A CFD Analysis of Air Flow Patterns in Face Area for Continuous Miner Making a Right Turn Cut

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Outline

- Problem Statement
- Goals and Specific Objectives
- Taylor's Experiments and CFD Validation
- CFD Modeling Studies
- Results and Discussions
- Concluding Remarks
- Future Work

Problem Statement

- Increased out–of-seam dilution and coal production rates require improved dust control practices.
- Dust control requires a knowledge of air flow patterns in the face area of room-and-pillar mining.
- Dust dispersion characteristics important for developing engineering controls are dependent on airflow patterns.
- Respirable dust particles (< 7 μm) will be under the influence of surrounding air properties.

Goal and Specific Objectives

Analyze airflow patterns in a room and pillar mining face area when CM is making a right turn cut

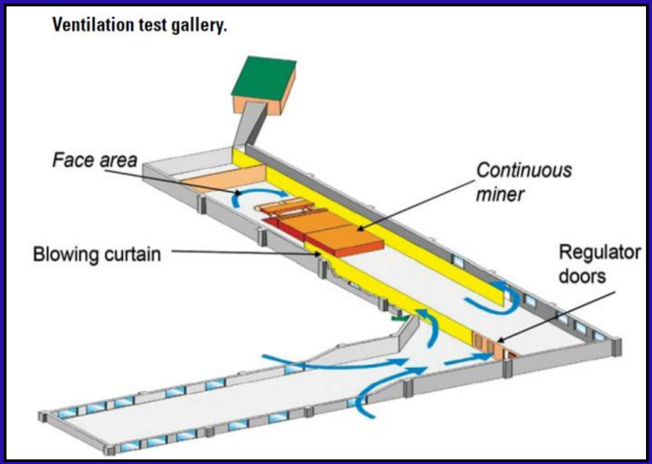
Specific Objectives:

- **Perform validation of CFD code "Fluent" for studying the airflow patterns using Taylor's research.**
- **Identify low air velocity (LAV) and recirculation (RC) zones.**
- **Study the effect of Line Curtain (LC) extension and air leakage through curtain on airflow patterns.**

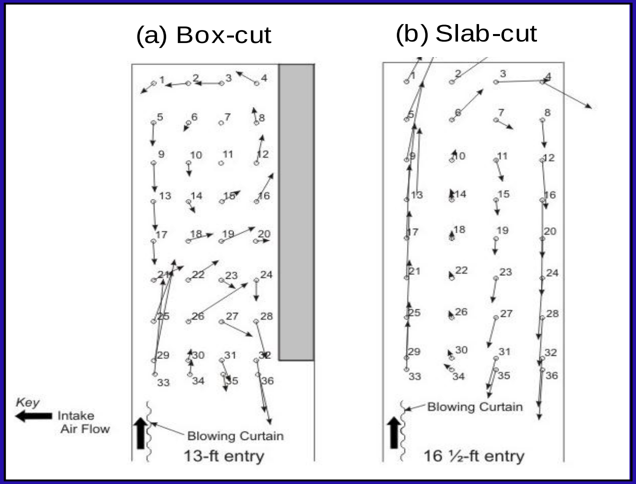
CFD Modeling

- Numerical technique to solve and analyze fluid flow problems.
- CFD has been previously used at SIUC for
  - *Analyzing airflow patterns – straight deep cut*
  - *Studying the effect of scrubber operation and line curtain installation on airflow patterns in the face area.*
  - *Analyzing dust dispersion in a room-and pillar mining.*
  - *Assessing the ventilation characteristics of different roof support systems.*
  - *Optimizing CM Wet-scrubber filter screen inclination.*
  - *Optimizing SIUC innovative spray system on CM.*
- Validation studies were performed for each study above.
- Thus, we believe CFD can be an effective tool for guiding research and development of engineering controls.

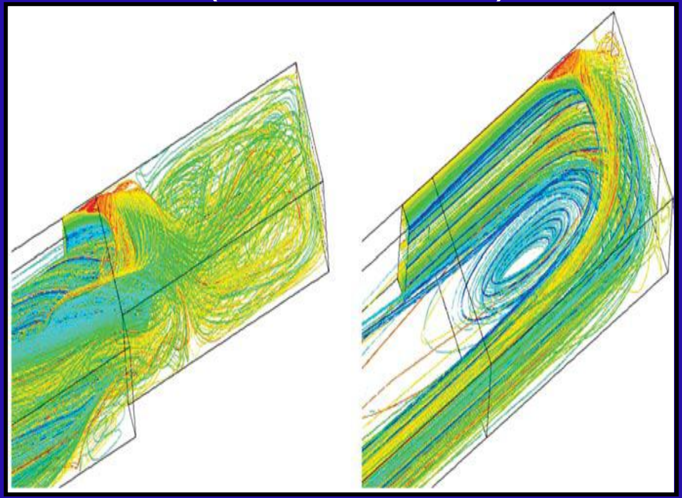
Taylor's Experiments and CFD Validation Studies



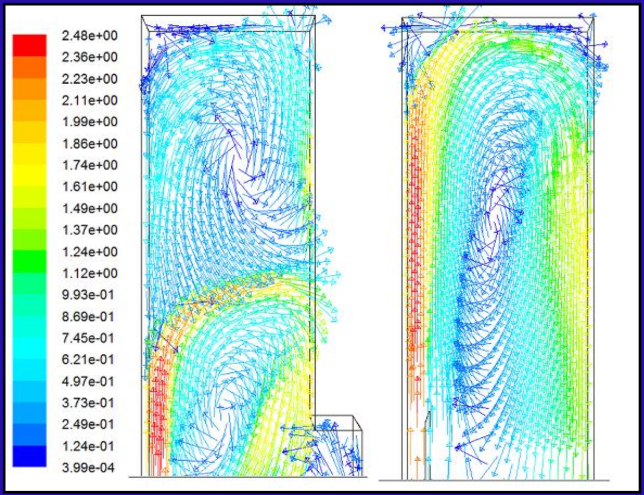
Pittsburgh Ventilation Research Gallery
(Wala et al., 2007)



Measured airflow patterns
(Taylor et al., 2005)

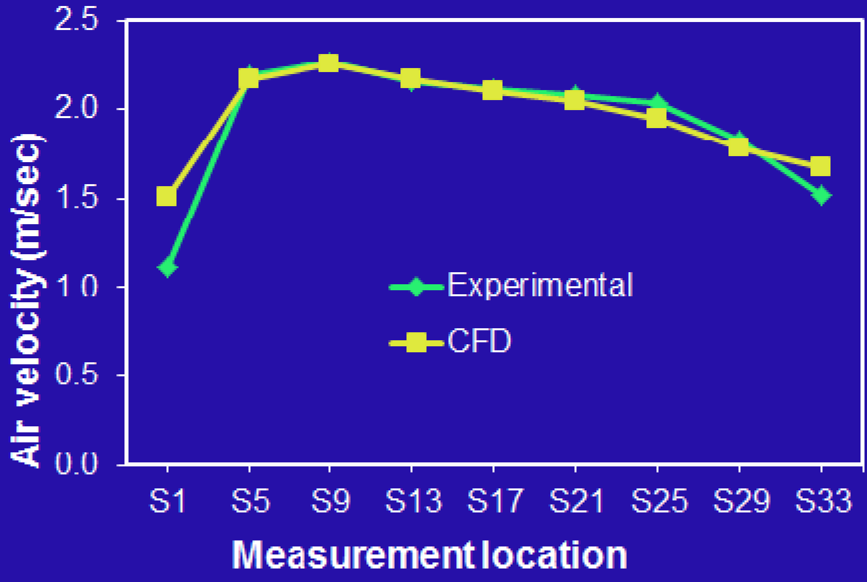


CFD predicted airflow patterns
(Wala et al., 2007)

