Eliminating FCC Regenerator Afterburn

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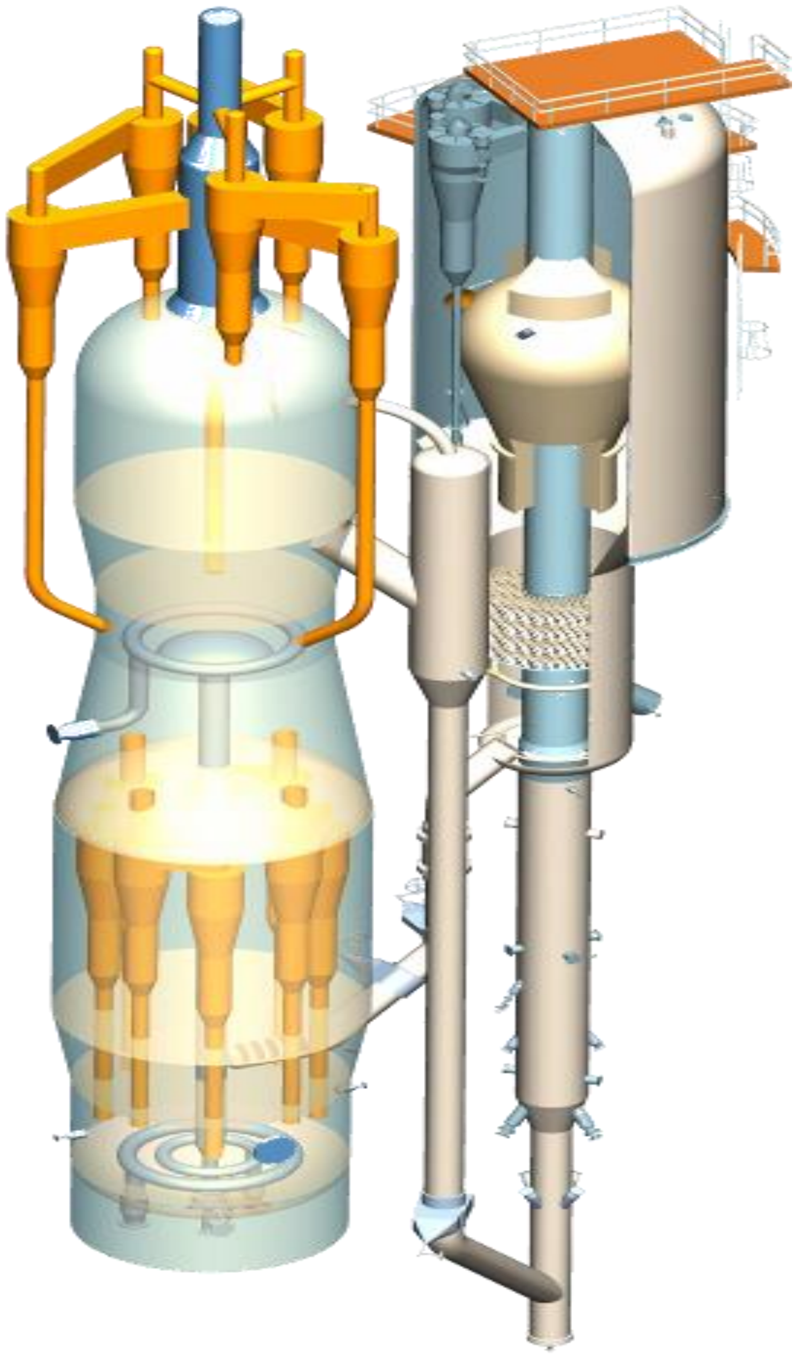
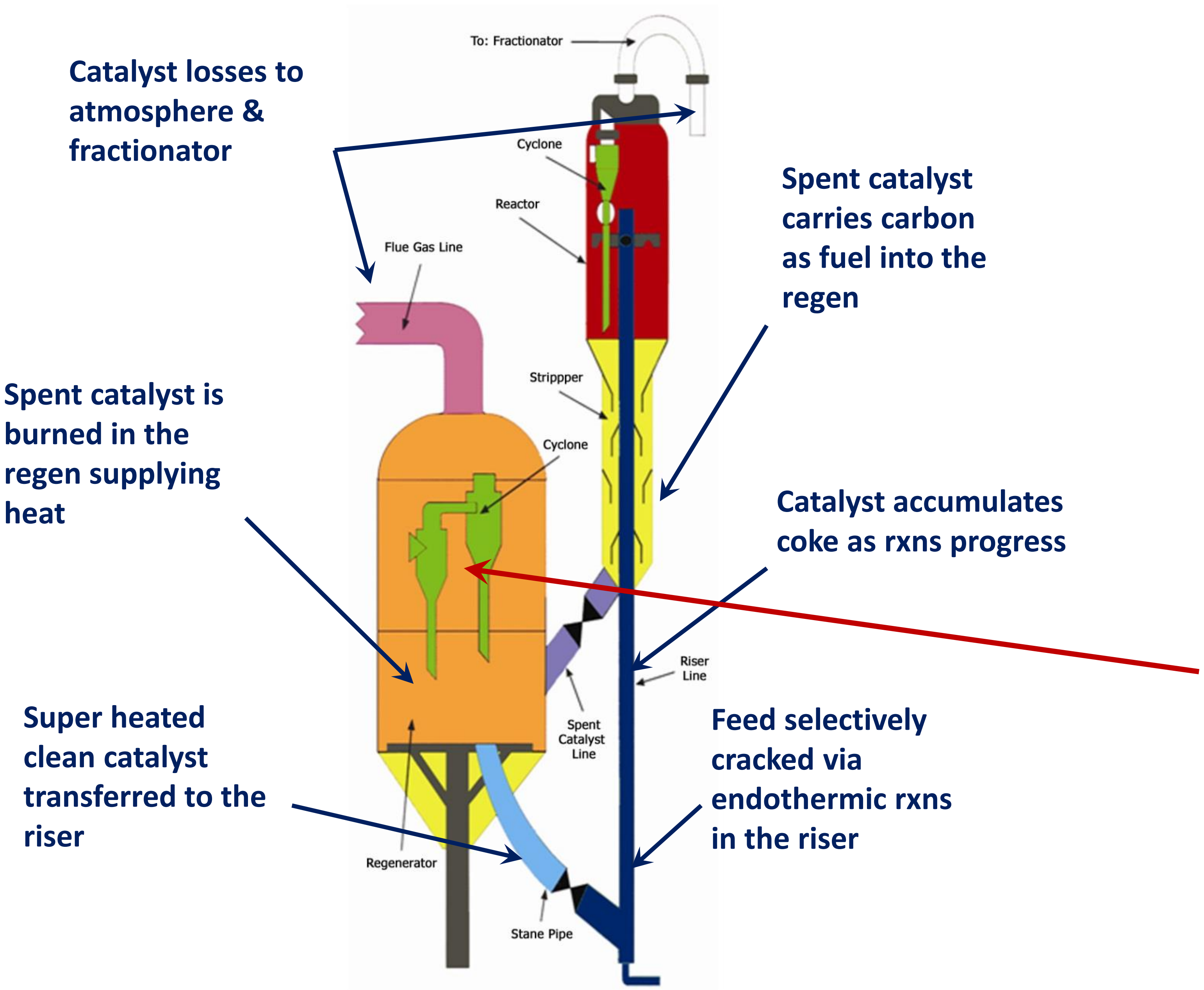


