Improvement of solid fuel combustion in calciners, oxygen injection and venturi

Cinar Ltd

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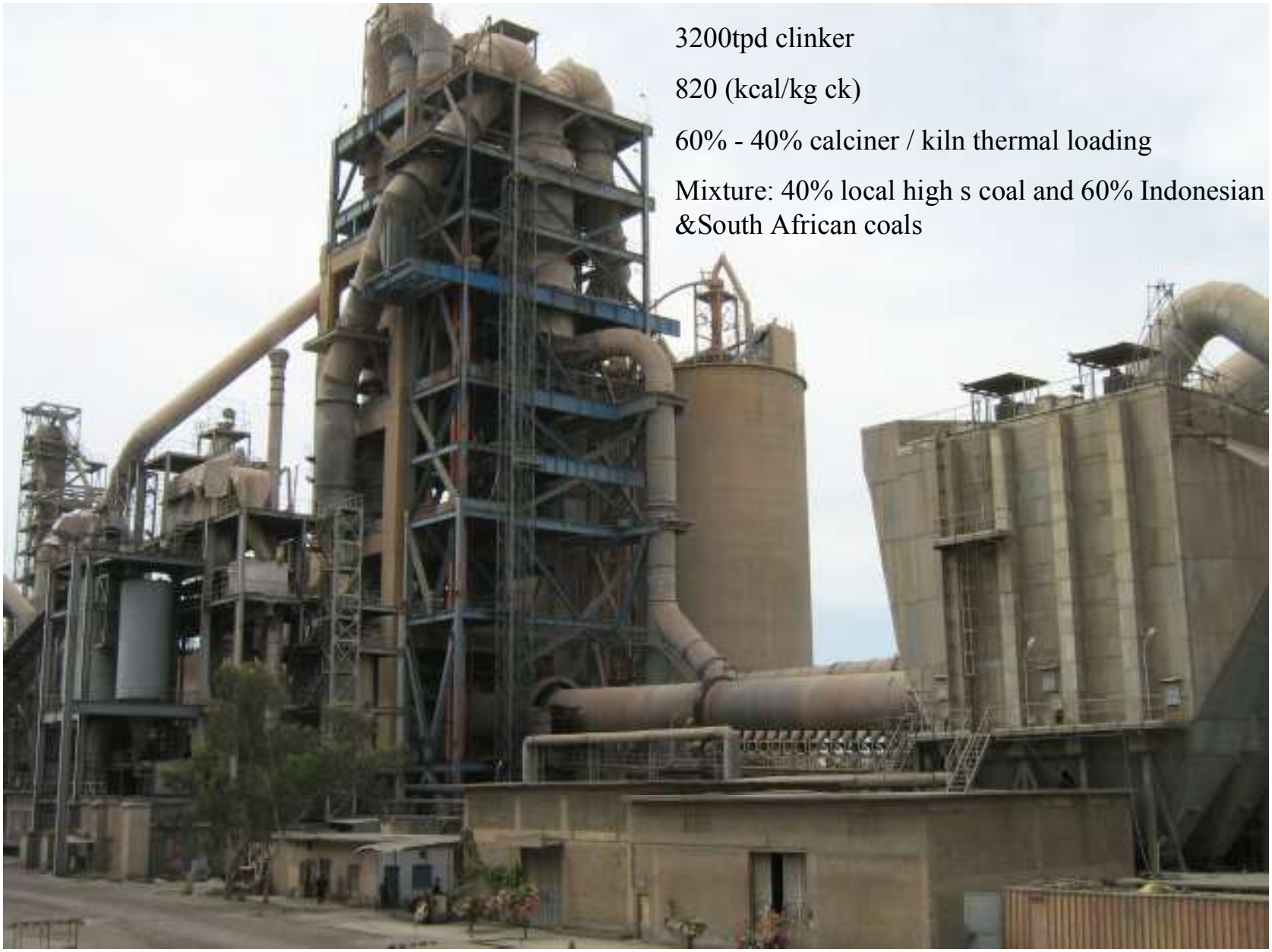
31-05-2012

Summary

- **Case study**
- **Venturi solution**
- **Oxygen injection**

CASE STUDY

Cherat Cement Company



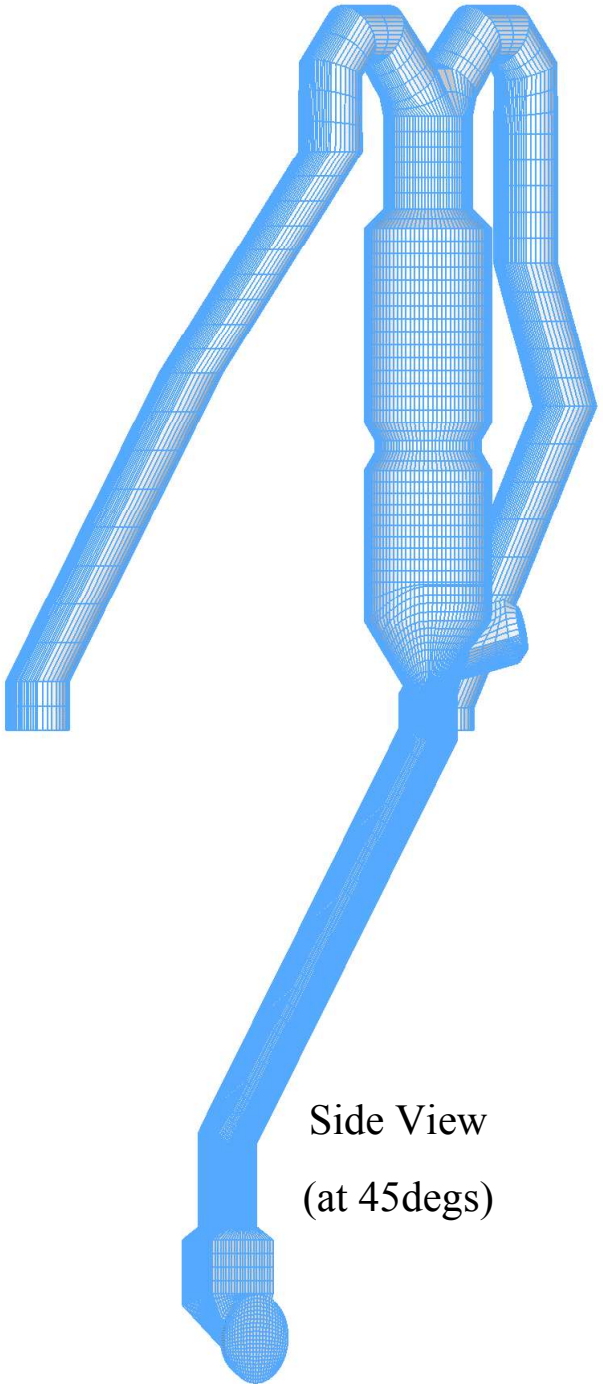
3200tpd clinker

820 (kcal/kg ck)

60% - 40% calciner / kiln thermal loading

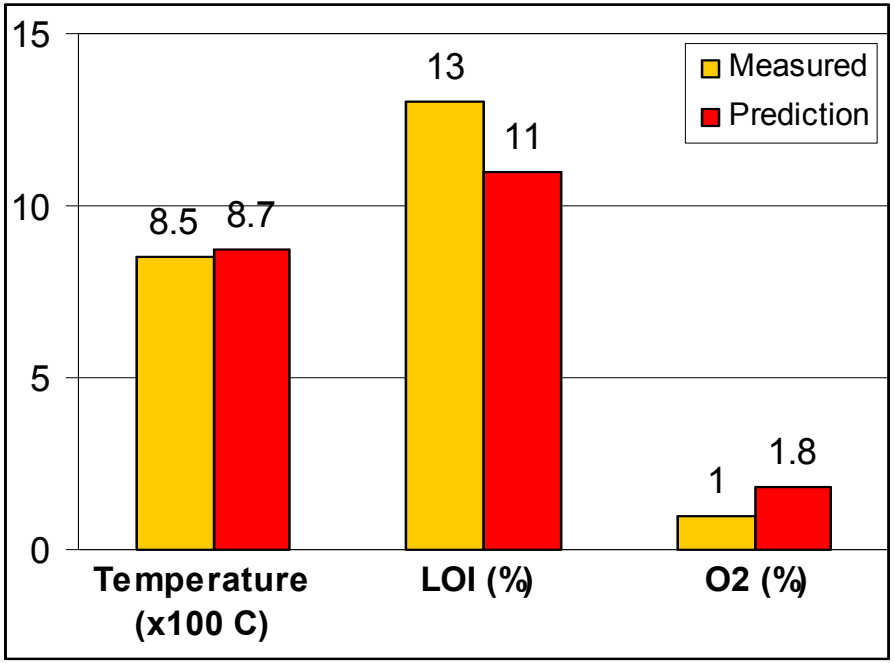
Mixture: 40% local high s coal and 60% Indonesian &South African coals

Base Case



Side View

(at 45degs)



Production	3270 tpd
Raw Meal inlet (tph) / Clinker factor	228 / 1.67
Meal in precalciner	LOI at 31.7%
Kiln Gases massflow (tph) (@ 1050 C)	80
Coal (tph)	10. 5
Transport Air (for both burners) (Nm3/h) (@ 30 C)	4700
Tertiary Air (Nm3/h) (@ 825C)	65000

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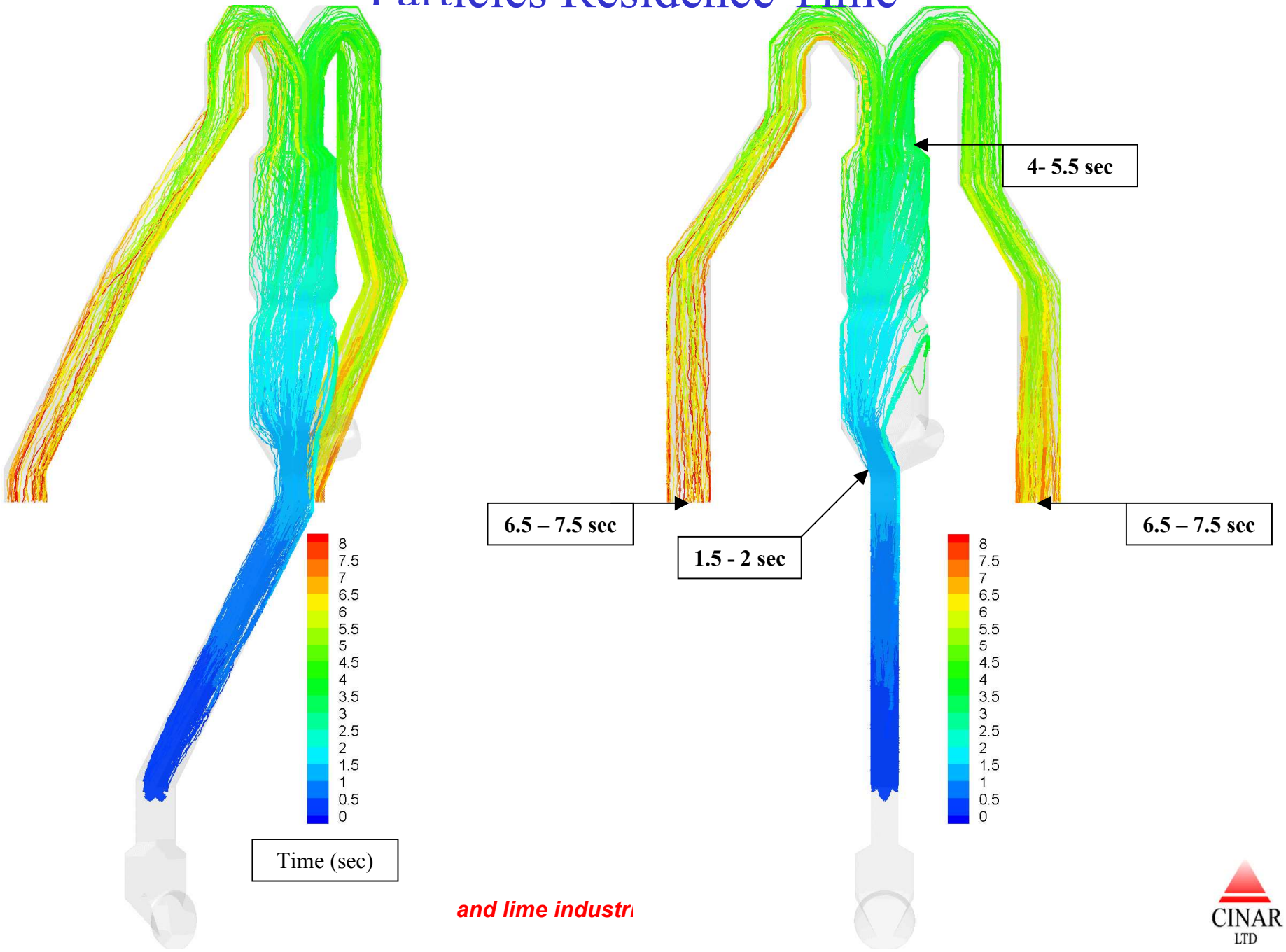
Particles Residence Time



