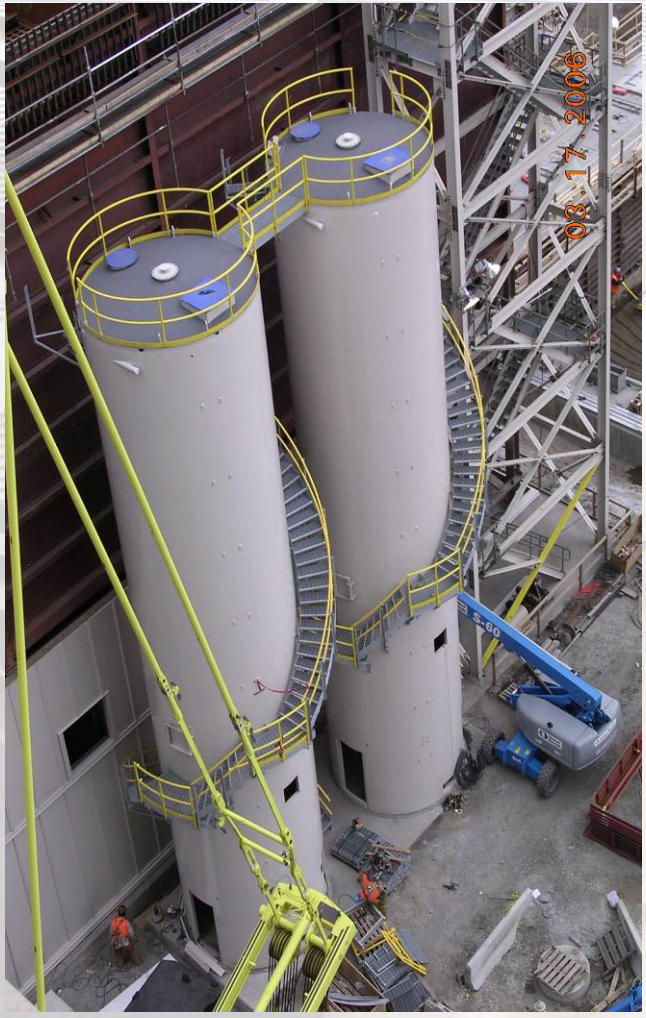


Auto-Ignition of PAC/Ash Mixtures in a TOXECON™ Configuration

EUEC 2009

Paul Johnson, ADA-ES

February 3, 2009

NASDAQ:ADES

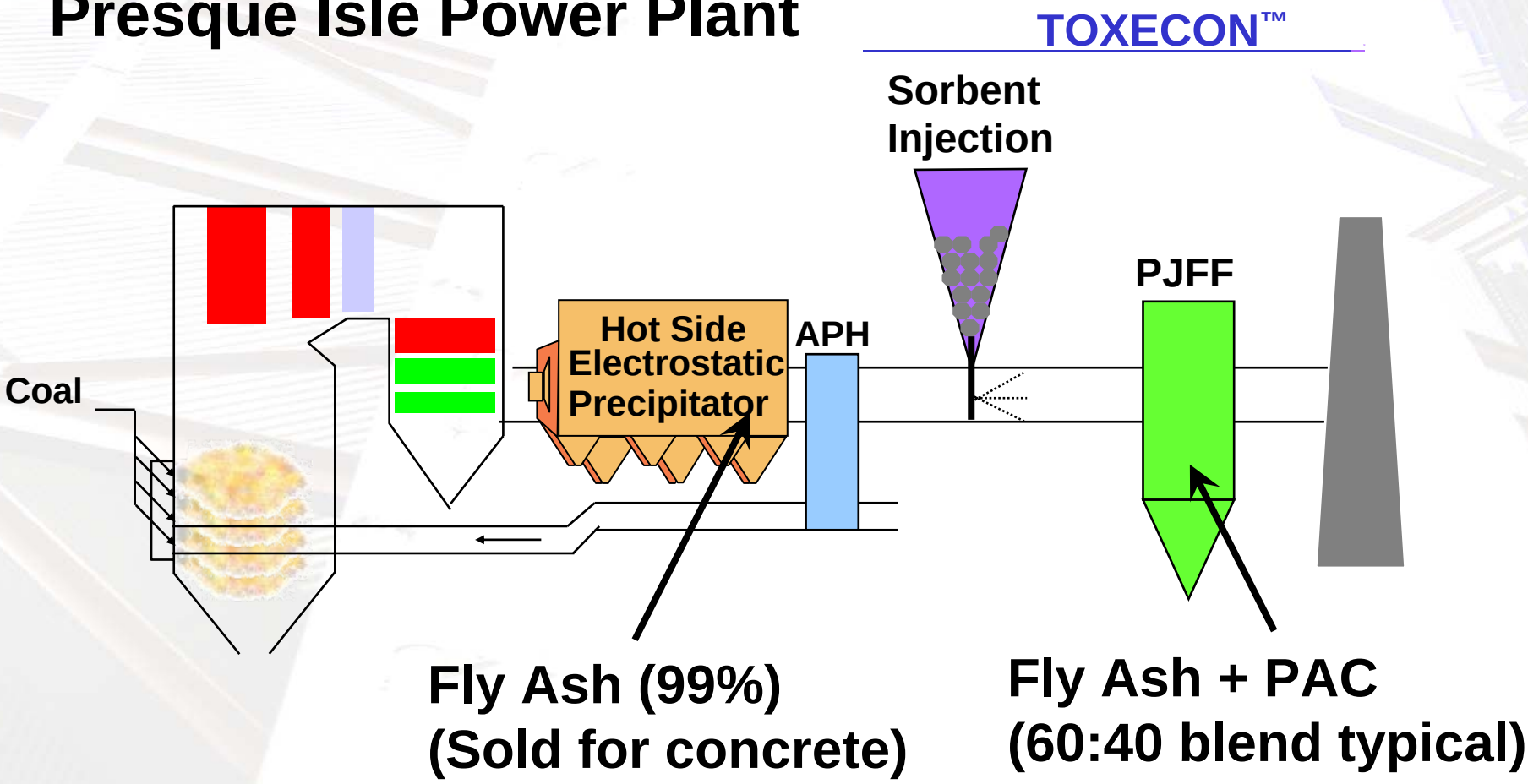
A Leader in Clean Coal Technology

TOXECON™ - 270 MW Demonstration

- Presque Isle Power Plant, Marquette MI
  - Units 7-9
  - PRB Coals
- $53.3M
  - $24.9M DOE
  - $28.5M We Energies
- Project Goals
  - 90% Hg - Continuous
  - 70% SO2 - Short-term
  - 30% NOX - Short-term
  - Ash Management - Use ash from baghouse

TOXECON™ Configuration

Presque Isle Power Plant

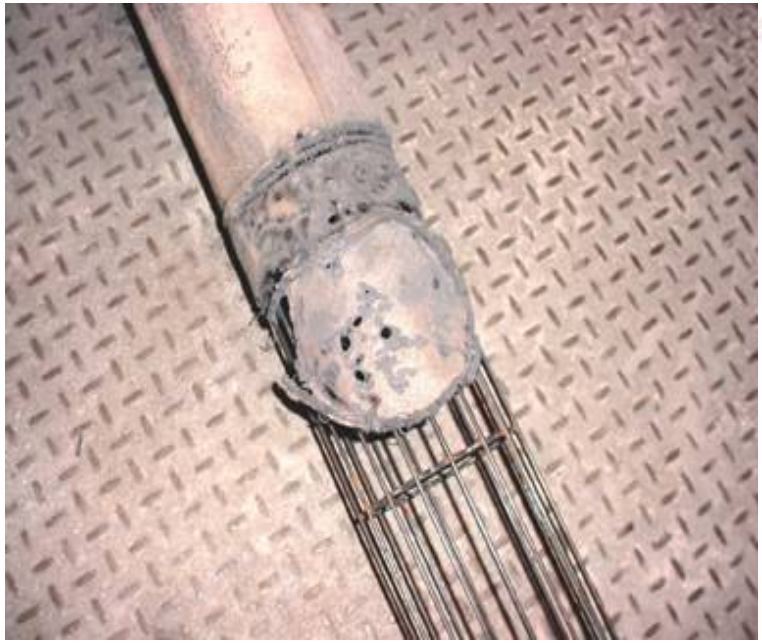


PIPP Overheating PAC/Ash Event

- Startup of the baghouse and PAC injection began mid-January 2006
- In February 2006, burning embers were found in all baghouse compartment hoppers
- Baghouse isolated to cool ash and clean out hoppers
- While extinguishing burning embers, unintentionally created flames in two compartments
  - 117 bags failed in Compartment #4
  - 83 bags failed in Compartment #3
- The flames were likely due to carbon monoxide from the smoldering PAC

Smoldering Ash in Hoppers

Bag Damage



Investigation into Causes

- PAC
  - Thermogravimetric test of PAC from the silo showed an ignition temperature of 852°F which is typical
- Hopper heaters
  - Thermocouples were installed on the interior walls of one hopper
  - A thermocouple was installed between a heater and the exterior wall of the hopper
  - Maximum temperature was 407°F
- Auto-ignition of PAC

