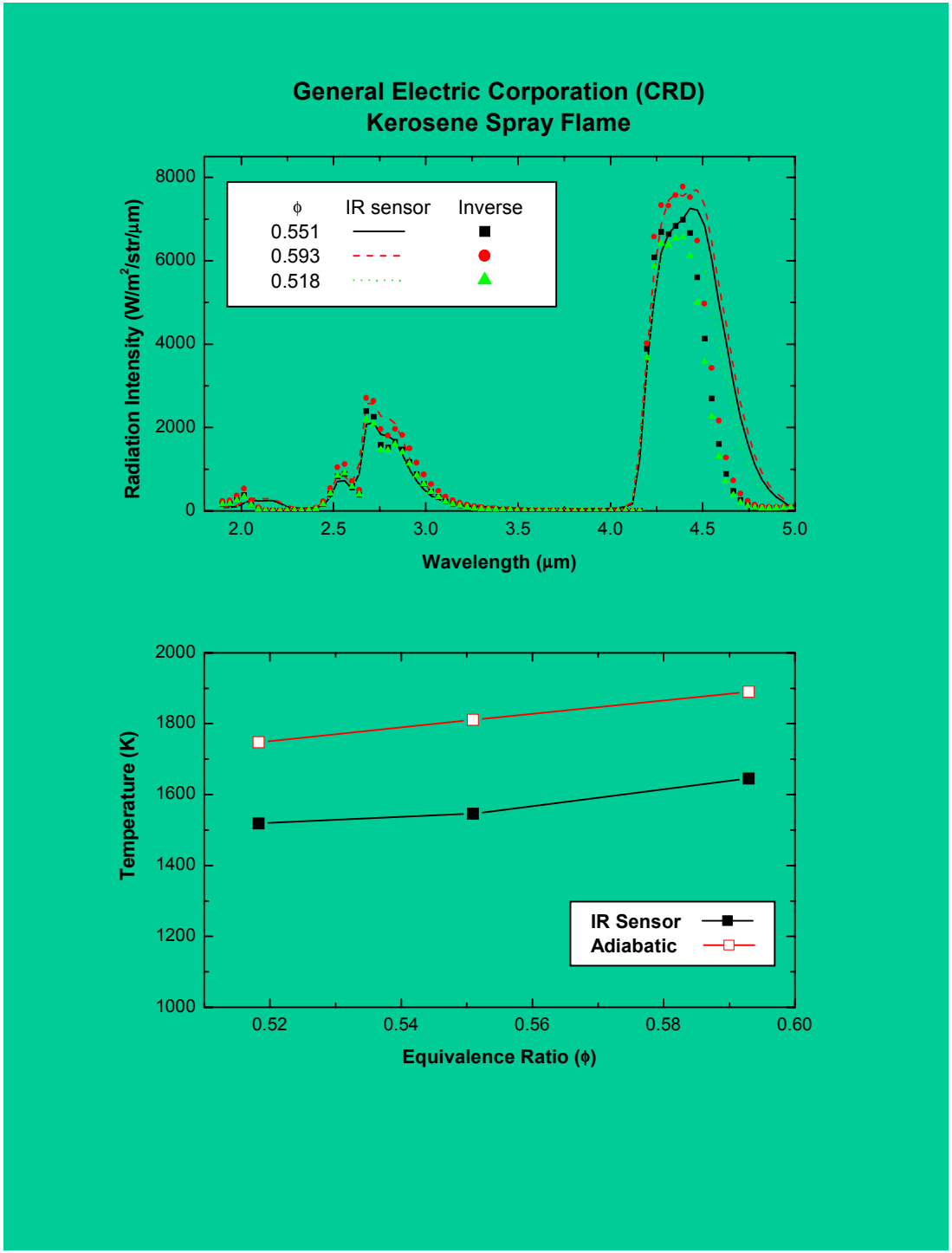
Accomplishments Industrial Study (GE)

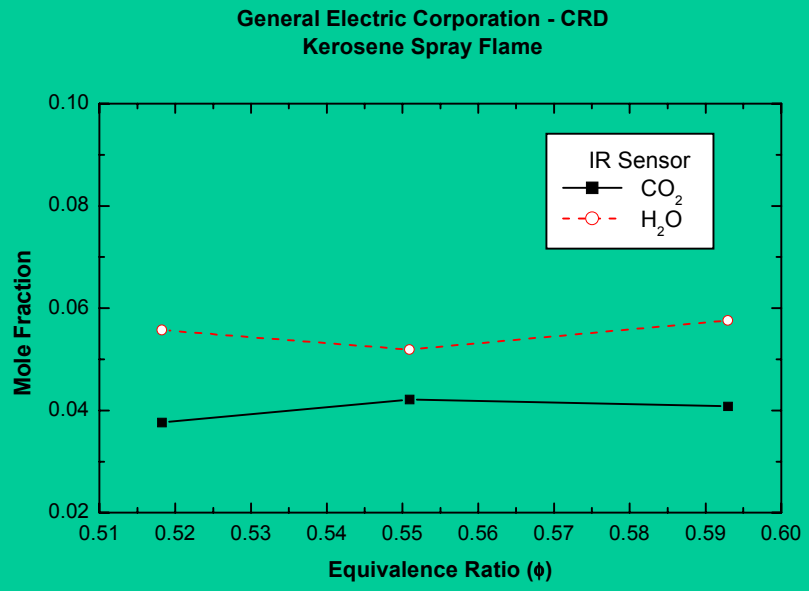
- Measurements of IR spectra for 3 gas turbine kerosene spray flames completed at **General Electric Central Research and Development**