The FCC Catalyst Cycle

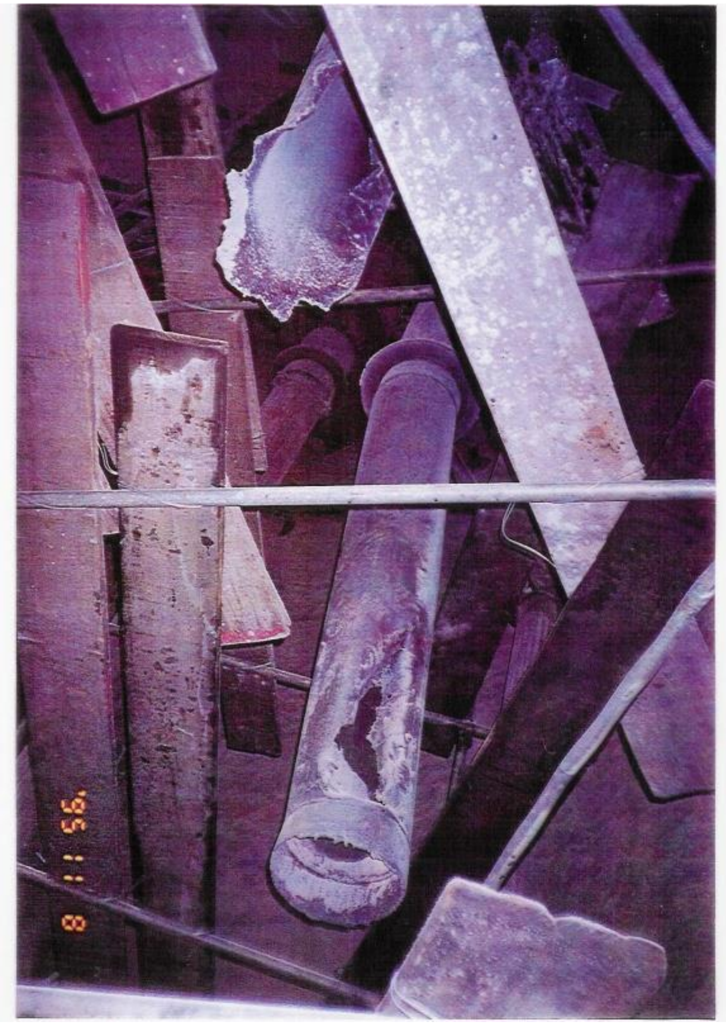


- **Catalyst cracks heavy oil into gasoline & diesel**
- **Side reaction is the deposit of carbon (coke) on the catalyst**
- **Spent catalyst is pneumatically transported to the regenerator**
- **Regenerator operation:**
  - Carbon is burned off in the dense bed
  - Cyclones separate catalyst from the combustion gasses
- **Afterburn occurs when the carbon burn occurs above the dense bed**

What is Afterburn?

- **Afterburning is any increase in flue gas temperature after leaving the dense bed**
  - May occur in dilute phase, cyclones, or flue gas
  - Little catalyst present to absorb heat of combustion
  - May limit throughput or feedstock flexibility
  - May result in serious damage to internals leading to premature shutdown & costly repairs

