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Düsseldorf, Germany
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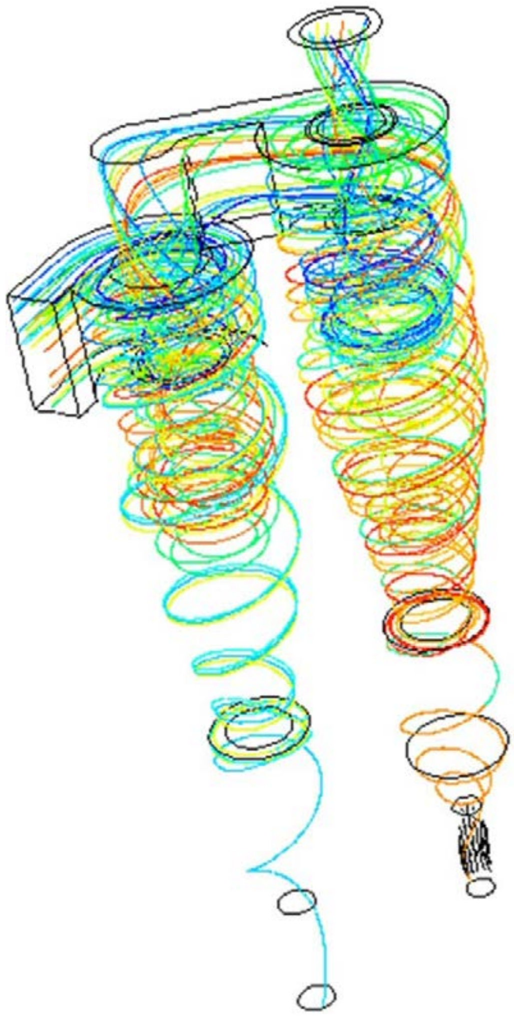
Barriers to Superior FCC Cyclone Performance

Primary Causes, Repair Options & Design Solutions

Ziad Jawad, Managing Director EMTROL LLC

OUTLINE

- Company Summary
- Review of Cyclone Systems Design and Operation
- Operational / Mechanical Problems
- Case Studies
    - First Stage Cyclone Inlet
    - Secondary Cyclone Crossover
    - Main Cone and Dust Hopper
    - Diplegs and Dipleg Valves
- Conclusions



COMPANY SUMMARY

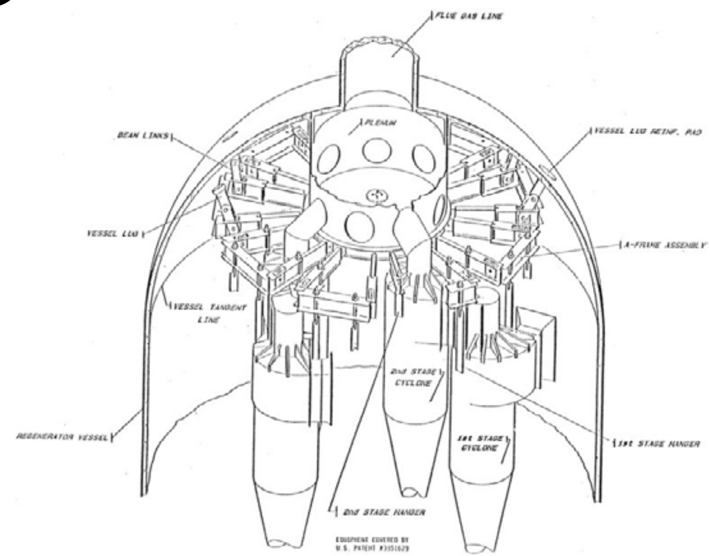
Emtrol is the World's leading supplier of FCC cyclones for the Petroleum Refining Industry

