REINHOLD ENVIRONMENTAL Ltd.

2015 APC Round Table & Expo Presentation

July 13 & 14, 2015, in Atlanta, GA / Hosted by Southern Company

CFD Flow Modeling to Improve Baghouse Performance for Circulating Fluidized Bed Scrubber

amec
foster
wheeler

2015 APC Round Table
July 13, 2015
Atlanta, GA

Agenda

1. Company Overview
2. CFB Scrubber Overview
3. Typical Baghouse Inlet Conditions
4. Baghouse Performance Analysis
5. Baghouse Compartment Inlet Designs
6. Typical PJFF Gas Flow Modeling
7. CFD Flow Model Results

1. Company Overview

Company Overview

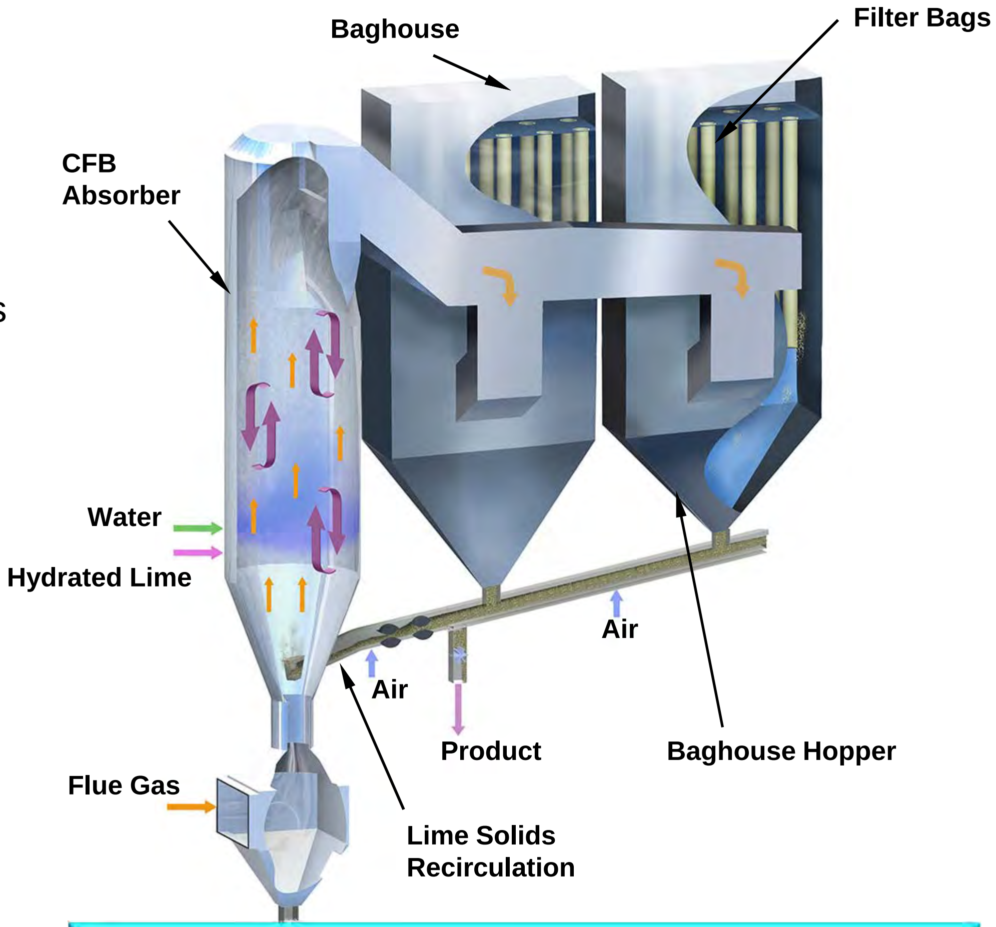
- AMEC and Foster Wheeler combine on 13 November 2014 to create a new force in global engineering, project delivery, asset support, power equipment and consultancy.
- Full portfolio of air pollution control equipment:
  - Wet FGD systems
  - CFB scrubbers
  - Dry sorbent injection
  - Spray Dryer Absorbers
  - Wet and dry ESP’s
  - Fabric Filters
  - Cartridge collectors
  - Low NOx combustion and SCR retrofits

2. CFB Scrubber Overview

Amec FW's Multi-Pollutant Circulating Fluidized Bed Scrubbing Technology

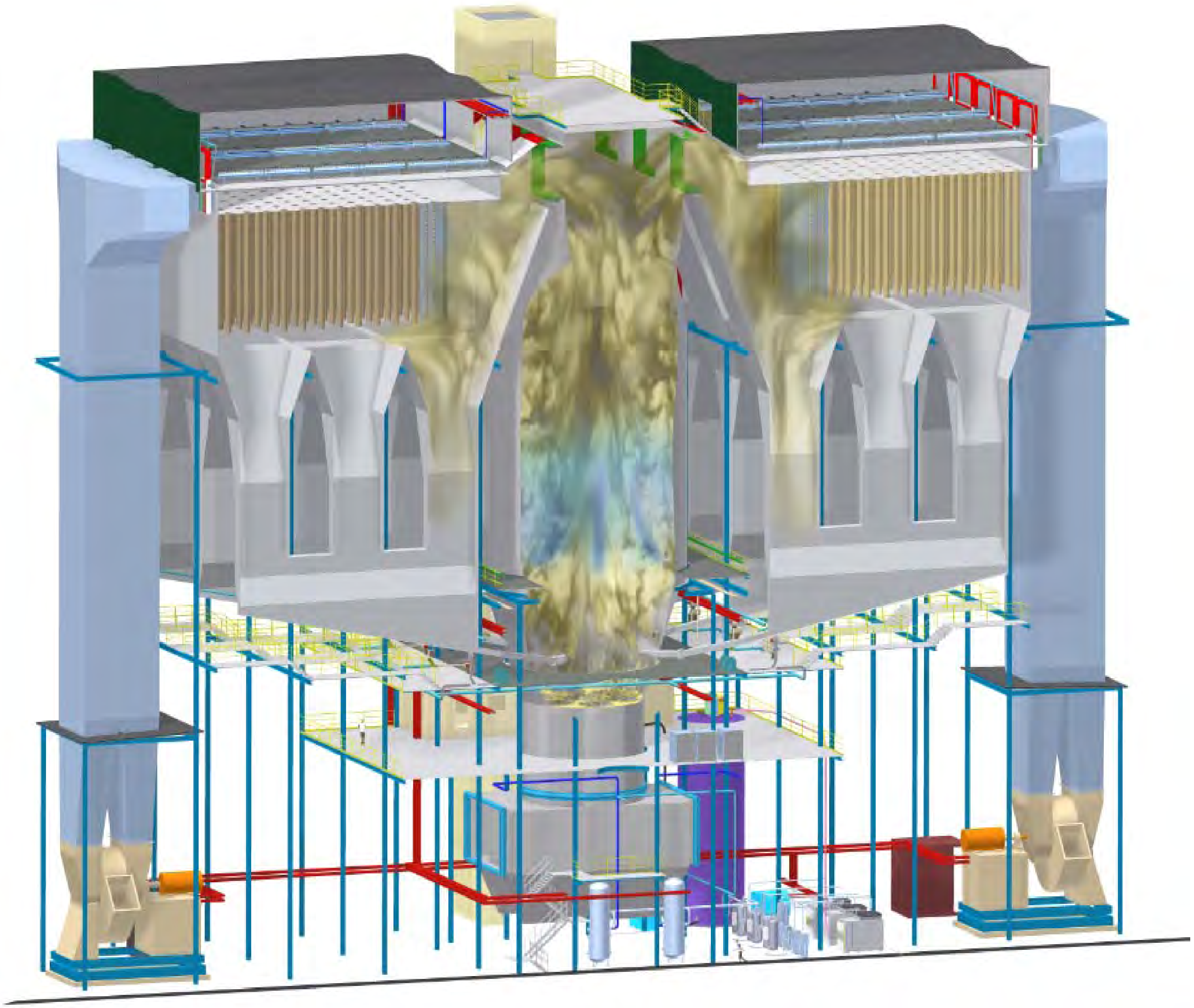
How it works?

- Flue gas with or without ash enters the bottom of the absorber, flowing upward through multi-venturi to accelerate the gas flow causing turbulence flow.
- Water, fresh hydrated lime, and recycled solids mix with the turbulent flue gas providing excellent mixing to cool the gas and capture a wide range of pollutants.
- The gas and solids then enter the baghouse where the solids are captured by the bags filters and a portion recycled back to the absorber via a reliable ash slide system to capture more pollutants
- As the gas passes thru the cake of solids coating the bags, the gas is further cleaned of fine particulates and vapor phase pollutants.
- Reactive absorpants like ACI, tronna, and others can be added to condition the circulating solids to target specific compounds depending on the flue gas pollutant concentrations.



Turbulent gas/solids mixing and high recirculation delivers efficient capture of multiple gas and solid pollutants

Basin Electric – Dry Fork Station Largest CFB Scrubber in the World



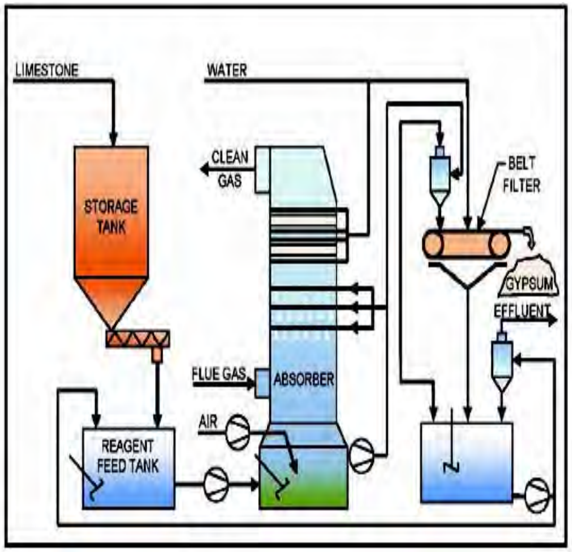
520 MWe@SL

1,792,000 ACFM

SO2 Removal:
77 - 97%

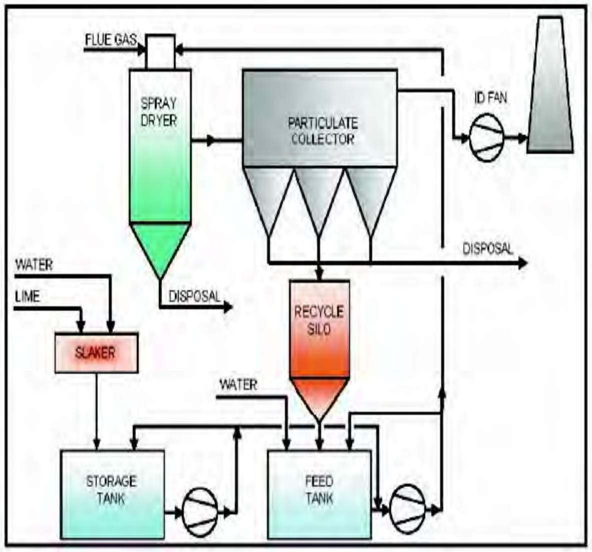
FGD Technologies Comparison

Wet FGD



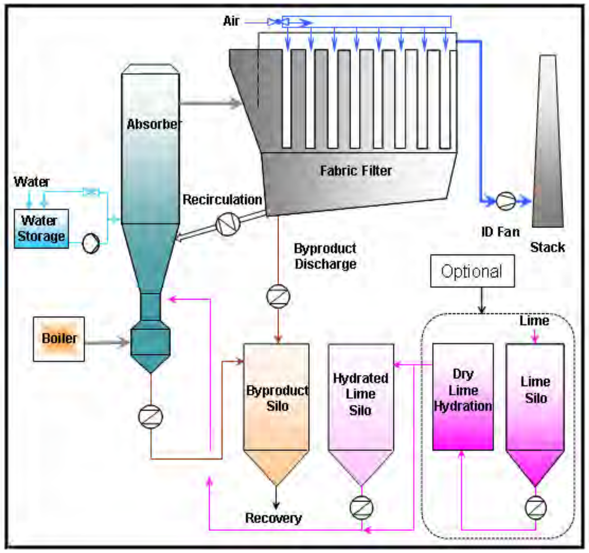
- ▶ High SO2 Removal
- ▶ High Installed Cost
- ▶ High Water Use
- ▶ Cheap Limestone Sorbent
- ▶ Liquid Waste Streams