Auto-ignition of Solids - Background

- Some combustible solids can ignite as a result of internal heating if an exothermic process liberates heat faster than it can be dissipated
- This can occur in materials with the following properties:
  - The material is sufficiently porous to allow air (O_2) to permeate it
  - The material is a good thermal insulator
  - The material has a high surface area
- Phenomenon is normally associated with relatively large mass of material (small surface to volume ratio)
- Combustion starts as a smoldering reaction within the bed and propagates slowly outwards and can be described by the Frank-Kamenetskii Model (1939)

Mehaffey, Jim, "Lecture # 12: Smouldering and Spontaneous Combustion", *Fire Dynamics 1,* Carleton Univ. (2002)

Mechanism for Auto-Ignition

- PAC has strong ability to oxidize
  - High surface area and porosity of PAC allows oxygen to permeate these areas
- Heat of oxidation builds faster than it can be liberated
  - The surrounding PAC acts as an insulator
- Key Factors of Frank-Kamenetskii Model
  - Bed size (surface to volume ratio)
  - Temperature surrounding bed
    - Hopper heaters create localized heating
    - High flue gas temperatures
  - Concentration of carbon (PAC and/or UBC)
  - Type of carbon (high vs. low surface area)
  - Gas oxygen concentration

ADA ENVIRONMENTAL SOLUTIONS

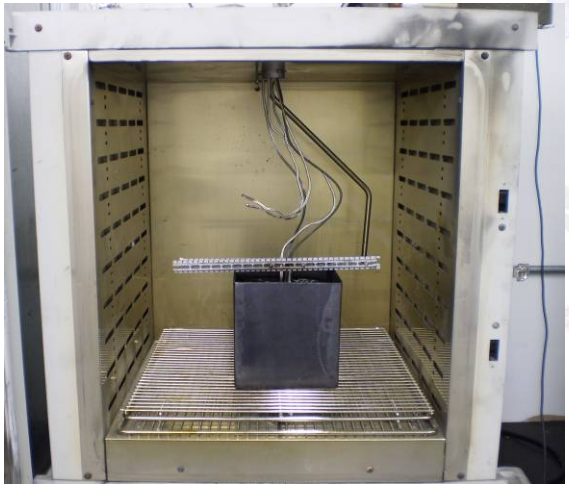
Example Spontaneously Combustible Materials

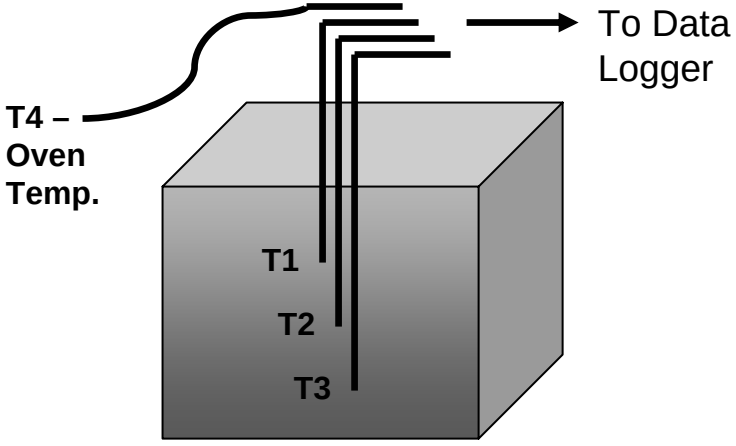
- Insulative Fiberboard
- Animal Feedstuff
- Skimmed Milk Powder
- Yeast-Based Powder
- <u>Powdered Activated Carbon</u>

Mehaffey, Jim, “Lecture # 12: Smouldering and Spontaneous Combustion”, *Fire Dynamics 1,* Carleton Univ. (2002)

Lab Test Description

- Convection oven
  - “Worst case” oxygen levels (21%)
- Steel cube
  - Tested sizes of 2”, 4”, 5”, 6”, 8”, 12”
- Thermocouples (4 total)
  - (1) Oven temperature
  - (3) Inside cube
    - Center
    - Halfway between center and bottom
    - Halfway between center and top