- **Elimination of afterburn is critical to stable FCC operations**



Severe damage to regenerator cyclones due to uncontrolled afterburn

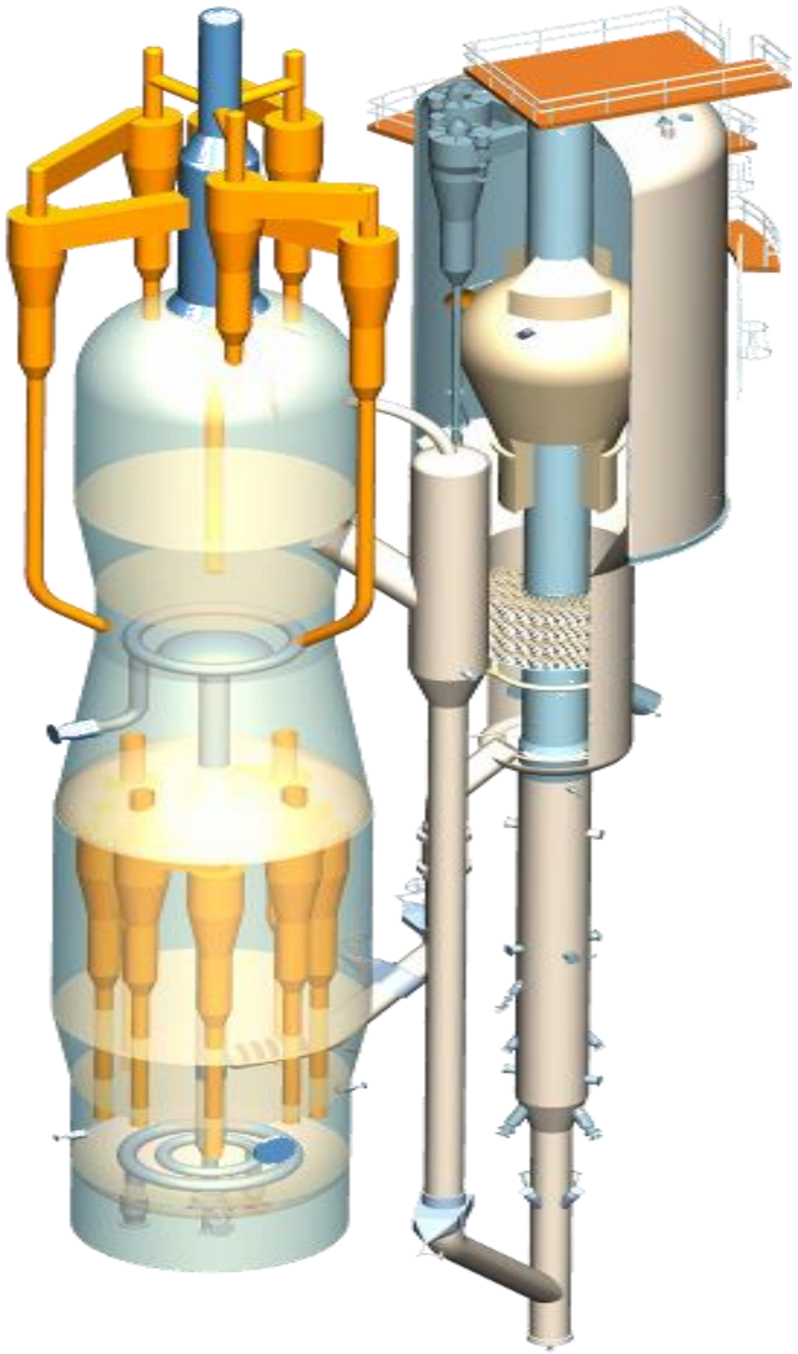
Goal of the Study

Overview:

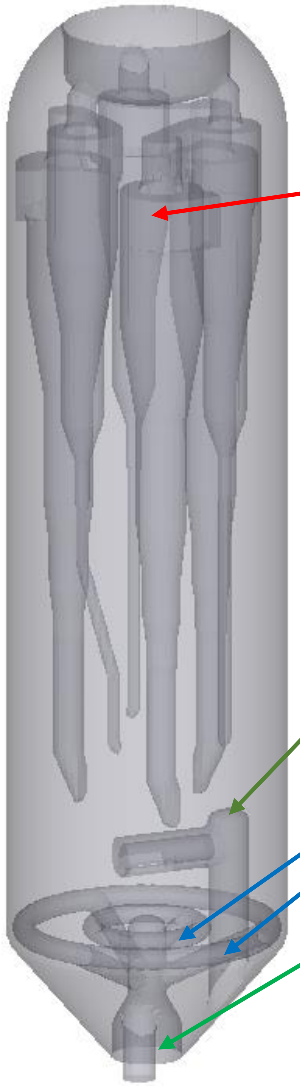
- Unit operating with continual afterburn
- Resulted in feed rate & feed quality limitations
- Refiner sought the root cause of afterburn for a hardware solution

Result:

- **CPFD** successfully identified the root cause
- **CPFD** worked with the refiner's engineering company to validate the improved spent catalyst distributor



