# Measuring the Emittance of Ash Deposits in a Coal Fired Reactor

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## Background

In a coal fired reactor, ash is formed and accumulates on the walls of the combustion chamber. This deposited ash can significantly affect the thermal transport in the boiler.

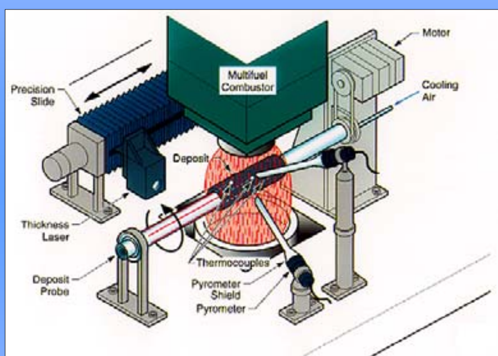
## Objectives

1. Develop a method to simulate the deposition of ash on reactor walls
2. Develop a procedure to make accurate, *in situ* measurements of the emittance of the deposited ash

## Importance

Knowledge of the properties of the ash deposits will result in better modeling capabilities and improved optimization of the design of coal fired reactors.

## Objective 1: Simulating Ash Deposition




### Method

An air-cooled, circular steel probe is placed at the outlet of a multi-fuel combustor. Coal is injected into the top of the furnace and the carbon in the particles is burned out before they reach the probe. The probe is rotated to ensure even accumulation of ash.

### Measurable Parameters

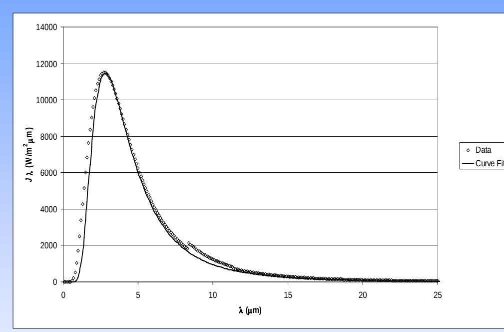
- **Flame temperature, $T_f$**
- **Surface temperature of ash layer, $T_s$**
- Outer surface temperature of probe, $T_r$
- Cooling air inlet temperature, $T_{m,i}$
- Cooling air outlet temperature, $T_{m,e}$
- Mass flow-rate of air through the probe, $\dot{m}$
- Ash layer thickness, $t$
- **Spectral radiosity of ash layer, $J_\lambda$**

## Objective 2: Calculating Emittance

Approximating the irradiation from the flame surrounding the probe as that from a black body and assuming the layer of ash to be an opaque surface, the total emittance of the layer of ash can be approximated as:

$$\varepsilon \approx \frac{1}{\sigma T_s^4} \sum_{n=1}^{N} \frac{\left(\lambda^5 J_\lambda + C_1\right)\left(1 - e^{C_2/\lambda T_s}\right) + \lambda^5 J_\lambda \left(e^{C_2(T_s+T_f)/\lambda T_s T_f} - e^{C_2/\lambda T_s}\right)}{\lambda^5 \left(e^{C_2/\lambda T_f} - e^{C_2/\lambda T_s}\right)\left(e^{C_2/\lambda T_s} - 1\right)} \Delta\lambda$$

Numerical experiments were used to verify this equation. Simulated experimental values of the spectral radiosity were generated and used to asses the accuracy of the proposed emittance measurements.




A nonlinear least squares method was used to fit a curve to the simulated data, resulting in the following equation which was used in the equation for the emittance:

$$J_\lambda(\lambda) = \frac{2.91 \times 10^8}{\lambda^5 \left(\exp(14.0/\lambda) - 1\right)}$$

## Results

Varying degrees of random error were introduced into the simulated temperature and spectral radiosity measurements, and this simulated data was used to estimate the emittance of the ash layer. The following table lists the error in the emittance measurements for various levels of measurement errors.

| Error in $J_\lambda$ / Error in $T$ | 0% | ±1% | ±5% | ±10% | ±20% |
|---|---|---|---|---|---|
| 0 | 0 | ±0.22% | ±1.30% | ±2.07% | ±4.30% |
| ±1 K | ±0.54% | ±0.37% | ±1.60% | ±2.61% | ±4.14% |
| ±2 K | ±1.08% | ±0.40% | ±1.15% | ±2.74% | ±3.93% |
| ±5 K | ±2.70% | ±0.66% | ±1.16% | ±3.60% | ±4.39% |

### Conclusions

These results show that this method can tolerate relatively high errors in both the temperature and spectral radiosity measurements. Therefore, it is concluded that the proposed method can be used to accurately estimate the emittance of the layer of ash that forms on the probe.

### Future Work

Planned future work includes the development of similar procedures to measure the thermal conductivity of the ash layer and to develop relationships between these properties and the structure of the ash. The experimental apparatus necessary to experimentally validate the proposed method is currently under construction.