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Using CFD to Reduce Unburned Carbon during Installation of Low NO_x Burners

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Outline

- Background
- Review Coal Modeling
  - Overview of CFD Model
  - Carbon in Ash (CIA) Model
- Existing Operation
- Low NO_x Burners & CIA Minimization
- Conclusions

Background

- **Numerous Methods for Coal NO_x Reduction**
  - Low NO_x Burners
  - Over Fire Air (OFA)
  - Selective Non-Catalytic Reduction (SNCR)
  - Advance Reburn
  - Selective Catalytic Reduction (SCR)
  - Etc.
- **Low NO_x Burners & OFA tend to be most economical**

Background

- Low NO_x Burners & OFA produce local reducing conditions
- Tend to increase CO and CIA
- Expect 50% increase in CIA over existing level

Background – AES Kilroot

- AES Kilroot Power
  - (2) 220 MW Coal (near Belfast)
  - T-fired
  - Current mandate – 650 mg/Nm^3
  - New Mandate – 500 mg/Nm^3

- RJM Site Survey
  - Optimize existing OFA
  - Low NO_x Burners
  - 430 mg/Nm^3 (~ 33% Reduction)

Background – AES Kilroot

- Current CIA ~ 8.0 - 6.5%, fuel dependant
- Must be below 7% to sell
- Can’t accept a 50% CIA increase
- Use CFD to verify NO_x performance & Estimate CIA