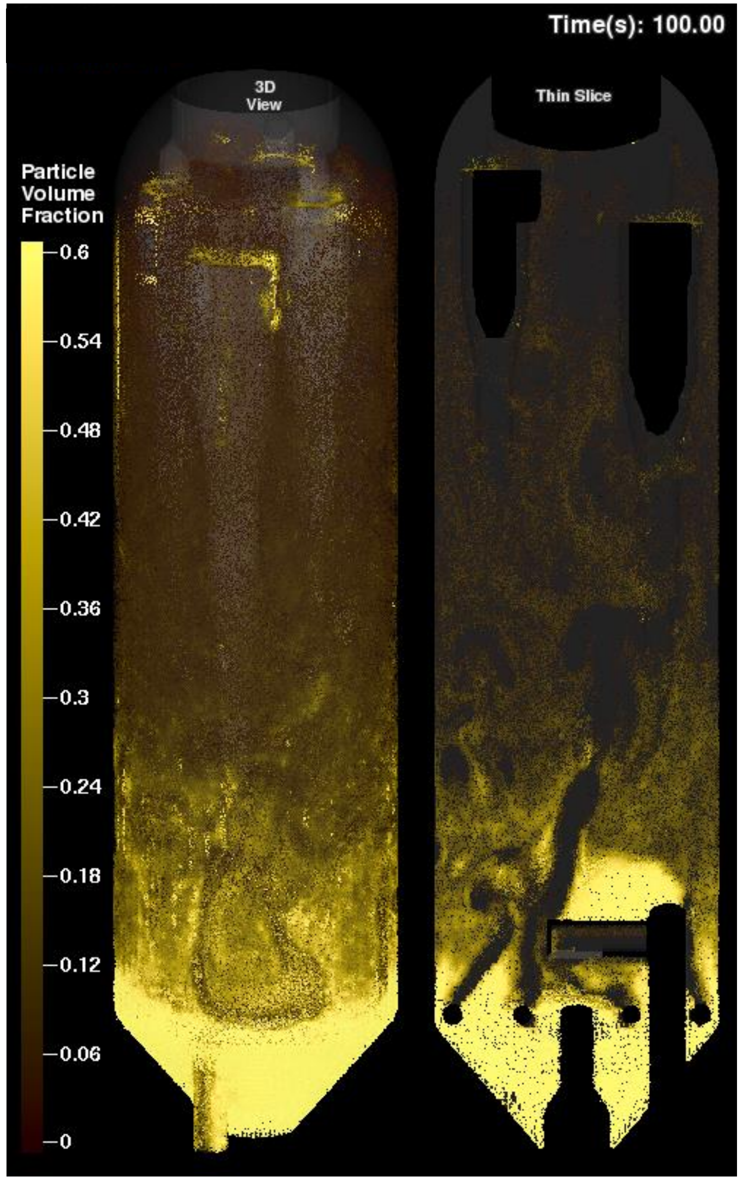
Regenerator Internal Structures



Overview: The FCC regenerator is 70' tall with an internal diameter of 18' 10". The 3D cad displays the primary internal hardware:

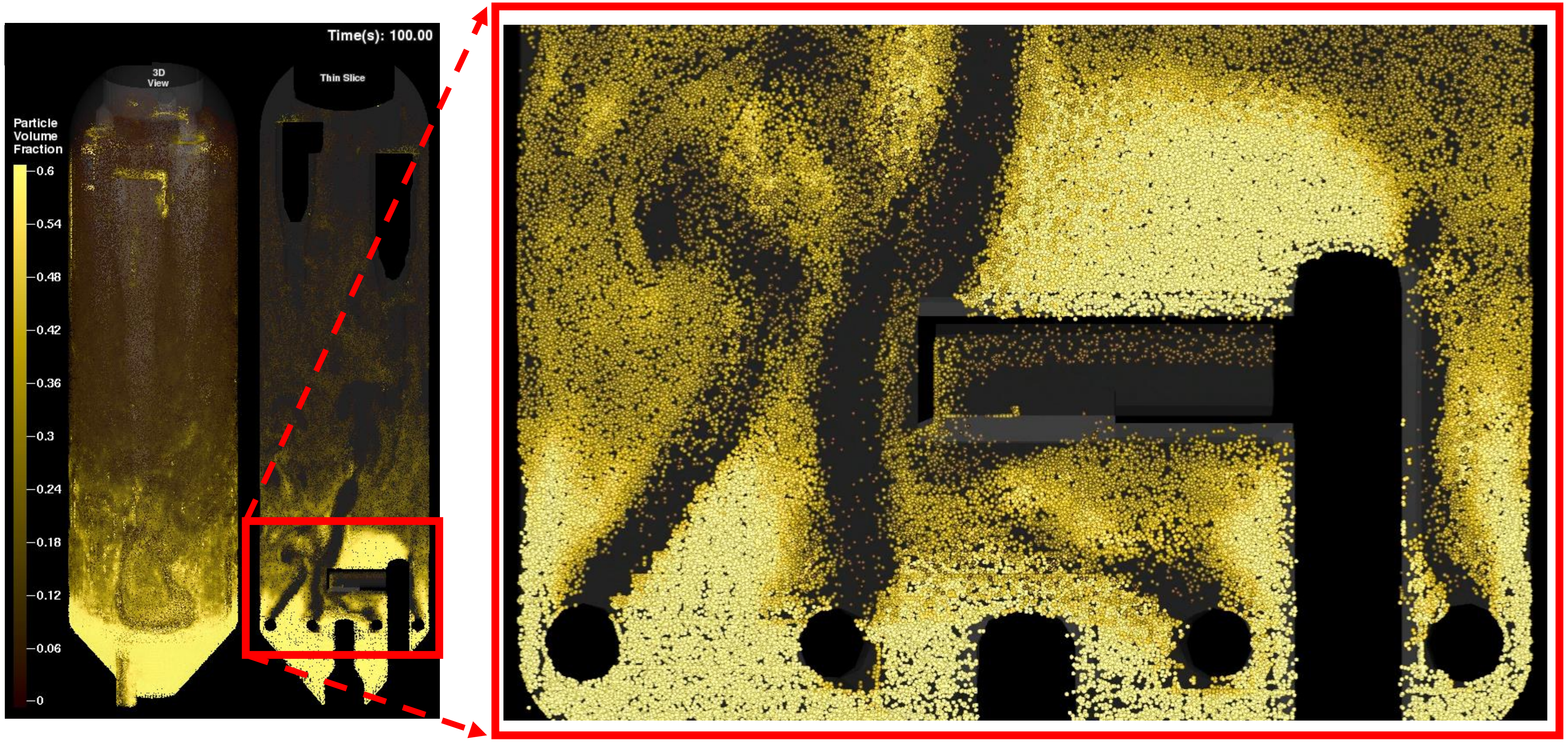
- **Cyclones** – Three primary and three secondary cyclones are included in the model.
- **Spent catalyst distributor** – Spent catalyst enters the regenerator through the distributor. A substantial fraction of total air enters through the distributor.
- **Air rings** – Fluidizing air enters through 415 nozzles located on two air rings.
- **Regenerated catalyst standpipe** – Regenerated catalyst leaves the system through the Regenerated catalyst standpipe (RCSP)