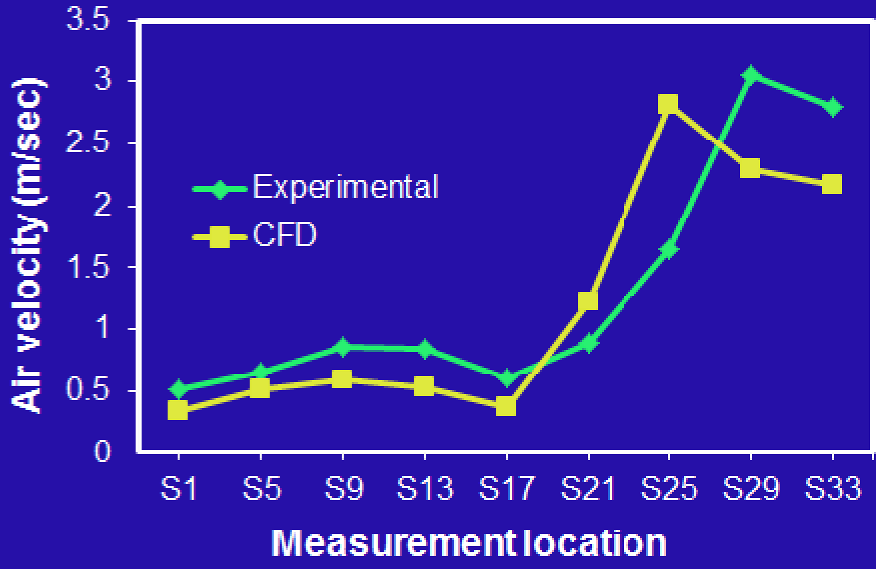


CFD predicted airflow patterns
(Current Study)

CFD Modeling and Validation Studies of Taylor's Experimental Studies- Kollipara and Chugh (2011)



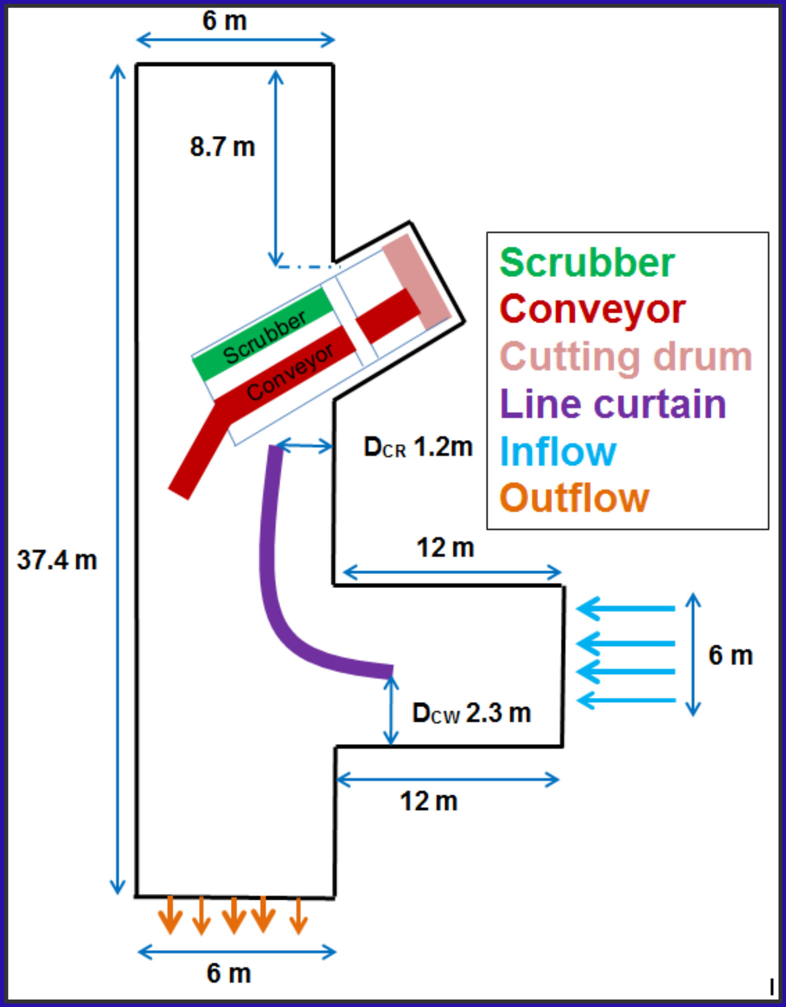
Box-Cut : 2.8 m³/sec



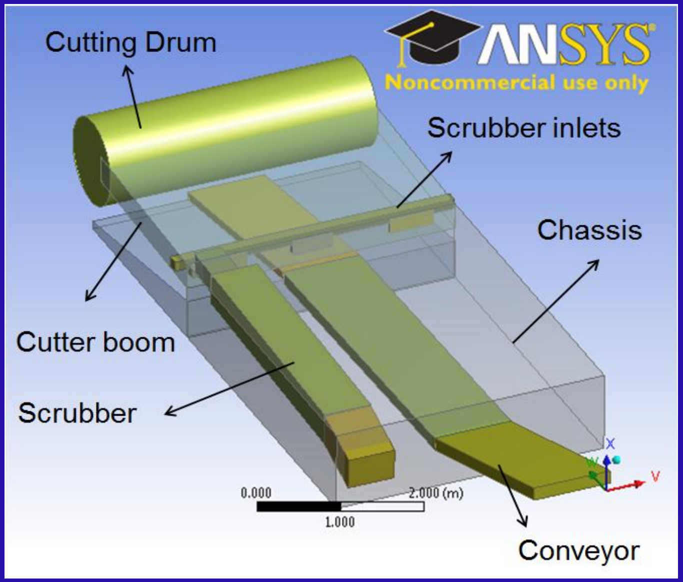
Slab-Cut : 2.8 m³/sec

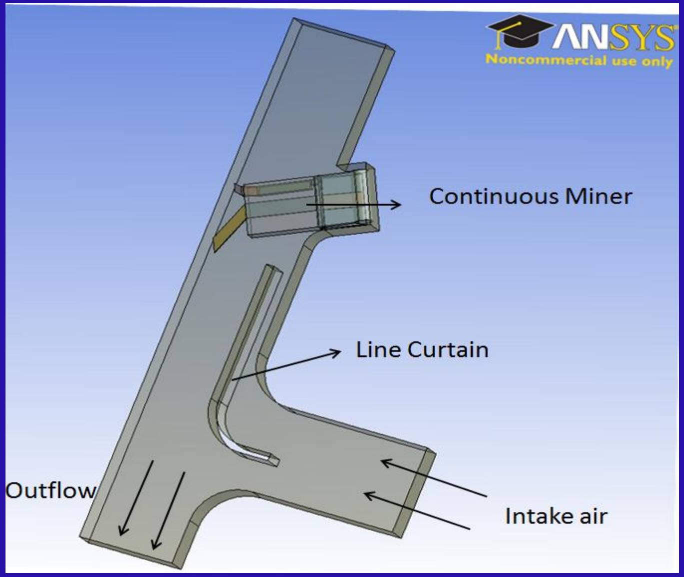
- **Agreement between CFD and experimental is reasonable.**
- **Thus, CFD was used to analyze the airflow patterns.**

Layout of the Physical Model



2-D schematic of CM making right turn cut





Modeling Parameters of the physical Model

- ✓ Continuous Miner (CM) dimensions (Joy Make):
  - ✓ Length - 10.7 m (35 feet)
  - ✓ Height - 1 m (3 feet)
  - ✓ Width - 3.5 m (11.5 feet)
  - ✓ Diameter of the drum - 1 m (3.3 feet)
  - ✓ Cutter boom length - 2.24 m (7.5 feet)

Scrubber Description:

- ✓ Five suction inlets - two on the scrubber side, one in center of the CM, two on operator side. There is one discharge outlet.
- ✓ Air volume at the end of LC – 3.3m^3/sec (~7,000 cfm)