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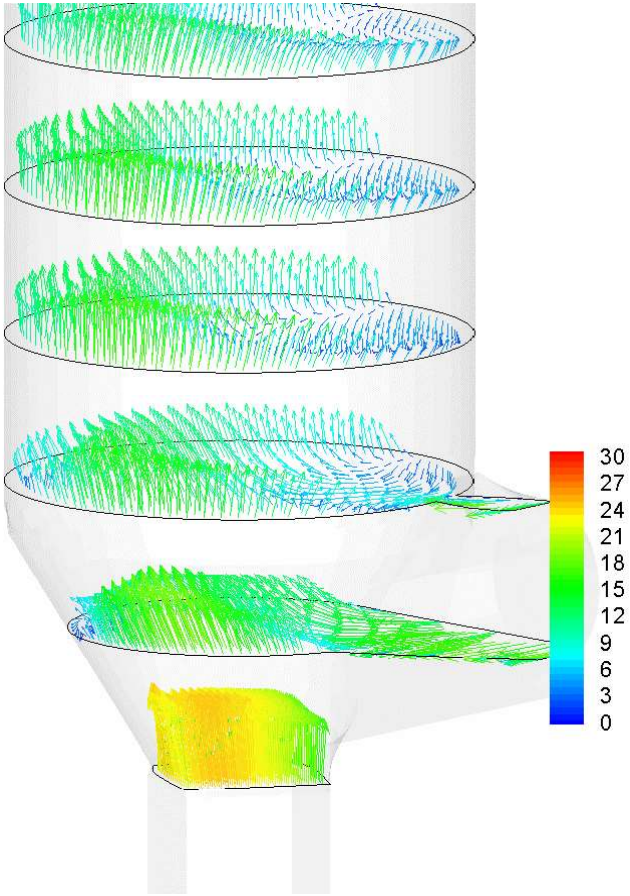
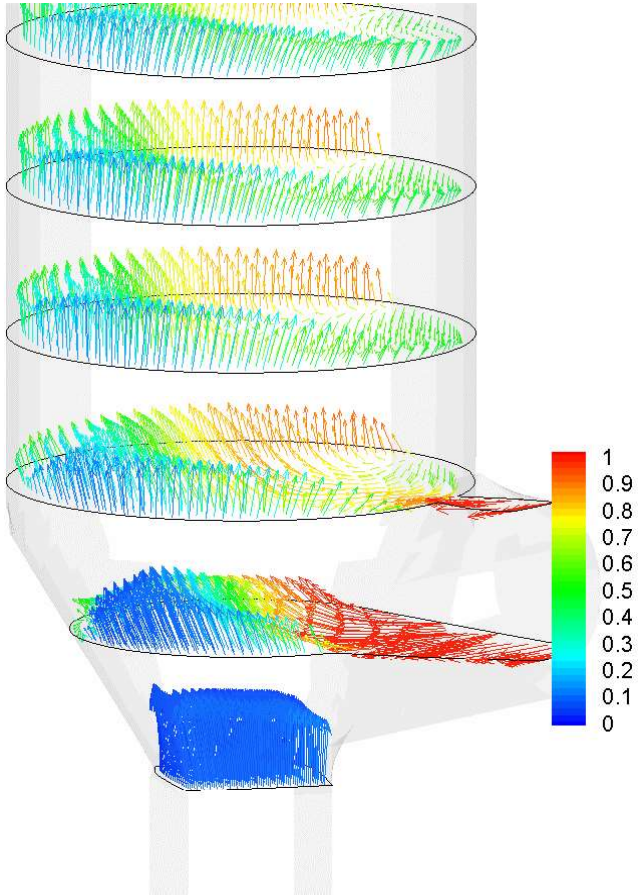
Aerodynamics - Mixing