Overall Flow Characteristics



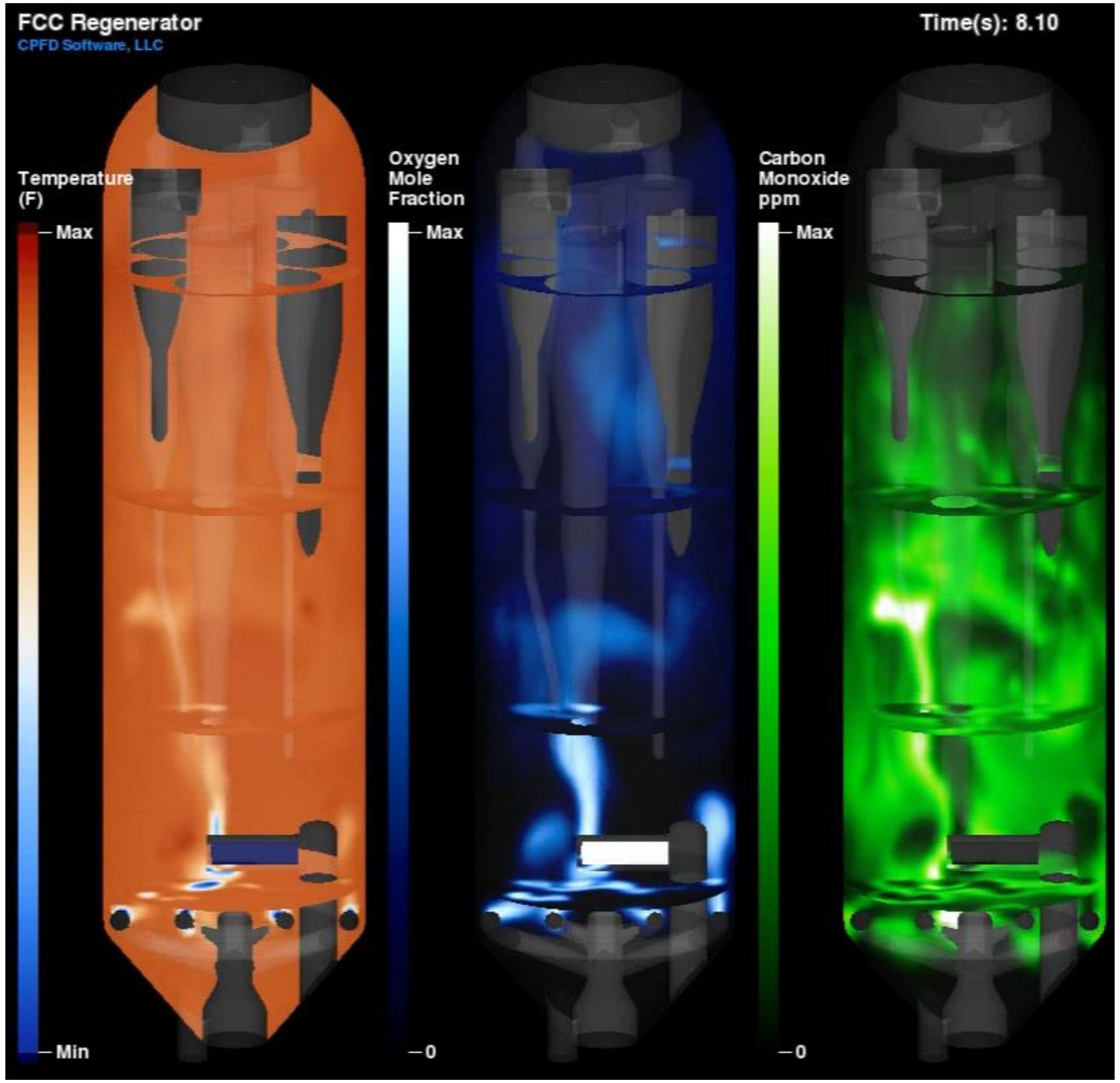
- **Animation demonstrates catalyst and combustion gas flows**
  - Full 3D system (left)
  - Center view aligned with spent catalyst distributor (right)
- **Maldistribution of gas flow from the spent catalyst distributor through dense bed**
  - Majority of spent catalyst & combustion gases by-pass the regenerator bed
- **Defluidized regions exist below air rings and above the spent catalyst distributor**

Detailed Spent Catalyst Flow



- **Majority of the spent catalyst is swept out of the dense bed**
- **Coke combustion is occurring primarily in the overhead leading to afterburn**