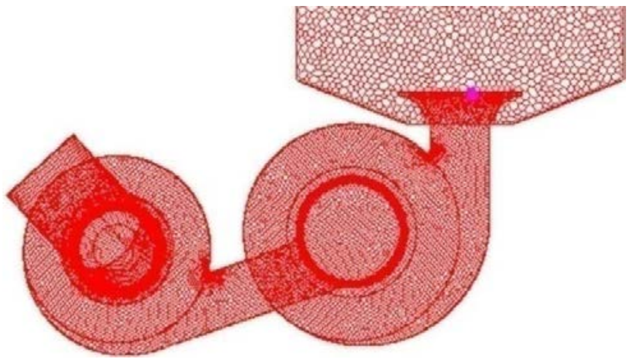
- Established in 1973
- Over 2100 projects completed worldwide
- Over 2500 cyclones fabricated since 2002
- Over 50 Third Stage Separator Systems
- High quality international fabrication facilities
- Experienced inspection staff

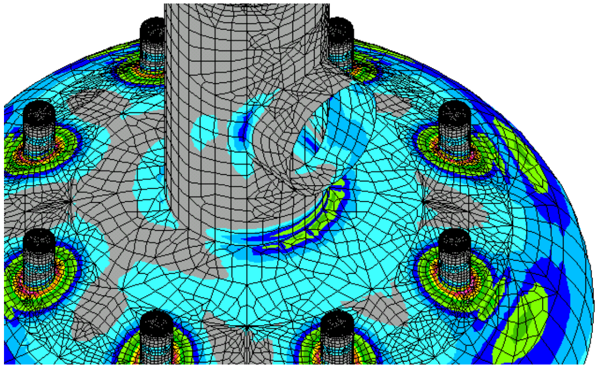
COMPANY SUMMARY

Engineering Capabilities

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







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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

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INLET / OUTLET VELOCITIES

Impact cyclone performance and erosion

TYPICAL REGENERATOR VELOCITIES	INLET	OUTLET
First Stage, m/sec (ft/sec)	16.8 – 21.3 (55-70)	19.8 – 25.9 (65-85)
Second Stage, m/sec (ft/sec)	19.8 – 25.9 (65-85)	36.6 – 45.7 (120-150)

TYPICAL REACTOR VELOCITIES	INLET	OUTLET
First Stage, m/sec (ft/sec)	16.8 – 19.8 (55-65)	18.3 – 21.3 (60-70)
Second Stage, m/sec (ft/sec)	18.3 – 21.3 (60-70)	24.4 – 36.6 (80-120)
Single Stage, m/sec (ft/sec)	16.8 – 22.9 (55-75)	27.4 – 36.6 (90-120)

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

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IMPACT FROM OPERATIONS

Process

- Gas Rate
  - Throughput / Regenerator Pressure
  - After Burn
- Bed Level / Fluidization
- Catalyst Type / Manufacture
- Upsets