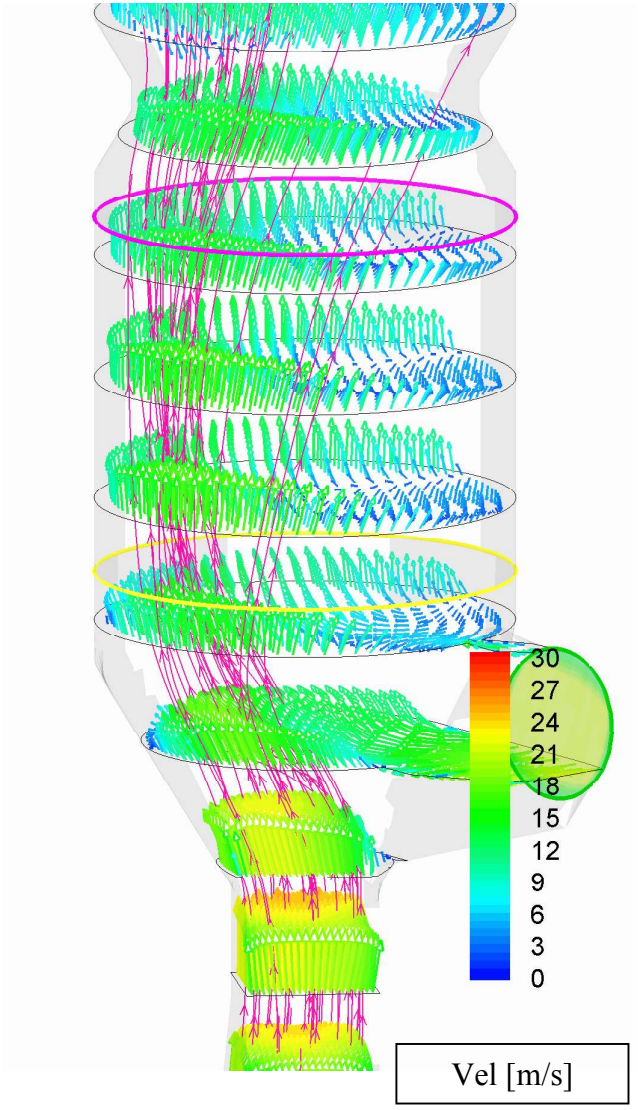


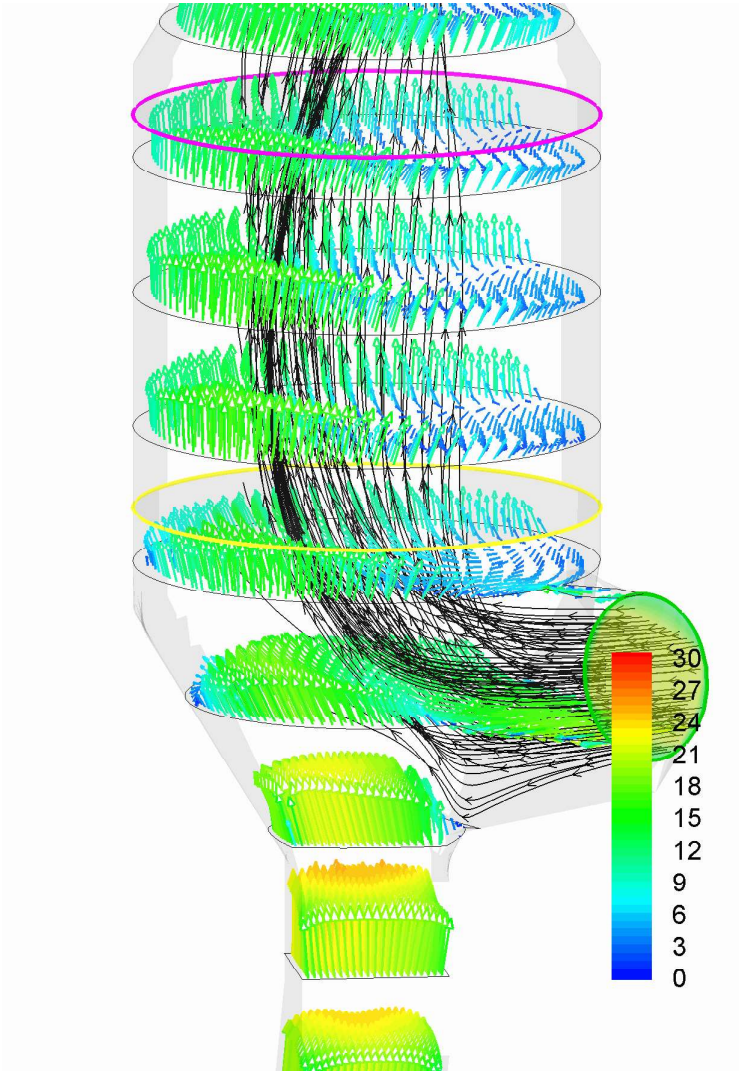
Velocity Magnitude



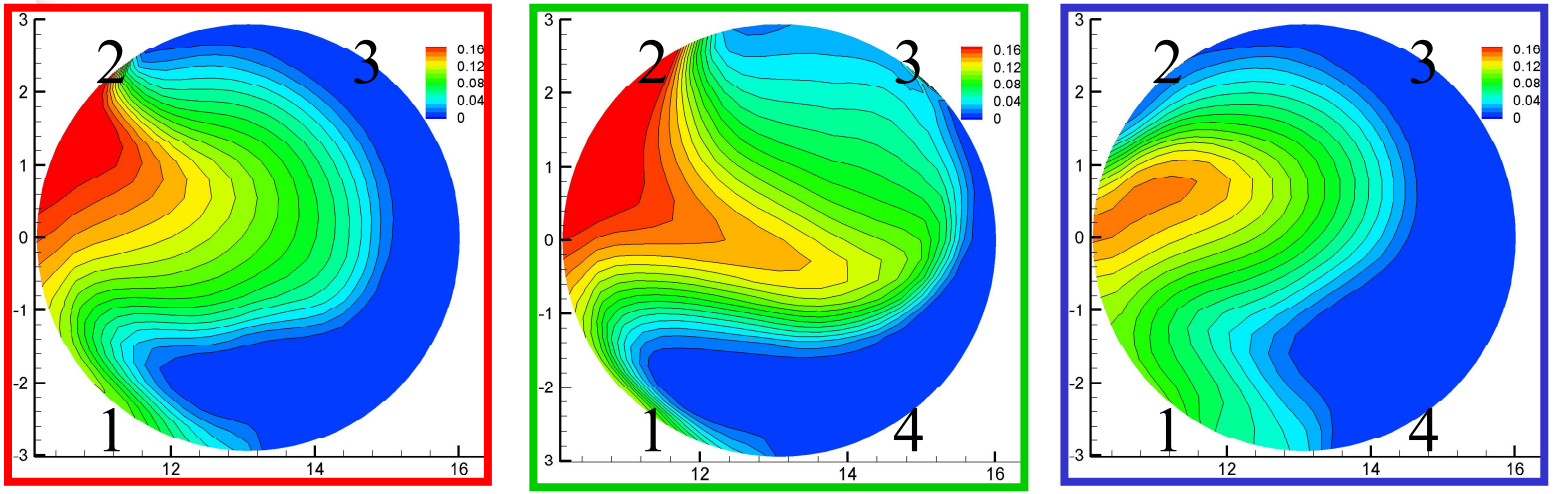
Mixing Magnitude

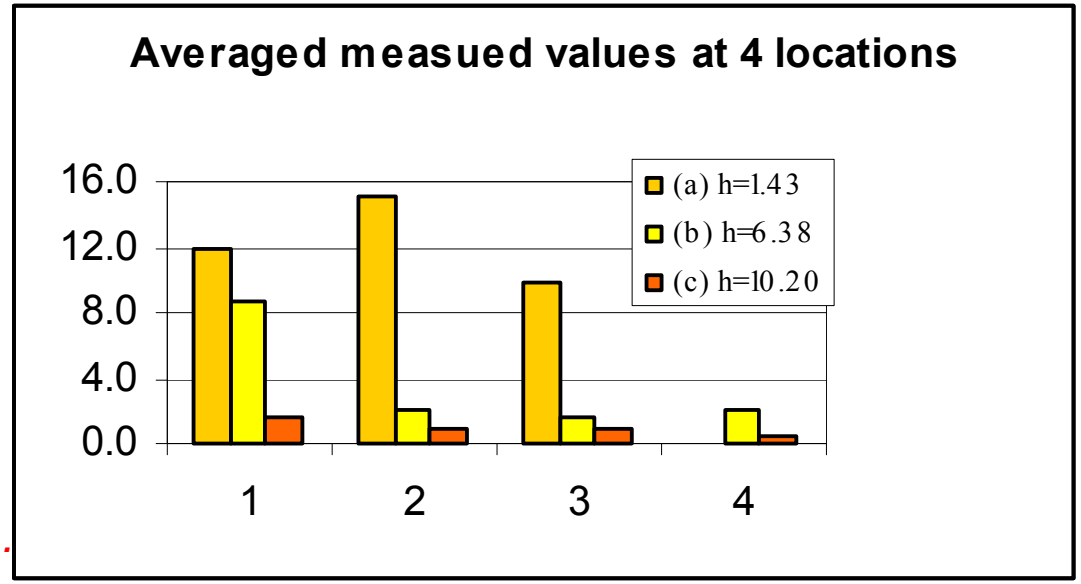
Velocity magnitude with streamlines





Oxygen Profiles





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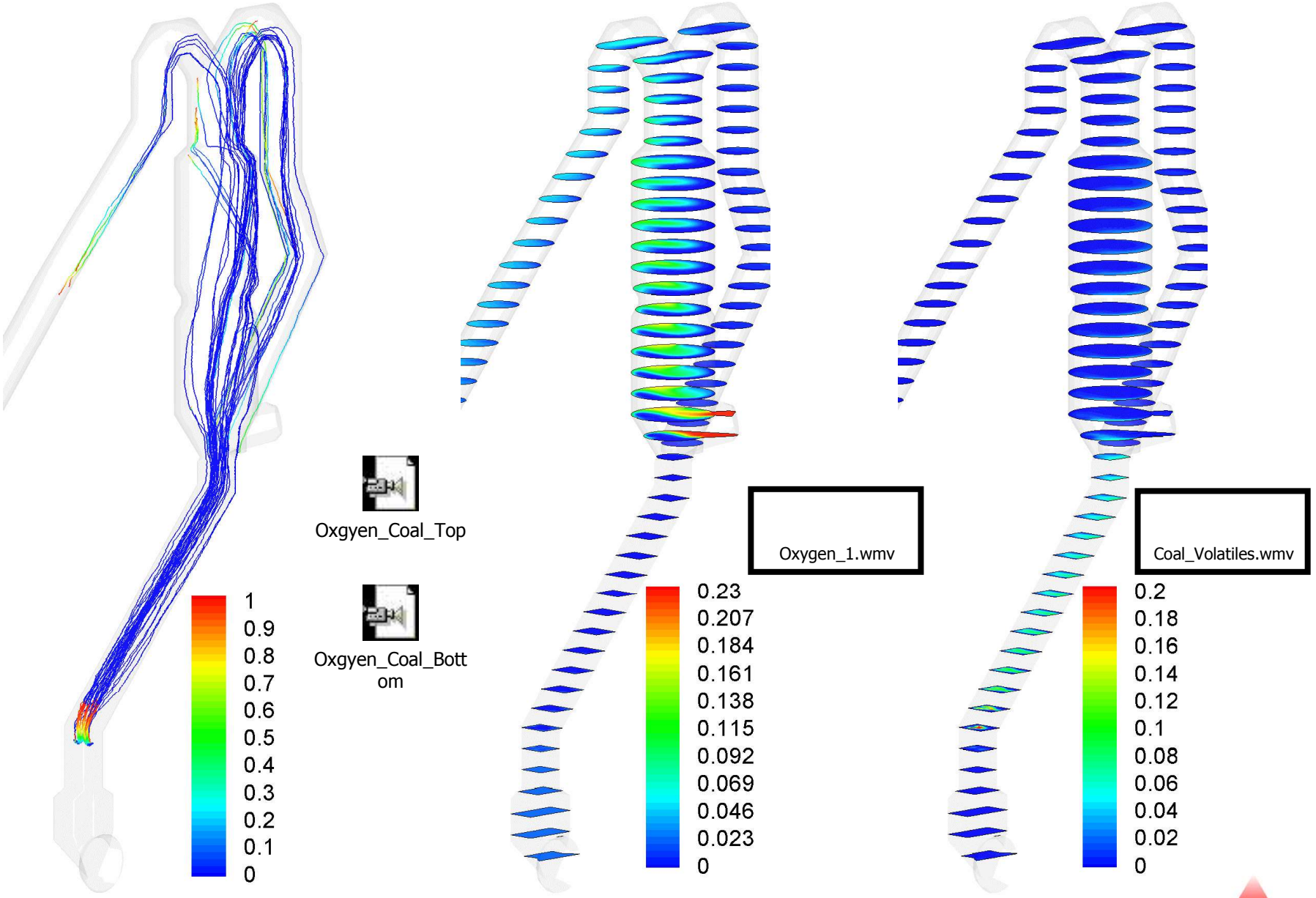
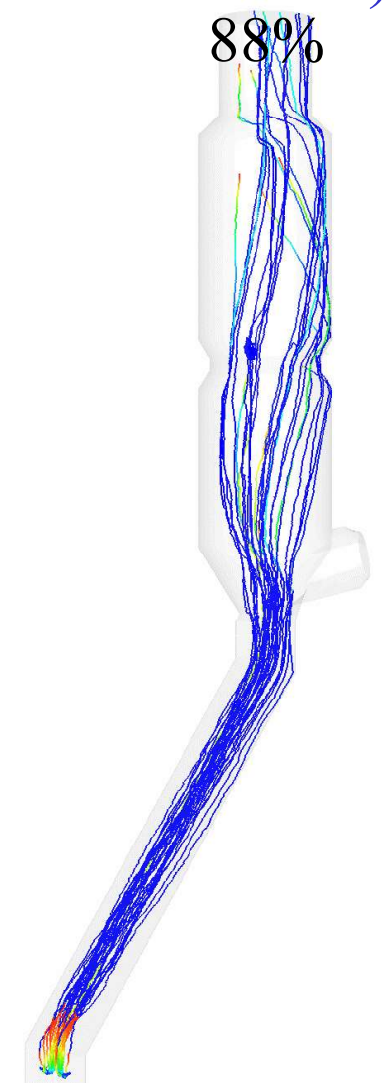
Coal - Oxygen - Volatiles



1) Coal burner/s in the TA duct

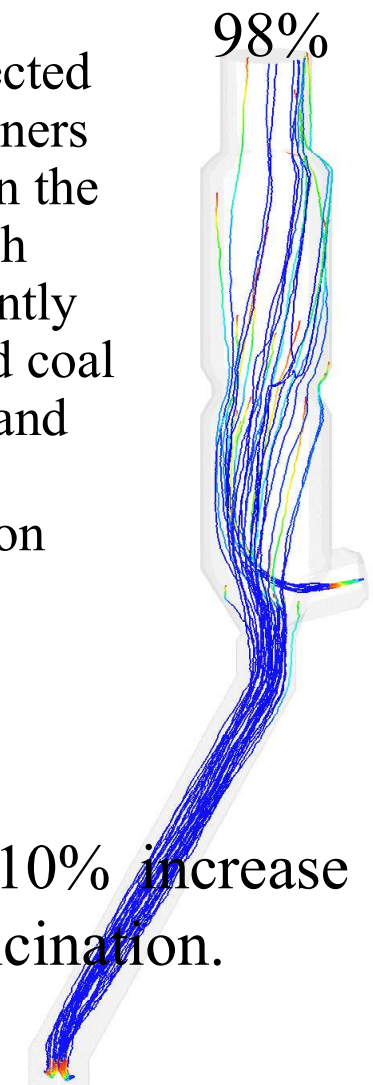
88%



Base Case

70% injected from burners located in the TA which significantly increased coal burnout and meal calcination levels.

98%



Also 10% increase of calcination.

Case PhI-1

11% B/out Improvement

98%

Also 10% increase of calcination.

Case PhI-2

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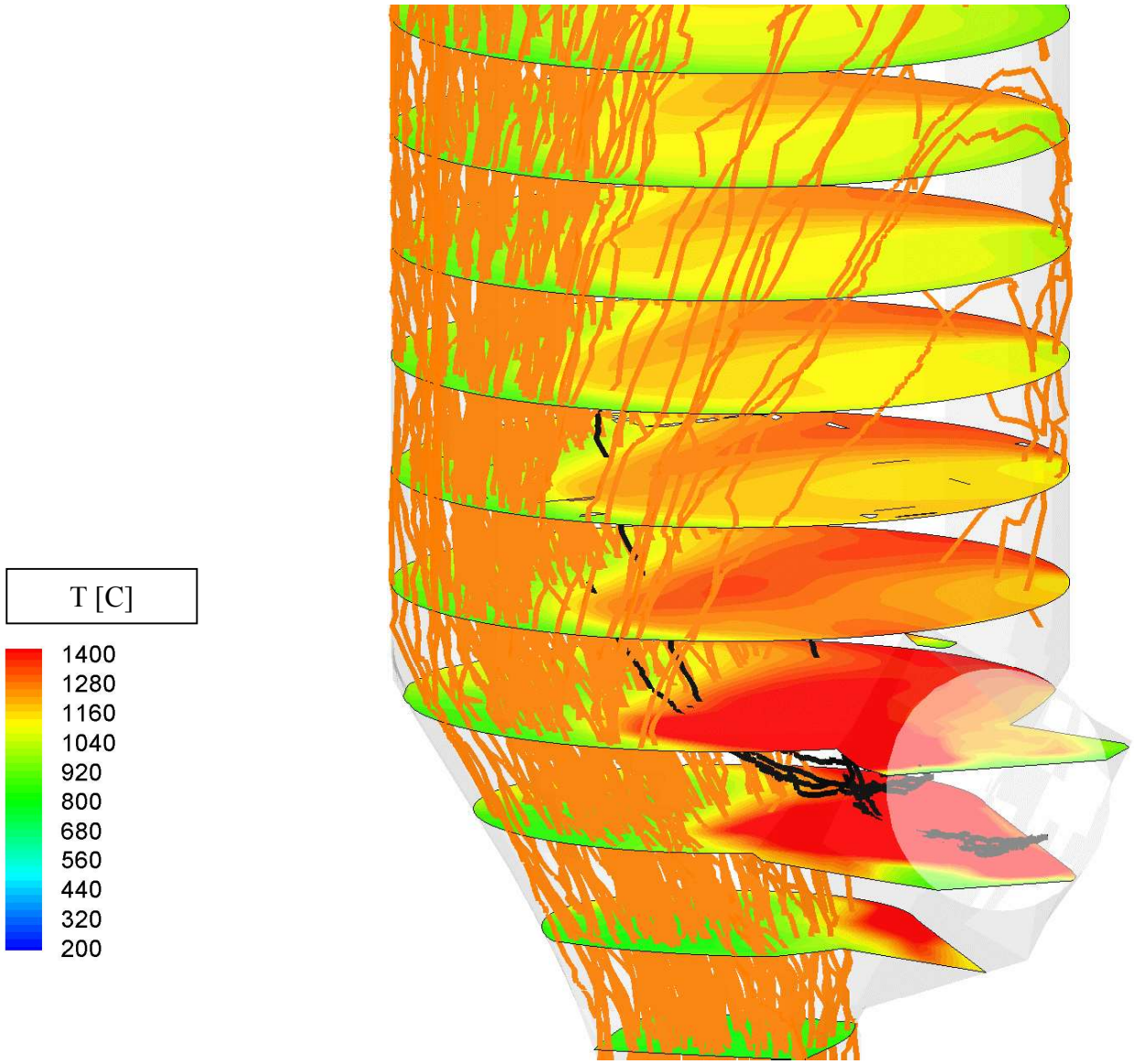
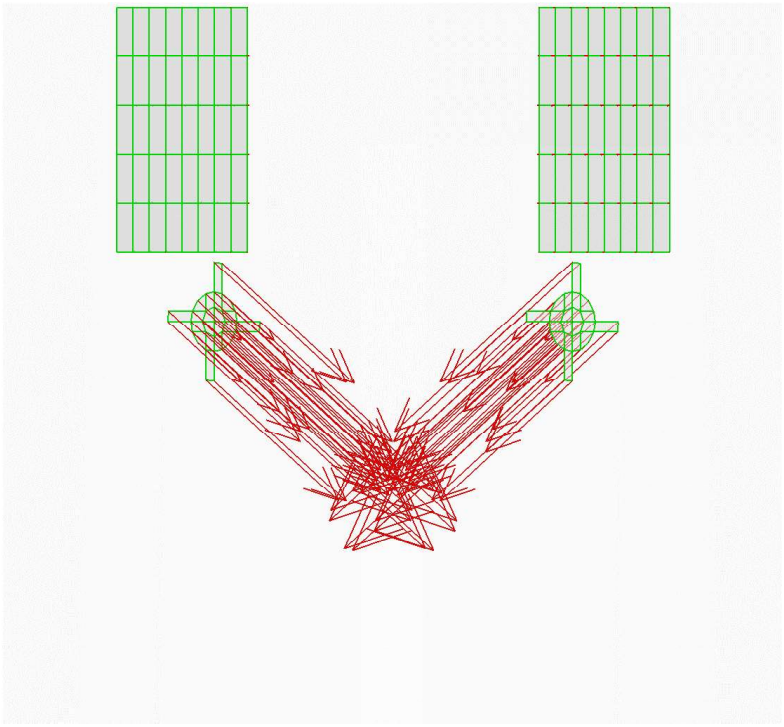
Increased heat regions - Explantion



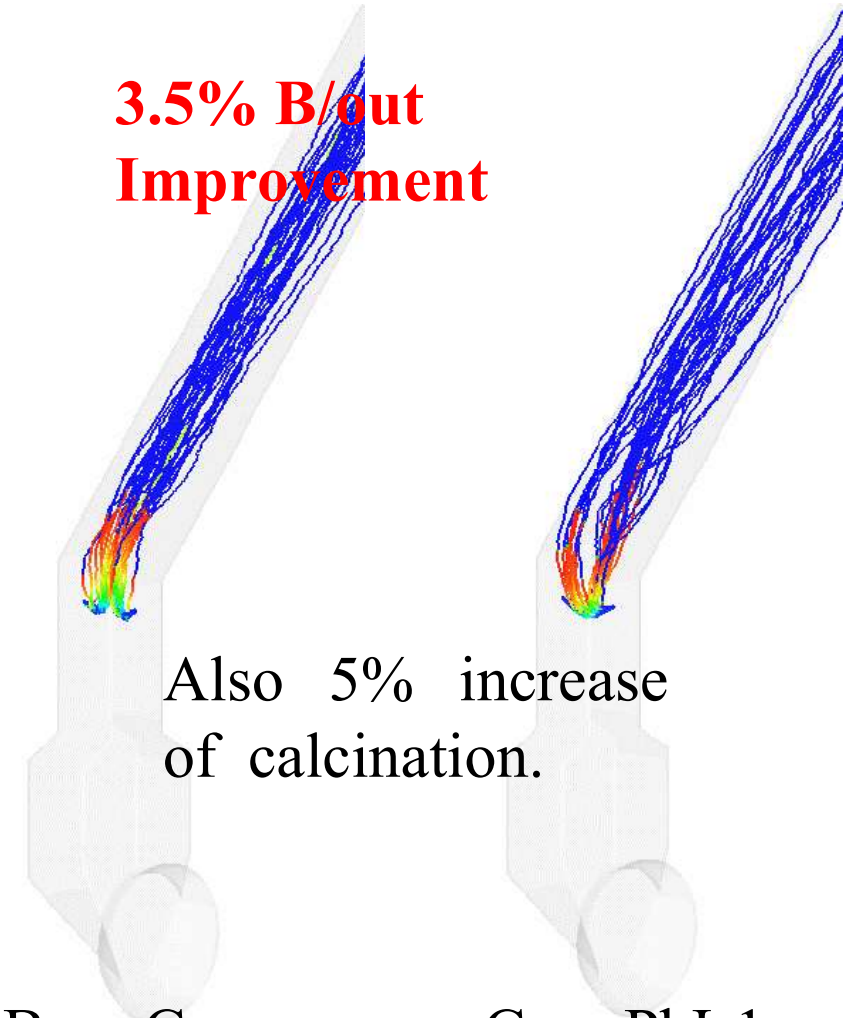
The ignited coal particles, injected from TA, do not come closer to meal particles, which are pushed away due to TA momentum.