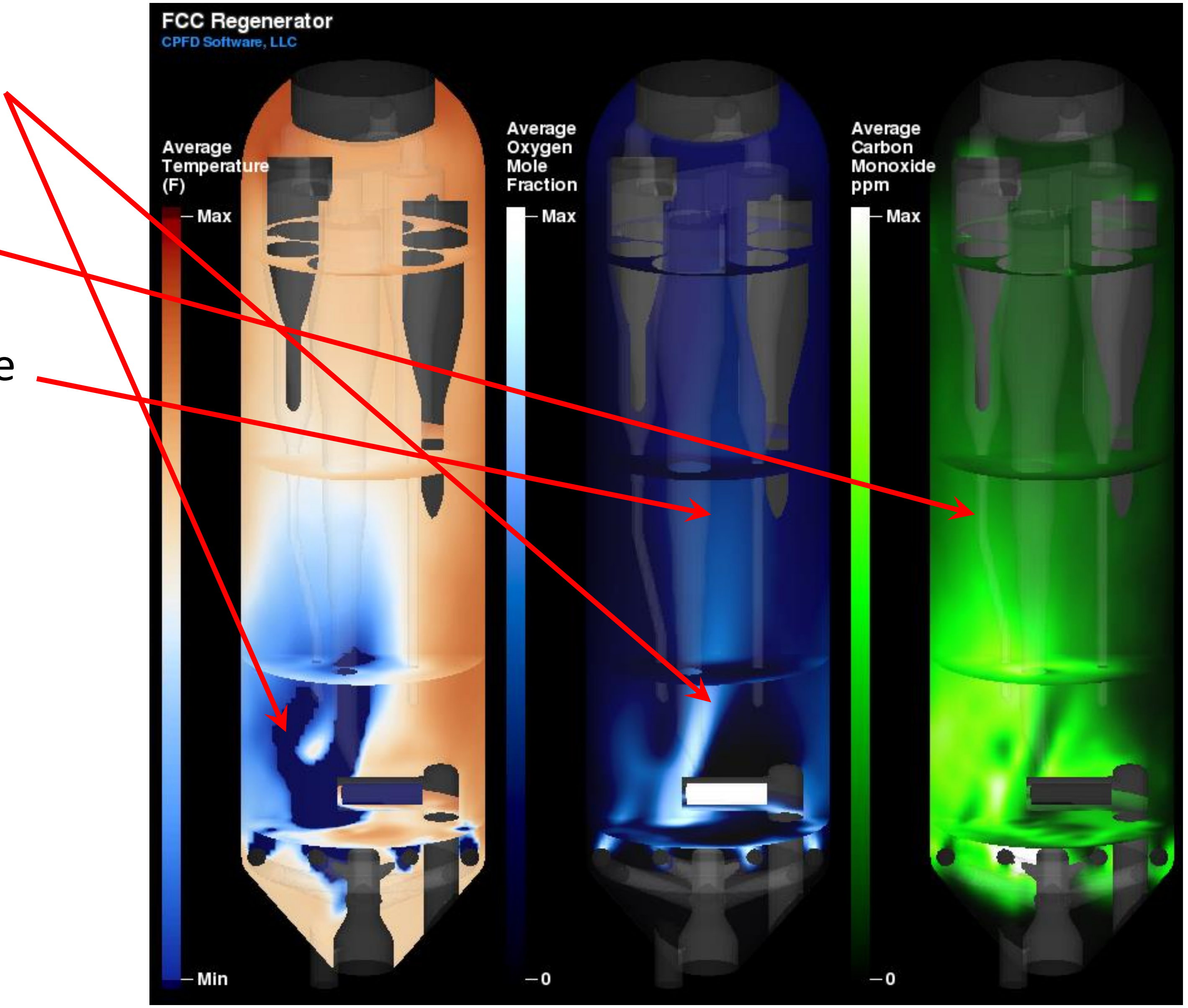
Regenerator Combustion Patterns



- **Temperature profile**
  - Large degree of burning is occurring in the vessel overhead
- **Oxygen profile**
  - Majority of oxygen channels through the regenerator
- **Carbon monoxide profile**
  - Significant concentrations of CO are observed in the vessel overhead resulting in afterburn

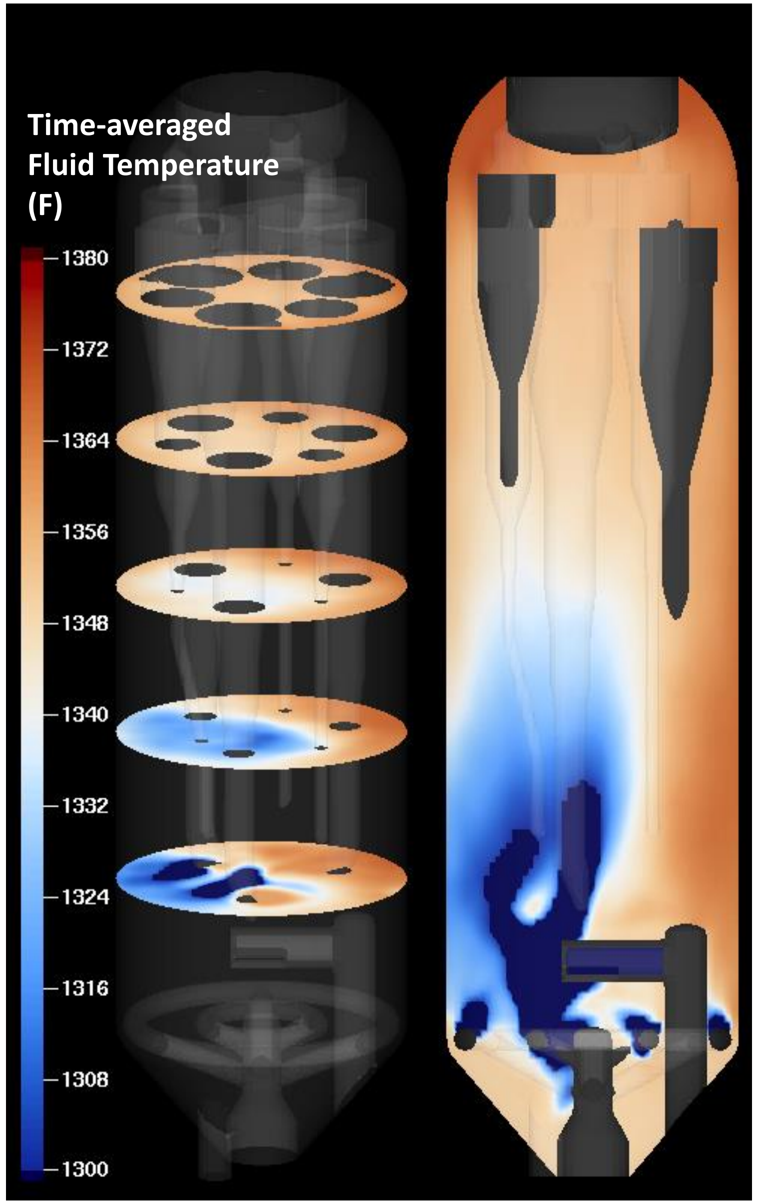
Time Averaged Combustion Patterns

- **Observations:**
  - Spent catalyst & combustion air bypasses the dense bed
  - Significant CO is present in the dilute phase along vessel walls
  - Oxygen reacts with CO leading to excessive temperatures



- **Afterburn root cause: maldistribution**
  - Poor spent catalyst distributor design