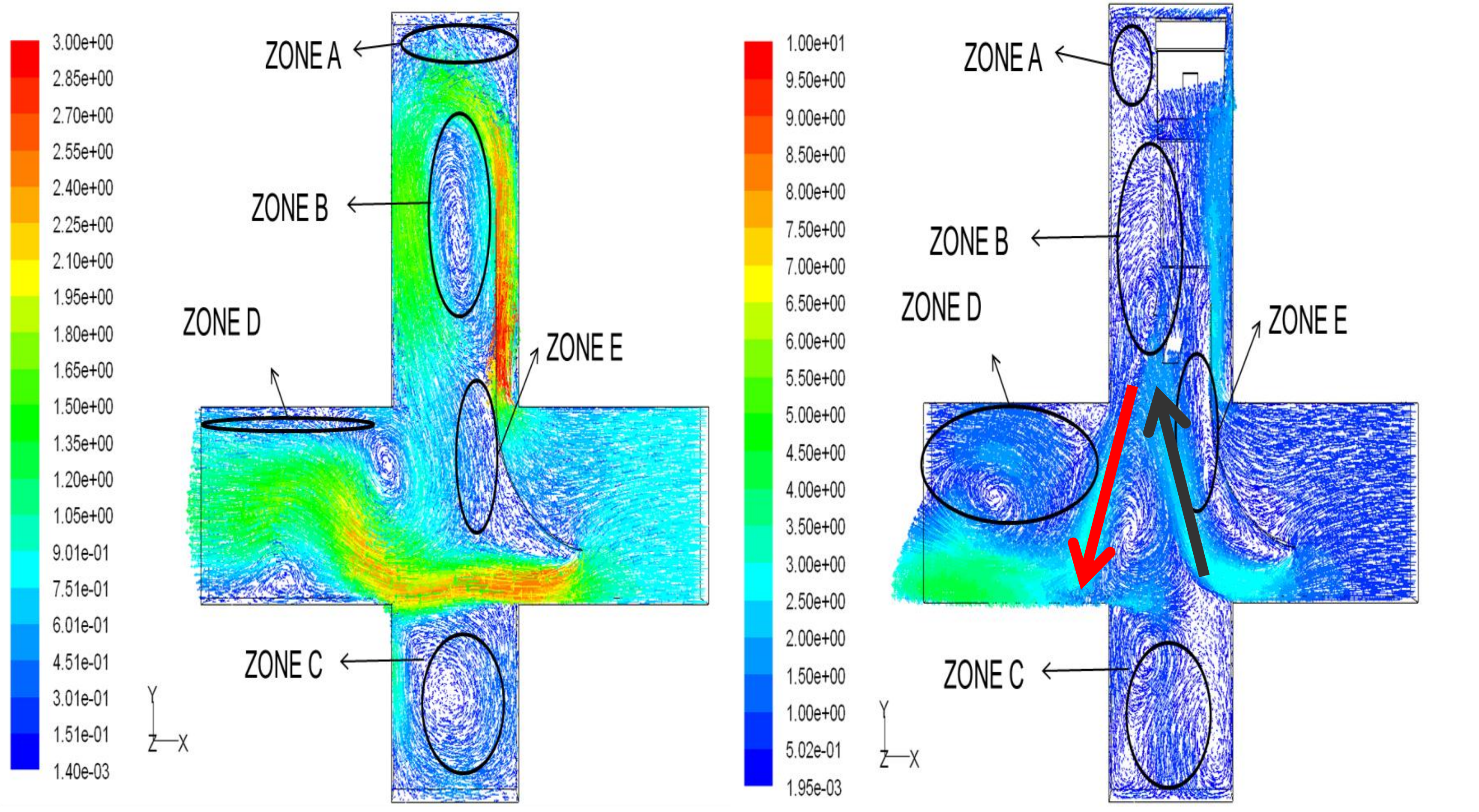
Different CFD Models Simulated

Model Name	Description	Leakage
A1	Right Turn Cut with LC only	without air leakage at LC
A2	CM about to make right turn cut but scrubber not operating	
A3	CM about to make right turn cut, scrubber operating	
A4	CM about to make right turn cut but scrubber not operating (LC extended)	
A5	CM about to make right turn cut, scrubber operating (LC extended)	
B1	Right Turn cut with LC only	with air leakage at LC
B2	CM about to make right turn cut but scrubber not operating	
B3	CM about to make right turn cut, scrubber operating	

Results and Discussion

CFD Modeling of Airflow patterns for Straight Deep Cut (Kantipudi., 2009)

The curtain was tight against the roof and floor with no leakage.