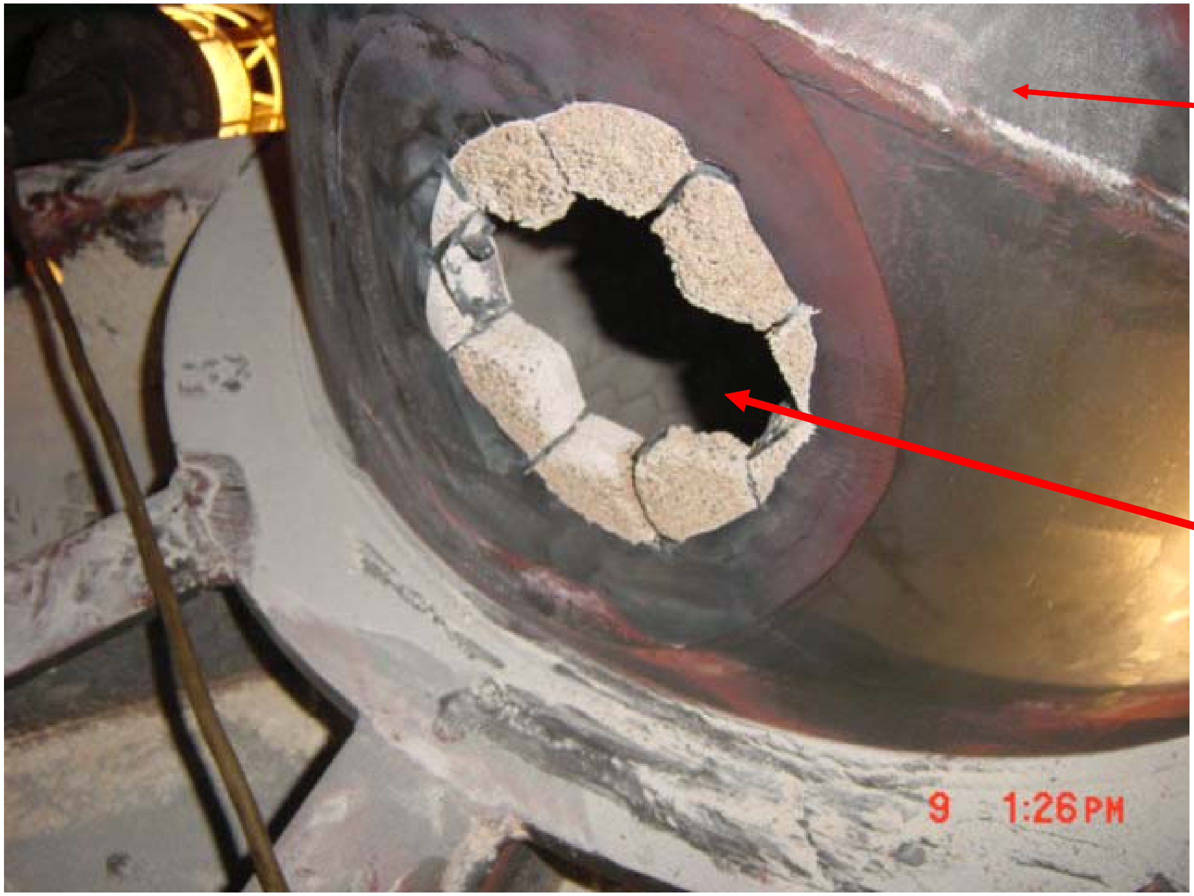
Mechanical

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

Plate Grid

Pipe Grid

BROKEN STEAM RING



2nd stage outlet tube

Holed through from outside due to broken steam purge