2) Axial Air supplied through riser burners

Burnout 88% 91%



3.5% B/out Improvement



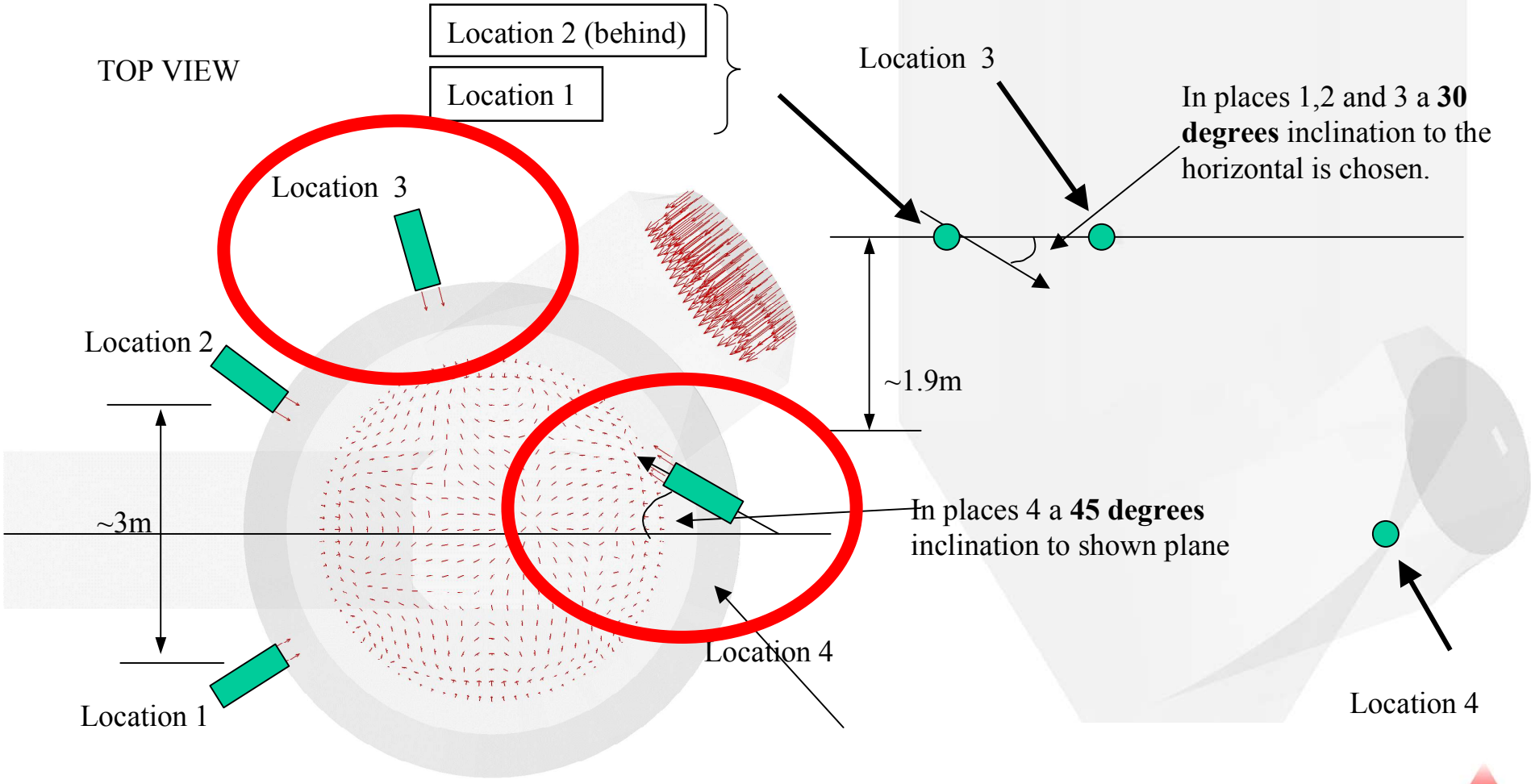
Also 5% increase of calcination.

- Axial air ~10% of Stoich. Air
- U> 100m/s

Base Case Case PhI-1

3) Top burners selected for the rest of the computations

Cases PhIII : 50% of the fuel supplied at top through 2 selected burners from the 4 used for PhII-5.



In places 1,2 and 3 a 30 degrees inclination to the horizontal is chosen.

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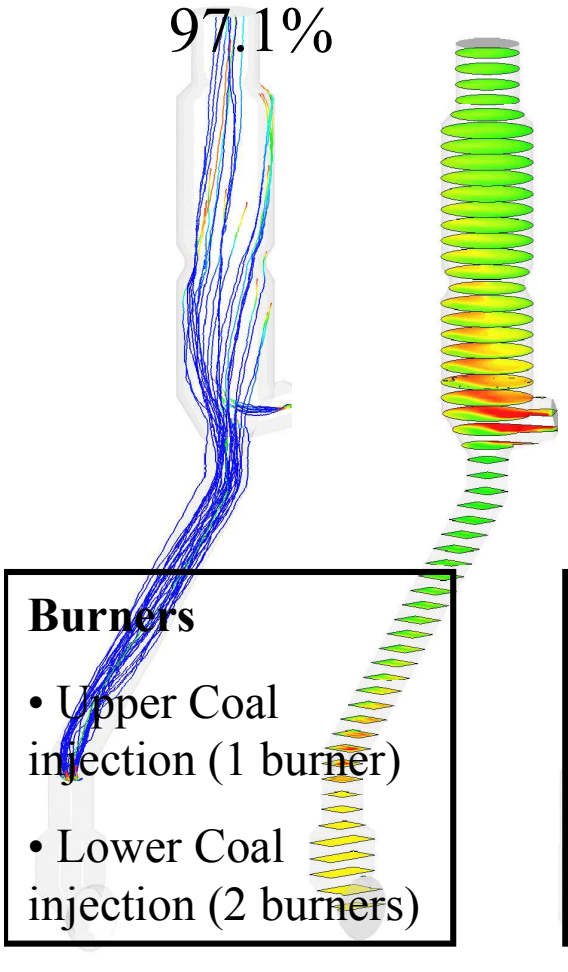
Improvements with alternative coal injection locations

97.1%

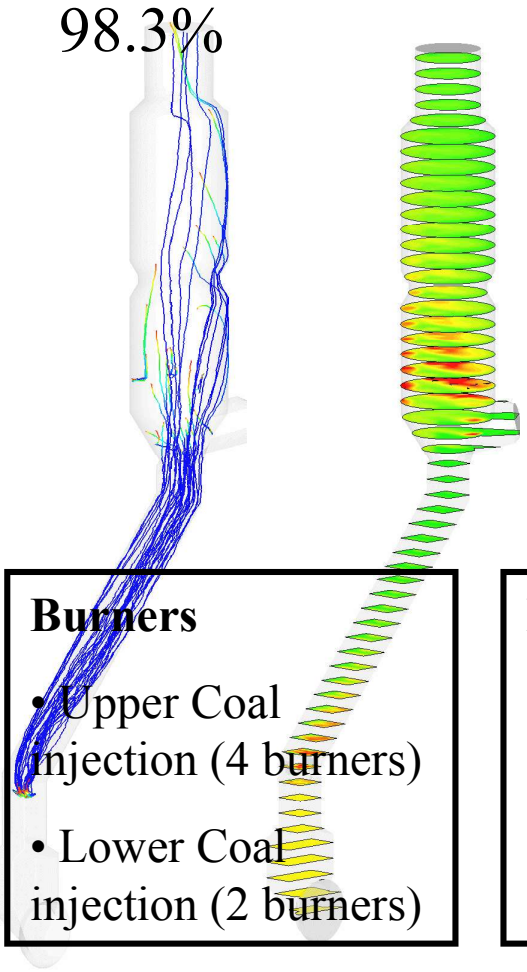


Burners

- Upper Coal injection (1 burner)
- Lower Coal injection (2 burners)

Case PhII-4

98.3%



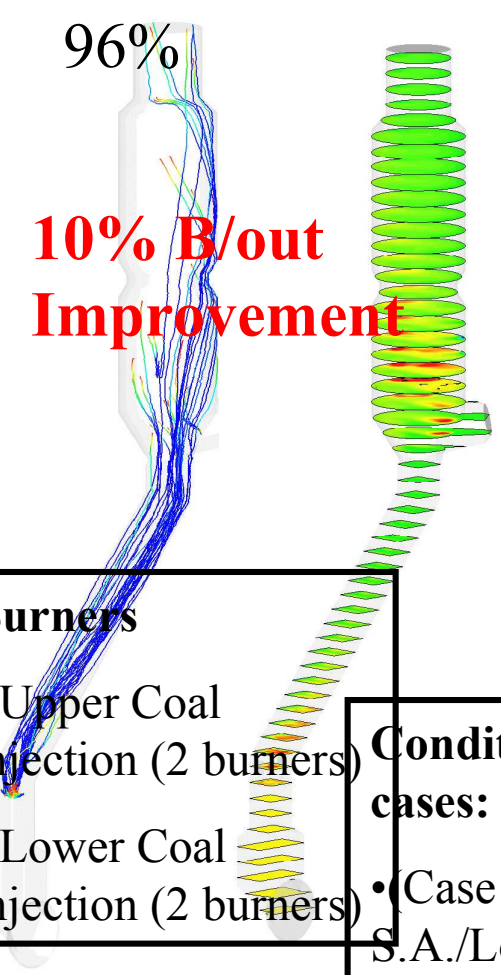
Burners

- Upper Coal injection (4 burners)
- Lower Coal injection (2 burners)

Case PhII-5

96%

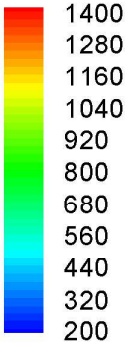
10% B/out Improvement



Burners

- Upper Coal injection (2 burners)
- Lower Coal injection (2 burners)

Case PhIII-1



Conditions for all cases:

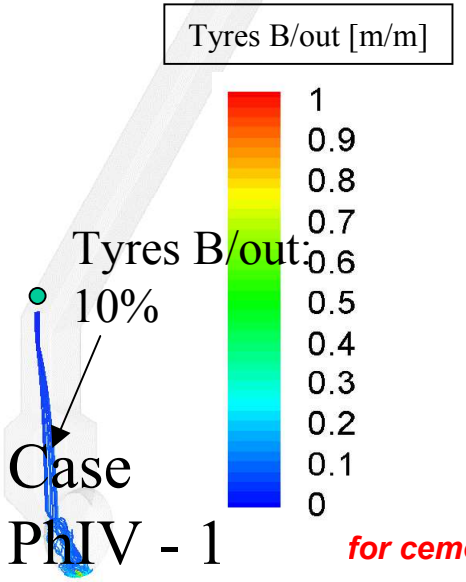
- (Case1,2): S.A./Local: 40/60
- Upper / Lower Split: 50/50
-

Chipped Tires Injection

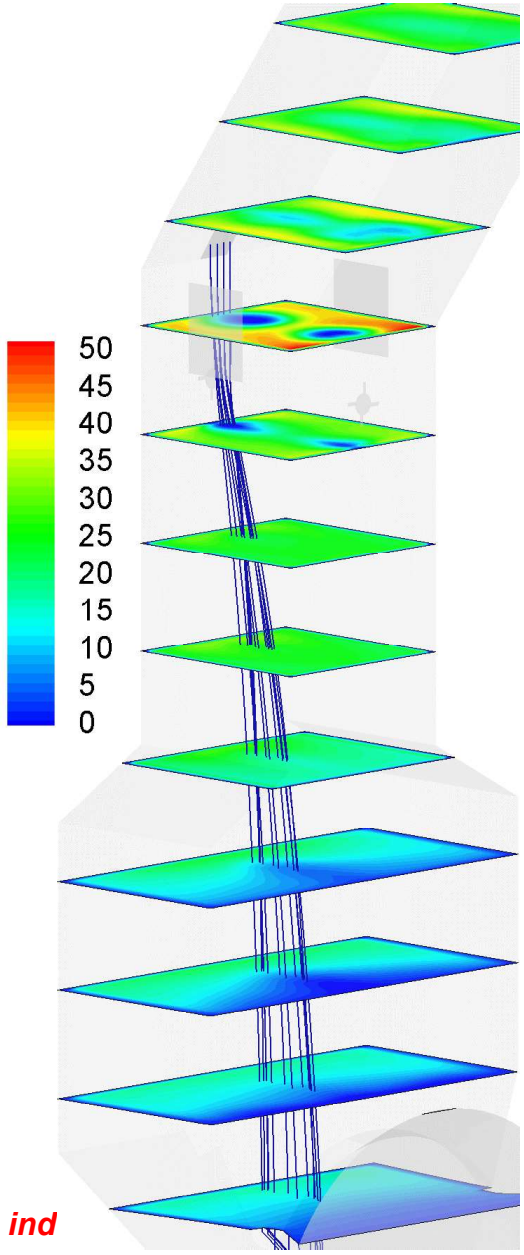
Tyres Burnout

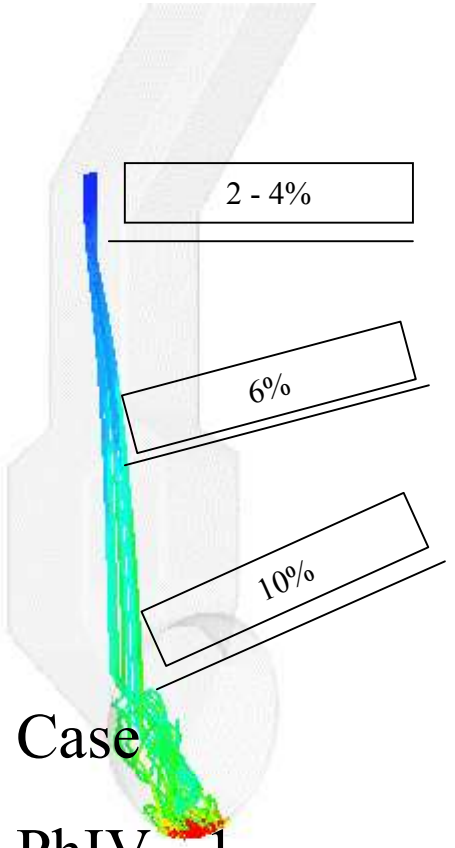
(70 %)

(75mm x 65mm x 10 mm)