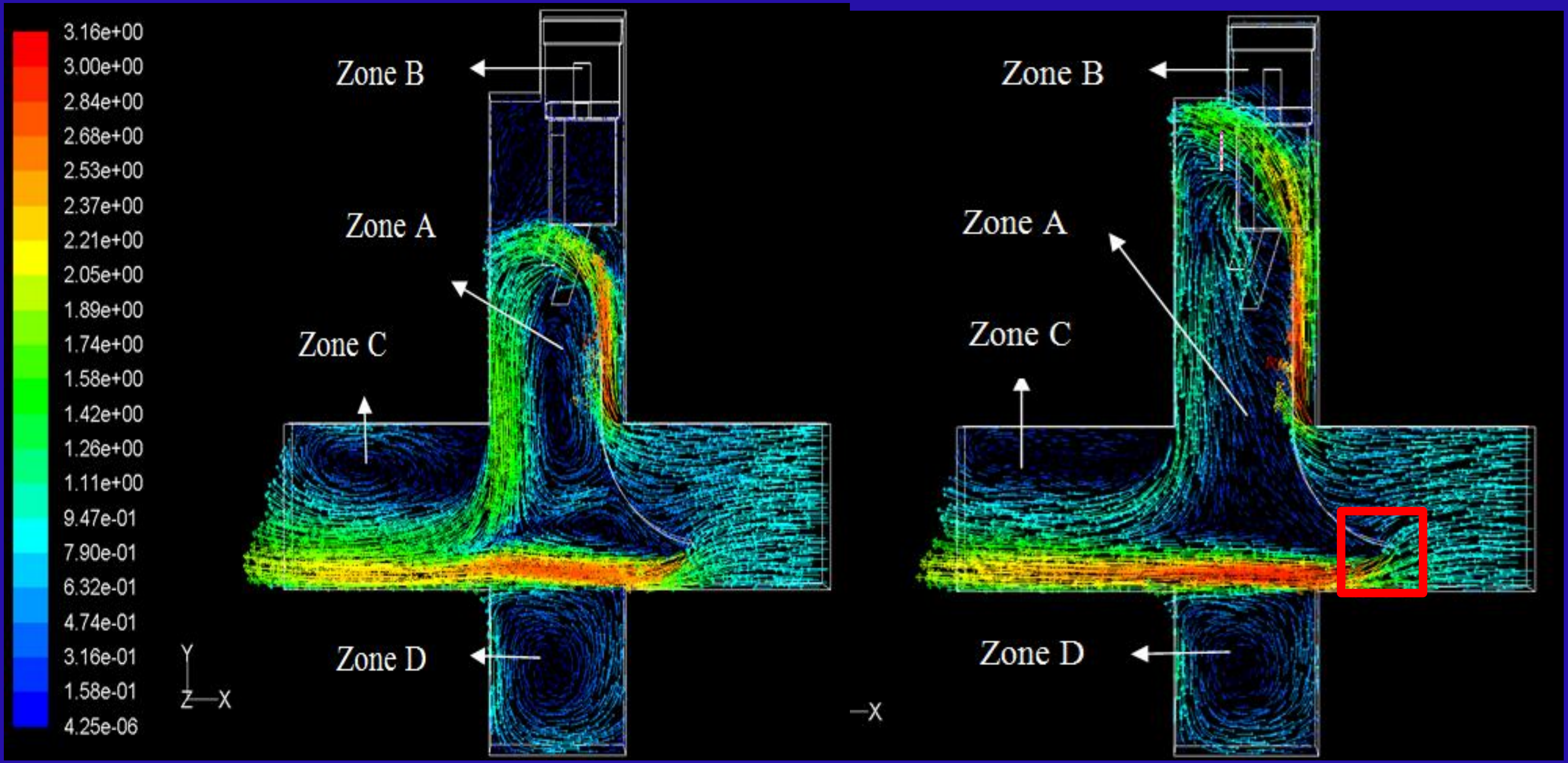


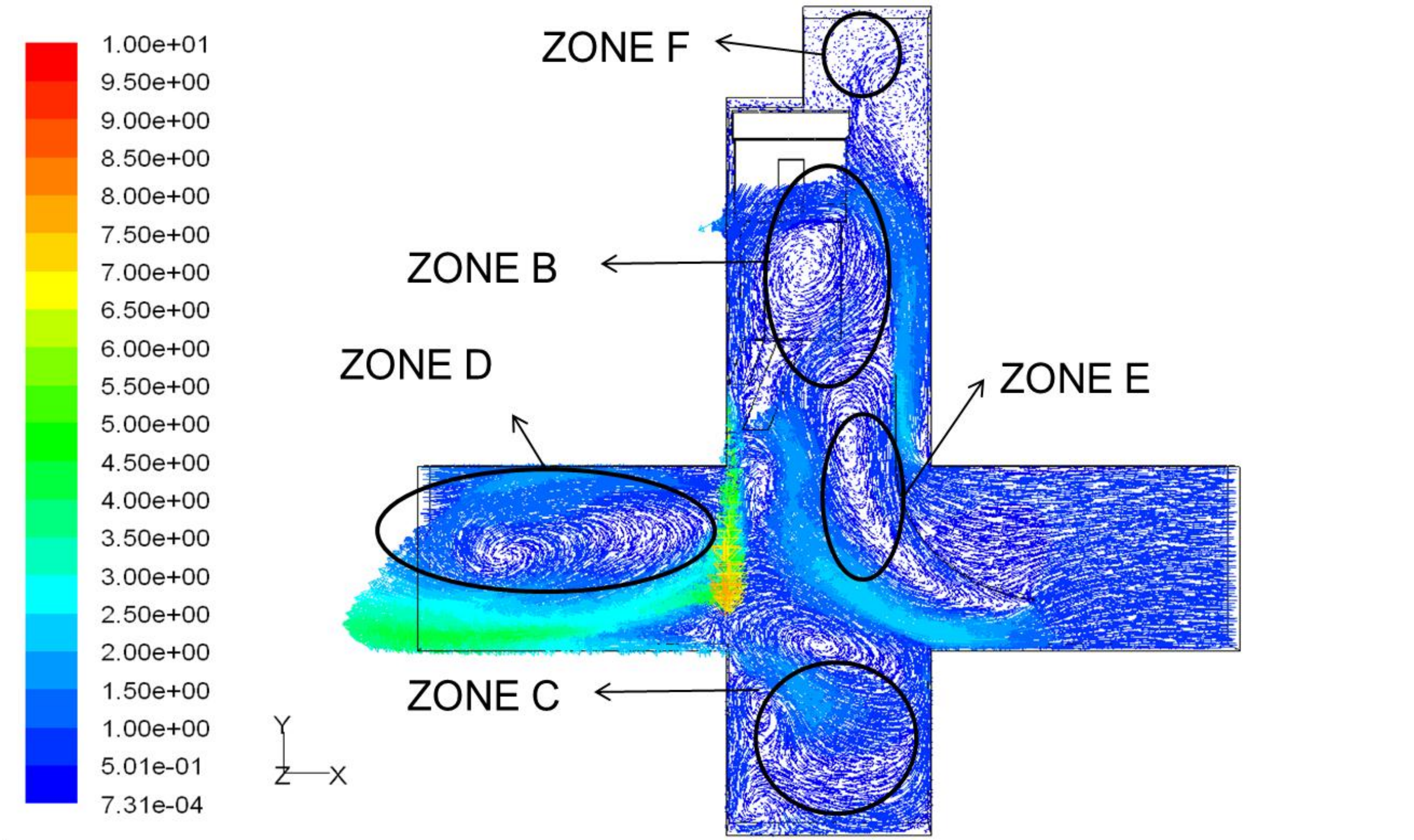
With Line Curtain (LC) only

With CM and LC, Scrubber ON

CM Completed 10ft Box-cut
LC not advanced

CM Completed 10ft Box-cut
LC advanced 10 ft





CM ready to make Slab cut

Summary Findings- Straight deep cut

- Identified the low velocity and re-circulation zones in face area.

- Scrubber operation radically changes airflow patterns. Air flows both behind the LC as well as in front of the LC.

- Scrubber be operated at lower pressures to avoid re-circulation.

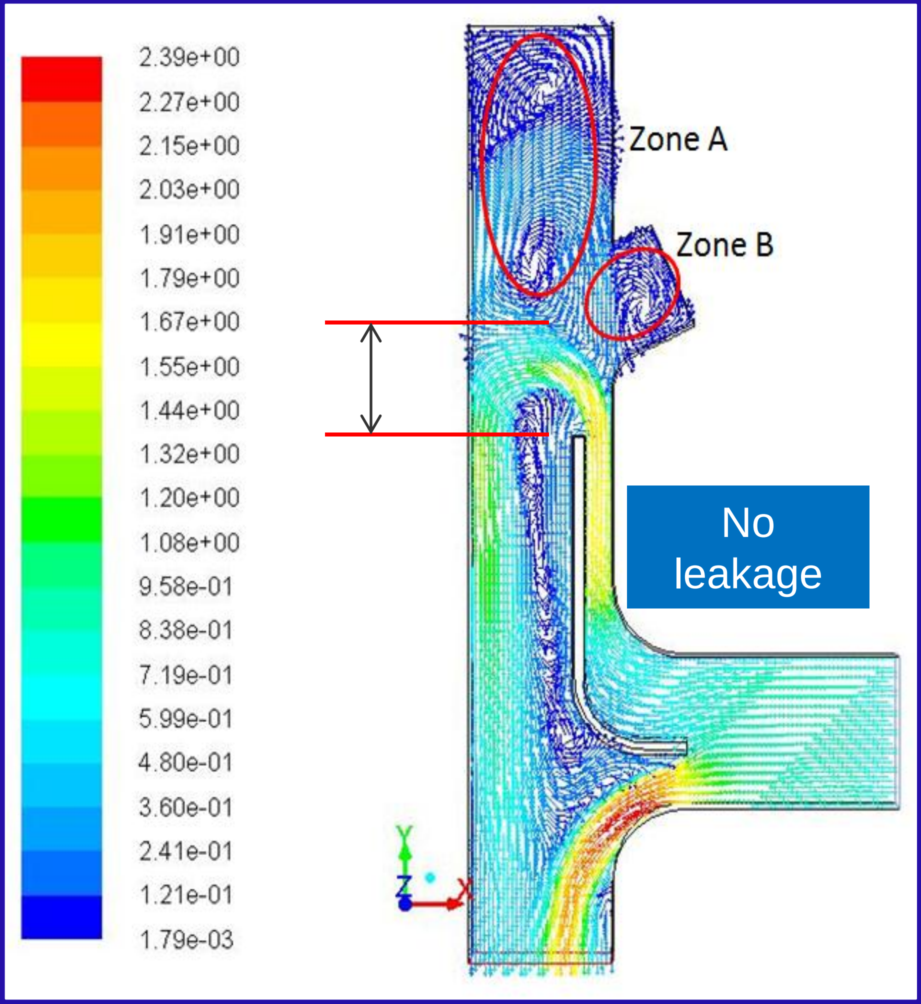
- Location of LC behind the CM is important. Advancing LC with face advance (in increments of about 5-ft) is recommended.

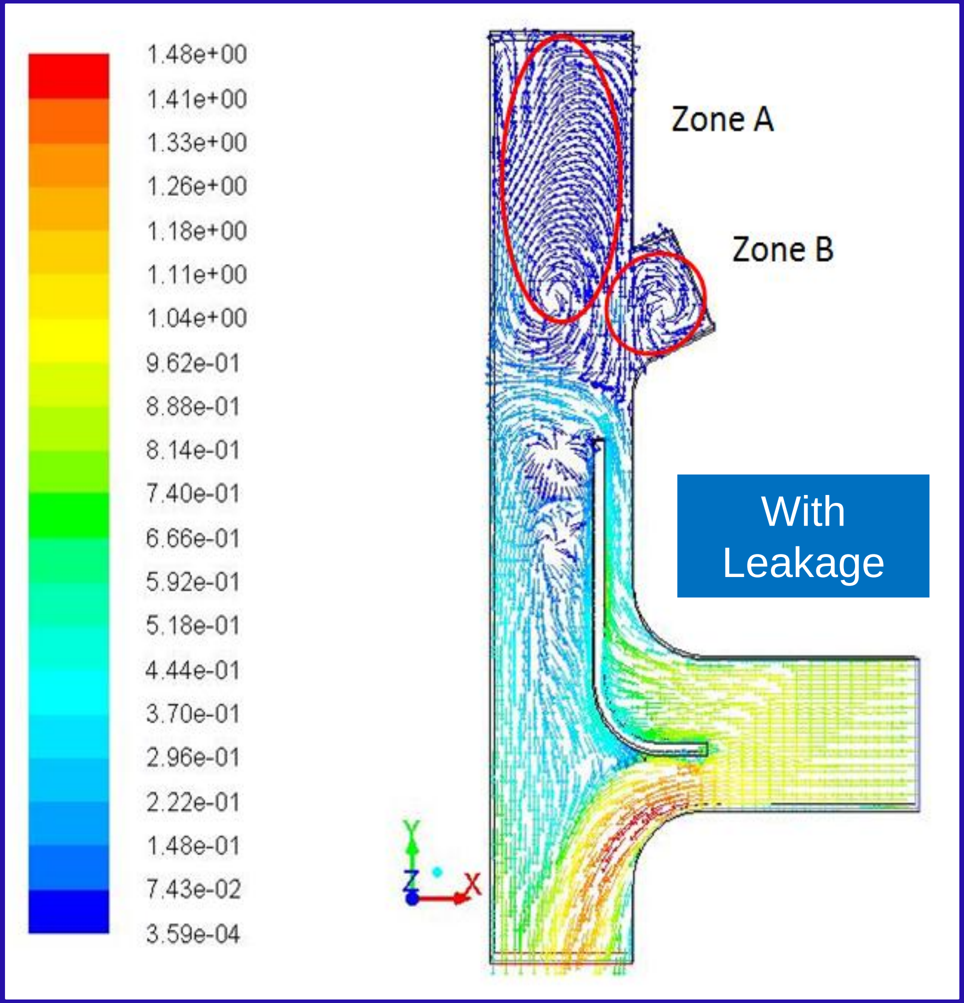
- Ratio of the scrubber volume to the volume of the air at the end of the line curtain is important from recirculation and roll-back of air points of view.