SDA FGD



- ▶ Moderate SO2 Removal
- ▶ Moderate Installed Cost
- ▶ Moderate Water Use
- ▶ Hydrated Lime Sorbent
- ▶ Dry Disposal

CFB FGD

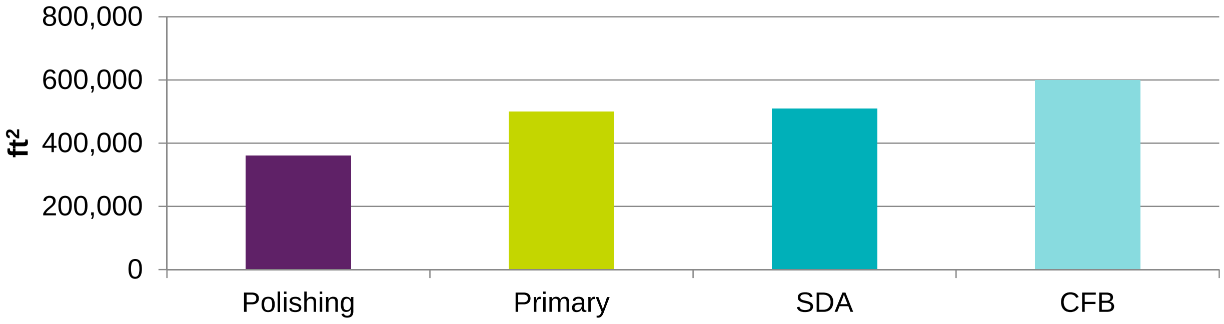


- ▶ High SO2 Removal
- ▶ Mod. – High Installed Cost
- ▶ Moderate Water Use
- ▶ Hydrated Lime Sorbent
- ▶ Dry Disposal

3. Typical Baghouse Inlet Conditions

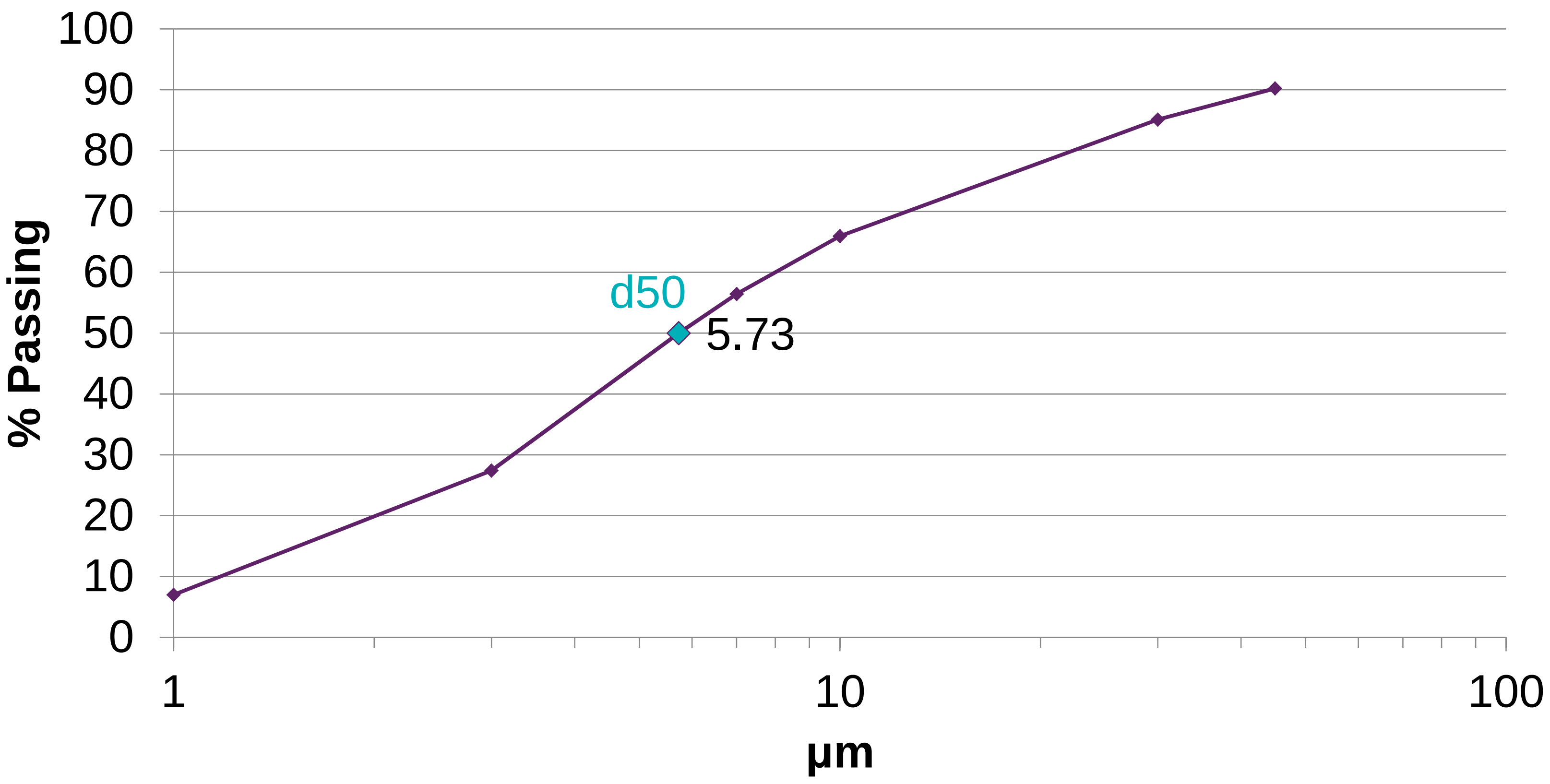
Baghouse Inlet Conditions Comparison Flue Gas

Description	Units	Polishing / TOXECON	Primary Collector	Spray Dryer Absorber	CFB Scrubber
Boiler Size	MW	500	500	500	500
Flue Gas Volume Flow	ACFM	2,000,000	2,000,000	1,800,000	1,800,000
Flue Gas Temperature	°F	300	300	170	170
Upstream PM Collection		Yes	No	Yes / No	Yes / No
Typical A/C Ratio	ft/min	5.5	4.0	3.5	3.0
Total Cloth Area	ft^2	360,000	500,000	510,000	600,000

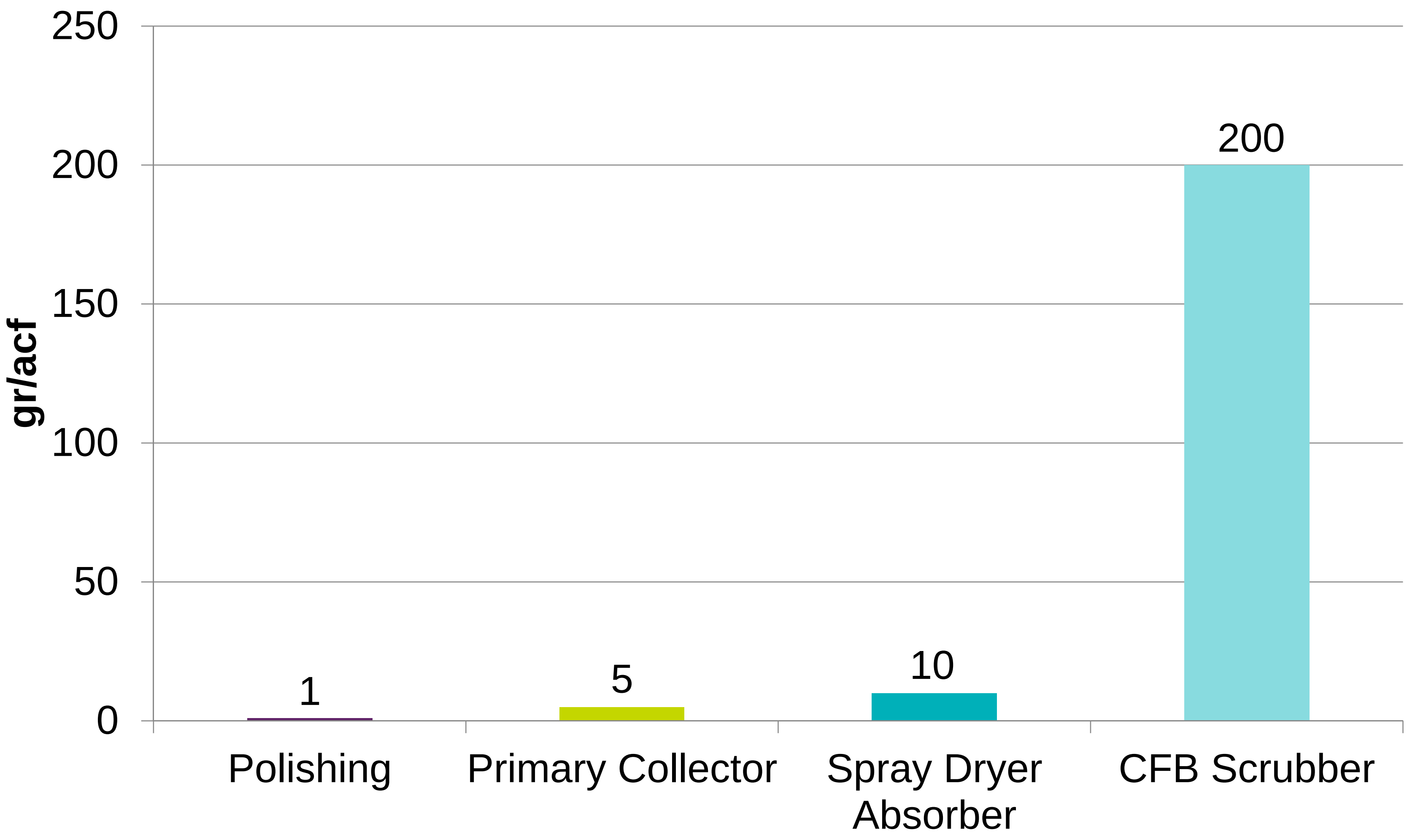


Typical CFB Scrubber Baghouse Inlet Conditions

By-Product Analysis



Baghouse Inlet Conditions Comparison
Dust Loading



4. Baghouse Performance Analysis

Performance Calculation

Modified Darcy Equation:

20X – 40X Greater Than "Normal"

$$dP = \left[S_E \times {}^{Air}/_{Cloth}\right] + \left[K_2 \times \frac{Dust\ Loading \times Cleaning\ Time}{Cloth} \times {}^{Air}/_{Cloth}\right]$$

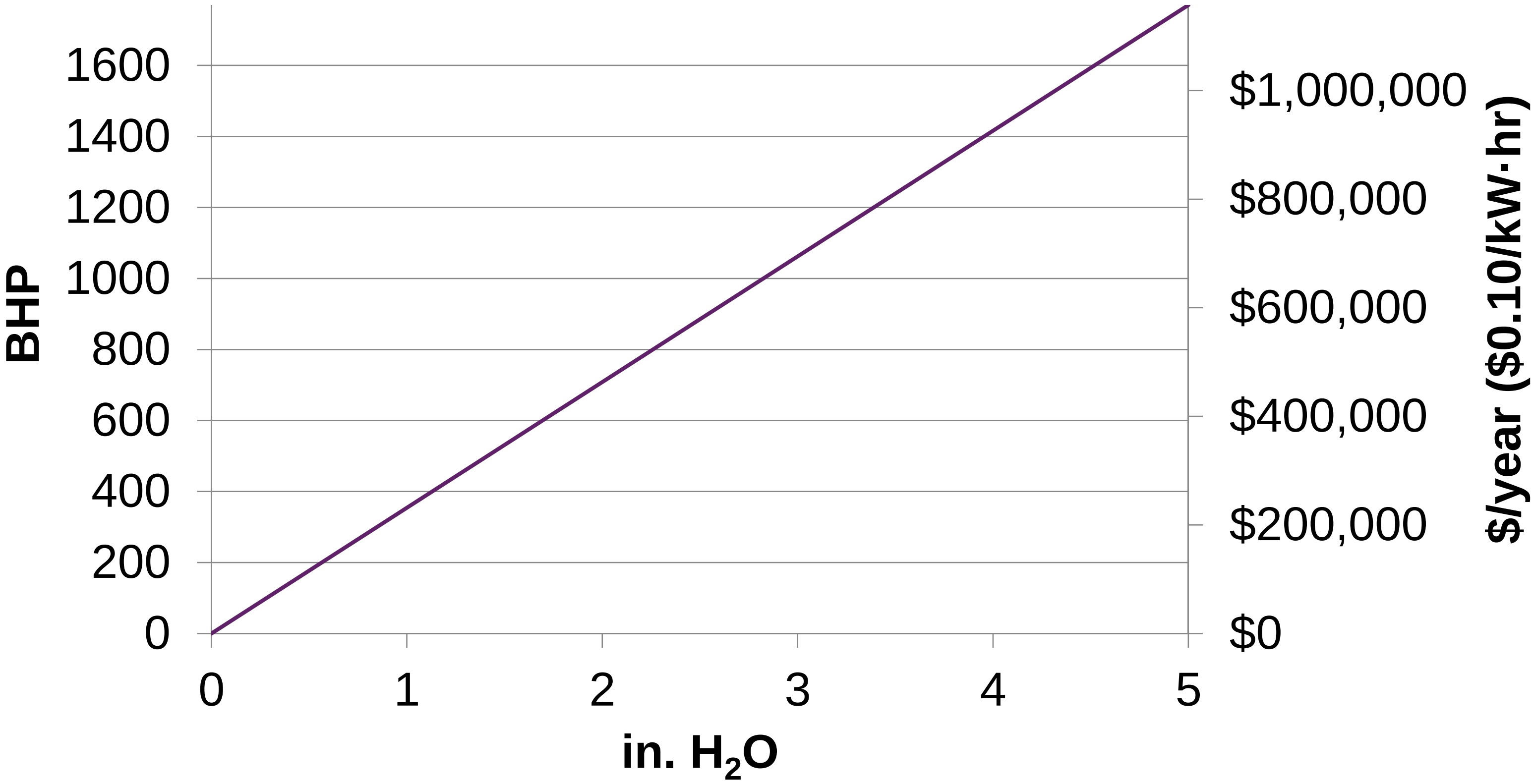
How Do You Compensate for Increased Dust Loading?

1. Higher dP: More Fan Power
2. Lower A/C Ratio: Larger Baghouse
3. Shorter Cleaning Time: Shorter Bag Life, More Compressed Air
4. Reduce Dust Loading to Bags – Dropout!

- Combination of All of the Above

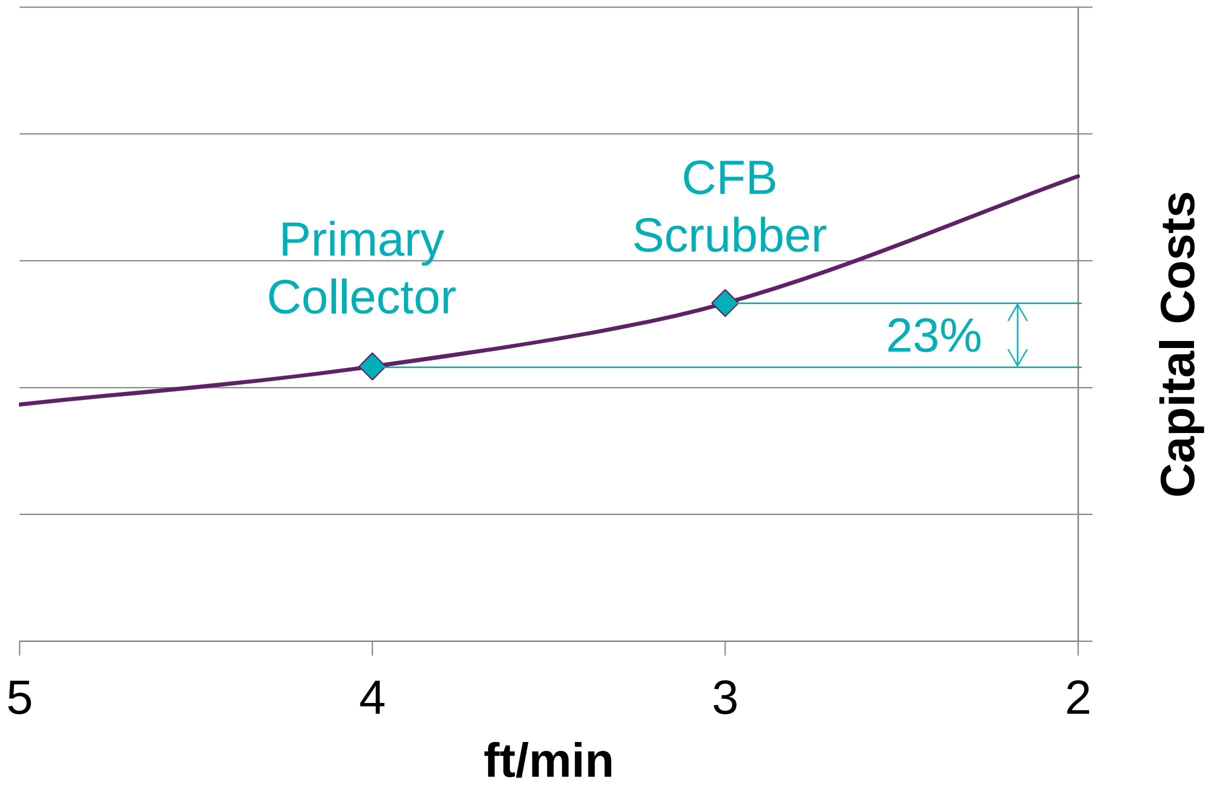
Design Implications for High Dust Loading
1. dP & Fan Power

$$BHP = \frac{1{,}800{,}000\ ACFM \times Static\ Pressure}{80\%\ Fan\ Efficiency\ \times 6356}$$



Design Implications for High Dust Loading
2. Lower A/C Ratio

$$PJFF\ Capital\ Costs \propto Cloth\ Area$$



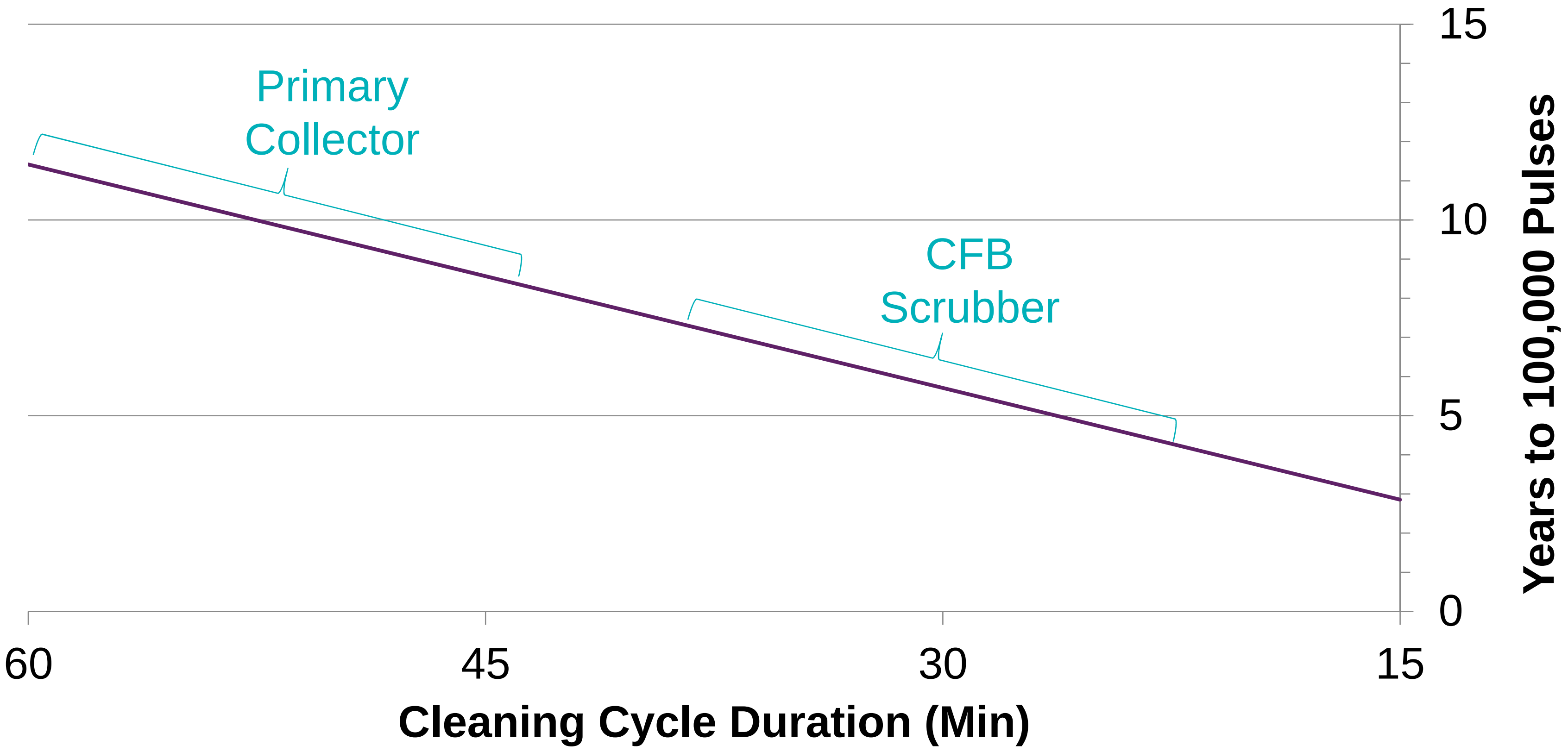
Design Implications for High Dust Loading
3. Shorter Cleaning Time