Case PhIV - 1





Case PhIV - 1

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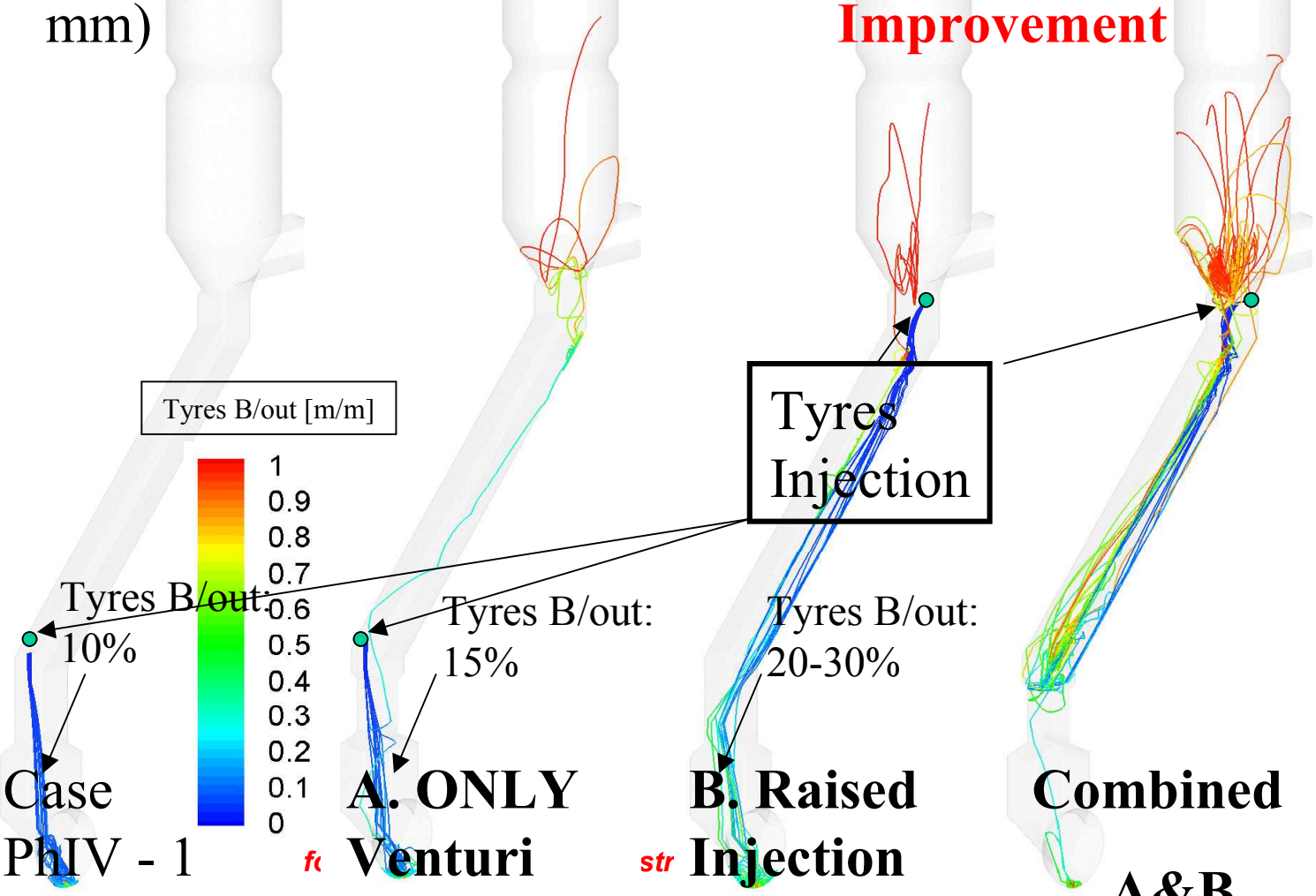
Tyres Burnout

(70 %) 74 % 82 % 91 %

(75mm x 65mm x 10 mm)

30% B/out Improvement



Case PhIV - 1

A. ONLY Venturi

B. Raised Injection

Combined A&B

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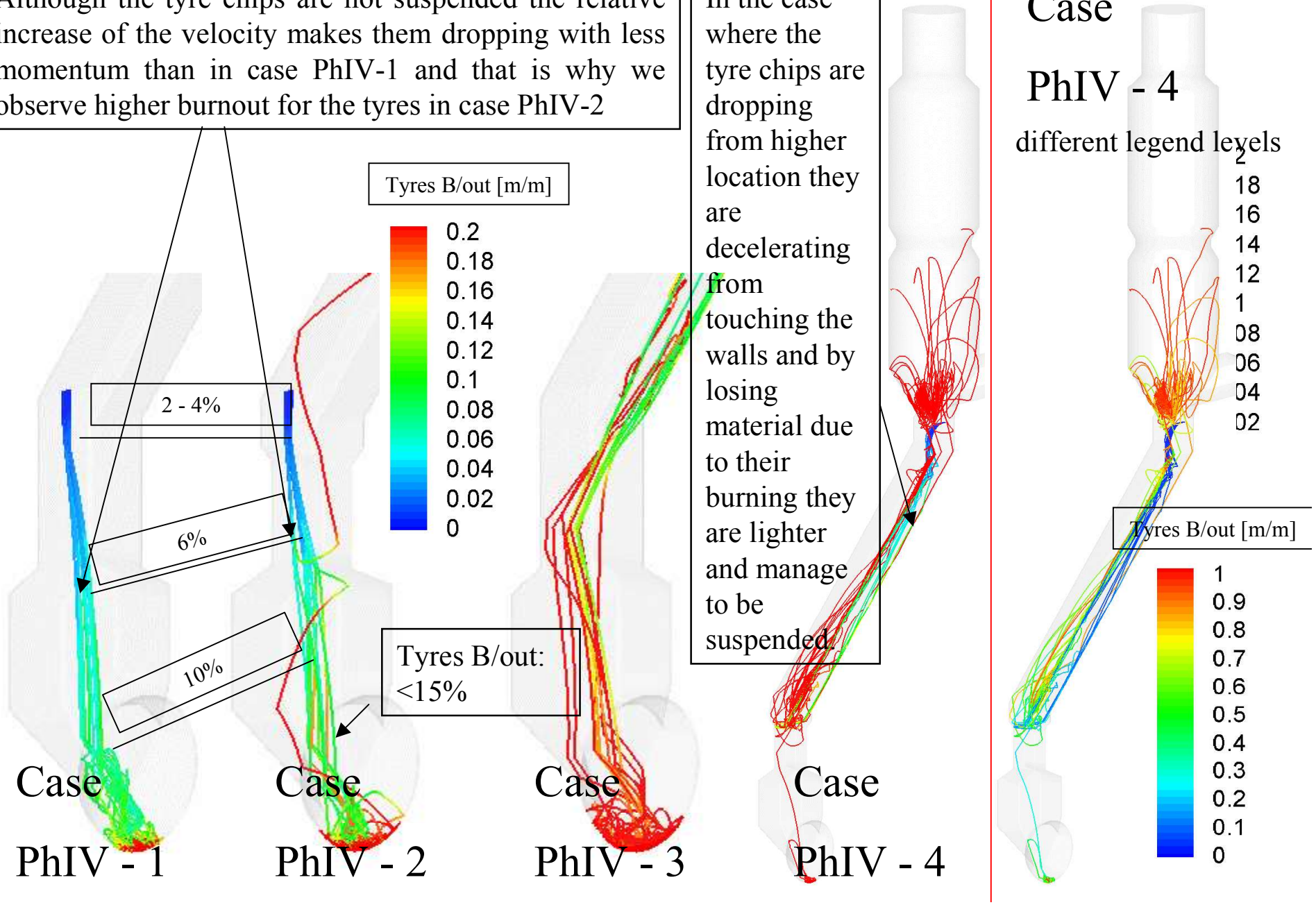
Tyre chip trajectories in Upward Velocity field

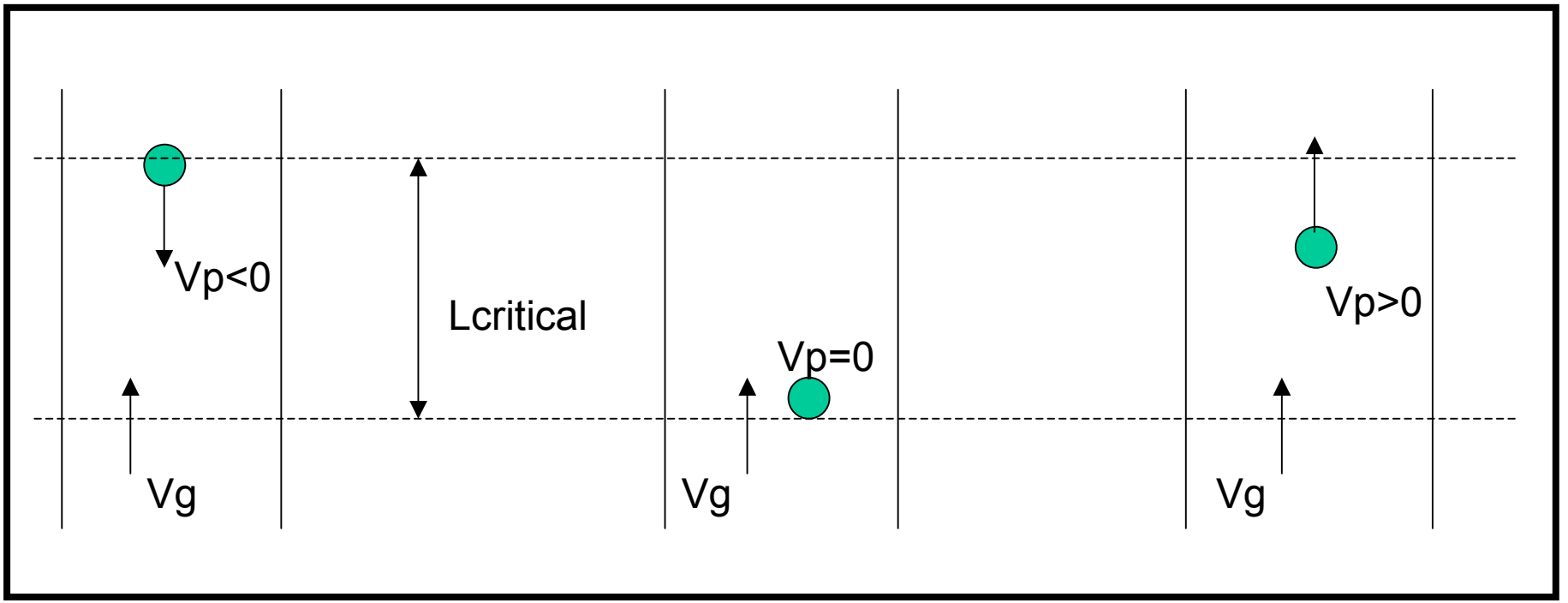
Although the tyre chips are not suspended the relative increase of the velocity makes them dropping with less momentum than in case PhIV-1 and that is why we observe higher burnout for the tyres in case PhIV-2

In the case where the tyre chips are dropping from higher location they are decelerating from touching the walls and by losing material due to their burning they are lighter and manage to be suspended.