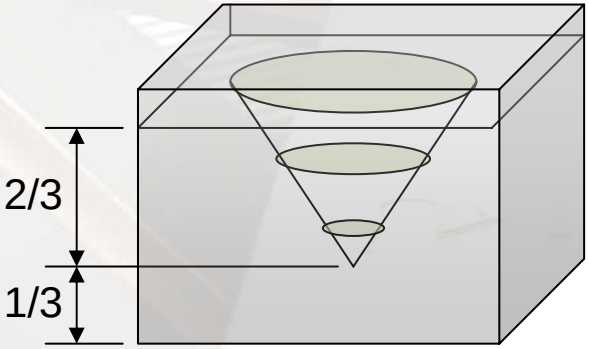




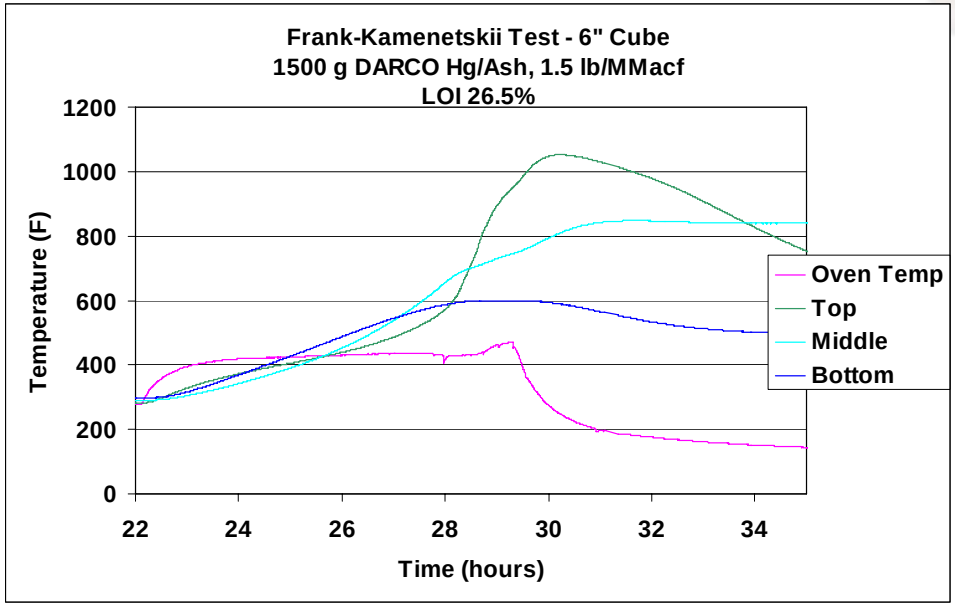
Smoldering Propagation

- Smoldering (oxidation of char) begins inside the material and slowly propagates radially and upwards

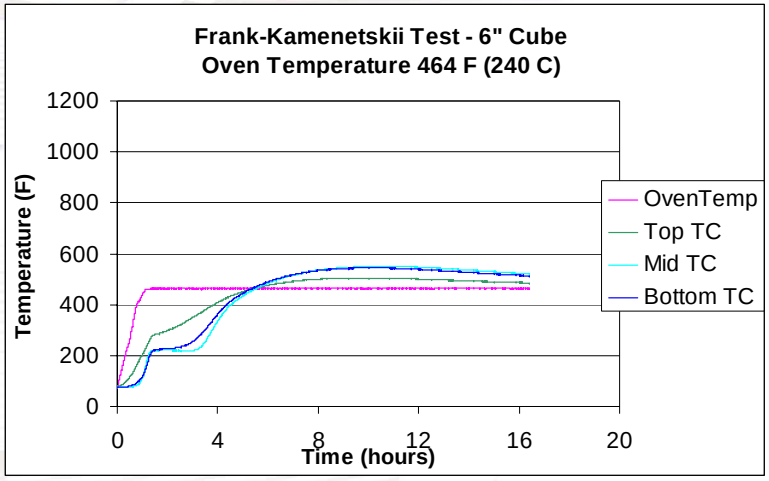
Top - 0.5” - 1.0” - 1.5” - 2.0” - 2.5” -3.0