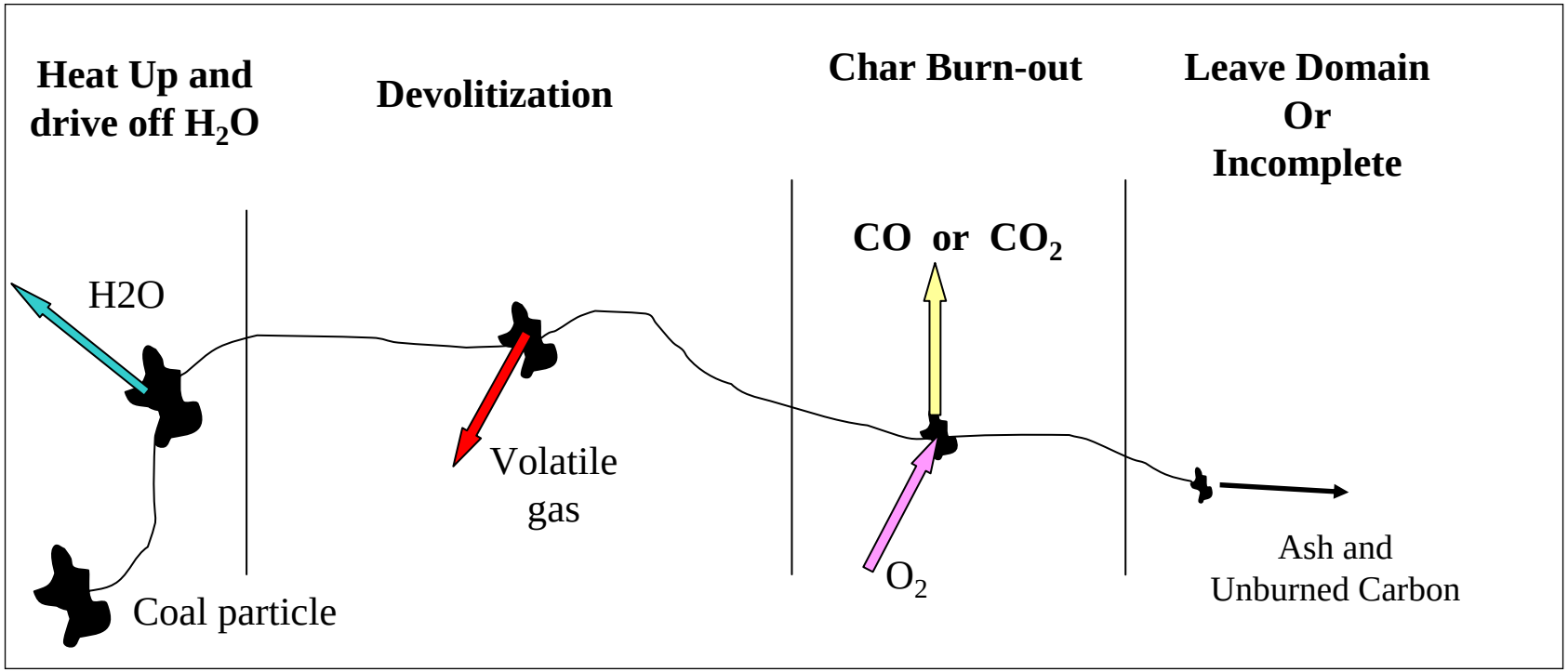
Review Coal Modelling

- **RJM Coal Modelling, over 10 years**
  - **FLUENT**
- **RJM has been very successful in estimating NO_x and CO trends**
  - **Goldring, et al, IPGC - 2006**

Review Coal Modelling

- **Standard RJM Practice:**
  - **FLUENT**
  - **Lagrangian Coal Particle tracking**
    - **“Path dependent”, 4 stages**