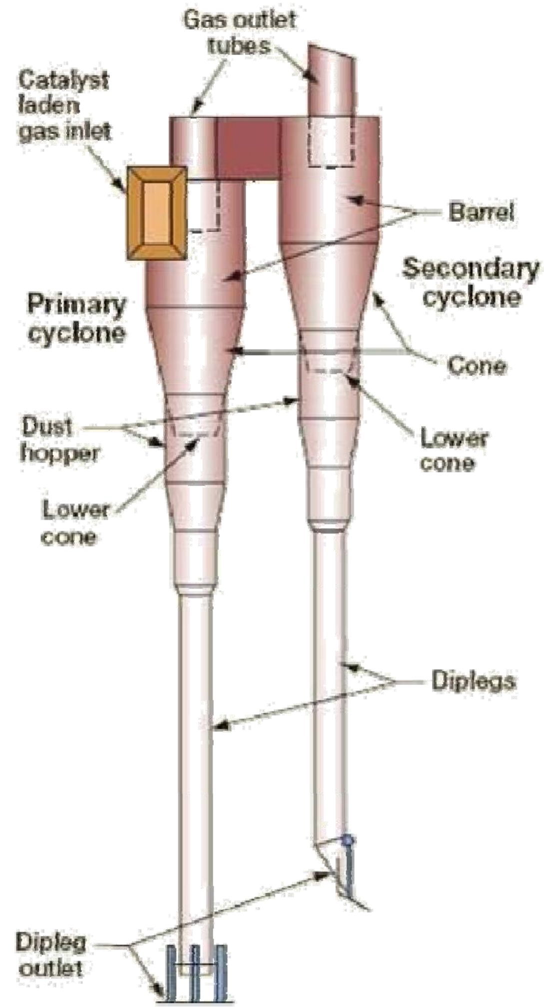
TYPICAL CYCLONE EROSION

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

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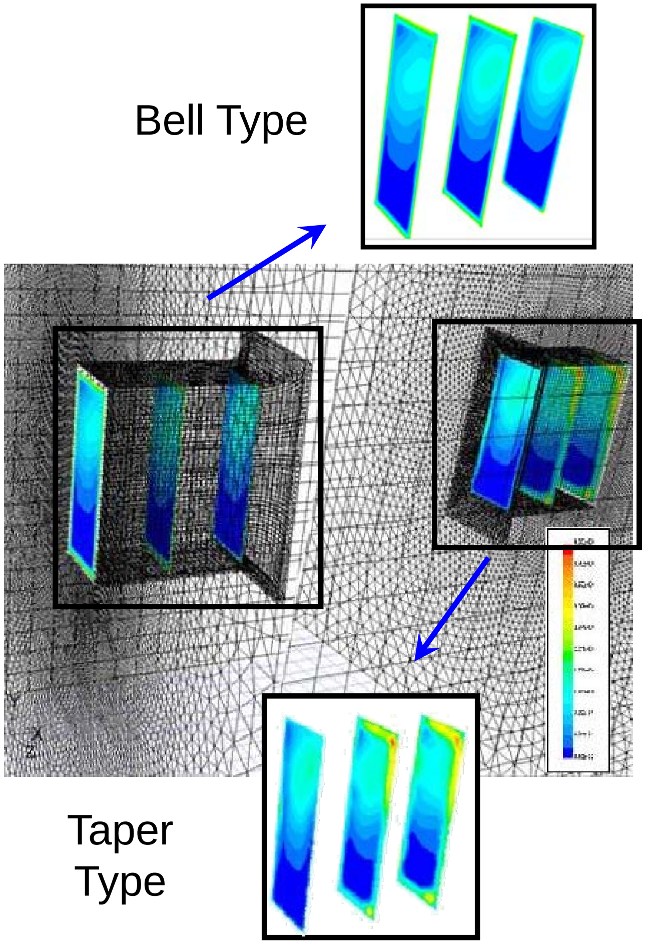
FIRST / SINGLE STAGE INLET

