Barriers to Superior FCC Cyclone Performance
Primary Causes, Repair Options & Design Solutions
Ziad Jawad, Managing Director EMTROL LLC

Düsseldorf, Germany
17 - 21 October 2011
OUTLINE

• Company Summary
• Review of Cyclone Systems Design and Operation
• Operational / Mechanical Problems
• Case Studies
  o First Stage Cyclone Inlet
  o Secondary Cyclone Crossover
  o Main Cone and Dust Hopper
  o DiPlegs and Dipleg Valves
• Conclusions
COMPANY SUMMARY

Emtrol is the World’s leading supplier of FCC cyclones for the Petroleum Refining Industry

- Established in 1973
- Over 2100 projects completed worldwide
- Over 2500 cyclones fabricated since 2002
- Over 50 Third Stage Separator Systems
- High quality international fabrication facilities
- Experienced inspection staff
COMPANY SUMMARY

Engineering Capabilities

- Engineering Process and Mechanical Studies
- Finite Element Analysis
- Computational Fluid Dynamics
- ASME Vessels and Vessel Heads
- Constructability Reviews
- Conventional & Custom design approaches
CYCLONE SYSTEMS

Two Principal Requirements

• Efficiently separate catalyst during continuous, extended processing periods.
• Withstand extreme erosion, high operating temperatures and periodic upsets, for an entire processing period.

Without excessive wear or damage
CYCLONE DESIGN

Design may be limited by vessel
  • Limited vessel diameter
  • Limited height above the bed

First Stage Inlet
  • Inlet bell versus sloped plate
  • Insufficient gas expansion angle
  • Compression ratio to high

Cross Over Duct
  • Radius versus tapered design
## INLET / OUTLET VELOCITIES

**Impact cyclone performance and erosion**

### TYPICAL REGENERATOR VELOCITIES

<table>
<thead>
<tr>
<th>Stage</th>
<th>INLET</th>
<th>OUTLET</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Stage, m/sec (ft/sec)</td>
<td>16.8 – 21.3 (55-70)</td>
<td>19.8 – 25.9 (65-85)</td>
</tr>
<tr>
<td>Second Stage, m/sec (ft/sec)</td>
<td>19.8 – 25.9 (65-85)</td>
<td>36.6 – 45.7 (120-150)</td>
</tr>
</tbody>
</table>

### TYPICAL REACTOR VELOCITIES

<table>
<thead>
<tr>
<th>Stage</th>
<th>INLET</th>
<th>OUTLET</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Stage, m/sec (ft/sec)</td>
<td>16.8 – 19.8 (55-65)</td>
<td>18.3 – 21.3 (60-70)</td>
</tr>
<tr>
<td>Second Stage, m/sec (ft/sec)</td>
<td>18.3 – 21.3 (60-70)</td>
<td>24.4 – 36.6 (80-120)</td>
</tr>
<tr>
<td>Single Stage, m/sec (ft/sec)</td>
<td>16.8 – 22.9 (55-75)</td>
<td>27.4 – 36.6 (90-120)</td>
</tr>
</tbody>
</table>

Allow for consideration for future operation.
RELIABILITY / PERFORMANCE

Some wear is to be expected

The Operating Environment
- Gas Volumes
- Dust Loadings
- Catalyst Properties

Materials of Construction
- Anchorage
- Erosion Resistant Lining

Service Life and Operating History

Past Maintenance
IMPACT FROM OPERATIONS

Process
• Gas Rate
  o Throughput / Regenerator Pressure
  o After Burn
• Bed Level / Fluidization
• Catalyst Type / Manufacture
• Upsets

Mechanical
• Mechanical Damage
• Bed Mal-Distribution / Channeling
• Catalyst Riser / Distributor
• Stripper

Plate Grid
Pipe Grid
BROKEN STEAM RING

2\textsuperscript{nd} stage outlet tube

Holed through from outside due to broken steam purge
TYPICAL CYCLONE EROSION

Areas
- First Stage Inlet
- First / Second Stage Crossover
- Main Cone / Dust Hopper
- Diplegs / Dipleg Valves

Case Studies
- Root Cause of Damage
- Repair Options
- Design Solutions
CYCLONE SHROUD REPAIRS

Often Used to Seal Holes

- Cross Over Ducts
- Inlet Target Plate
- Dust Hopper Cone
- Cone / Dipleg Junction
- Diplegs