Results and Discussion

CFD Modeling Studies for Box-Cut of Right-Turn Cut
Part 1: Analyzing the airflow patterns

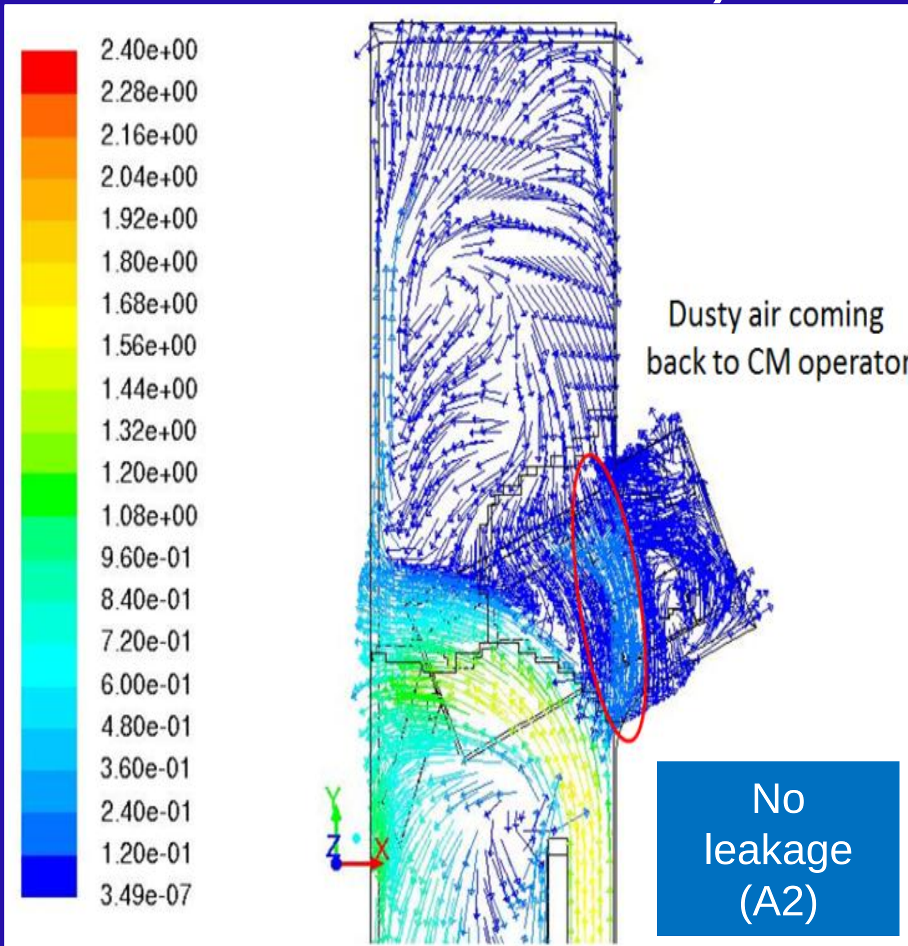
Results – with LC only

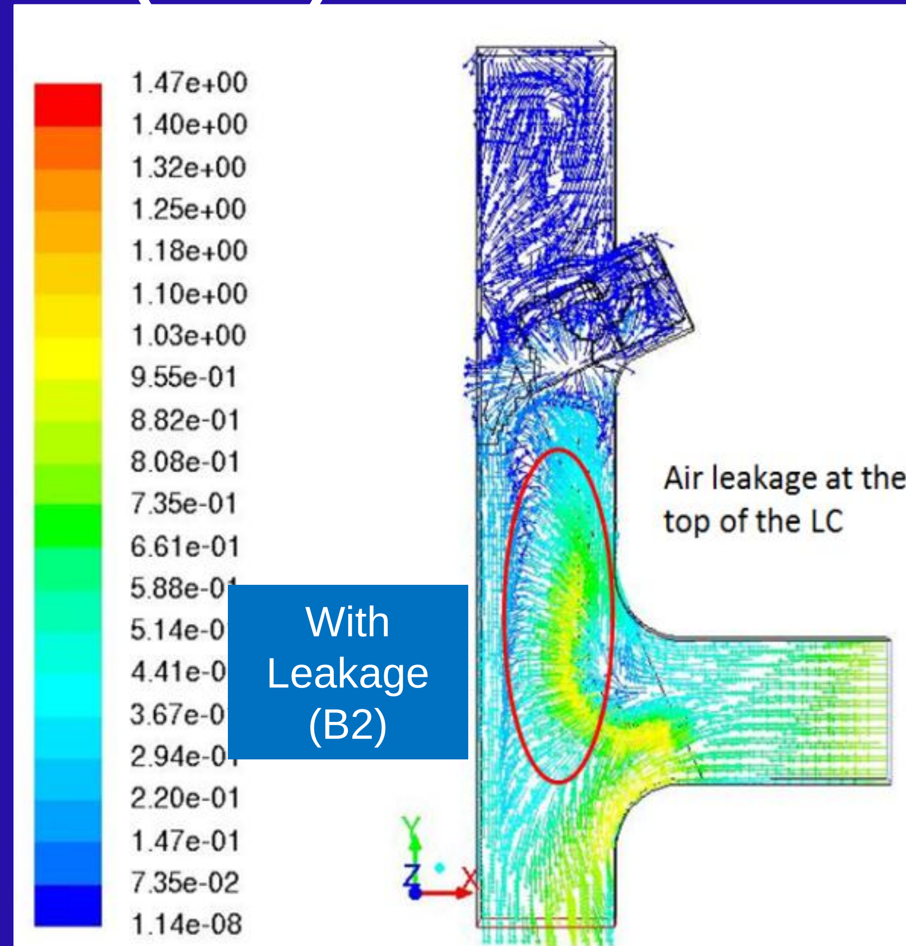




- ✓ **Identified Zones A and B which are both LAV and RC Zones**
- ✓ **Air separation point is decreased from 4 m to 2.5 m.**

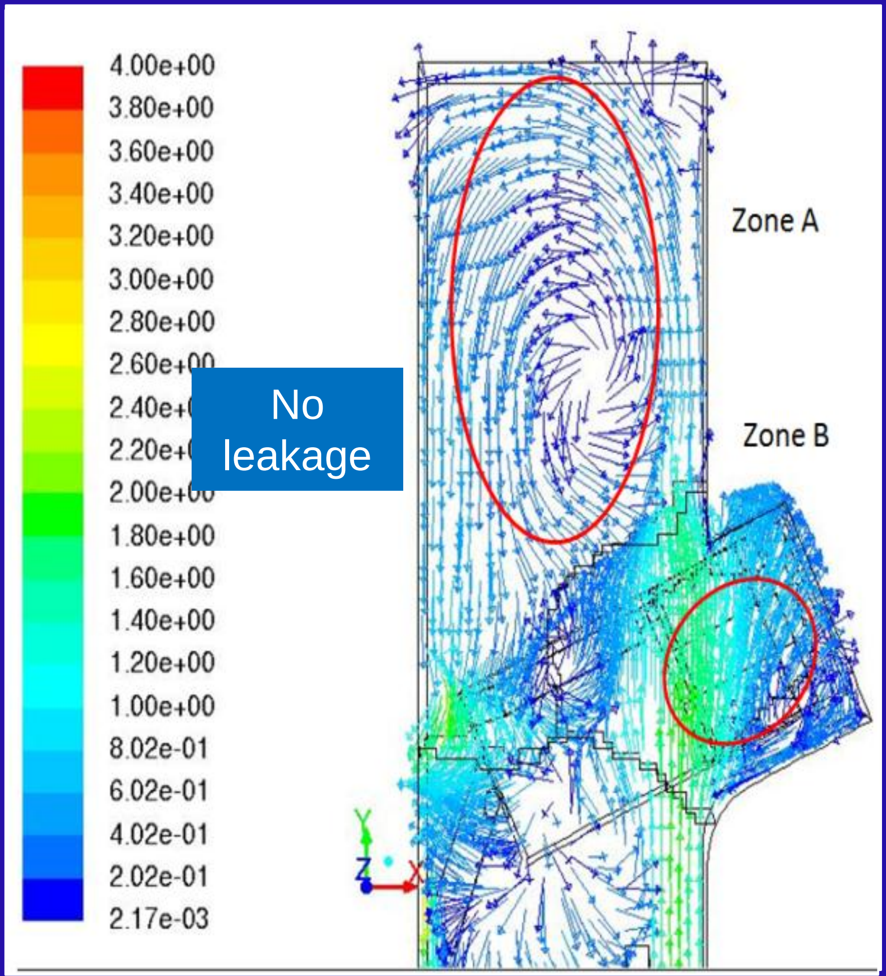
Results – with CM about to make box-cut, scrubber off, LC 4.6 m (15 ft) behind