- Overall Cleaning Cycle Design
  - Multiple valves and/or compartments cleaned at the same time
- Compressed Air System Design
  - Compressors, dryers, receivers, piping, etc.
- Filter Bag Design, Additional Wear & Tear
  - Heavy felt weights
  - Wear cuff designs
  - Scrim-support

Parameter	Value
Gas Flow	1,800,000 ACFM
Cloth Area	600,000 ft^2
No. of Bags (10 m)	14,000
Bags / Pulse Valve	20
No. of Pulse Valves	700
Cleaning Cycle	30 min
No. of Valves Pulse Simultaneously	Time Between Pulses
1	2.6 sec
4	10.3 sec
8	20.6 sec

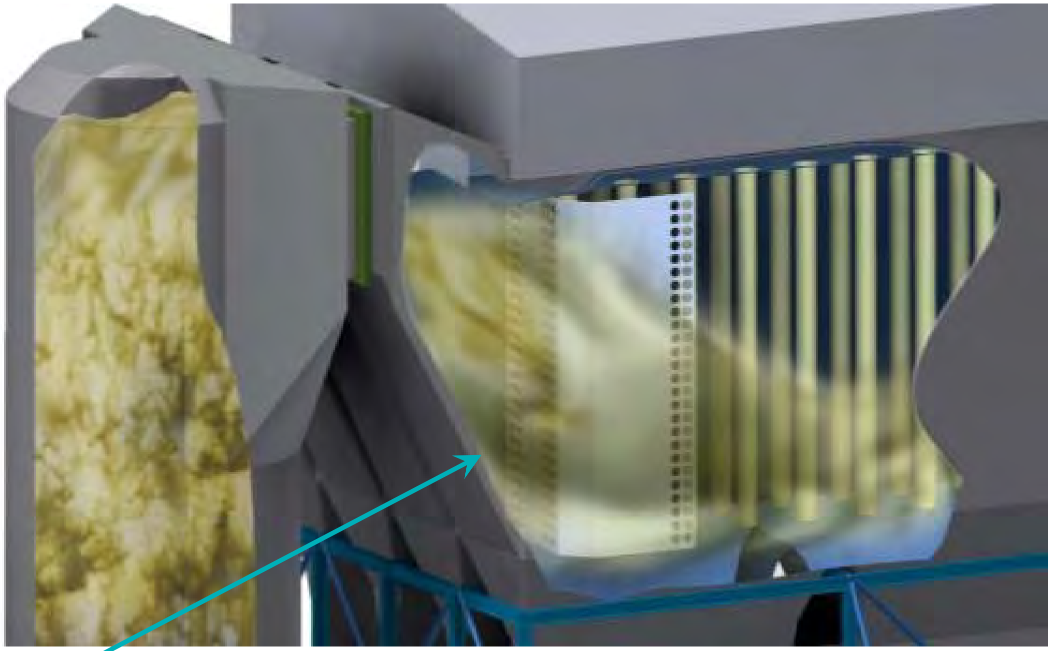
Design Implications for High Dust Loading
3. Shorter Cleaning Time

Bag Warranty Capped at 100,000 Pulses?



Design Implications for High Dust Loading
4. Dropout

- Advantages
  - Gas / dust separation caused by low gas velocity in desired locations
  - No additional energy needed to cause separation
- Disadvantages (Minor)
  - Large particles fall out → smaller particle size distribution (PSD) to filter bags
  - Low gas velocity is produced by larger cross-section → $$



Dropout Chamber

Dropout is the Best Means to Compensate for High Dust Loading Needs to be Optimized!!

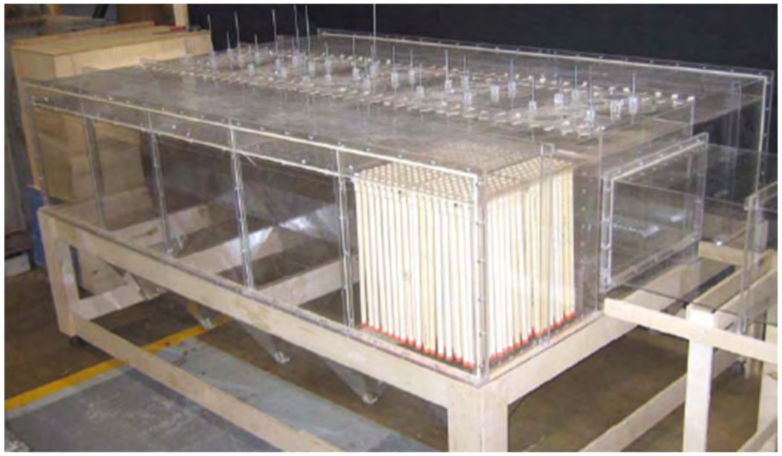
5. PJFF Gas Flow Modeling

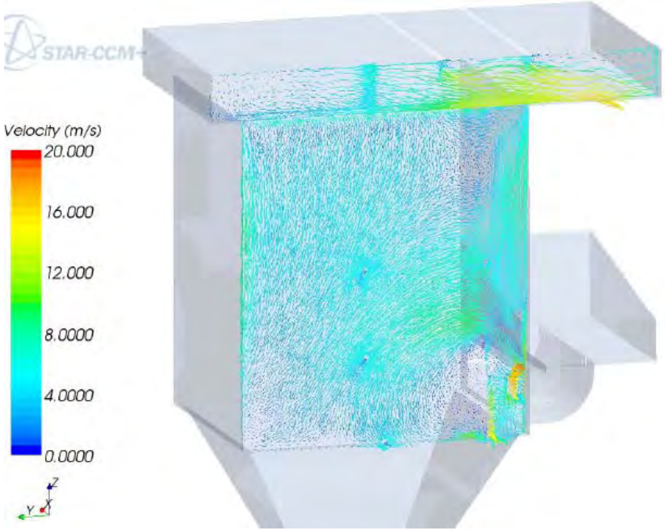
Typical Requirements

PJFF Gas Flow Modeling

Typical Requirements

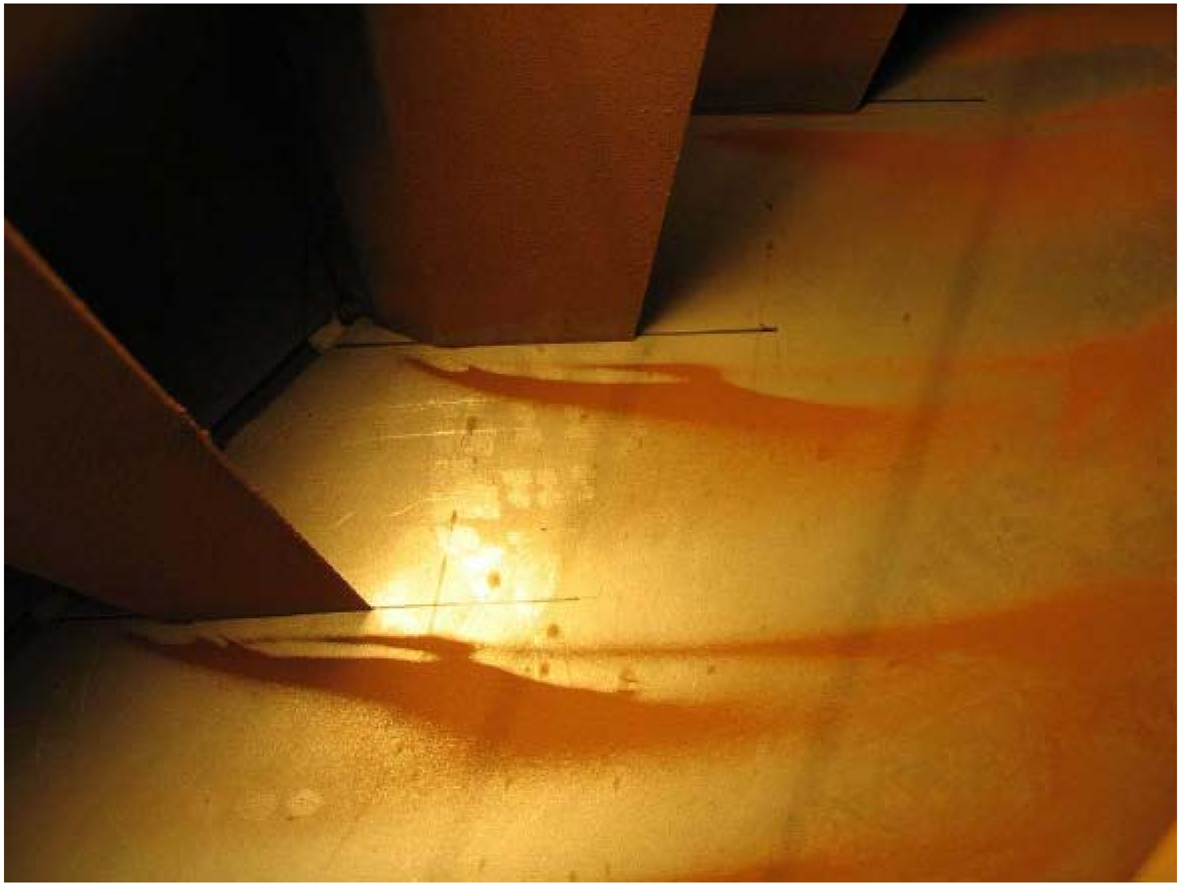
- Physical or CFD analysis
- ICAC F-7 – Fabric Filter Gas Flow Model Studies
  - RMS distribution at inlet flange (≤ 7.5%)
  - Distribution to each compartment (≤ 10%)
  - No “excessively high velocity regions”
  - Minimize pressure drop
  - Smoke testing – qualitative analysis turbulence & flow direction
  - Cork dust testing – qualitative analysis of dust dropout
- Additional PJFF supplier criteria
  - Compartment baffle optimization