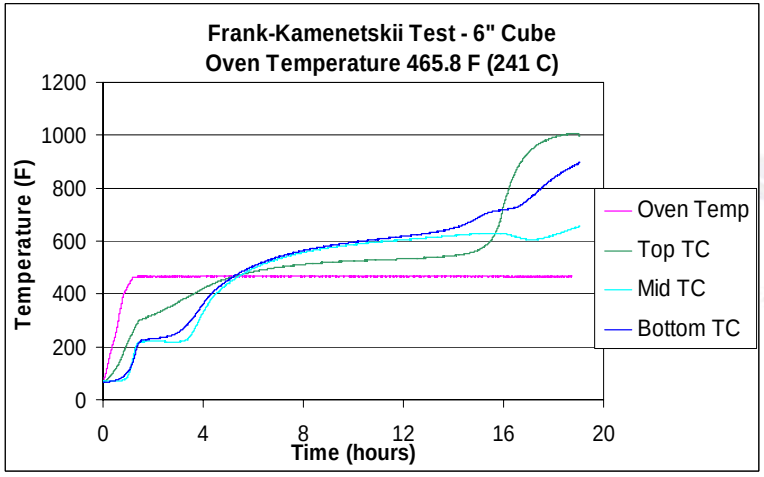
Typical burn pattern



Temperature Sensitivity



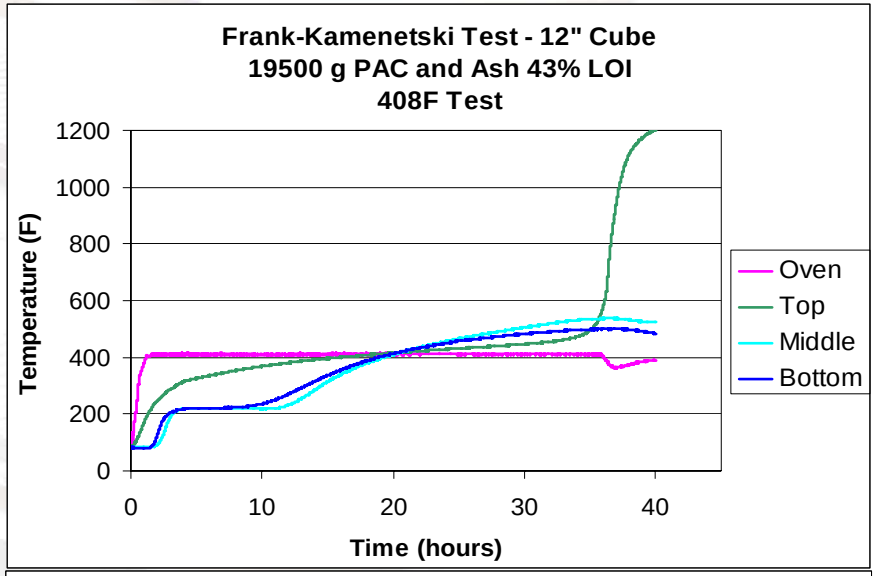
Over-heating

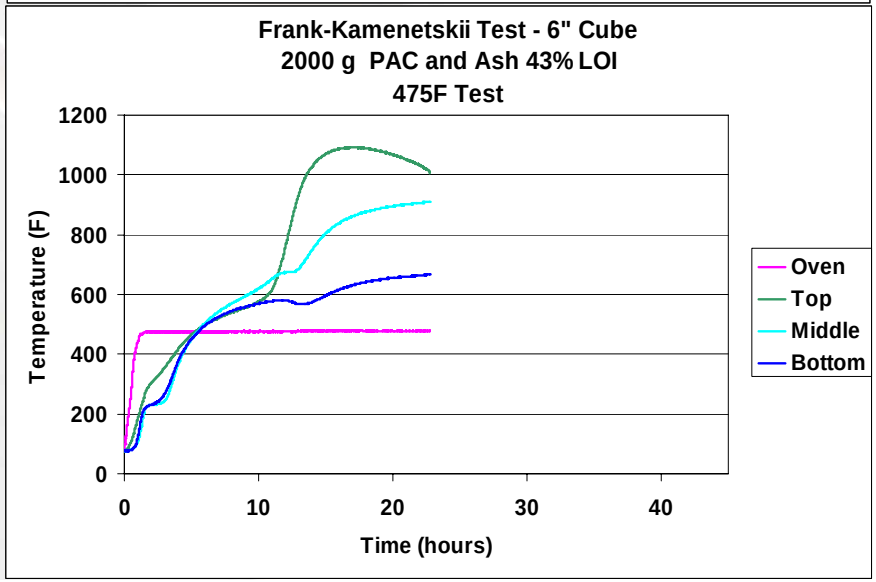


Auto-Ignition

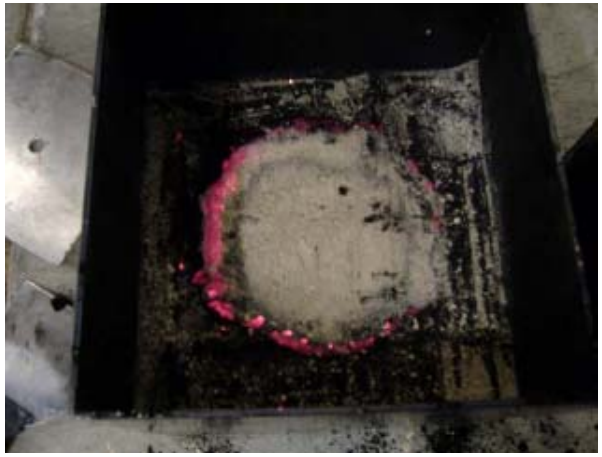
- One degree Celsius can be the difference between over-heating and auto-ignition

