FCC Process Safety: Prevention of ESP Fires and Explosions

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Presentation Overview

- Overall objective is to understand what:
  - Scenarios can lead to ESP fire/explosions
  - Measures that can be considered to mitigate the risk

- Topics:
  - FCC Explosions
  - Flammable gases and ignition sources
  - Scenarios to consider for ESP Hazard Analysis
  - Potential preventative measures
  - Challenges to minimising risk
Reactor-Regenerator System
Flammable Gases and Ignition Sources

- Fire or explosion requires fuel+O2 in certain proportions and an ignition source
- ESP ignition sources: electrical sparks and/or hot internal surfaces
- Lower/Upper Explosivity Limits some gases encountered in the FCC

<table>
<thead>
<tr>
<th>Gas</th>
<th>LEL</th>
<th>UEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>12.5</td>
<td>74.0</td>
</tr>
<tr>
<td>Methane</td>
<td>5.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Ethane</td>
<td>3.0</td>
<td>12.4</td>
</tr>
<tr>
<td>Gasoline</td>
<td>1.2</td>
<td>7.1</td>
</tr>
</tbody>
</table>

- Various scenarios can lead to flammable gases passing to the ESP
FCC Explosions

- Air from the Regen entered the Main Frac
  - 2018: During shutdown for T/A, air/HC ignited by pyrophoric FeS (preliminary analysis as investigation ongoing)

- 2001 NPRA survey: 20% of 52 ESP’s experienced fires or explosions

- Hydrocarbons (HC’s) from the cat fractionator (Main Frac) enter the ESP
  - 1994: During shutdown for T/A, explosion caused by high temperature ignition of air and fuel gas, (believed that the ESP had been de-energised)
  - 2015: During standby operation, explosion occurred with the ESP energised

- HC’s fed to the Regen enter the ESP
  - 2013: Following a unit upset, torch oil fed to the Regen at low air rate caused an ESP explosion
Scenarios to Consider for ESP Hazard Analysis - 1

- **Hydrocarbon vapour** from Main Frac/Rx to Regen
  - Improper pressure balance with Main Frac P > Rx P, i.e. barrier steam loss
  - Loss of catalyst seals

- **Feed** from the Rx riser to the Regen
  - Poor feed atomisation
  - Flow reversal, e.g. due to pressure balance changes
  - Oil injection at low riser temperature

- **Unburned torch oil** from the Regen:
  - Excessive torch oil rate
  - Low Regen bed temperature
  - Low Regen bed level
  - Poor bed fluidisation due to low air rate
Scenarios to Consider for ESP Hazard Analysis - 2

- **Unburned fuel gas** from air preheater:
  - Excessive fuel gas rate
  - Low air rate
  - Flame-out

- **Unburned supplementary fuel gas** to CO boiler:
  - Excessive fuel gas rate
  - Low air rate
  - Flame-out

- **Excessive flue gas CO** to ESP inlet:
  - Poor CO combustion in CO boiler
  - High regenerator flue gas CO
    - Low O2/coke, catalyst/air maldistribution, unit upsets etc.)
Some Potential Preventative Measures to Consider - 1

- Keep the ESP shutdown until stable operations achieved
- Minimise personnel around the ESP during startup, shutdown, or an upset
- Automatic ESP shut down if:
  - Main FCC ESD system is tripped
  - Initiated by the operator using a separate ESP shutdown button
- De-energise the ESP when using torch oil and/or fuel gas in the air preheater
- Provide air preheater and CO boiler with an ESD system that trips the ESP
- Trip torch oil on low regen bed temp or low regen bed level
- ESP should not have the possibility of re-energizing itself after a trip or electrical power interruption
Some Potential Preventative Measures to Consider - 2

- Provide flue gas analyser at the ESP inlet
  - De-energises ESP if max. CO or min. O2 vol% limits are passed

- Limit the power to the ESP operating transformer and rectifiers at startup
  - Stay below the threshold of sparking in the precipitator

- Tight catalyst slide valve closure

- Provide sufficient reactor steam during abnormal operations to provide a barrier
  - Rx P > Main Frac P to prevent hydrocarbon backflow to Rx
  - Rx P > Regen P to prevent air leakage to Rx

- Maintain catalyst seals above slide valves to provide barriers

- Install Main Frac blind if a long shutdown, e.g. > 72 hrs
Some of the Challenges

- ESD system may not cover all scenarios where ESP should be de-energised
- Availability of Procedures to cover abnormal events
- Adequacy of Operator training to ensure correct actions taken during upsets
- Local authority requirements to minimise catalyst losses
- Reactor - Cat Fractionator delta P measurement, monitoring and control
- Catalyst slide valves may not be tight shut-off
- Maintaining catalyst seals above slide valves, especially spent slide valve
- Measuring catalyst level above slide valves
We create chemistry