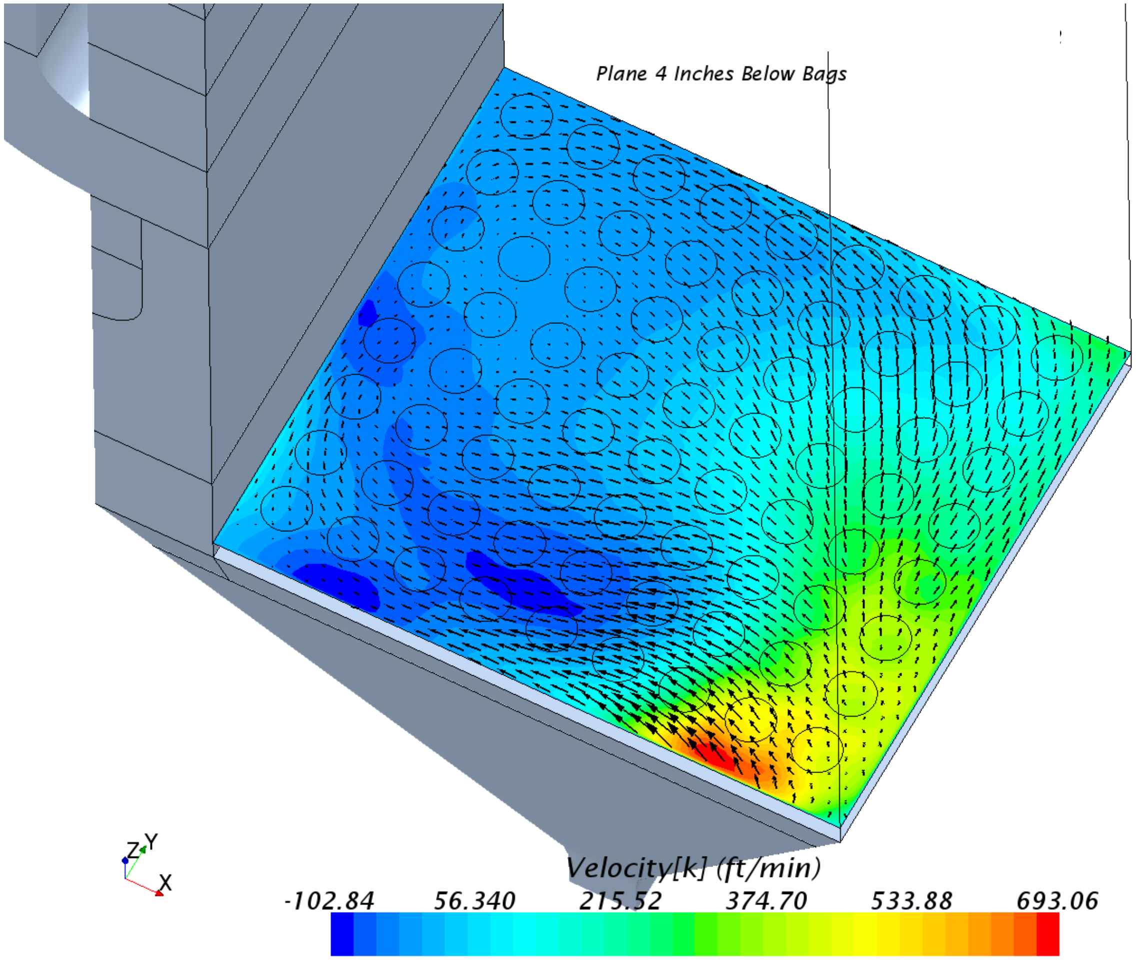
PJFF Gas Flow Modeling

Cork Dust Testing



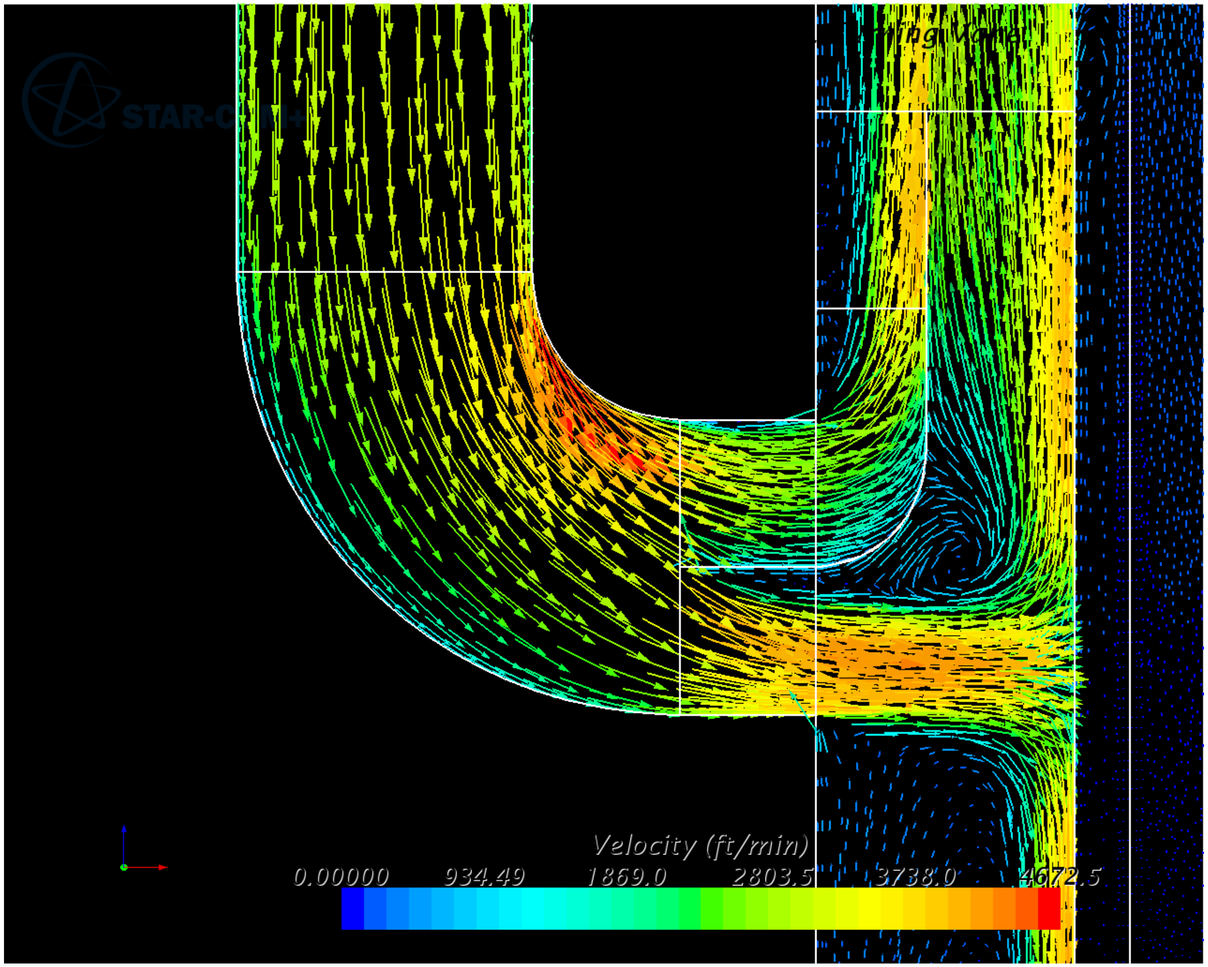
PJFF Gas Flow Modeling

Can Velocity Below Bags



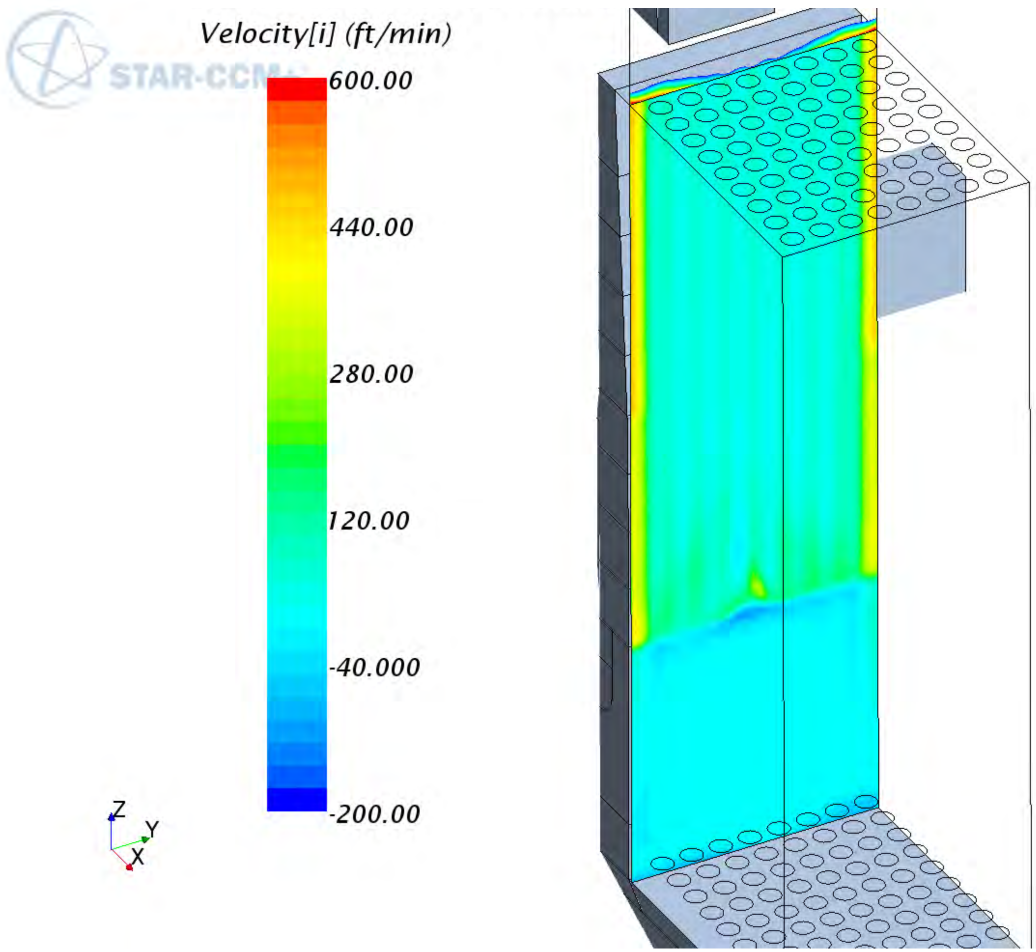
PJFF Gas Flow Modeling

Baffle Analysis (Flow Split)