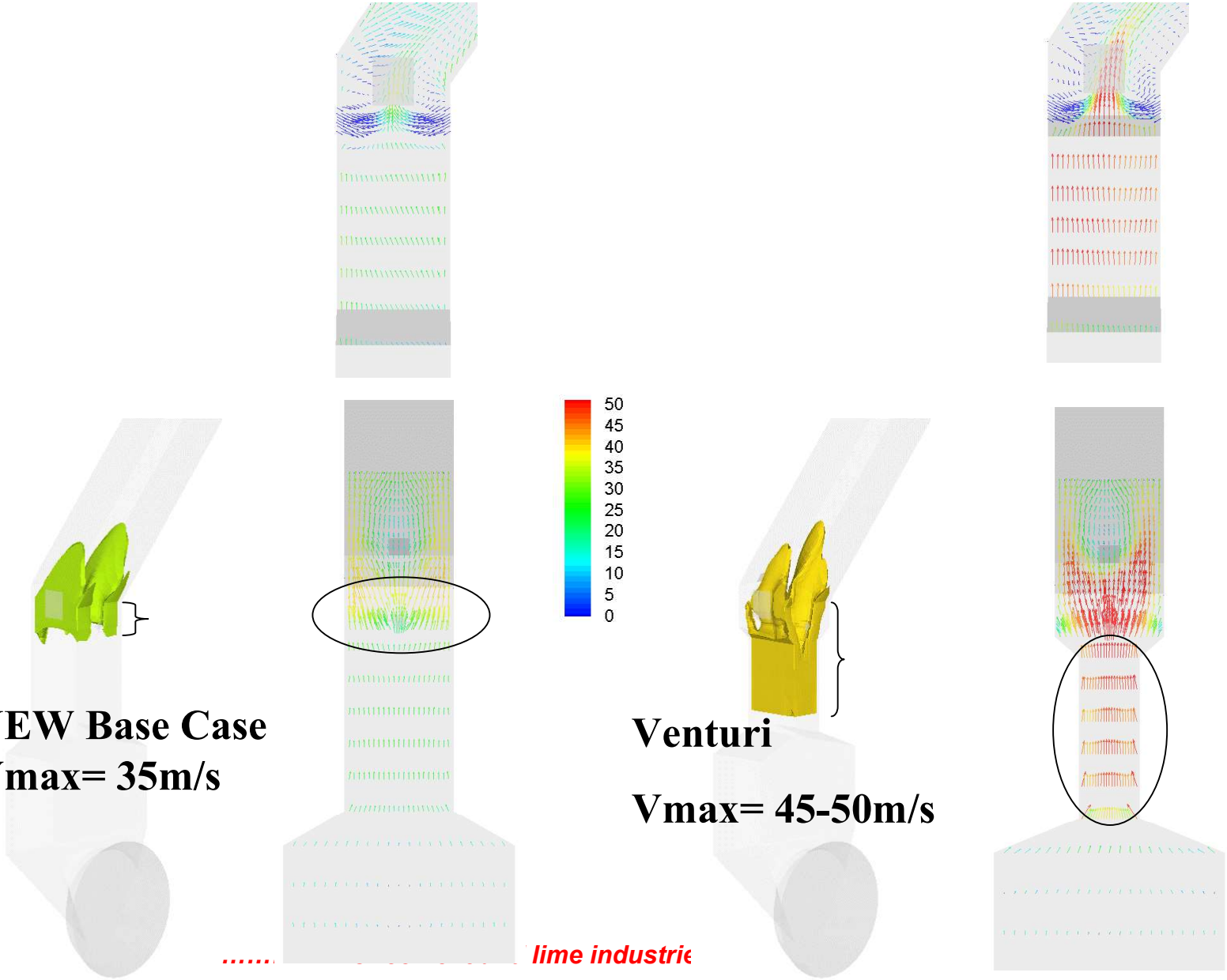


VENTURI

Larger solid matter behaviour in calciner



Effects of Restriction to Velocity



NEW Base Case
Vmax= 35m/s

Venturi

Vmax= 45-50m/s

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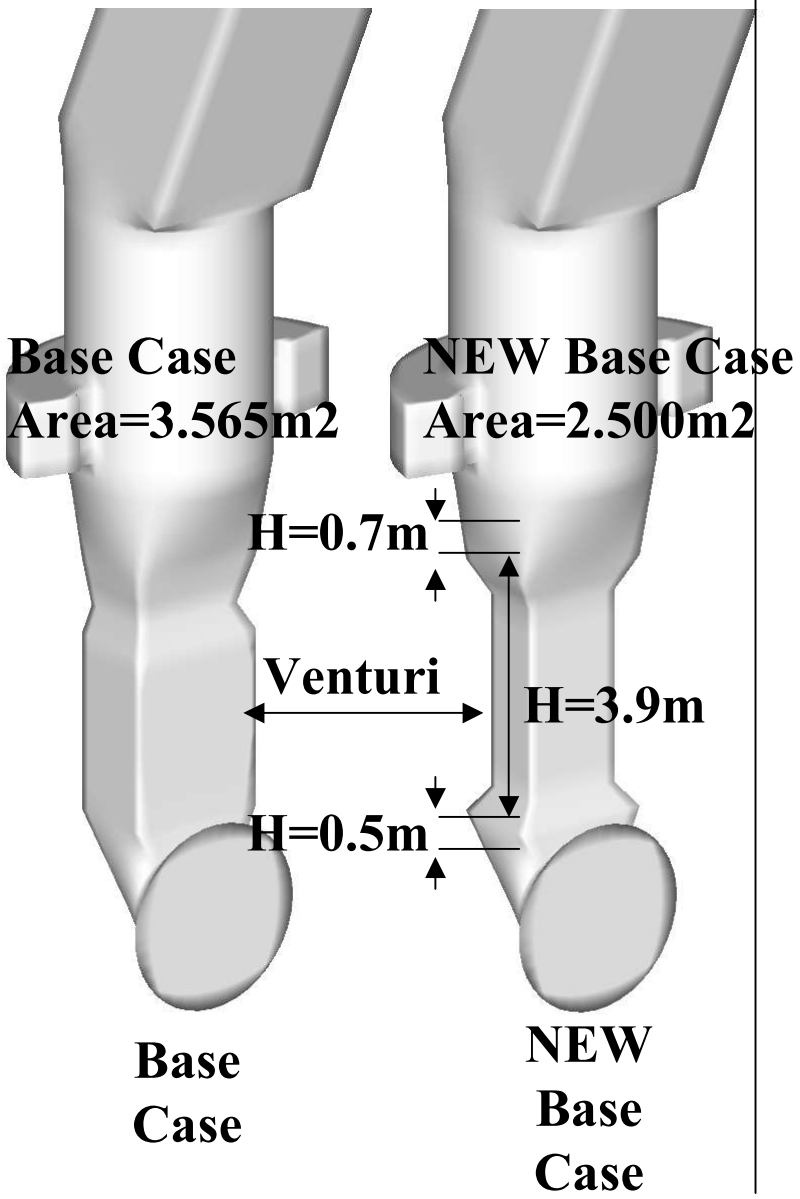
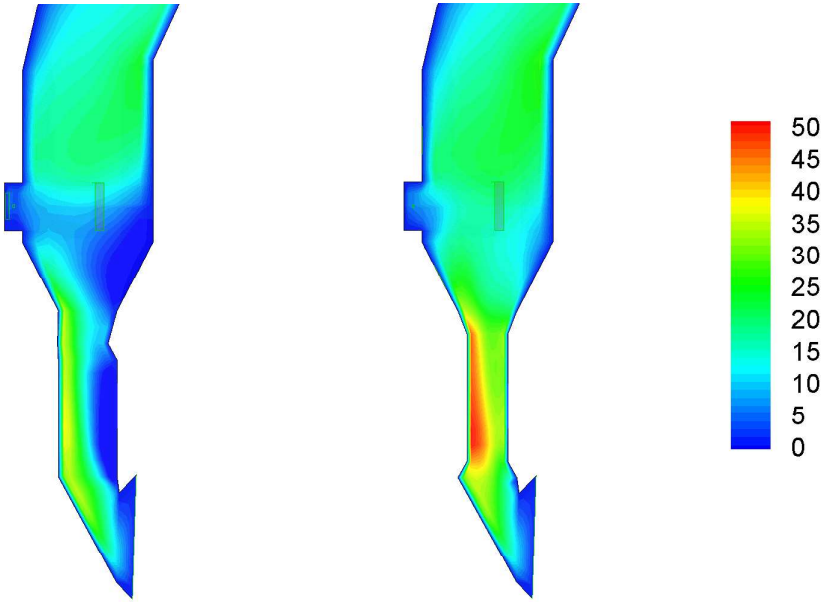
Calciner 2 - Restriction avfter kiln hearth



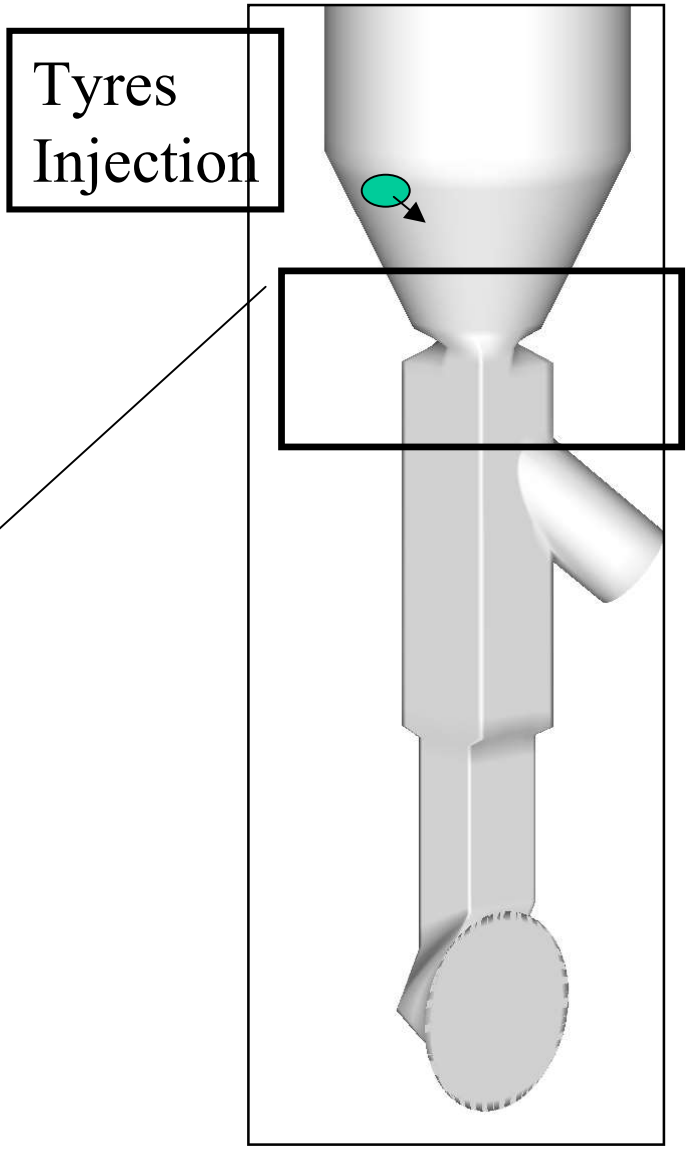
The upwards velocity has increased from a range of 10-30 to a range of 35-50 m/s.

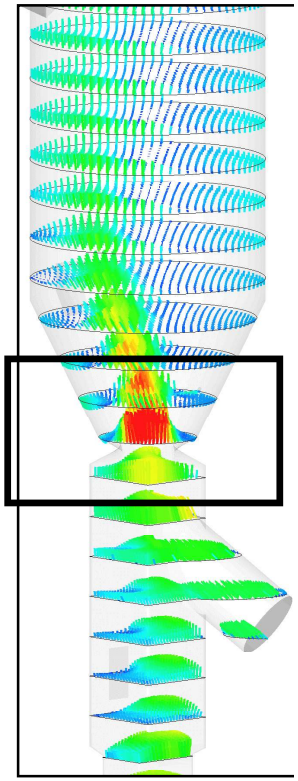
There are still areas of less than 45 m/s but further reduction of the area would not be practicable.



Calciner 3 - Throat after riser duct

Tyre chips PSD (thickness 10mm)	
mm x mm	%
S1: <35 x 35	10
S2: 35 x 35	15
S3: 55 x 25	24
S4: 55 x 45	25
S5: 75 x 45	18
S6: >75 x 45	8
Total	100.0



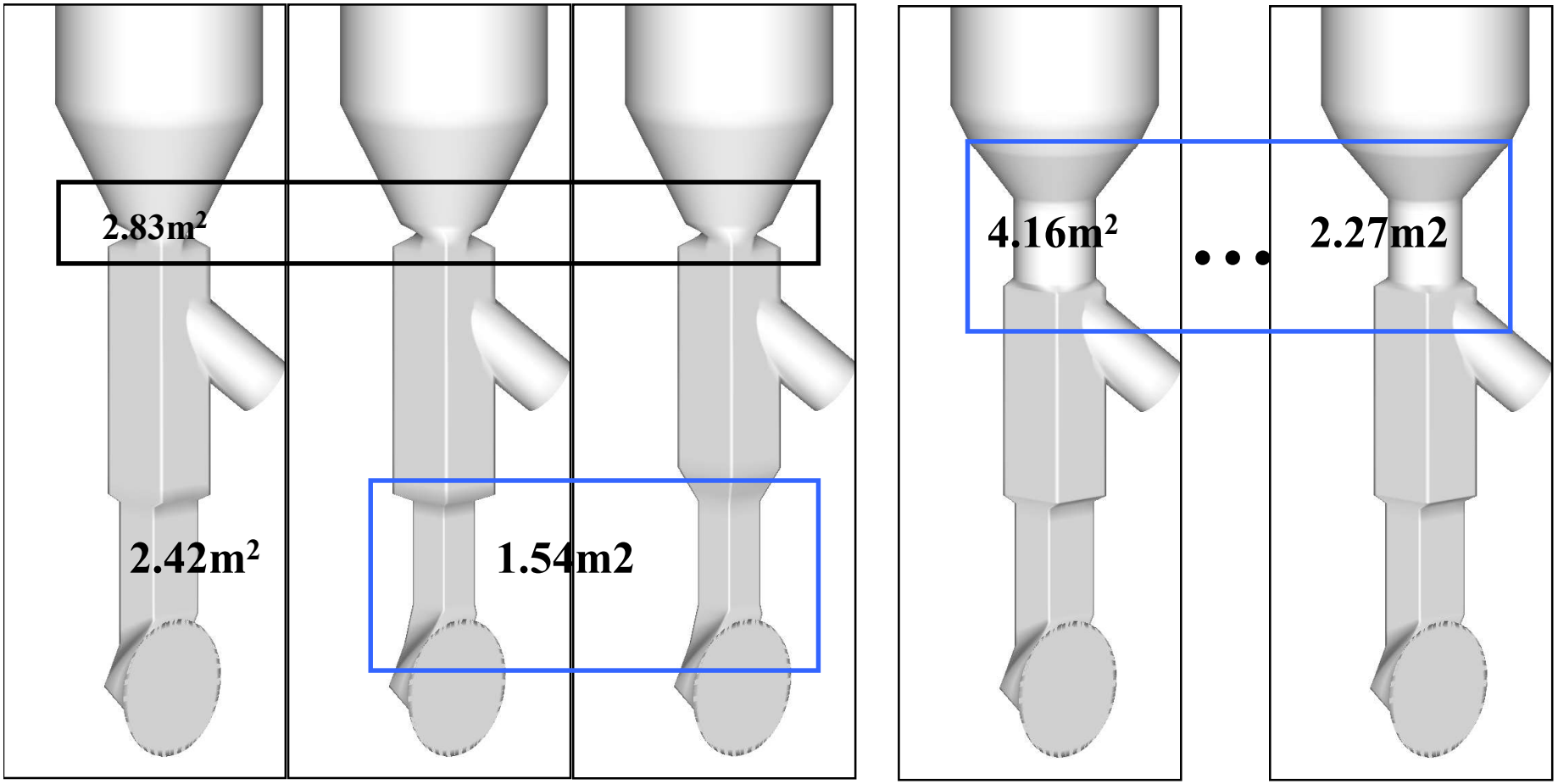


U>50m/s
VERY
short
distance

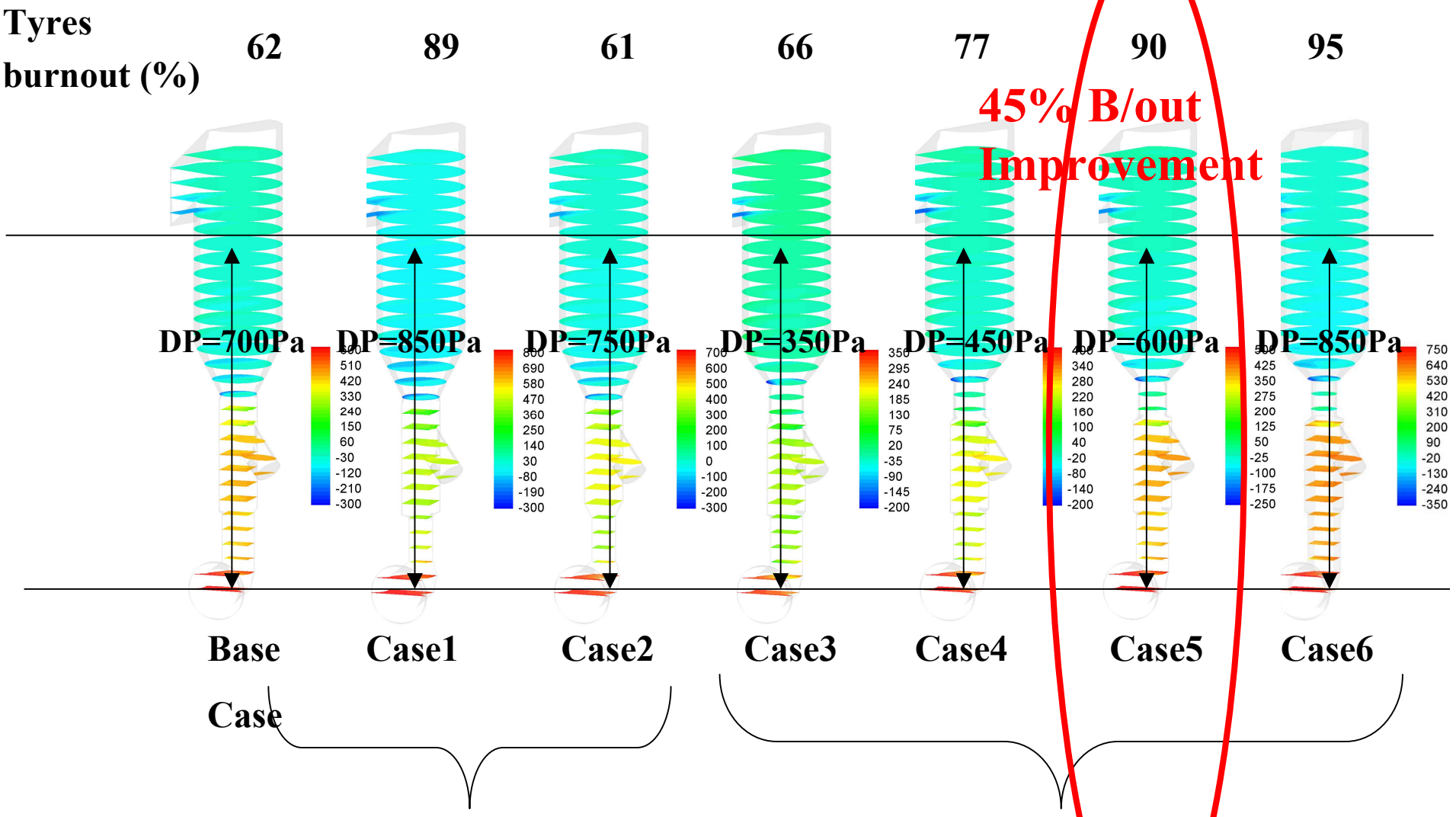
Improving the Tyre Chips Burnout

- **Case 1:**
  - As of Base Case configuration the orifice above TA is kept, but, a restriction is added at the lower riser region.
- **Case 2:**
  - Same as of Case 1 configuration with an improved Venturi smoothness.
- **Case 3:**
  - The Base Case orifice is removed. Instead a Venturi restriction is placed above the TA inlet (Venturi pipe radius R=1.15m).
- **Case 4:**
  - As of Case 3 configuration (Venturi pipe radius R=1.05m).
- **Case 5:**
  - As of Case 3 configuration (Venturi pipe radius R=0.95m).
- **Case 6:**
  - As of Case 3 configuration (Venturi pipe radius R=0.85m).