Review Coal Modelling



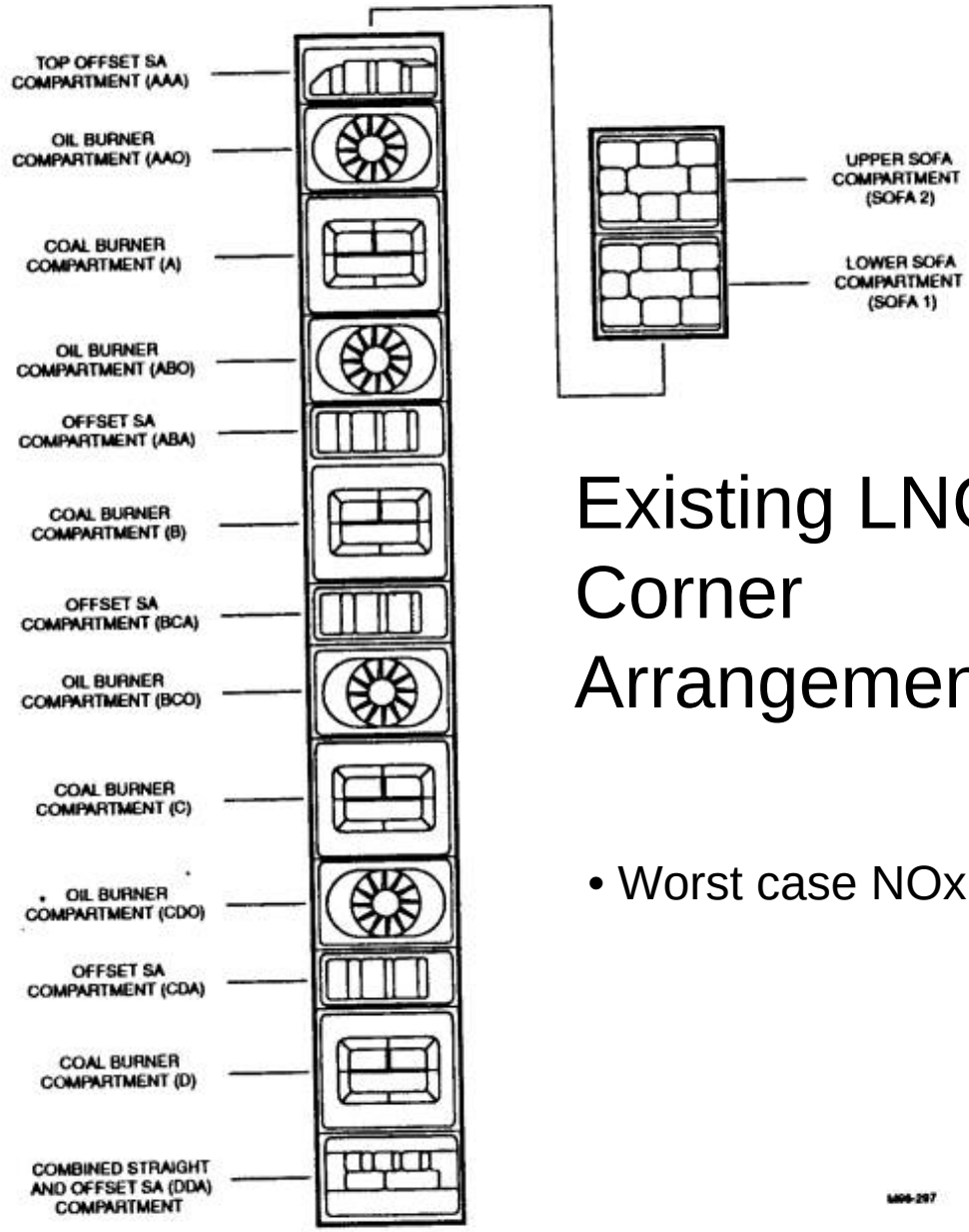
- COAL MODEL STAGES

Review Coal Modelling

- **Previous CIA predictions**
  - **FLUENT allowed 1 product**
  - **Either too high (~ 25% CIA with CO_2)**
  - **Too low (~ 0.01% with CO)**

- **FLUENT 6.2 allows multiple char reactions**

Reaction 1 - C + O2	**=>**	**CO2**
Reaction 2 - C + CO2	**=>**	**2CO**
Reaction 3 - C + H2O	**=>**	**CO + H2**



Existing LNCFS Corner Arrangement

- Worst case NOx is Top Mills

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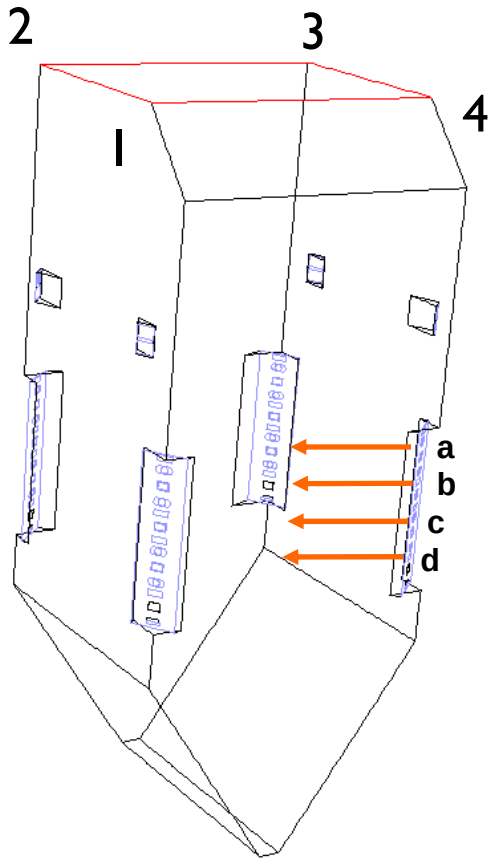
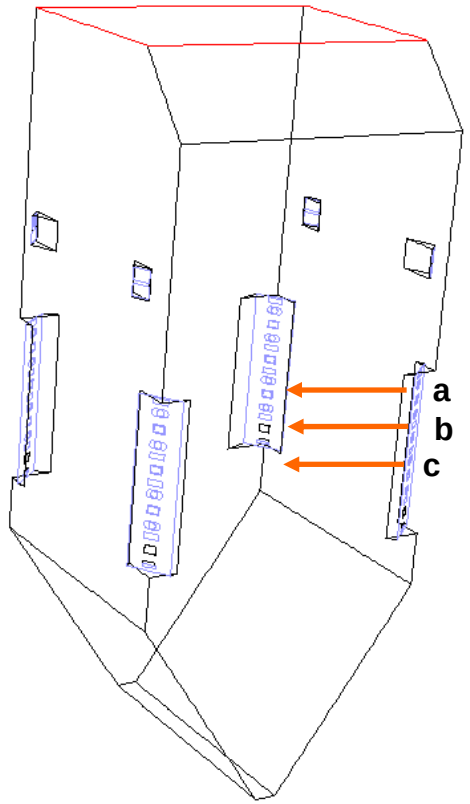
Existing Operation