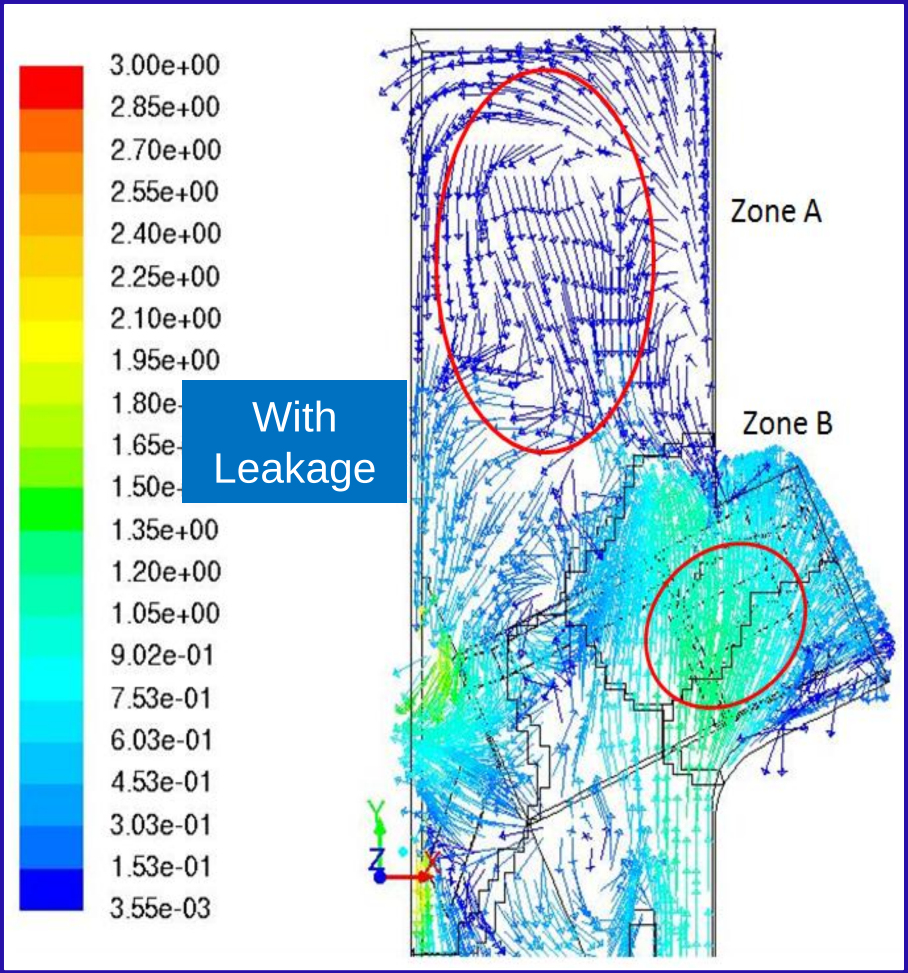




- ✓ **Potential for roll-back to the MO (Model A2).**
- ✓ **Air separation point increased from 4 m to 5 m (Model A2).**

Results – with CM about to make cut, scrubber ON





- ✓ **RC Zone A reversed its direction. Zone B is better ventilated. Zone C area increased. Potential for roll-back to MO.**
- ✓ **Scrubber suction efficiency of dusty air is decreased. HUO is not in a safe zone.**

Results and Discussion
Part 2: Effect of air leakage at the LC on the volume of the air at the end of the LC.

Effect of LC air leakage on the volume of the air at the end of LC (V_{LC}).

Model	V_{LC} (m^3/sec)	Comments
A1	3.54	which is 33% of intake air volume.
B1	0.53	which is 85% less compared to Model A1
A2	3.45	which is 2.5% less compared to Model A1
B2	0.68	which is 83% less compared to Model A2
A3	3.9	scrubber operation increased air volume by 13%
B3	2.3	which is 41% less compared to Model A3 and 73% more (scrubber operation) compared to Model B2.

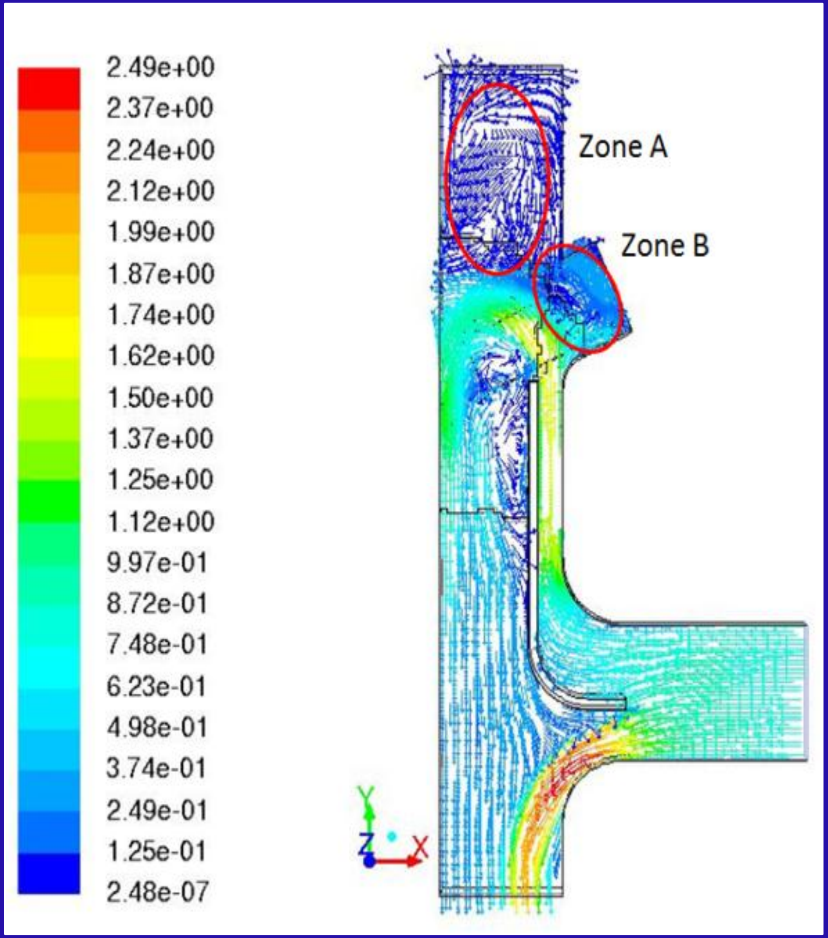
Effect of LC air leakage on the volume of the air at the end of LC.