PJFF Gas Flow Modeling

Baffle Analysis (Horizontal Velocity into Bag Area)

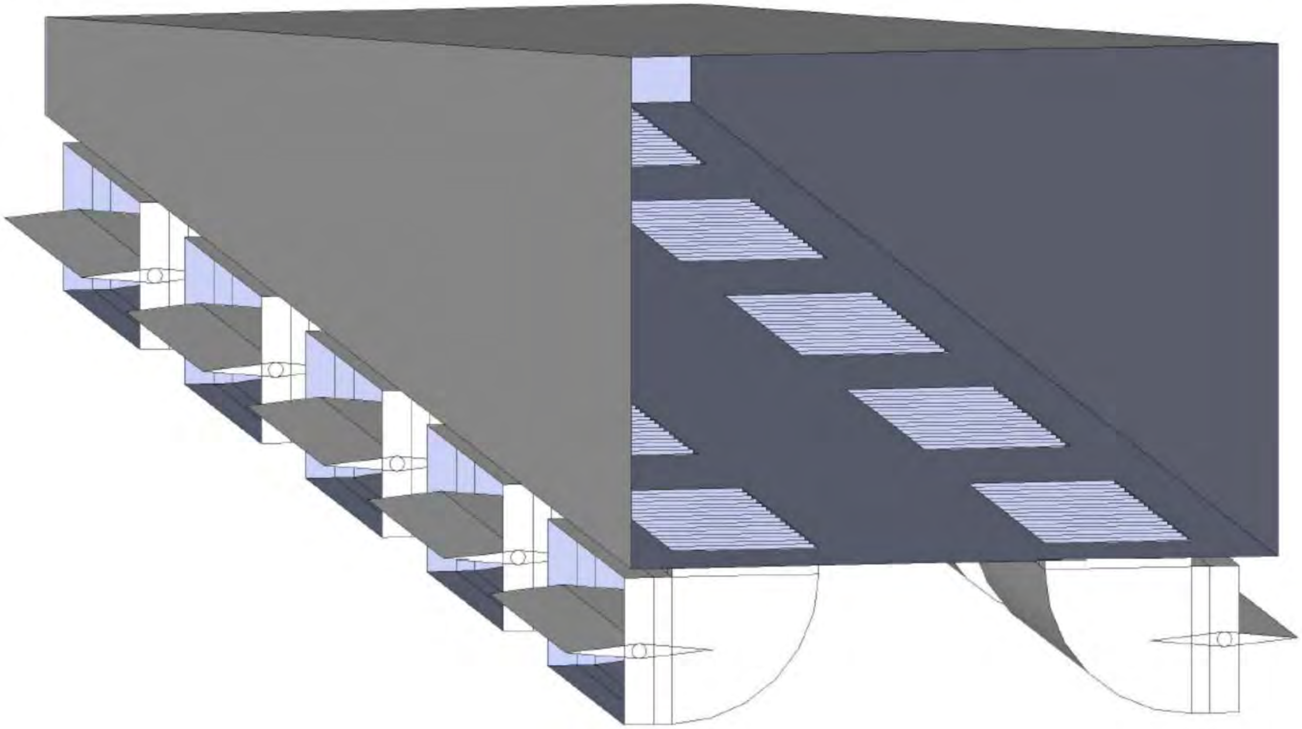


6. Typical Baghouse Inlet Designs

Where Can Dropout Be Optimized?

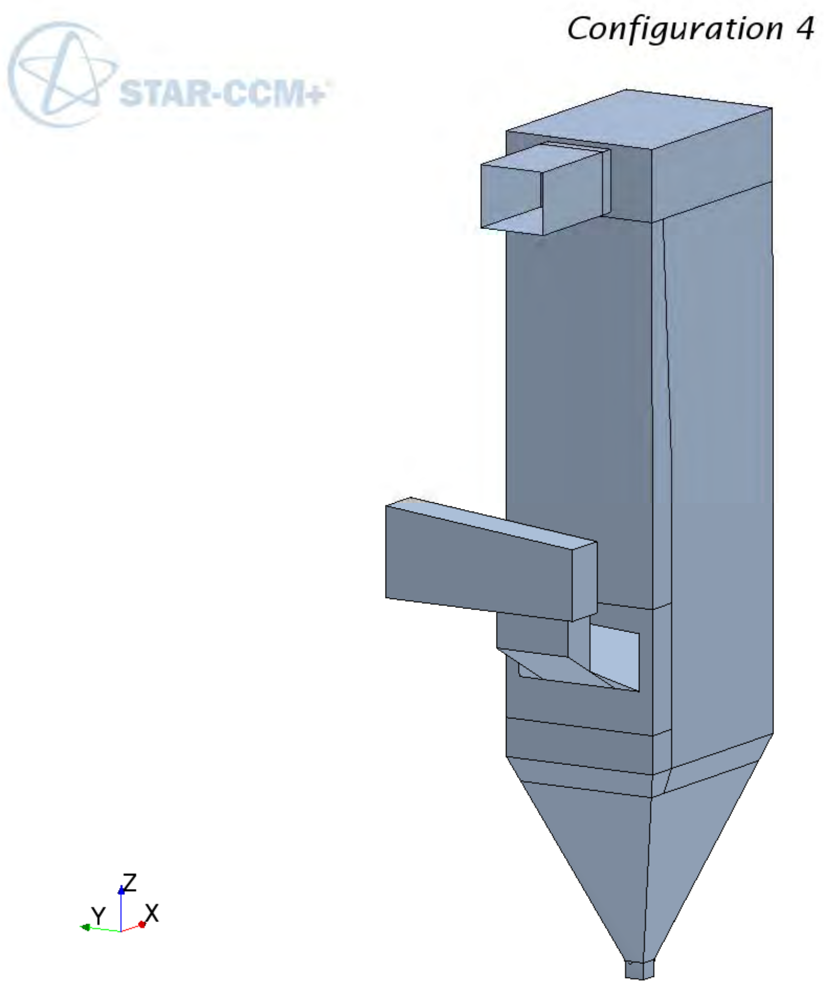
Baghouse Compartment Inlet Designs
Basic Side-Entry

Baghouse Compartment Inlet Designs
Inlet Elbows



Baghouse Compartment Inlet Designs
Downward Chute

Baghouse Compartment Inlet Designs
Downward Chute Low Velocity



7. CFD Flow Model Results

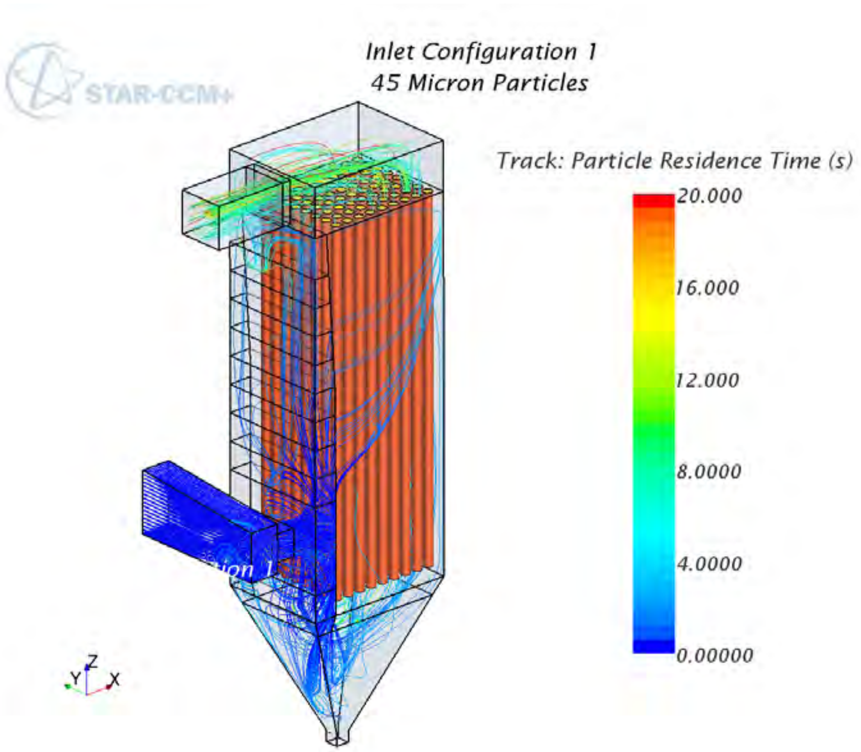
CFD Flow Model Results

- Investigate How Geometry & Trajectory of Compartment Inlet Impacts Dropout
  - Four (4) different inlet styles
  - Three (3) particle sizes

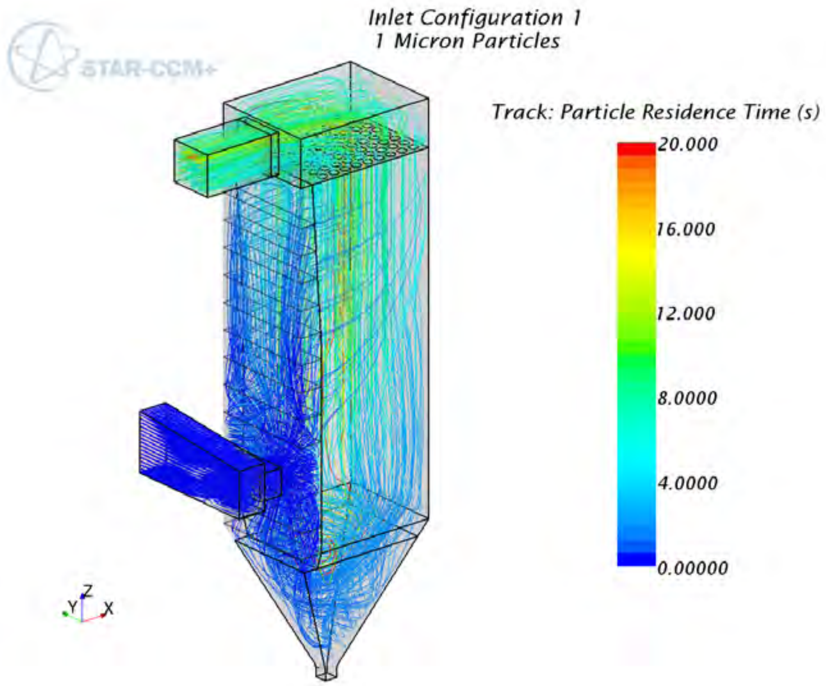
- Inject a “Shot” of Particulate at Inlet
  - Portion of PM settles in hopper
  - Portion of PM passes through simulated filter bag