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



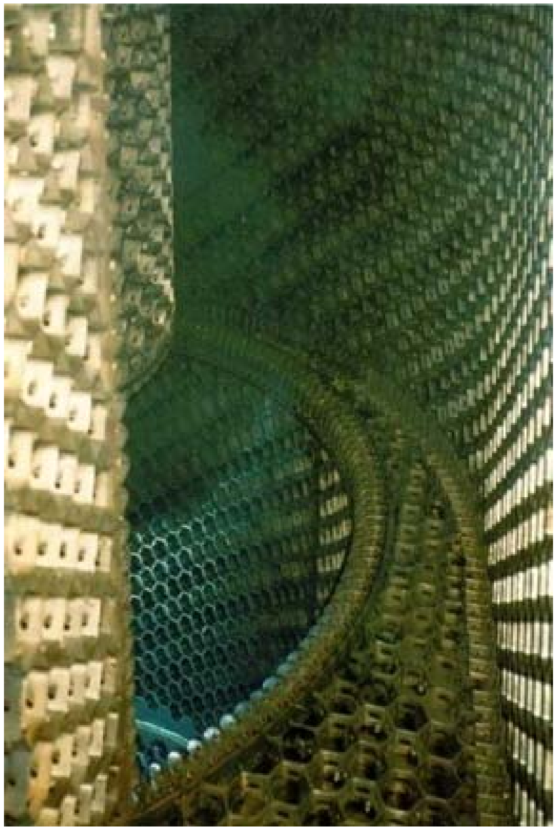
INLET ASPECT RATIO

First Stage Cyclones

- Highly Loaded
- Inlet Height to Width: 2.35 – 2.6

Second Stage Cyclones

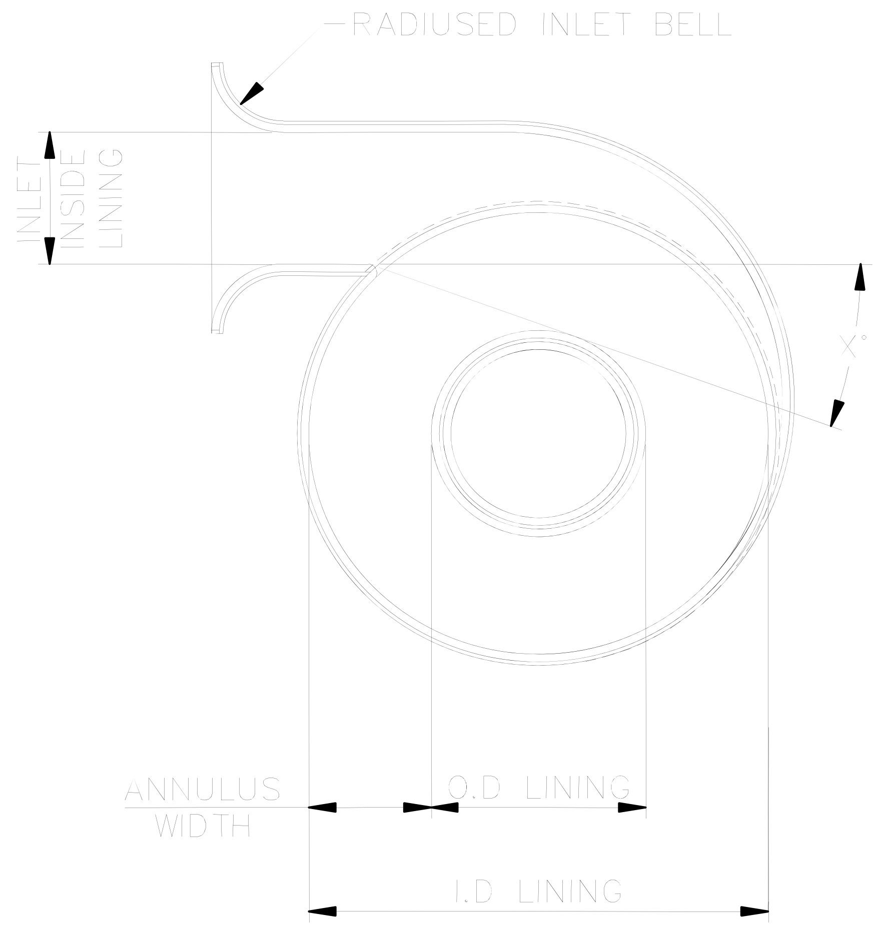
- Lightly Loaded
- Inlet Height to Width: 2.6 – 3.0



EXPANSION ANGLE (X)