Calciner 3 - Improvements



Improvement and Pressure Drop (Pa)



Summary of Results

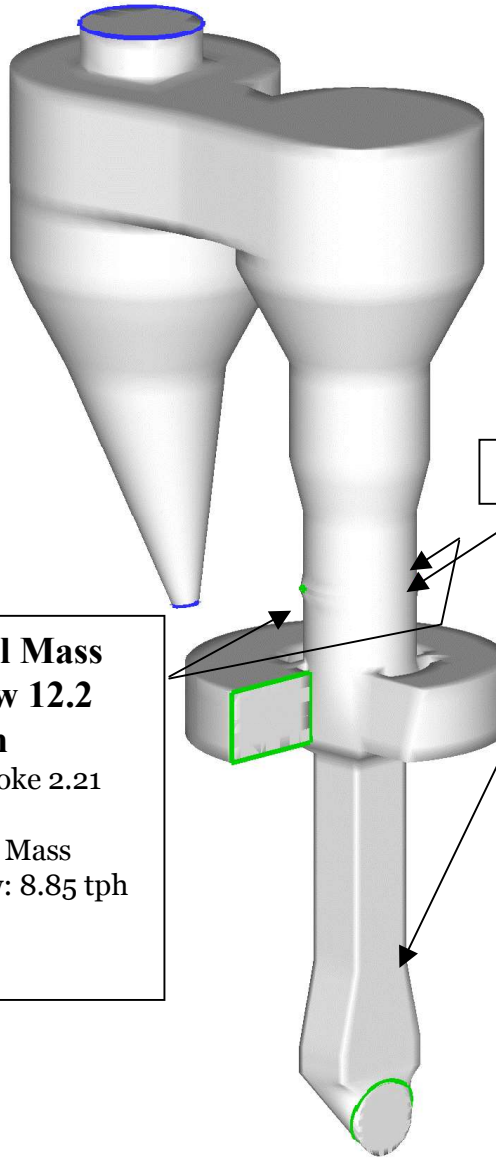
Case	Base Case	C1	C2	C3	C 4	C 5	C 6
Coal Burnout (%)	99	99	99	98	99	98	98
MBM Burnout (%)	92	91	93	91	91	92	92
Tyre Chips Burnout (%)	**62**	**89**	**61**	**66**	**77**	**90**	**95**
Calcination (%)	95	96	95	90	89	92	93
ExitO2 (%)	3.2	2.49	3.22	3.29	2.88	2.52	2.37
δP (mbar)	**7.0**	**8.5**	**7.5**	**3.5**	**4.5**	**6.0**	**8.5**
Exit Temperature (C)	920	982	924	983	981	967	965

OXYGEN INJECTION

Oxygen Injection

- Oxygen is injected for the following reasons:
  - To improve the fuel consumption
  - To reduce the mass of the gases when the pressure is a limiting factor.
- Problems:
  - High temperatures
  - Expensive
  - Needs optimisation

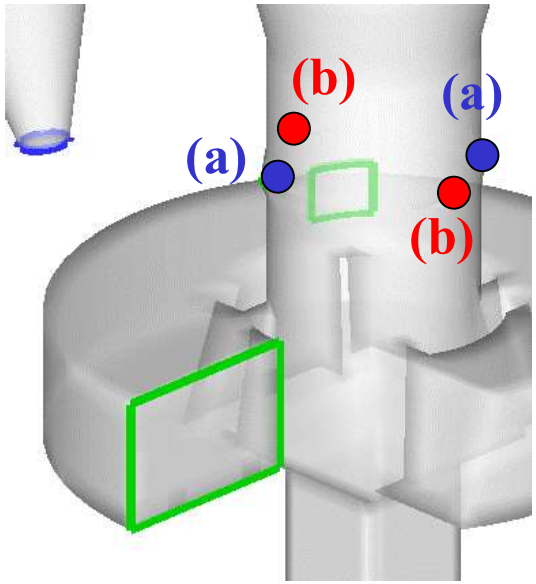
Geometry



5000 tpd cement

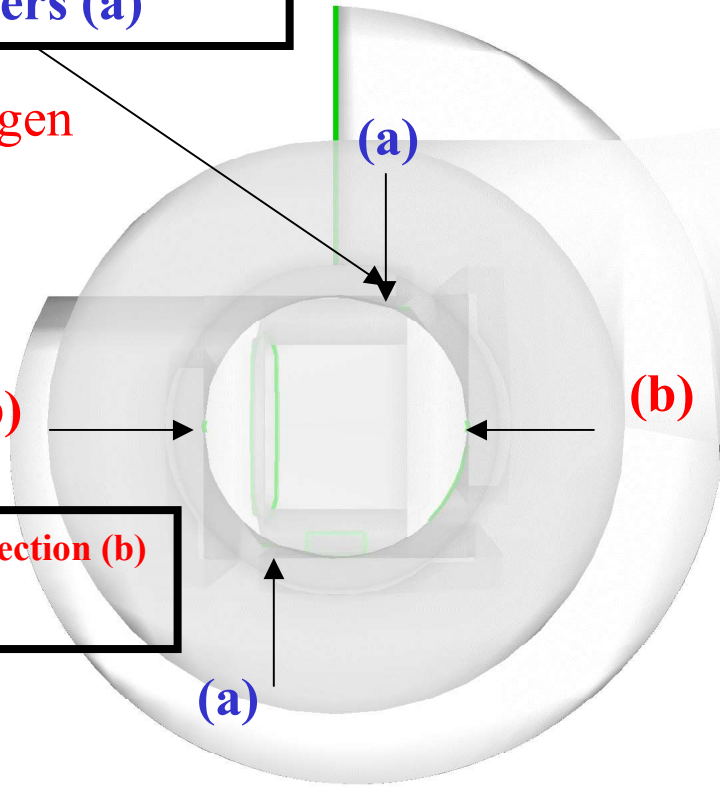
Meal (LOI 27)

Fuel Mass Flow 12.2 stph
Petcoke 2.21 tph
Coal Mass Flow: 8.85 tph



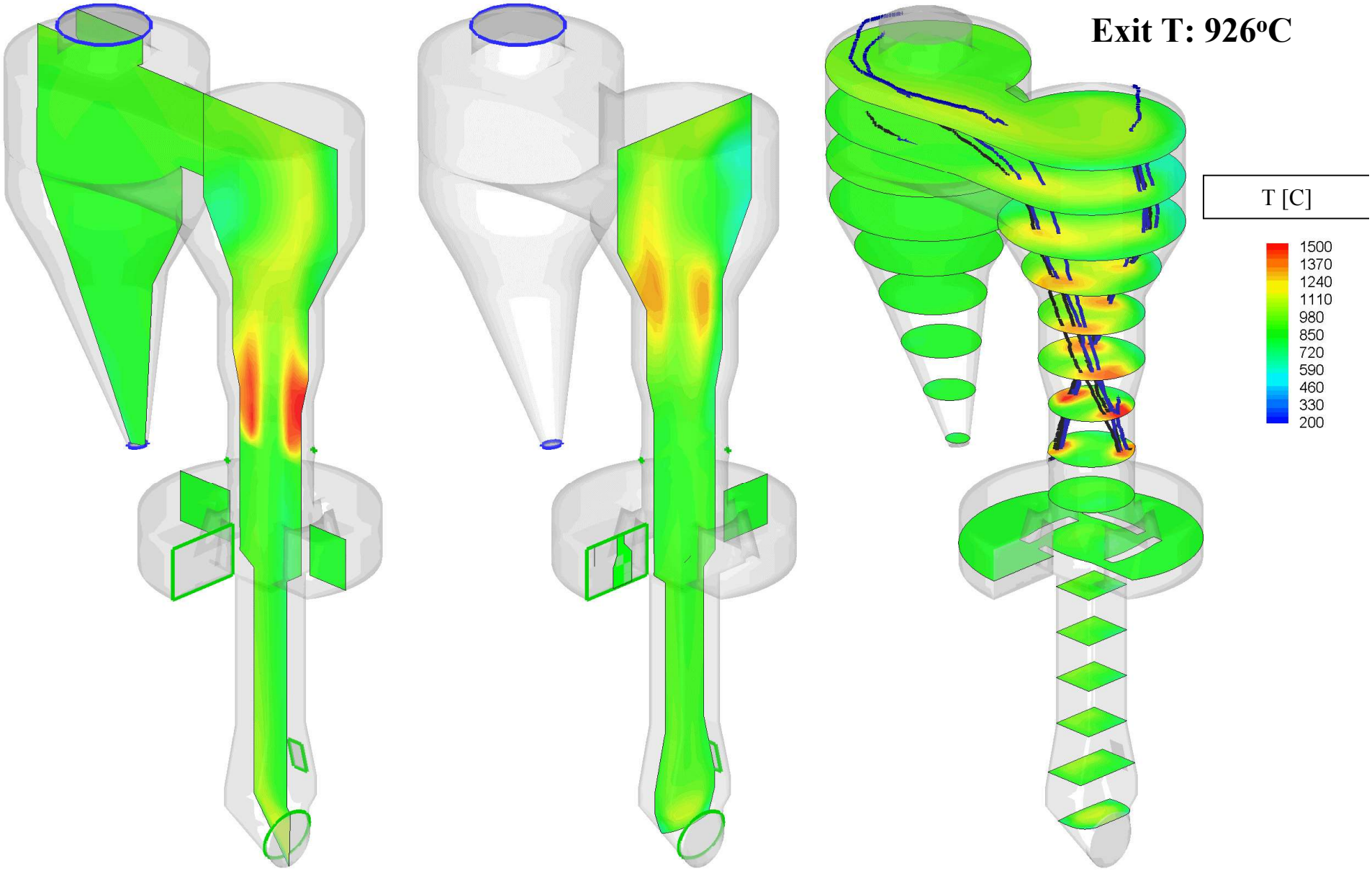
Burners (a)

90% oxygen and 10% Nitrogen mix.



Oxygen Injection (b)
2'' pipe

Temperature Profiles [C]



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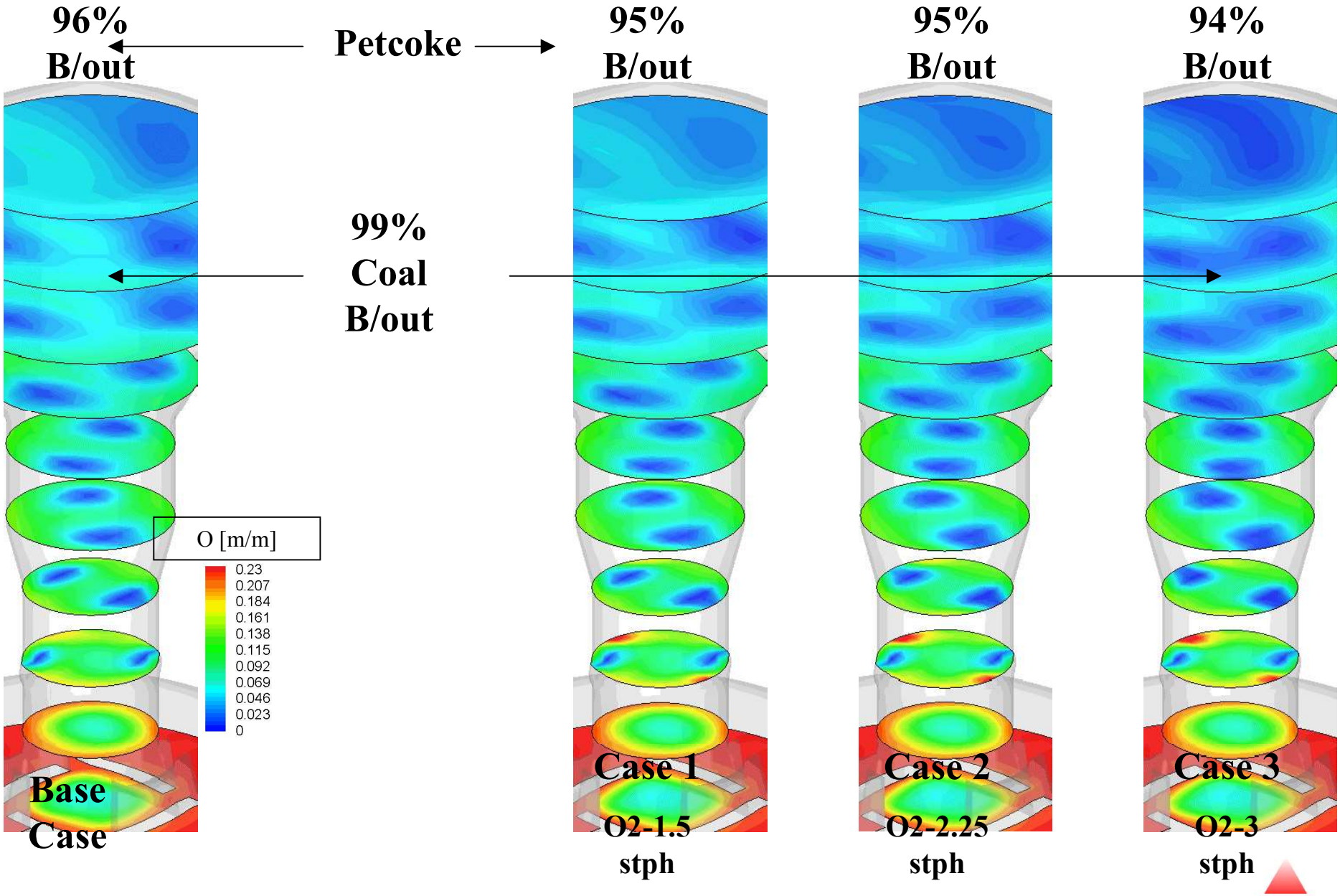
Modifications Conditions

