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Safety Aspects in the use of Carbonaceous Sorbents for Entrained-Phase Adsorption

Anthony Licata  
Babcock Power Environmental Inc.

Juergen Wirling  
RWE Power AG,

Roderick Beittel  
Riley Power Inc.,

Robert Lisauskas Ph.D  
Riley Power Inc.,
Safety Considerations

- The activated carbons employed consist primarily of carbon, which in principle makes them combustible.
- Due to their high surface area and porosity, these activated carbons also react with oxygen, releasing heat.
- Like any other combustible, pulverized activated carbons can be explosive under certain circumstances.
Volatile emissions during the production of Activated Carbons (900°C)

- Typical bituminous coal PC boiler at an AC injection rate of 10 lb/MMACF would be <1% of ash
Good News

- Over 400 WTE plants operating with carbon based technologies
- No reported incidences
Evaluation of Safety Behavior

Activated carbon

Test samples

Analyses:
Grain size, moisture
volatile matter, ash etc.

Deposited dust

Flammability
- Auto-ignition
- Smouldering temp.

Fire risk assessment

Explosion risk assessment

Dispersed dust

Explosibility
- Max. explosion overpressure
- Max. rate of pressure rise
- Lower explosion limit
- Minimum ignition energy
- Limiting oxygen concentration

Ignition temperature
<table>
<thead>
<tr>
<th></th>
<th>HOK Pulverized</th>
<th>HOK Super</th>
<th>typical pulverized coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture, wt%</td>
<td>0.5</td>
<td>0.5</td>
<td>11</td>
</tr>
<tr>
<td>Top grain size, mm</td>
<td>0.4</td>
<td>0.13</td>
<td>0.5</td>
</tr>
<tr>
<td>$d_{50}$, µm</td>
<td>63</td>
<td>24</td>
<td>55</td>
</tr>
<tr>
<td>Combustibility class (100 °C)</td>
<td>BZ2</td>
<td>BZ3</td>
<td>BZ4</td>
</tr>
<tr>
<td>Self-ignition temperature, °C</td>
<td>250</td>
<td>250</td>
<td>110</td>
</tr>
<tr>
<td>Smoldering temperature, °C</td>
<td>&gt;450</td>
<td>&gt;450</td>
<td>240</td>
</tr>
<tr>
<td>Ignition temperature, °C</td>
<td>560</td>
<td>590</td>
<td>450</td>
</tr>
<tr>
<td>Lower Explosion Limit, at 20 °C, g/m³</td>
<td>60</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>Maximum overpressure, bar</td>
<td>7.6</td>
<td>8.6</td>
<td>9</td>
</tr>
<tr>
<td>KSt value, bar-m/s</td>
<td>96</td>
<td>92</td>
<td>150</td>
</tr>
<tr>
<td>Dust explosion class</td>
<td>St 1</td>
<td>St1</td>
<td>St1</td>
</tr>
<tr>
<td>Minimum ignition energy, Joules</td>
<td>200-500</td>
<td>200-500</td>
<td>0.185-0.245</td>
</tr>
</tbody>
</table>
# Explosion Risk

An explosion hazard only exists if the following conditions are fulfilled **simultaneously:**

- Activated carbon is dispersed in air, in a concentration range between lower and upper explosive concentration limits **and**
- The limiting oxygen concentration required for an explosion of the mixture is exceeded **and**
- An ignition source sufficient for ignition of the dust/air mixture is present
Safety Aspects in Respect of Entrained-Phase Adsorption with AC

Explosion

Caused if simultaneously:
- Dust is whirled up and concentration is within the explosion limit and
- O_2-content exceeds the oxygen limiting concentration and
- Ignition source has sufficient energy

Prevented by:
- Exclusion of efficient ignition sources or
- Operation below the temperature-dependent O_2 limiting concentration (at 200 °C, 12 % vol.) or
- Inert portion (e.g. process dusts or inert additives dosed)
Influence of the inert portion on explosibility

\[ \frac{p_{\text{max}}(n)}{p_{\text{max}}(n=0)} \]

Hydrated lime portion (n) in % wt

- Initial temperature
  - 50 °C
  - 200 °C

\[ V = 1 \text{ m}^3 \]
\[ E = 10 \text{ kJ} \]
In order to avoid fires in beds or deposits containing carbon, two aspects must be taken into account

• the fire risk from ignition sources
• the potential for auto-ignition.

To avoid auto-ignition, the following measures are recommended:

• Avoid major ash deposits in the process stream, for example, through continuous ash discharge from the ESP or baghouse hoppers.
• Preclude low-velocity air flows through the stored carbon or in spent solids. Low-velocity gas flows involve the danger that the reaction heat developed in the gas flow channel causes local overheating in the bed.
Safety Aspects in Respect of Entrained-Phase Adsorption with AC

Fire

Caused by:

- Ignition sources introduced (e.g. sparks with high energy content, etc.) or
- Spontaneous ignition in the case of larger dust deposits

Prevented by:

- Prevention of efficient ignition sources being fed (e.g. by upstream coarse dust separator, gas scrubber, etc.)
- Prevention of larger dust deposits (e.g. by continuous dust discharge appropriate structural design, etc.)
Good Design/Housekeeping

- Cleanup
- Grounding
  - Static electric
- Confined space
  - Adsorbs oxygen
- Dust protected motors and switch gear
  - Do not need explosion or dust ignition proof
  - TEFC motors recommend
Good Operating Practice

- Avoid direct flame or heat
  - Welding etc.
- Keep hoppers free flowing
  - Empty during outages
Electric Forces

- Possible ignition sources include static build-up from conveying solids, spark discharge in an ESP, hot equipment surfaces, and carryover of burning fuel from plant upset conditions.
- Personnel protection from shock
Typical Entrained Phase Design

Pulverized activated lignite

Flue gas

1st Adsorption stage "Injection"

2nd Adsorption stage "Entrained phase"

3rd Adsorption stage "Coating" or "Cloud"

Ash separator

Clean gas
HOK Addition for Hg-Separation in an Industrial Power Plant

1. Sewage sludge transport (truck / container)
2. Sewage sludge storage
3. Wheel loader
4. Feeding hopper / discharging system with screw
5. Solids pump
6. Raw lignite bunker
7. Circulating fluidized-bed firing system
8. Dosing - fuel feeding system
9. Heavy metal separating system with activated lignite
10. Electrostatic precipitator
11. Stack
Mercury Control Based On Activated Lignite HOK Technology

- Operating Plants
  - Circulating Fluidized Bed Boilers
  - ESP PM Control
  - Fuel Lignite + Sewage Sludge
    - Berrenrath
      - Dose Rate 6.3 lb/MMACFM
      - + 85% Hg removal
      - 1999
    - Wachtberg
      - Dose Rate 8.9 lb/MMACFM
      - + 85% Hg removal
      - 2003
Typical Installation

- Filling system
- Star feeder
- Conveying air
- Dosing station
- Pulverized activated lignite
- Waste gas duct with injection nozzle
HOK Injection at the RWE Power Plant - Berrenrath
Pneumatic Transloading of HOK

1. silo
2. silotrack
3. compressor
4. stationary air cooler
5. conveyor pipe
6. inert gas connection
7. gate valve
8. silo filter
9. safety relief valve for excess pressure
10. safety relief valve for vacuum
11. manhole
12. temperature sensor
13. level indicator
14. level controller
   (high - low)
15. electrostatic grounding
16. loosening
17. double magnetic valve
   with deaeration
Conclusion

There is always safety issues when handling powdered products such as activated carbon and coal. Good engineering practices have been established for material handling to mitigate safety issues.