Effect of Bed Size



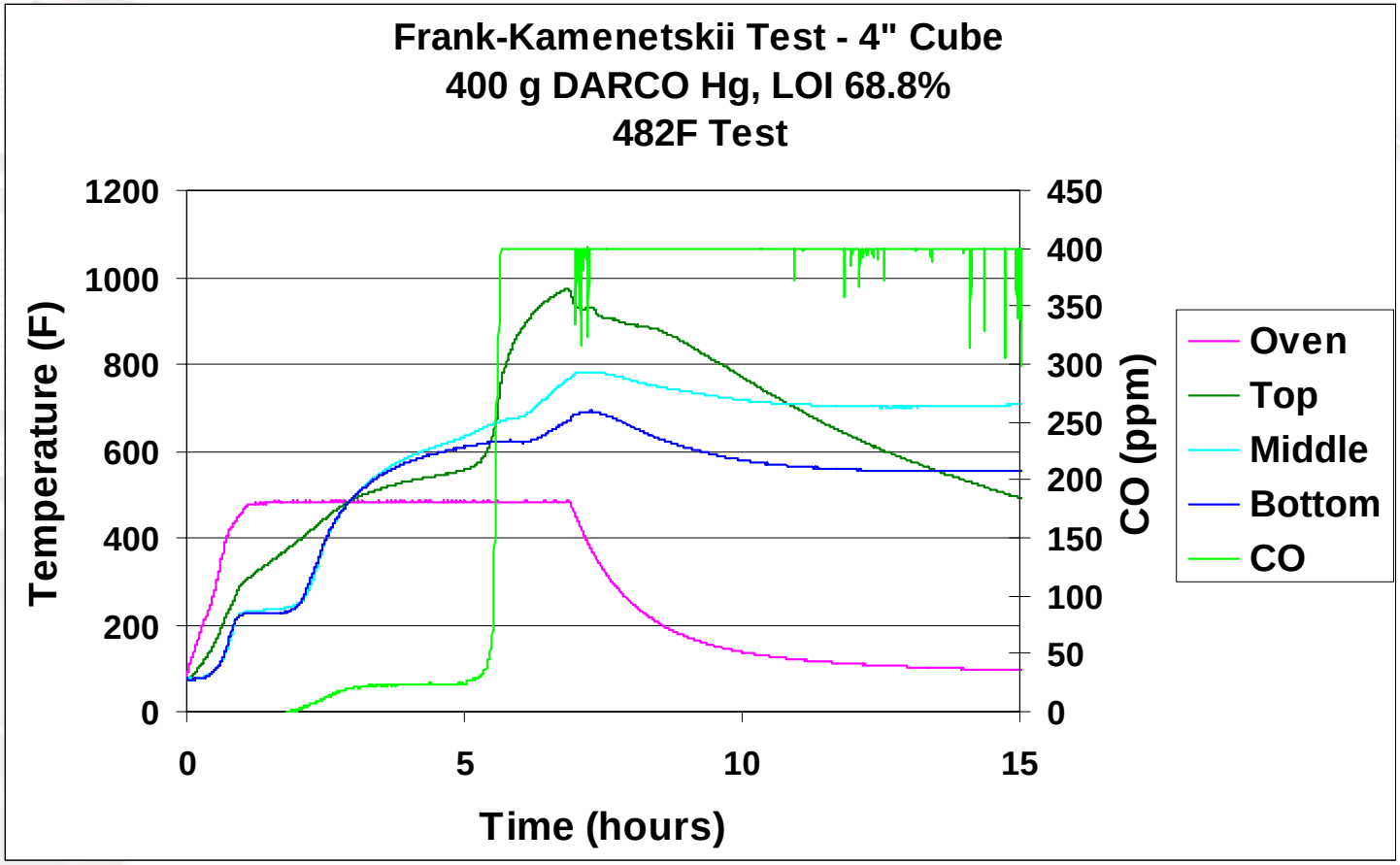


Larger beds require lower temperature and longer time to ignite at the critical temperature



Burning PAC/Ash in 6” cube at apx. 3” into the bed

CO Production During Auto-Ignition



Frank-Kamenetskii Model

- Provides a relationship between
  - $T_{a,cr}$ = critical ambient temperature for ignition (K)
  - R_o = dimension of sample (m) (side of a cube = $2r_o$)
  - δ_{cr} = critical parameter dictated by geometry of sample