CFD Flow Model Results
Basic Side Entry

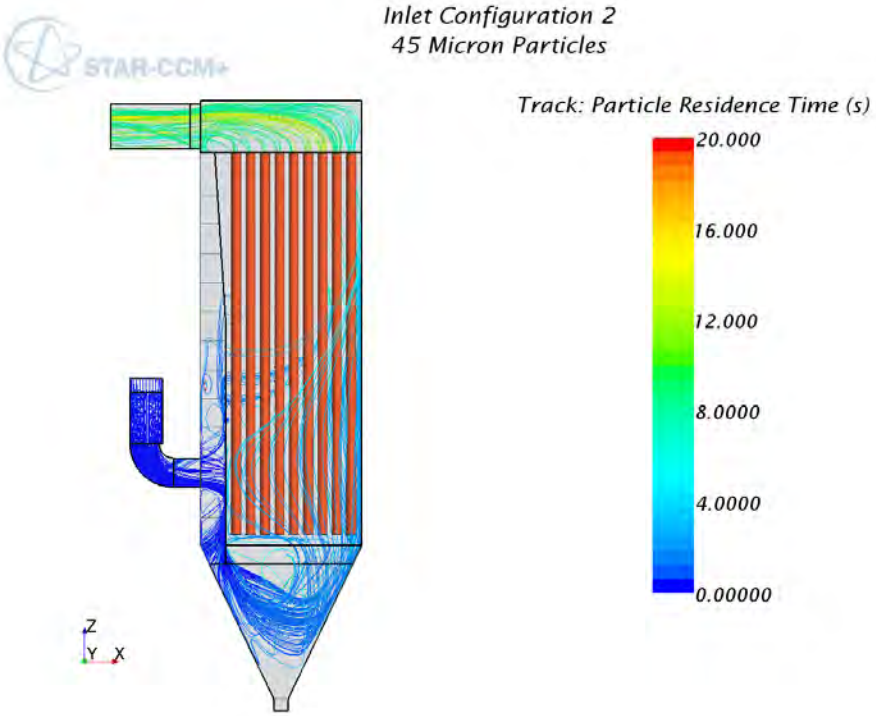
Particle Size	Dropout
1 µm	8%
6 µm	7%
45 µm	68%



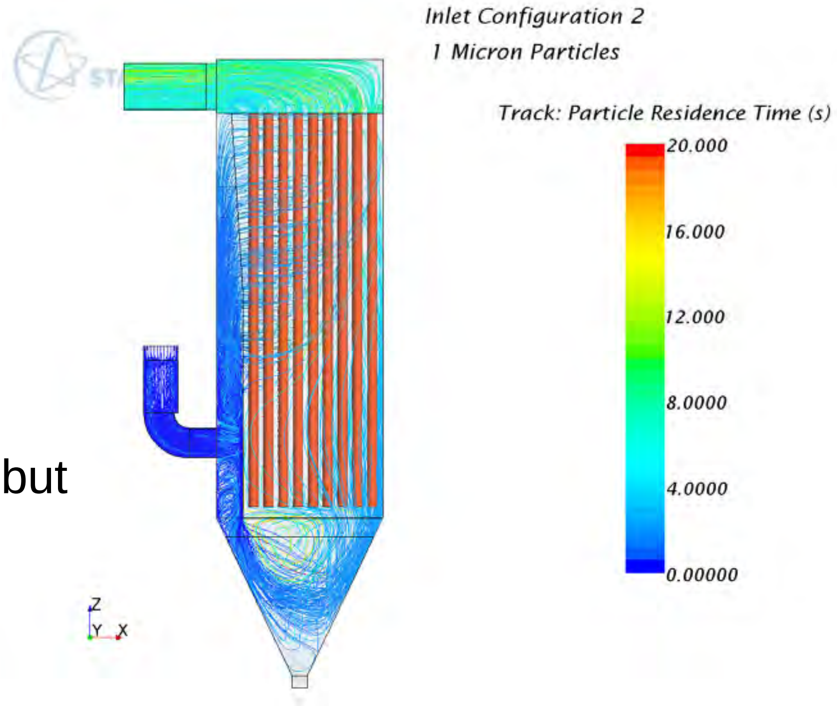
- High loading to downstream side of module
- Small particles follow gas flow



CFD Flow Model Results
Inlet Elbows



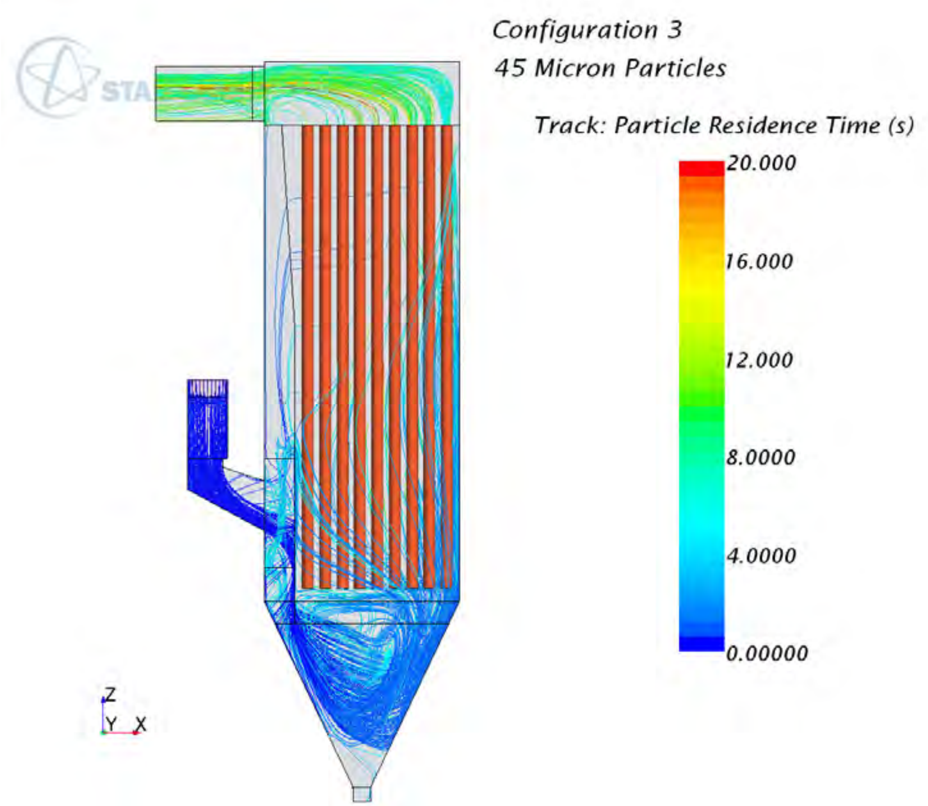
Particle Size	Dropout
1 µm	8%
6 µm	10%
45 µm	69%



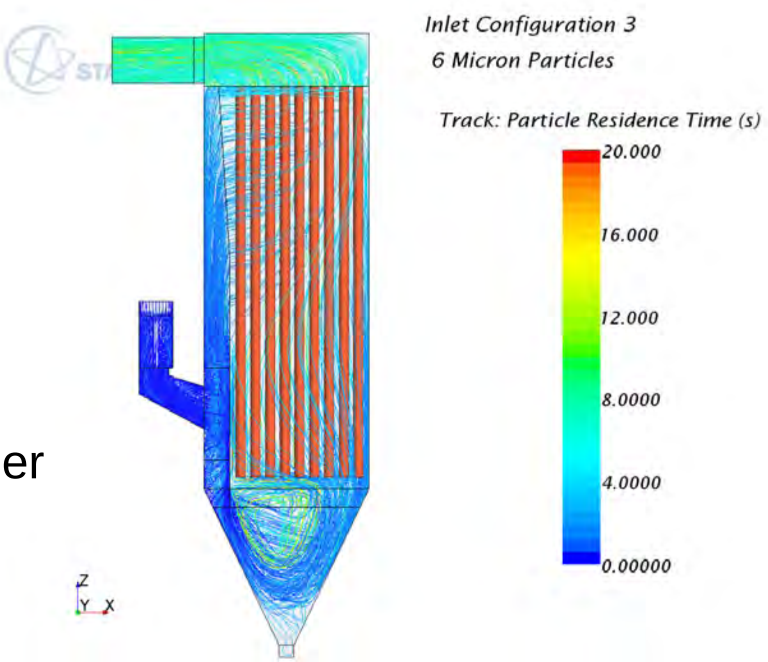
- Most large particles drop into hopper but are swept up the back wall
- No improvement to small particles

CFD Flow Model Results
Downward Chute

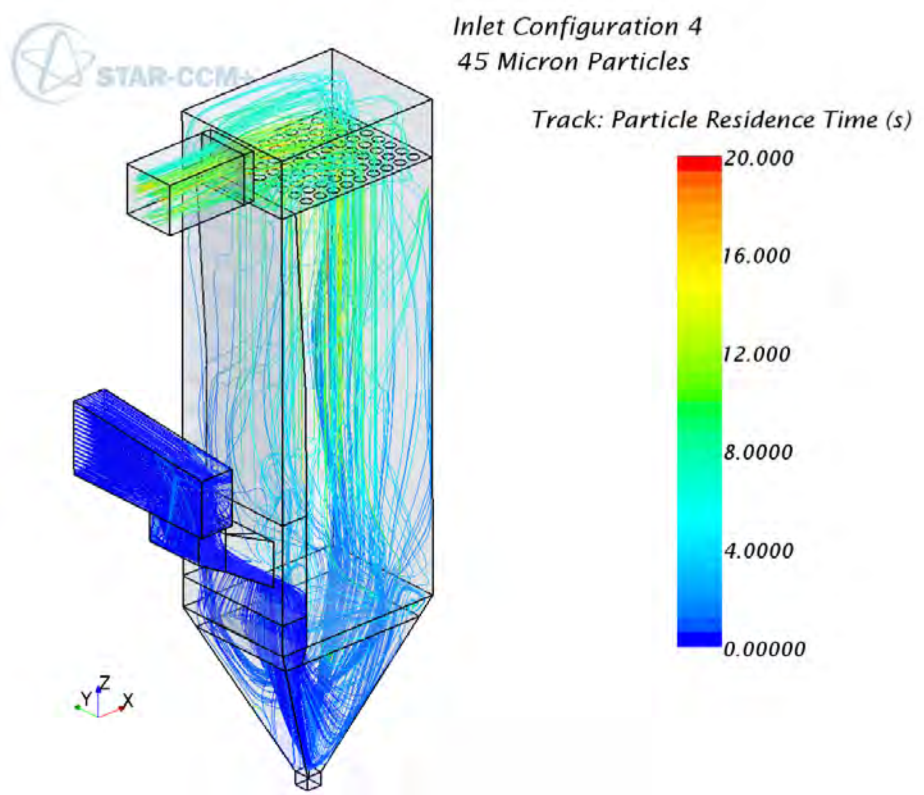
Particle Size	Dropout
1 µm	8%
6 µm	8%
45 µm	58%