Not a permanent solution and should be removed at the next opportunity.
FIRST STAGE CYCLONE

Inlet Sweep
Gas Outlet Tube

- External / Internal
- Improper Geometry / Flux Limited Main Barrel
- Mechanical Design
- Vessel Constraints
- High Loading
- Closed Coupled
FIRST STAGE INLET EROSION

External

Internal
FIRST / SINGLE STAGE INLET

Radius Type (Bell / Horn)
- Minimizes eddy currents/wear
- Suitable for full range operation
- Uniform distribution across inlet

Tapered Plate Type
- Non-uniform inlet distribution
- Limited for full range operation
INLET ASPECT RATIO

First Stage Cyclones
• Highly Loaded
• Inlet Height to Width: 2.35 – 2.6

Second Stage Cyclones
• Lightly Loaded
• Inlet Height to Width: 2.6 – 3.0
First Stage Cyclones

- Minimizes Eddy Currents
- Maximum Separation Efficiency
- Minimizes Wear
  - First stage inlet & gas outlet
  - Crossover duct
  - Second stage inlet
SECOND STAGE CROSSOVER

Second Stage Inlet Sweep and Crossover Duct

- Excessive velocities due to gas rates and temperatures
- Design Geometries
- Support System
- Fabrication / Repair Quality
- First Stage Cyclone Design
REPAIR OPTIONS

Shroud Repair
- Tangential Repair Plate
- Target Plate

‘K’ Bar Anchors in Lieu of Hexmesh
- ‘K’ Bar - Easier to replace small areas
- Can be Contoured
PROPRIETARY TAPERED DESIGN

- Minimizes eddy currents
- Reduces wear
- Enhances efficiency
- Minimizes maintenance
MAIN CONE / DUST HOPPER

- High Gas Rates
- Gas Leaking Up Dipleg
- Defluidization of Dipleg
- First Stage Cyclone Design
- Fabrication / Repair Quality
DUST HOPPER / DIPLEG SHROUD
VORTEX LENGTH

- Conical shape (from gas outlet tube)
- Function of gas rate and outlet tube
- Increases in length and Gas Volume
- Increased blower rate
  - After-burn
  - Increased operating temperature
  - Decreased operating pressure
MODIFIED DUST HOPPER

Minimize Affects of Dipleg Leakage/Vortex Encroachment

- Slope of Dust Hopper Cone
- Area of Dipleg Opening
- Catalyst Velocities
- Eddy Currents
- Lining Thickness (Optional)
HOPPER EROSION

Cold Flow Erosion Study
- FCC Catalyst 70°F, 1750 ACFM
  10 lbs in 10 min test
  5 test total

Erosion Indicator
- Black – Less Severe
- Red – Medium
- Yellow – More Severe
DIPILEG & DIPLEG VALVES

Dipleg Valve
- Second Stage Cyclone
- Hopper Suction
- Bed level and dipleg seal
- Rough Field Weld

Dipleg
- First / Second Stage
- Grooved / Swirled Pattern
- Dipleg Solids Level
- Oversized Dipleg / Low Flux
DIPLEG TERMINATIONS

Trickle Valve - Dilute and Dense Phase
- Model “N” - Dilute Phase
- Models “P” and “S” - Either Phase

Concerns
- Installation / Clearance
- Hinge ring / Support Rod Wear
- Cage / Flapper
- Refractory lined flapper
TRICKLE VALVES TERMINATIONS

Flapper Plate Angle
- 3° ± 1° recommended angle
- De-aeration of solids

“Half Moon” Plate
- Lightly loaded Applications
- Open area of valve discharge
- Vapor flow up the dipleg
- Shielded, partially shielded or non-shield valves
CONCLUSIONS

• The normal FCC operating conditions in which cyclones are designed to operate are severe. As a result some erosion is expected.

• FCC process upsets can be common and cyclones need to accommodate these extreme conditions to reduce the risk of an unscheduled shutdown.

• There are some types of cyclone damage that are typical and are the result of process conditions, design constraints, or outdated design practices. There are a variety of repair options available for most of these types of damage.

• Recent advances in cyclone design have resulted in improved separation efficiency and minimize wear on internal surfaces.
QUESTIONS?

Ziad Jawad
Managing Director, Emtrol LLC
+44 (0) 1480 475 071
zsj@emtrol.co.uk

EMTROL
emtrol.co.uk