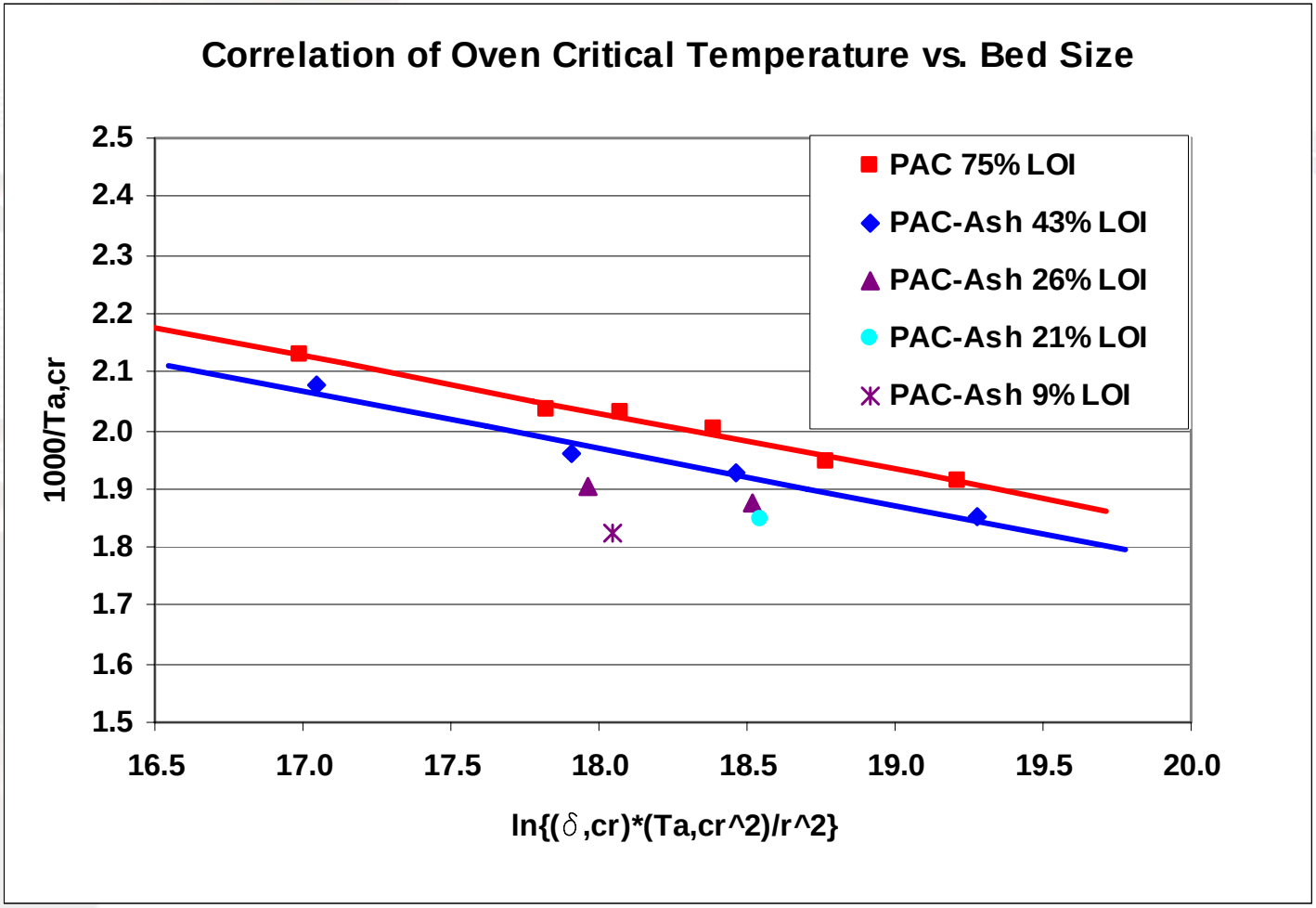
    - $\mathrm{Ln}\{\delta_{cr} T_{a,cr}^2 / r_o^2\} = C_1 - C_2 / T_{a,cr}$

    - $C1 = \ln\{E H_c a \rho / (k R)\}$

    - $C2 = E / R$

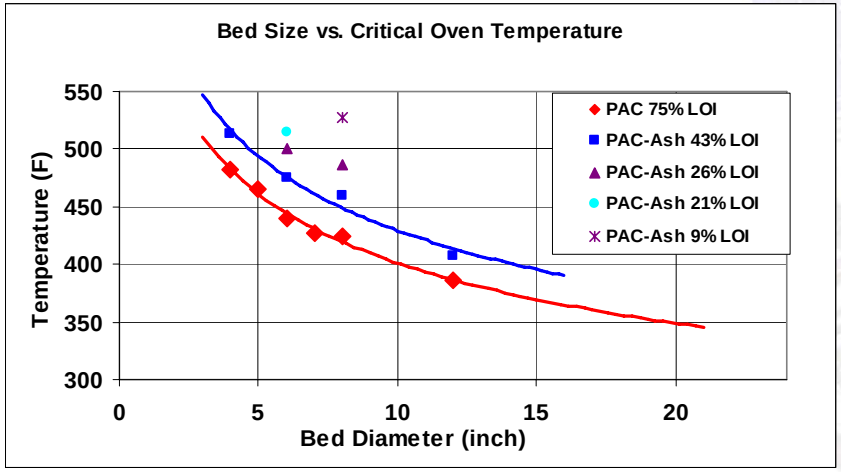
Mehaffey, Jim, "Lecture # 12: Smouldering and Spontaneous Combustion", *Fire Dynamics 1,* Carleton Univ. (2002)