- Measurements at GE CRD show excellent qualitative agreement with adiabatic temperatures

- Measurements of CO_2 and H_2O are reasonable

P U R D U E


General Electric Corporation (CRD)
Kerosene Spray Flame
Radiation Intensity (W/m²/str/μm)
Wavelength (μm)
ϕ
IR sensor
Inverse
0.551
0.593
0.518
8000
6000
4000
2000
0
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Temperature (K)
Equivalence Ratio (ϕ)
IR Sensor
Adiabatic
2000
1800
1600
1400
1200
1000
0.52
0.54
0.56
0.58
0.60


General Electric Corporation - CRD
Kerosene Spray Flame
Mole Fraction
0.10
0.08
0.06
0.04
0.02
0.51
0.52
0.53
0.54
0.55
0.56
0.57
0.58
0.59
0.60
Equivalence Ratio (ϕ)
IR Sensor
CO2
H2O

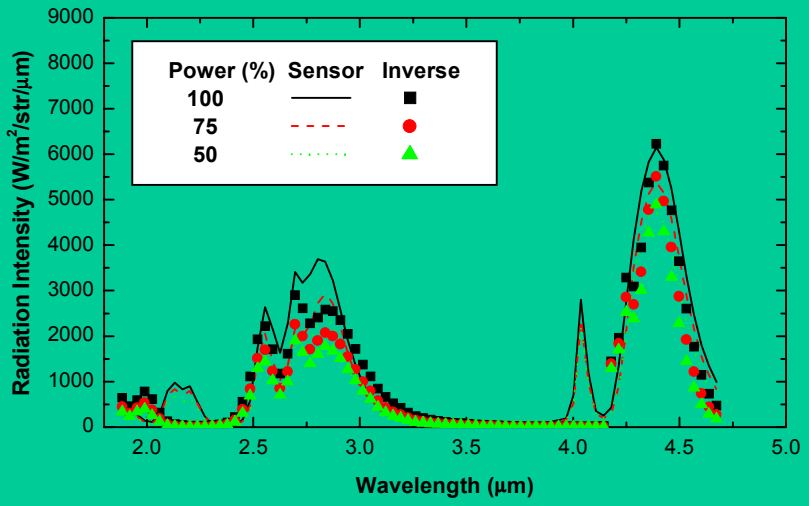
Accomplishments Industrial Study (SW)

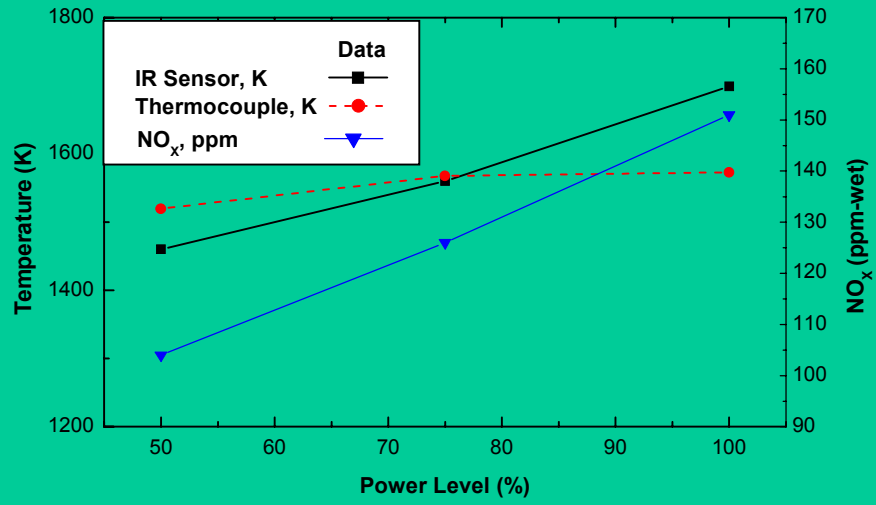
• Measurements of IR spectra for 36 operating conditions (natural gas and oil fired) in a high pressure combustor completed for **Siemens Westinghouse** at the National Research Council facilities.