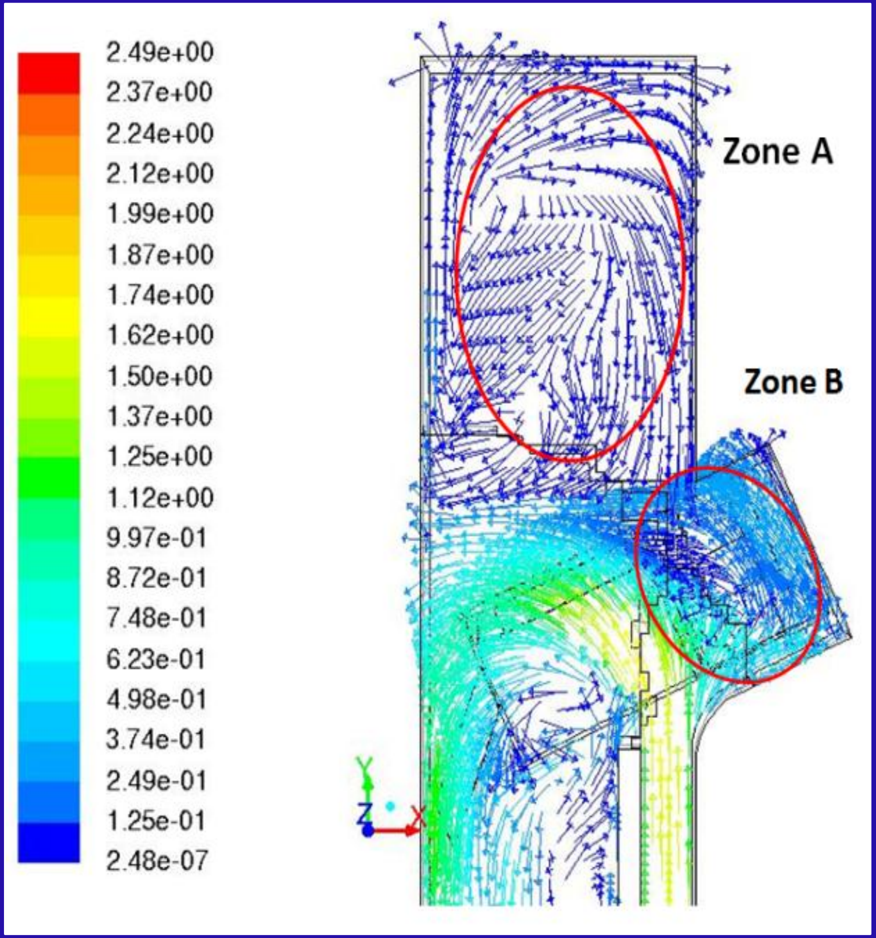
- ✓ On an average, air leakage of 0.3m on the top and bottom of LC can decrease the end of the LC air volume by about 84% (scrubber off) and 41% (scrubber on).

Results and Discussion
Part 3: Effect of extending LC on airflow patterns in the face area.

LC was extended until behind the CM chassis

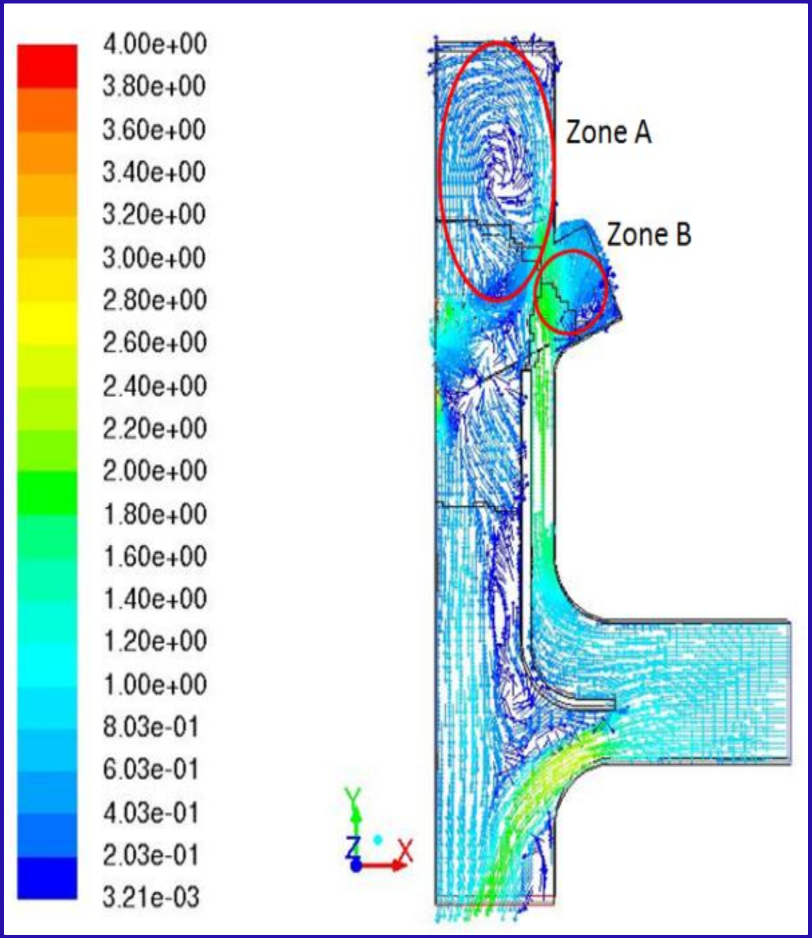
Results –CM about to make box cut, scrubber OFF

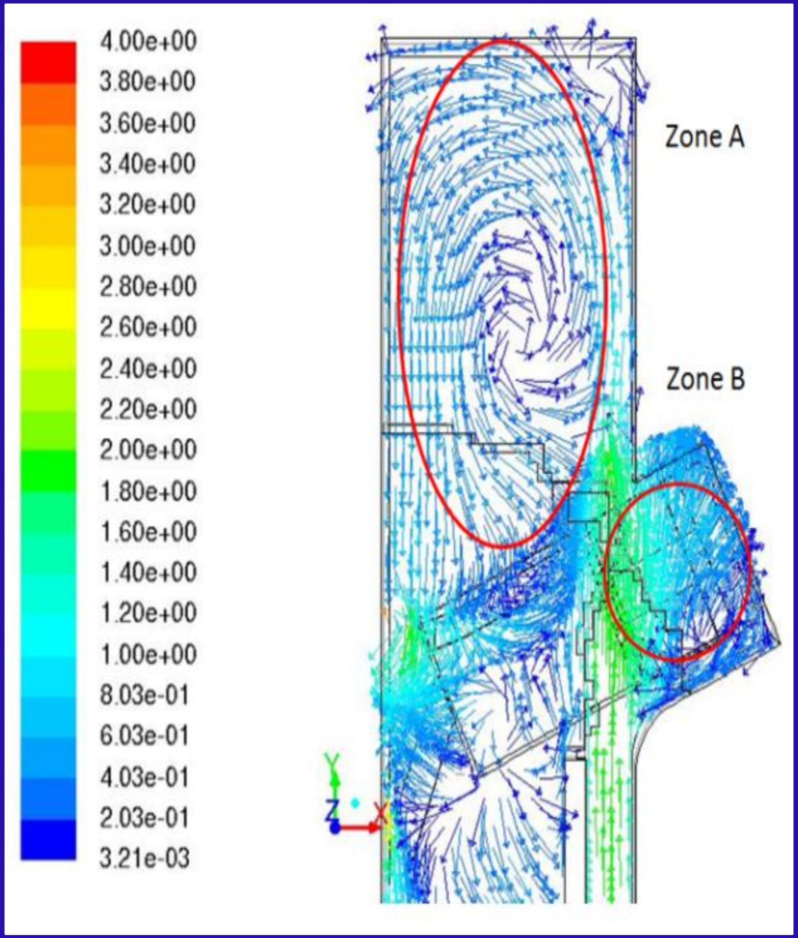




- ✓ Air separation point is increased from 5 m to 6.7 m.
- ✓ Decreases the re-circulation in Zone A.
- ✓ Zone B is better ventilated without scrubber operation.
- ✓ Air volume at the end of LC decreased/remained same.

Results –CM about to make box cut, scrubber ON





- ✓ Re-circulation in Zone A is reversed and Zone B is better ventilated with some RC.
- ✓ Air volume at the end of the LC remained same at 3.9 m^3/sec.
- ✓ Scrubber operation pushes more fresh air into the face area.

Summary conclusions – Right Turn Cut

- Identified low air velocity and re-circulation zones.

- LC position and scrubber operation significantly affect the air flow patterns in the face.

- Air leakage along the LC can drastically reduce the volume of fresh air reaching the face and increase recirculation zones.

- LC extension to right behind the chassis of CM when making this cut is a good practice.

Future work

- Similar analyses will be extended for slab cut and for other typical CM cuts.

- These analyses can be used for optimizing cut-sequence, CM cut-advancement, scrubber operation and LC position for improved dust control.