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

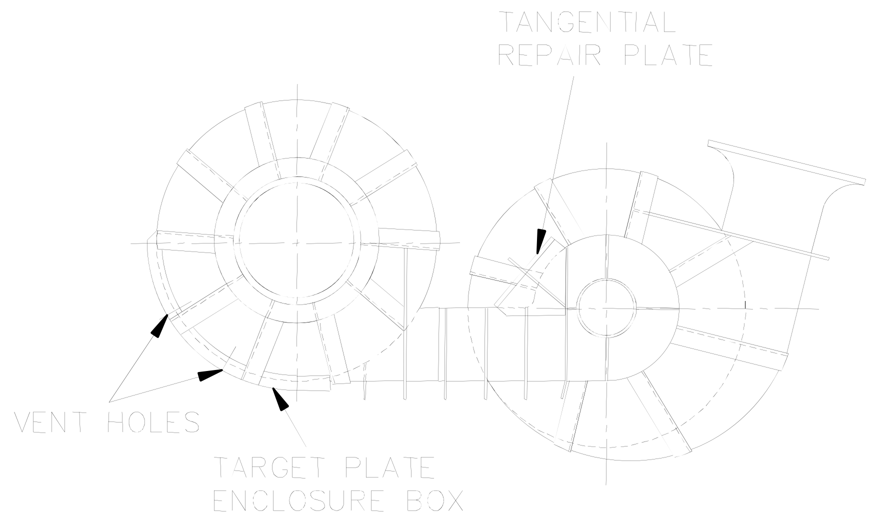
REPAIR OPTIONS

Shroud Repair

- Tangential Repair Plate
- Target Plate

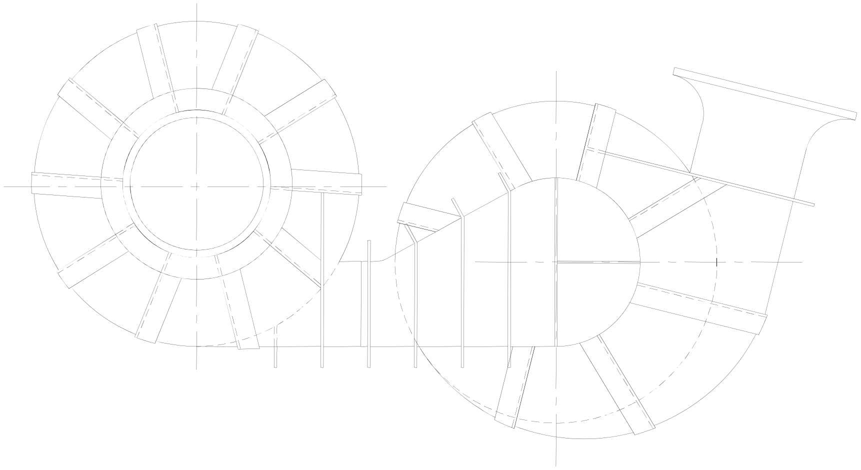
'K' Bar Anchors in Lieu of Hexmesh

- 'K' Bar - Easier to replace small areas
- Can be Contoured



PROPRIETARY TAPERED DESIGN

- Minimizes eddy currents
- Reduces wear
- Enhances efficiency
- Minimizes maintenance



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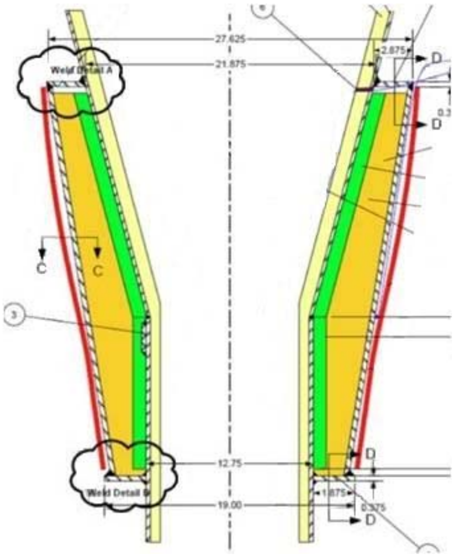
MAIN CONE / DUST HOPPER

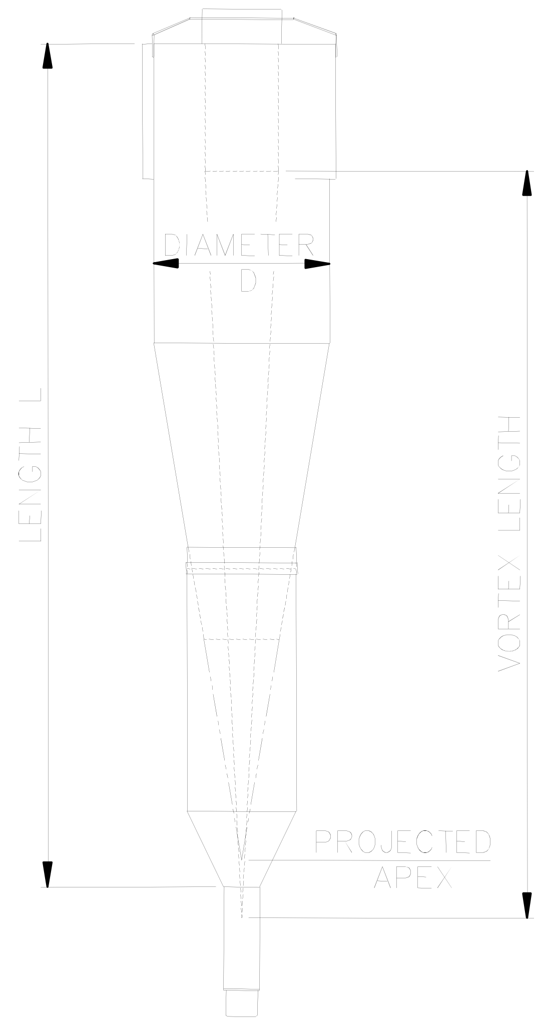
- High Gas Rates
- Gas Leaking Up Dipleg
- Defluidization of Dipleg
- First Stage Cyclone Design
- Fabrication / Repair Quality