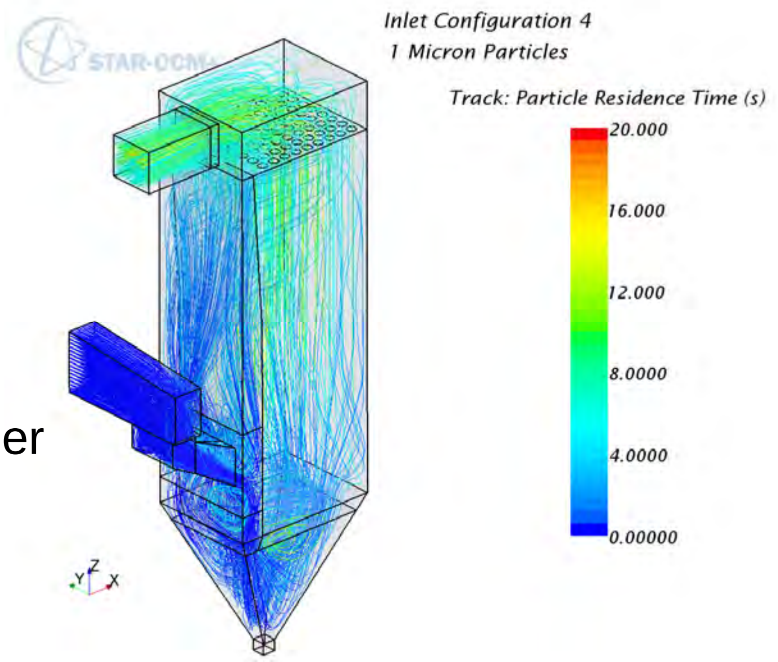
- Nearly all large particles drop into hopper but are swept up the back wall
- No improvement to small particles



CFD Flow Model Results
Downward Chute Low Velocity

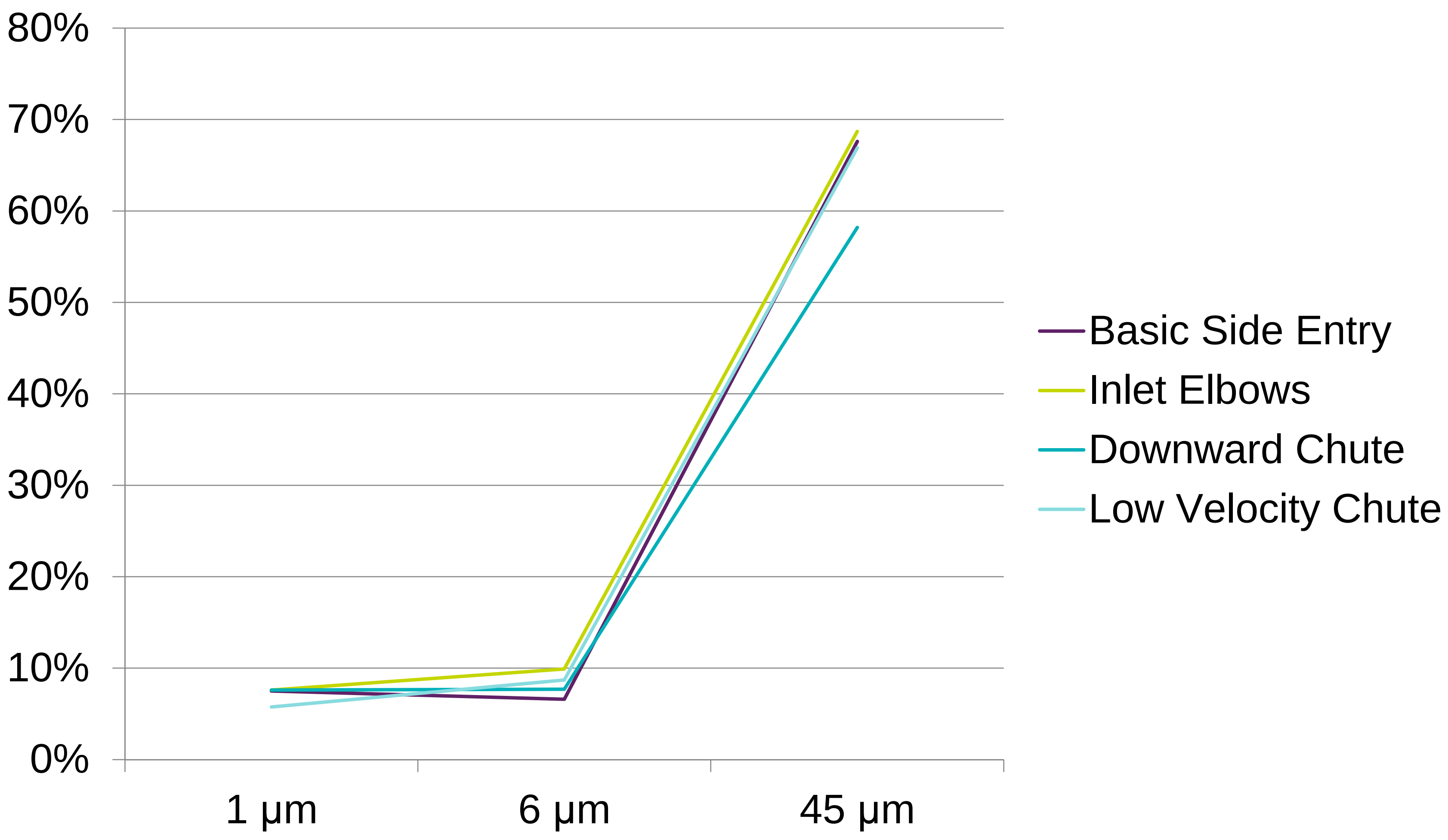


Particle Size	Dropout
1 µm	6%
6 µm	9%
45 µm	67%



- Nearly all large particles drop into hopper but are swept up the back wall
- No improvement to small particles

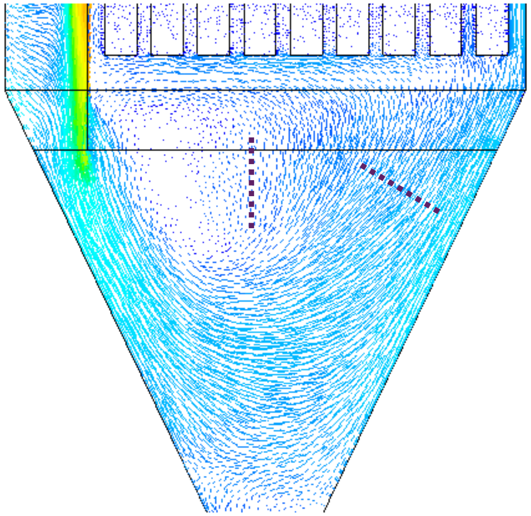
CFD Flow Model Results Summary



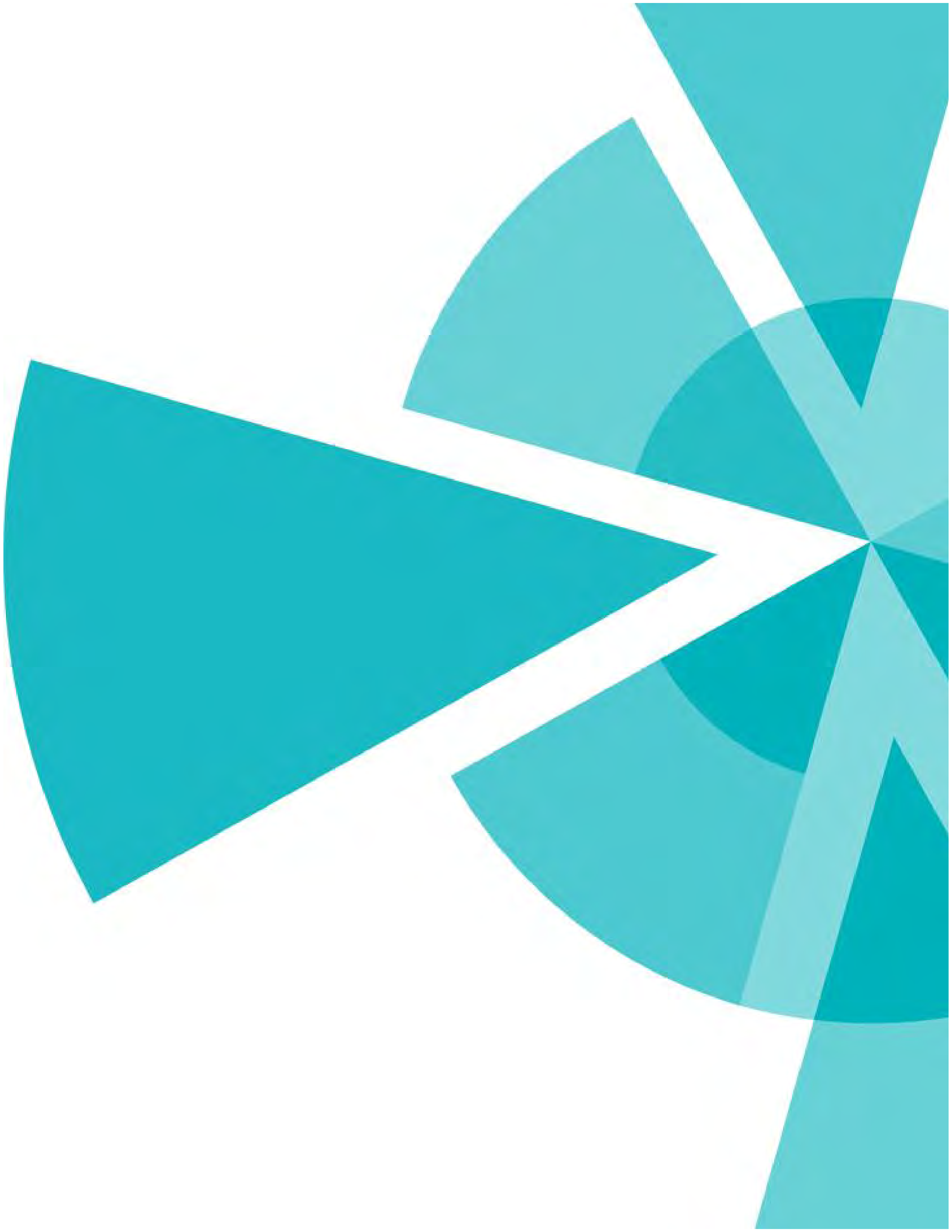
CFD Flow Model Results Summary

- Inlet Shape Has Negligible Impact on Overall Dropout
  - Downward chute directs more dust into hopper area
  - Hopper baffling would favor the downward chute configurations
  - Downward chutes have additional benefits (less dropout in plenum)

- Detailed Optimization
  - Compartment interior baffle
  - Wall baffles in hopper to reduce velocities
  - Target plates to knock down particulate



8. Summary



Summary

- CFB Scrubber Baghouse is Different Than Typical Industry PJFF Applications
  - Modeling requirements should extend beyond ICAC F-7

- Existing CFB Scrubbers
  - Analysis of dust dropout to improve performance
  - Modify design and flow baffles if necessary

- Future CFB Scrubbers
  - Dropout must be analysed and optimized through CFD flow modeling