- Three levels only
- Increases on-line reliability
- Have two sets of current operation data
  - a,b,c (upper mills)
  - b,c,d (lower mills)
- Corner numbers shown



Existing Operation – Upper Mills

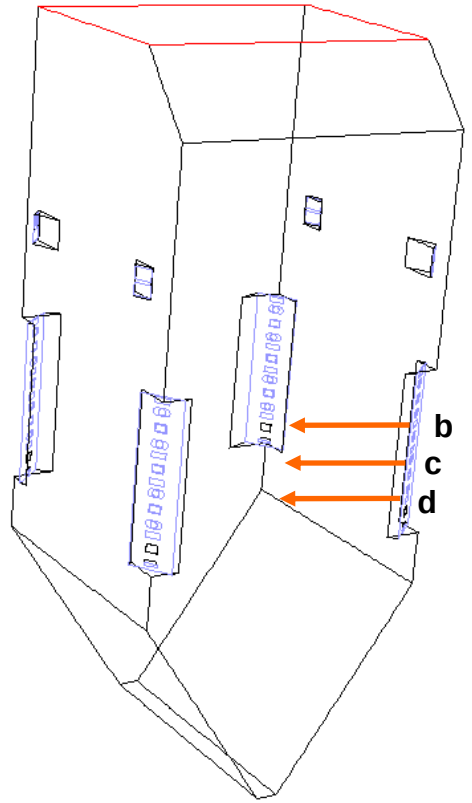
	DATA	CFD
NO_x	**641** mg/Nm^3	**649** mg/Nm^3
CIA	**6.2%**	**6.48%**
O_2	**4.3%**	**4.3%**



Coal Injection Levels

Existing Operation – Lower Mills

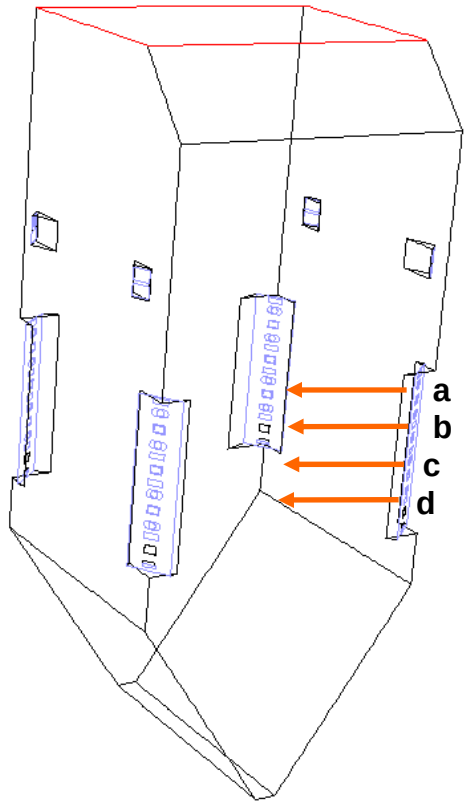
	DATA	CFD
NO_x	**554** mg/Nm^3	**560** mg/Nm^3
CIA	**4.4%**	**5.98%**
O_2	**3.7%**	**3.5%**