CO Combustion Kinetics



- **Average temperature profile indicates that a cooler region extends from the dense bed well into dilute phase of the regenerator**

- **Effects on CO combustion rate are significant. Reaction rate chemistry indicates that a reduction of temperature from 1370 F to 1320 F reduces the homogeneous CO combustion reaction rates by 63%**

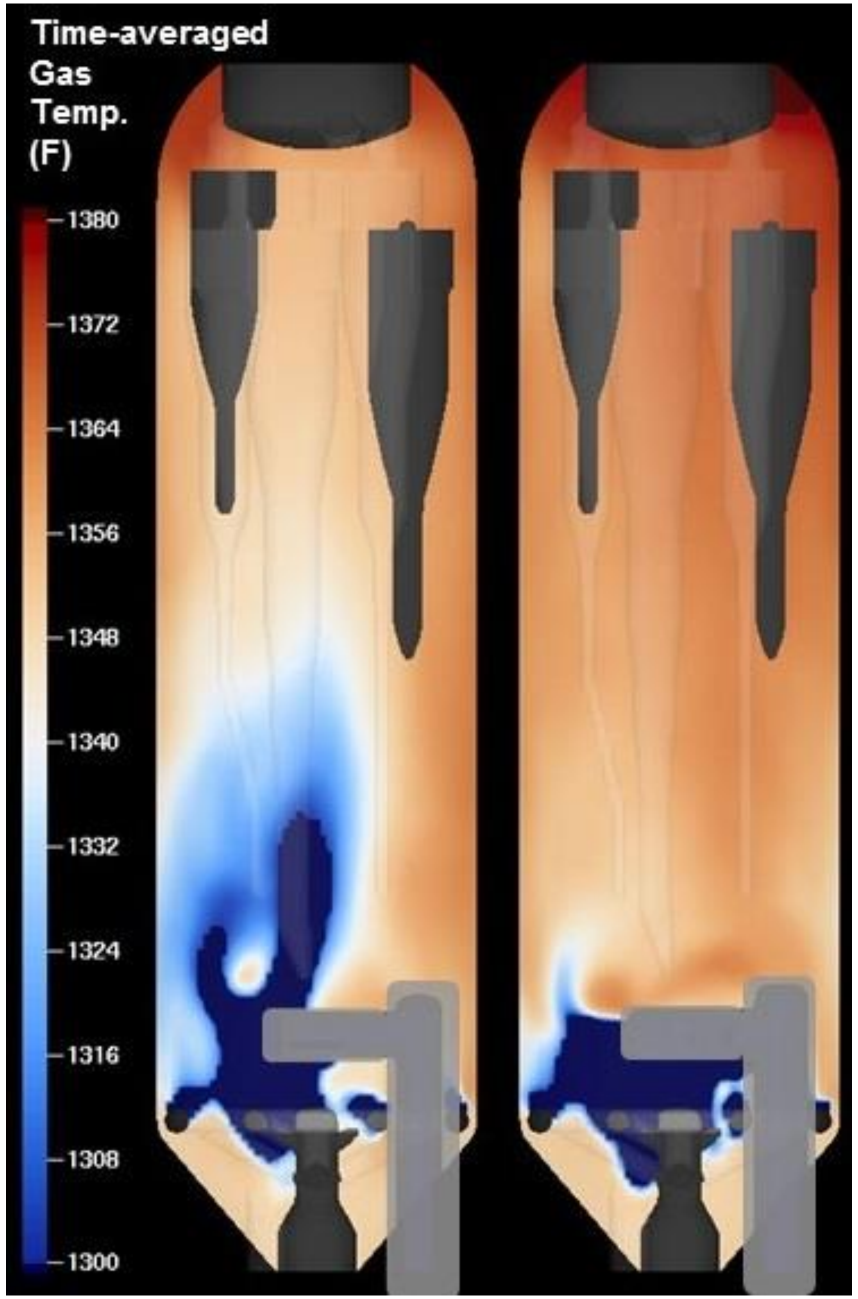
Improved Regenerator Design (1)

Proprietary distributor design details omitted

- **An improved spent catalyst distributor design was recommended based on the simulation results**

- **The alternative distributor was designed to:**
  - More uniformly distribute spent catalyst within the bed
  - More uniformly distribute the combustion air within the bed

- **A comparison of the simulation results for the improved spent catalyst distributor shows a much more uniform temperature profile in the bed**