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



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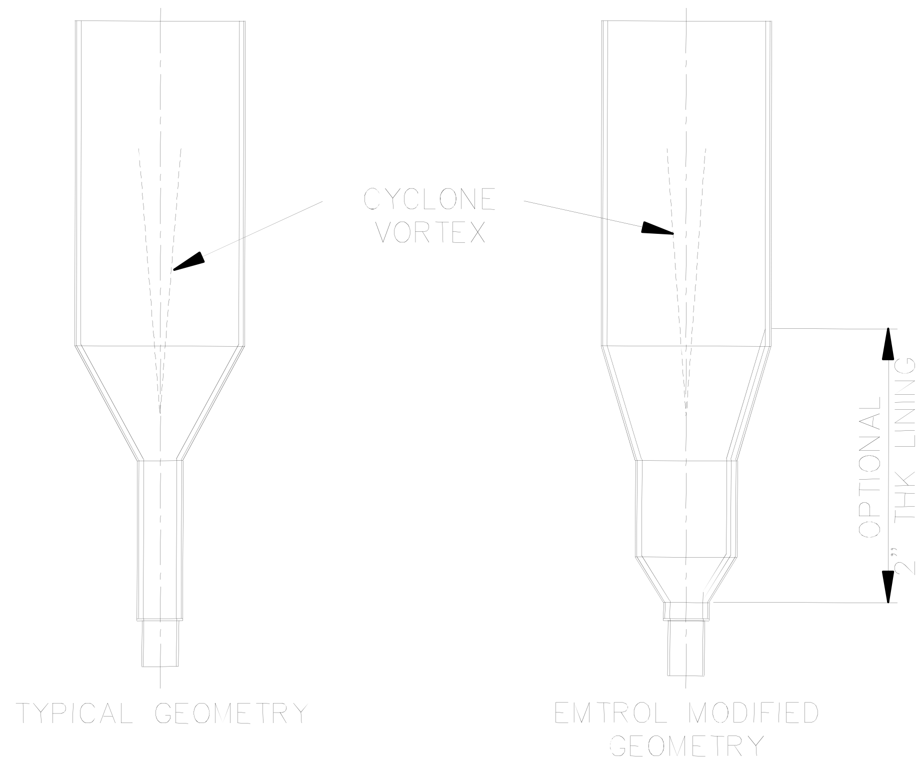
MODIFIED DUST HOPPER