Reserve Slides

Description of the Different Models Simulated

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Air properties

Mass Density	1.243 kg/m^3
Temperature	289.14 K
Atmospheric pressure	103169 Pa
Viscosity	1.80E-05 kg/ m-s

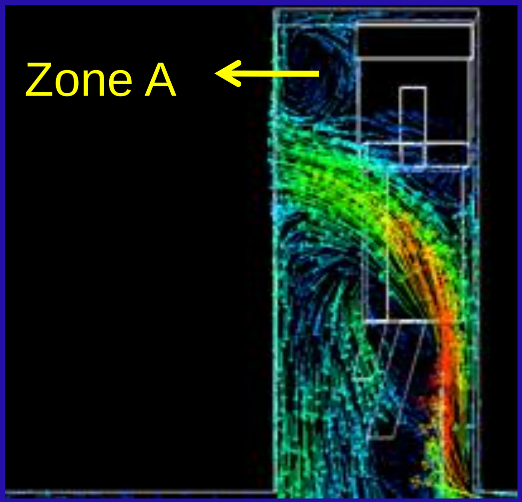
Boundary Conditions

Model	At Inlet	At Outlet
A1	13.1 kg/sec (23,000 cfm)	13.1 kg/sec (23,000 cfm)
A2	13.1 kg/sec (23,000 cfm)	13.1 kg/sec (23,000 cfm)
A3	2.62 pa (3.8e-04 psi)	-0.145 pa (2.11e-05 psi)
A4	13.1 kg/sec (23,000 cfm)	13.1 kg/sec (23,000 cfm)
A5	0.55 pa (8.03e-05)	-0.64 pa (9.36e-05)
B1	13.1 kg/sec (23,000 cfm)	13.1 kg/sec (23,000 cfm)
B2	13.1 kg/sec (23,000 cfm)	13.1 kg/sec (23,000 cfm)
B3	2.76 pa (4e-04)	-0.18 pa (2.65e-05)

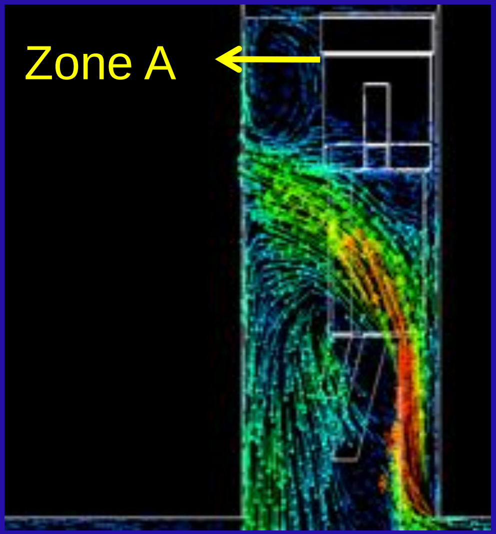
VARYING D_{CR} (DISTANCE b/w LC and COAL RIB)

Q_O – Mass Inflow to LOXC
Q_{LC} – Mass Inflow at the end of LC

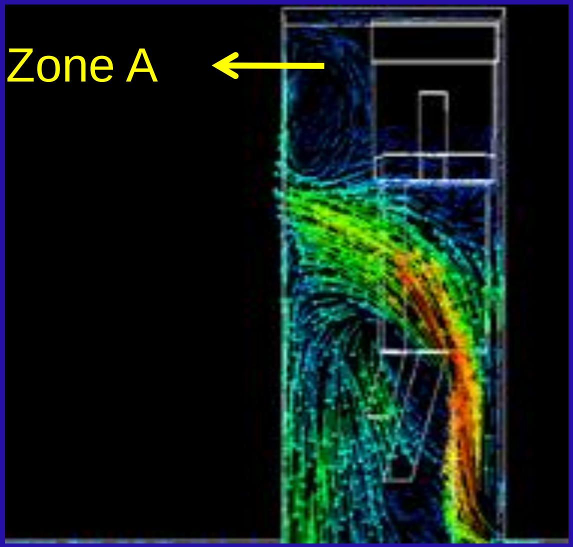
- Significant variation in Zone A is seen



D_{CR} = 3.2 ft



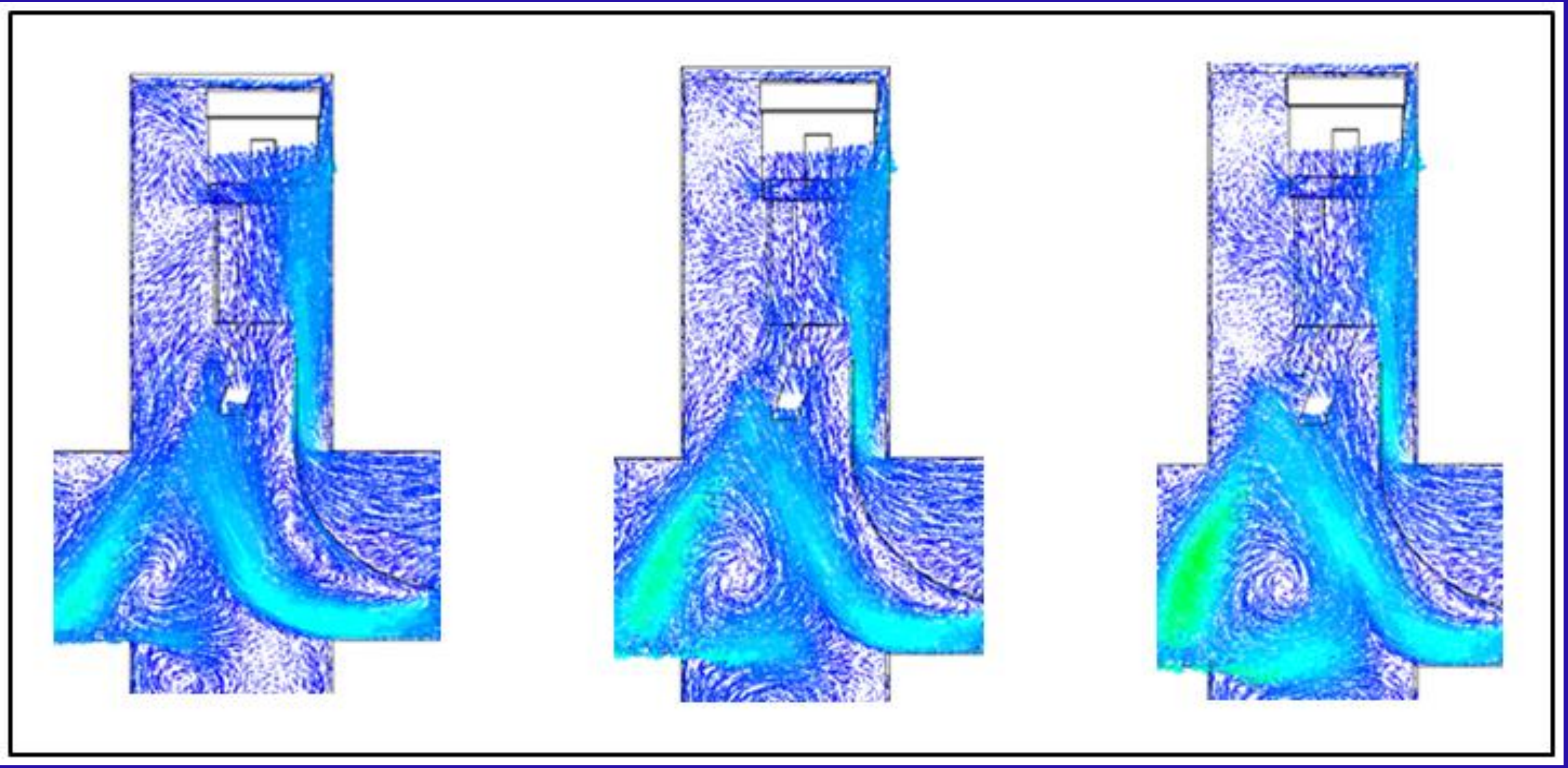
D_{CR} = 4 ft



D_{CR} (ft)	Q_O (cfm)	Q_{LC} (cfm)	Q_{LC}/Q_O
3.2	23,000	9000	0.40
4	23,000	9400	0.41
4.5	23,000	9900	0.43

Effect of P_{SC} on Q_{LC} and Q_F

Q_O – Mass Inflow to LOXC, Q_{LC} – Mass Inflow at the end of LC, Q_F – Mass flow at scrubber discharge



a) 300 Pa b) 450 Pa c) 575 Pa