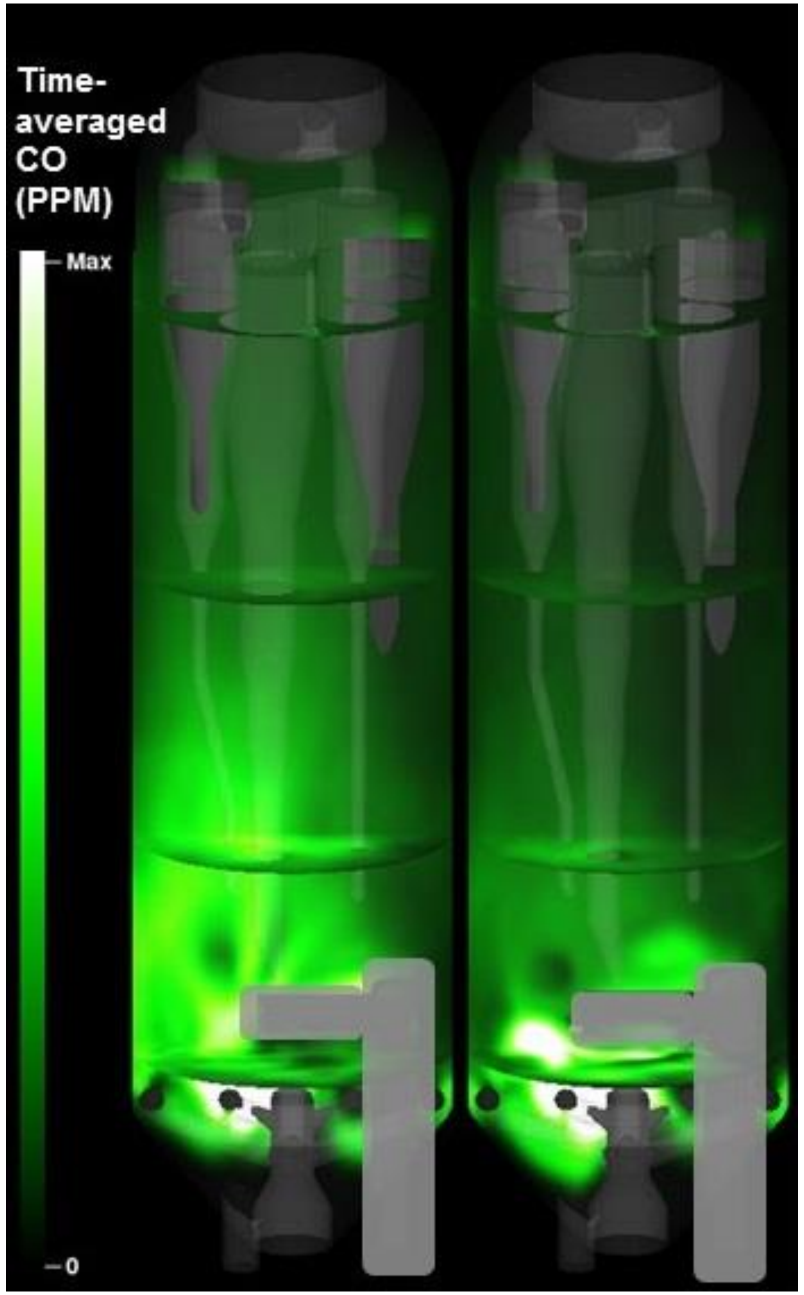
Baseline New Design

Improved Regenerator Design (2)

Proprietary distributor design details omitted

- **The improved distributor significantly reduces CO levels and afterburn**

- **Close collaboration between the refiner, the engineering company & CPFD enabled the refiner to verify whether the proposed distributor would actually eliminate afterburn**



Baseline **New Design**

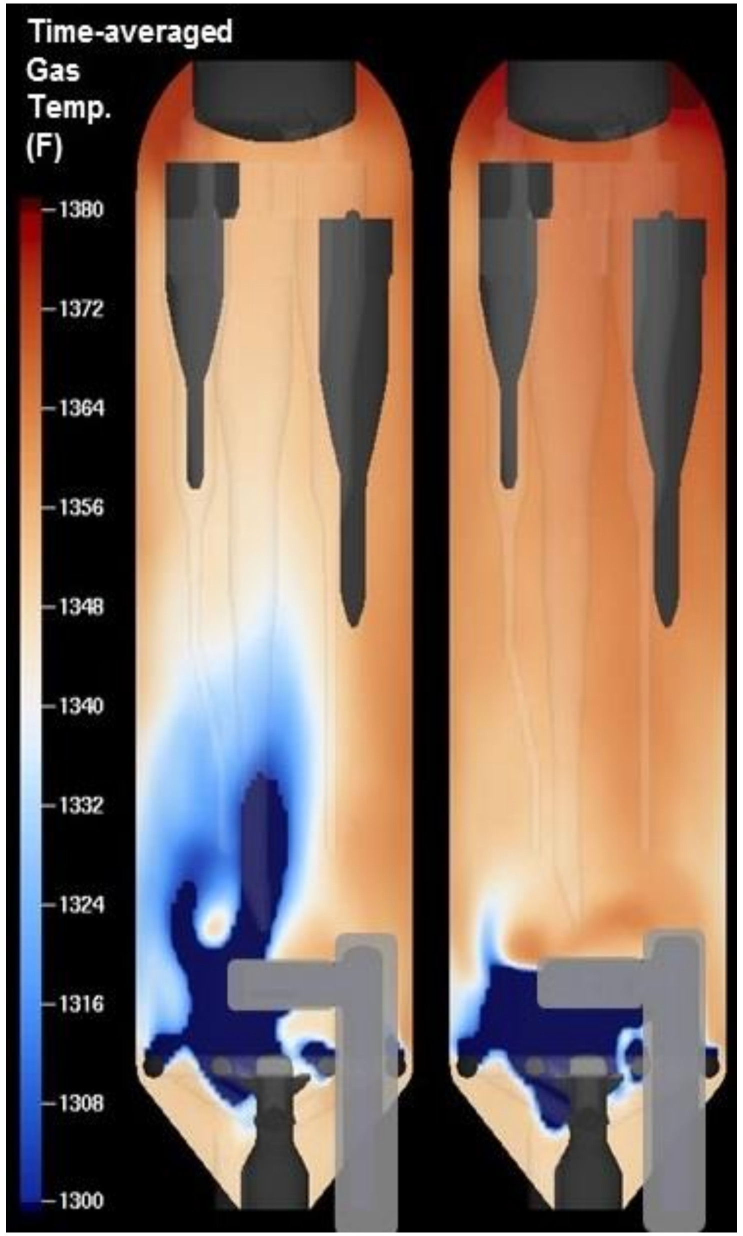
Conclusions

- **Significant maldistribution exists due to poor spent catalyst distributor design**
  - Majority of the spent catalyst by-passes the regenerator bed resulting in combustion in the dilute phase
  - Excess oxygen is present in the center of the regenerator while excess CO is present along the walls resulting in significant afterburn

- **A collaborative approach led to a significantly improved distributor design**
  – CPFD, refiner & engineering company

- **CPFD strongly recommends similar collaborations to ensure successful revamps in FCC & other processes**

Proprietary distributor design details omitted



Baseline New Design