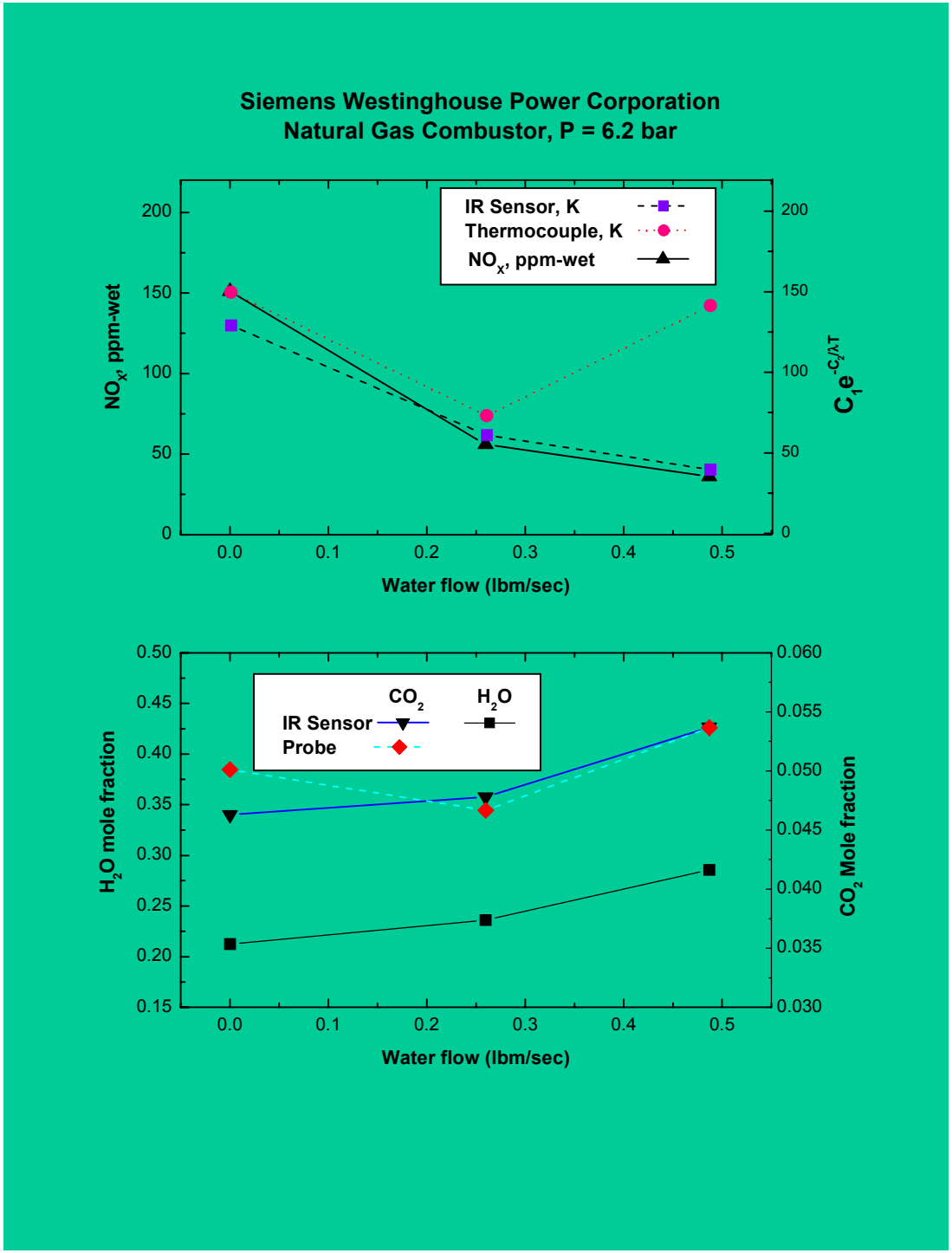
•Functions of the measured IR temperature shows excellent correlation with NOx analyzer data. Corresponding function calculated using thermocouple data does not correlate at all

P U R D U E

Siemens Westinghouse Power Corporation
Natural Gas Combustor, P = 6.2 bar






Siemens Westinghouse Power Corporation
Natural Gas Combustor, P = 6.2 bar
IR Sensor, K
Thermocouple, K
NOx, ppm-wet
NOx, ppm-wet
C1e-C2/λT
Water flow (lbm/sec)
CO2
H2O
IR Sensor
Probe
H2O mole fraction
CO2 Mole fraction
Water flow (lbm/sec)

Siemens Westinghouse Combustor

- IR sensor measurements of CO_2 concentrations agree with exhaust probe measurements

- Effects of water addition on CO_2, H_2O, NO_x concentrations and temperatures captured well by the IR sensor

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Conclusions

- Radiation model verified in laminar flame studies
- Radiation sensor verified in laboratory turbulent and laminar flame studies
- Effects of turbulence on temperature sensing by IR detectors need further study

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Conclusions

• IR sensor can provide excellent temperature and species concentration measurements in practical gas turbine flames

• Effects of pressure on emission properties must be considered. Property data at high pressures are needed.

•Wavelength selection for a practical sensor must account for effects of pressure

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Future Work

- Measurements of temperatures at Solar Turbines, Pratt and Whitney, and Rolls Royce Allison

- Measurements of high pressure spectral emission coefficients for CO_2 and H_2O

- Improved models of turbulence-radiation interactions

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