Correlation of Ignition Data Frank-Kamenetskii Model

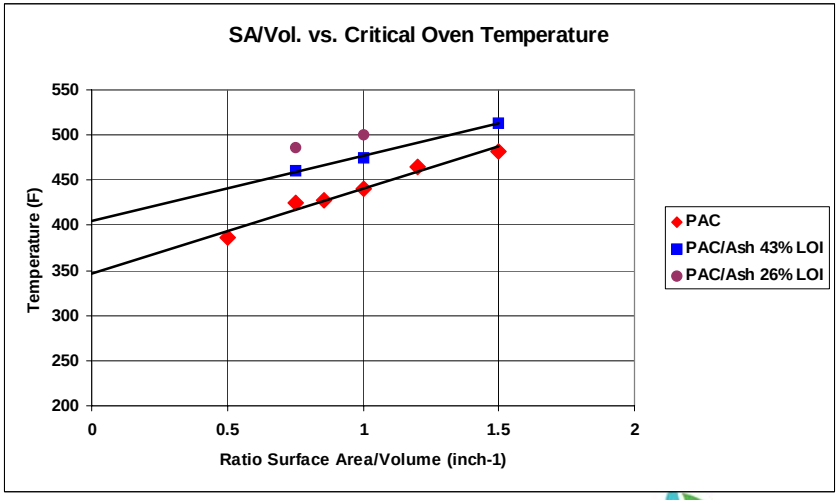


Auto-Ignition Curves

- LOI affects critical auto-ignition temperature
  - Lower LOI, higher critical temperature



- Surface area to volume ratio
  - This data is for cubes tested in the lab
  - Another method to correlate temperature effect



Preventative Operations

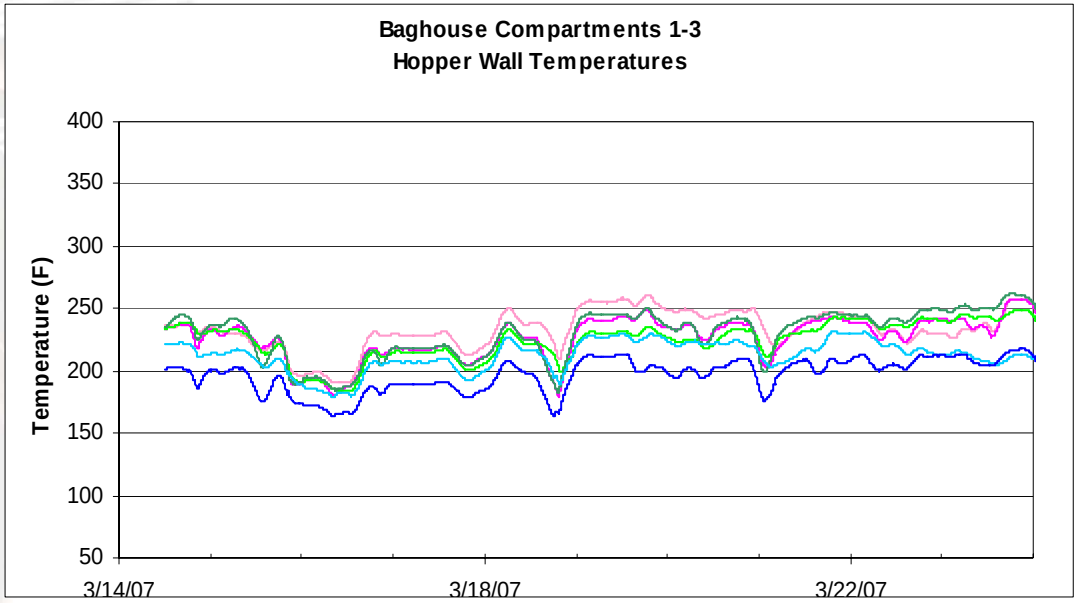
- Operational changes have successfully prevented problems
  - Ensure complete emptying of ash hoppers
  - Minimize ash/PAC residence time
  - Lower set point on hopper heaters

- CO monitors
  - CO detection can signal combustion
  - Difficult to measure in hopper conditions

ADA ENVIRONMENTAL SOLUTIONS

PIPP Current Operating Parameters

- Baghouse cleaning based on time
  - 3 units in service = 1 hour
  - 2 units in service = 2 hours
  - 1 unit in service = 4 hours
- Ash pulled every 4 hours
- Ash hopper heaters set close to flue gas temperatures



Contact Information

Paul Johnson

303-962-1931

pauljohnson@adaes.com

Robin Stewart

303-734-1727

robins@adaes.com