	Base Case	Case 1	Case 2	Case 3
Coal (stph)	**9.76**	**9.76**	**9.76**	**9.76**
Petcoke (stph)	**2.44**	**2.44**	**2.44**	**2.44**
Transport Air for Fuel (stph) (@ 95F)	**7.92**	**7.92**	**7.92**	**7.92**
Swirl Air for Fuel (scfm) (@ 95F)	-	-	-	-
Axial Air for Fuel (scfm) (@ 95F)	-	-	-	-
Oxydant (90% O) (stph) (@ 95F)	-	**1.5**	**2.25**	**3.0**
Tertiary Air (stph) (@ 910C)	**112**	**106.1**	**103.2**	**100.2**

11% reduction of TA

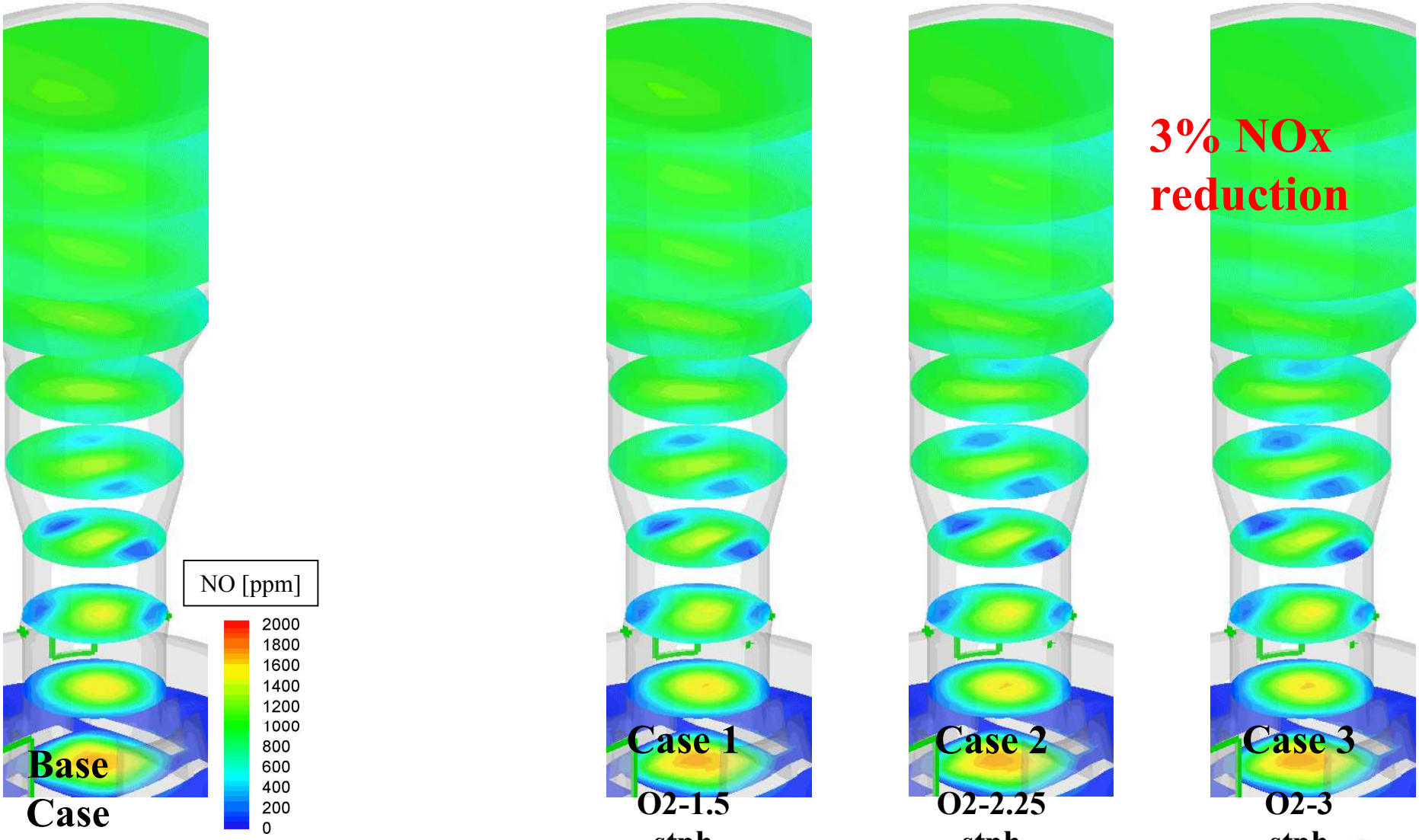
Comparison of Cases O2



Comparison of Cases NOx

Exit NO ppm

813	803	792	783

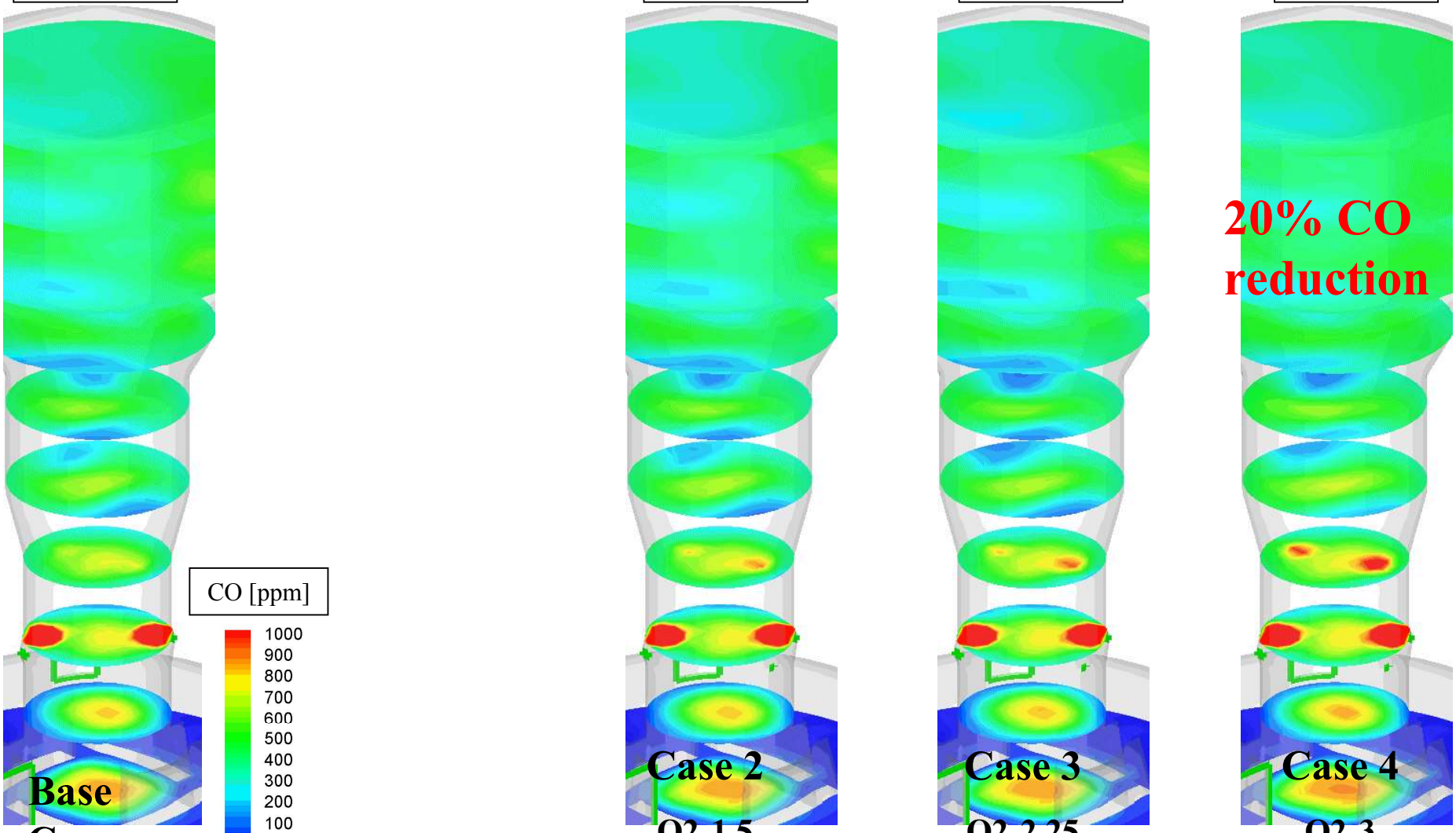


3% NOx reduction

Comparison of Cases CO (II)

Exit NO ppm

393	364	340	311



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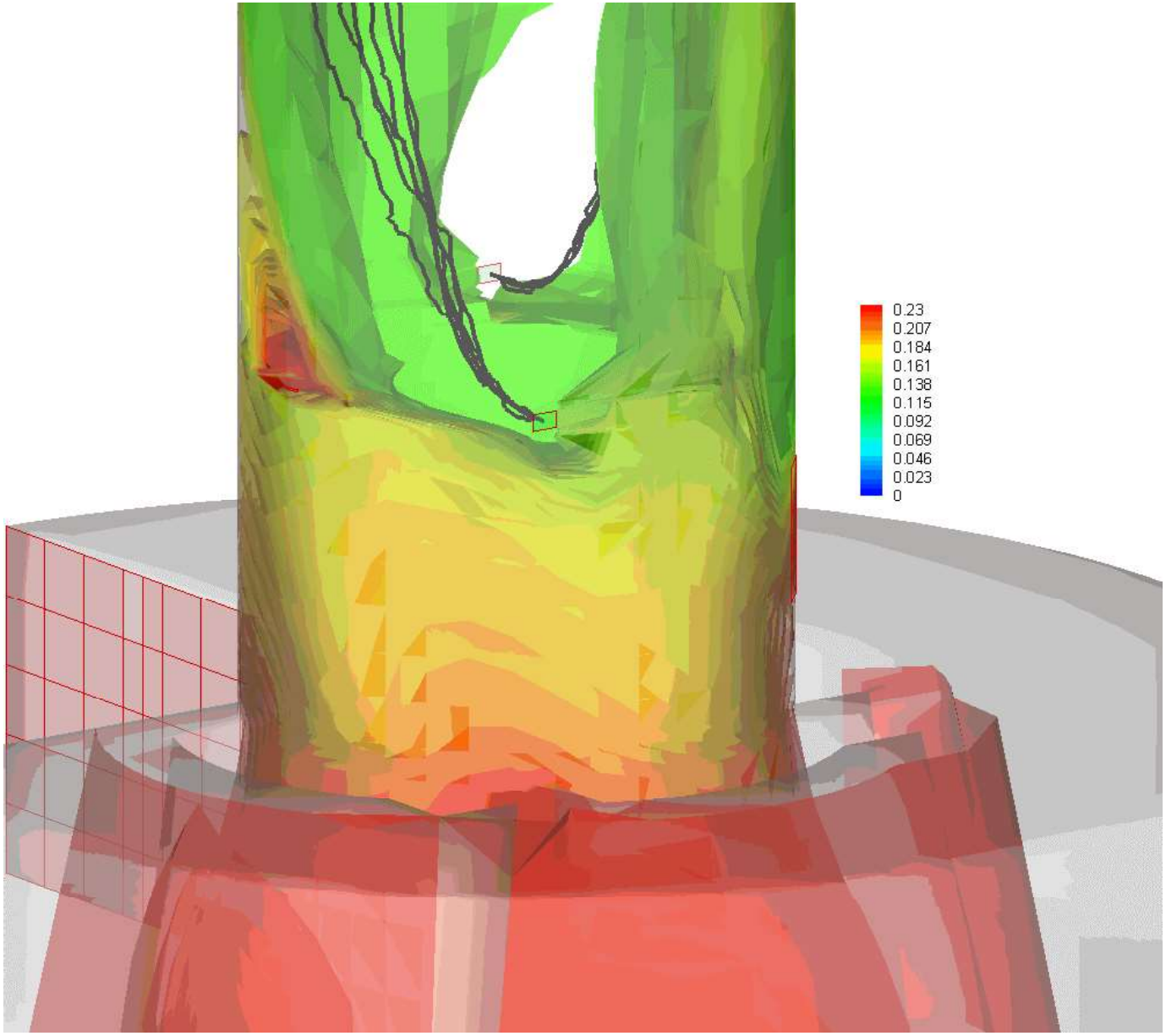
Explanation



Oxygen_particles_big.wmv

Oxygen_Particles_small.wmv

Summary

- **Stratification** of the gases is something that is unavoidable in the majority of the calciners, as there is a lack of mixing mechanism away from the first TA inlet.
- Understanding the aerodynamics developed within the calciner is very important for improving traditional solid fuel combustion in the calciner, because with **correct positioning** of the burners it is very important to optimise the utilisation of the available oxygen.
- **Tire chips can fall through** to the kiln hearth and burn there under reducing conditions. An increase of the momentum over sufficient length. Although that is highly depending at the point of injection and the size of the chips, usually a Venturi raising the velocity to around 45 m/sec over a length of around 3-5 metres to ensure suspension of the larger size fraction of the tyre chips.
- The **injection of oxygen** can have little effect if its locationis away from the burners as it simply mixes with the tertiary air, far from the fuel particles. It can be optimised by either injecting it **closer to the fuel particles** such as through multi-channel burner or below TA duct with about 1/3 of fuel;
- Oxygen injection has slightly positive effect on NOx but it would be far more effective if oxygen is injected below TA in order to reduce NOx through 'Hot-reburn'.

Thank you

Any questions?