Minimize Affects of Dipleg Leakage / Vortex Encroachment

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



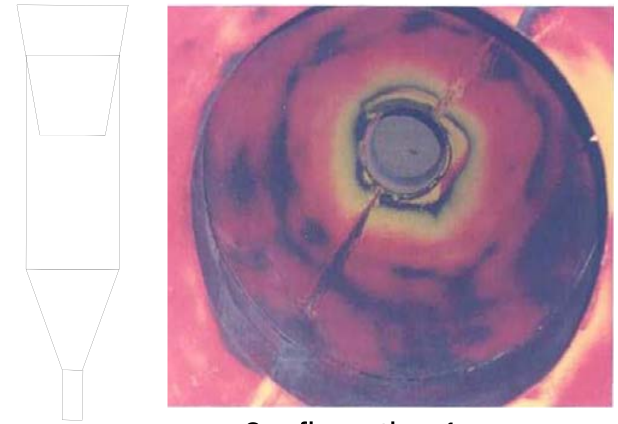
HOPPER EROSION

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



Configuration 1
Conventional Hopper

Configuration 2
Modified Hopper

DIPLEG & 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

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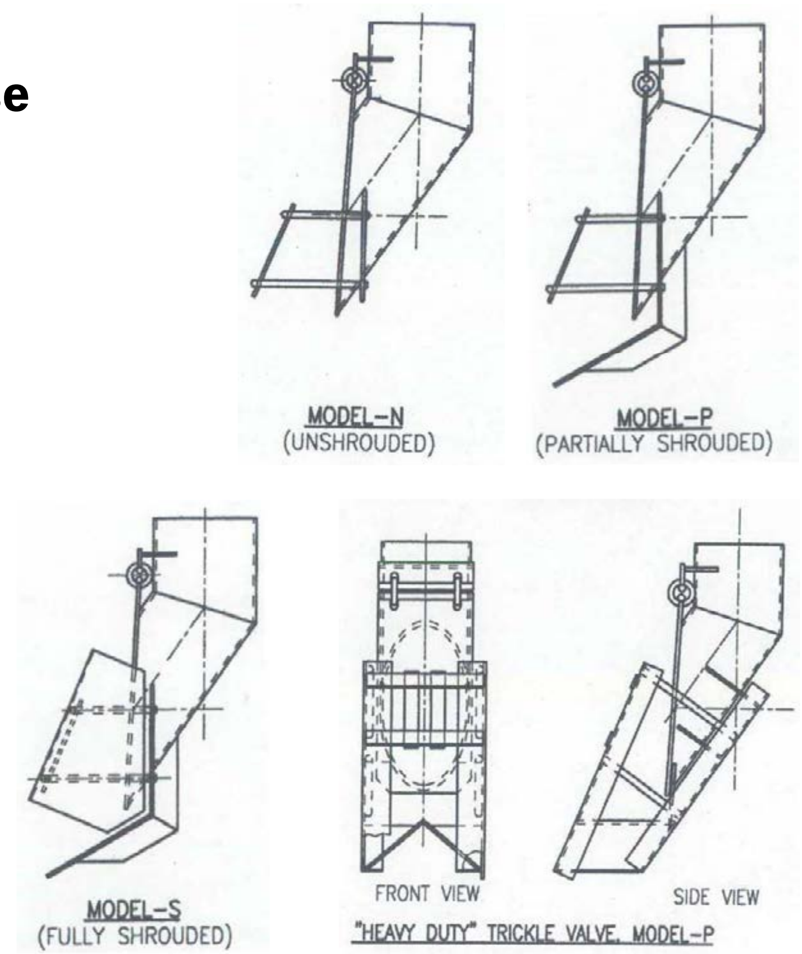
DIPLEG TERMINATIONS

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



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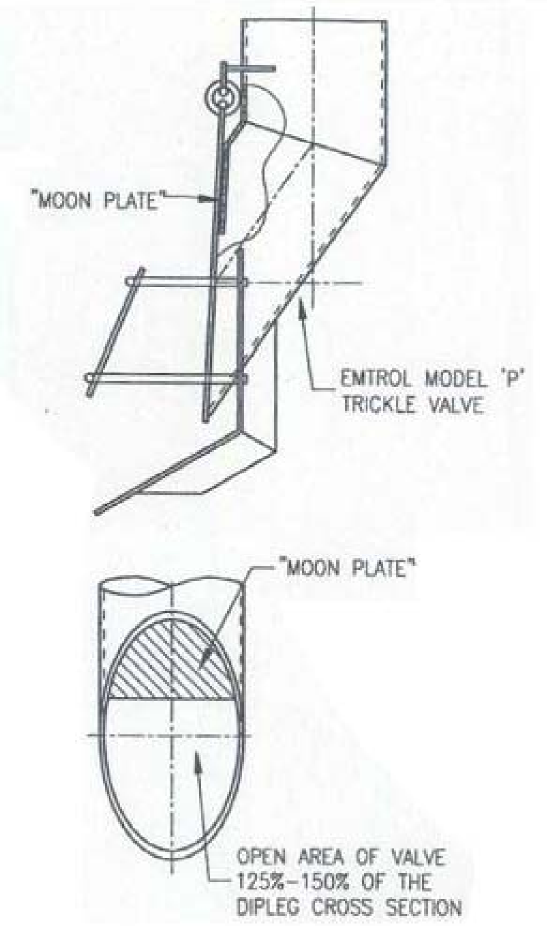
TRICKLE VALVES TERMINATIONS

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



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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?

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