Coal Injection Levels

Existing Operation

	DATA	CFD
CIA Upper Mills	**6.2%**	**6.48%**
CIA Lower Mills	**4.4%**	**5.98%**



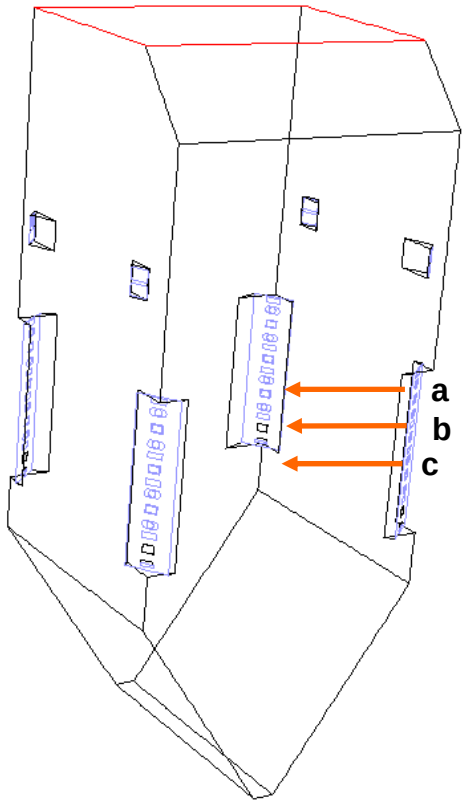
Coal Injection Levels

- **Improved char model allows prediction of CIA trends !**

Low NOx Burners & CIA Minimization

- **Upper Mill Operation – CFD Modelling**

	Existing Operation	Low NO_x Burners	% Change
NO_x	649 mg/Nm^3	430 mg/Nm^3	(-) 34%
CIA	6.48%	14.7%	(+) 127%



Low NOx Burners & CIA Minimization

Upper Mill Operation – CFD Modelling

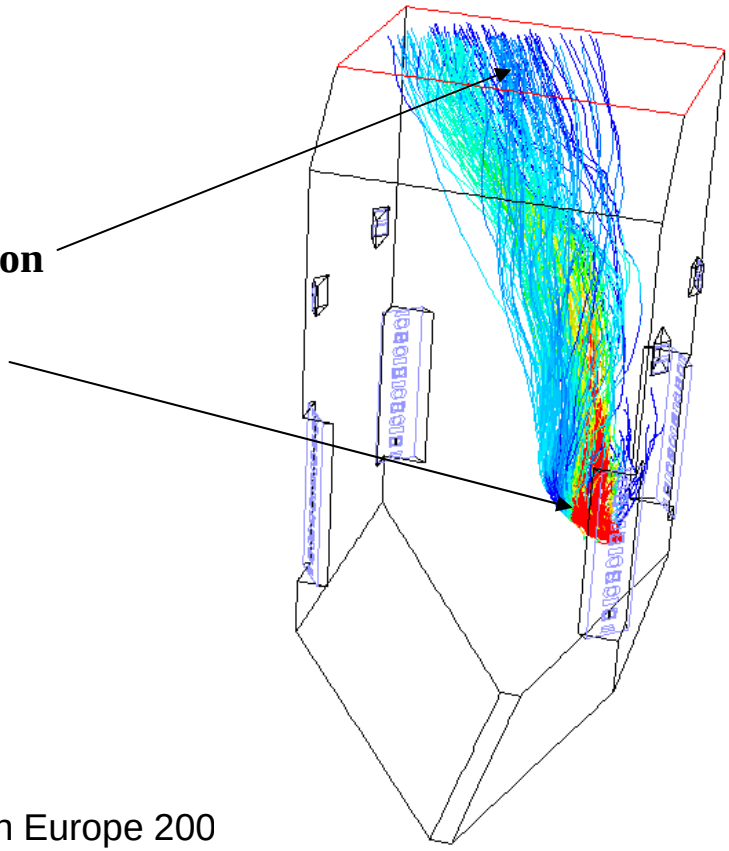
- CIA predicted to increase
- Use CFD model as diagnostic tool

Low NOx Burners & CIA Minimization

CIA Modelling - Diagnostics

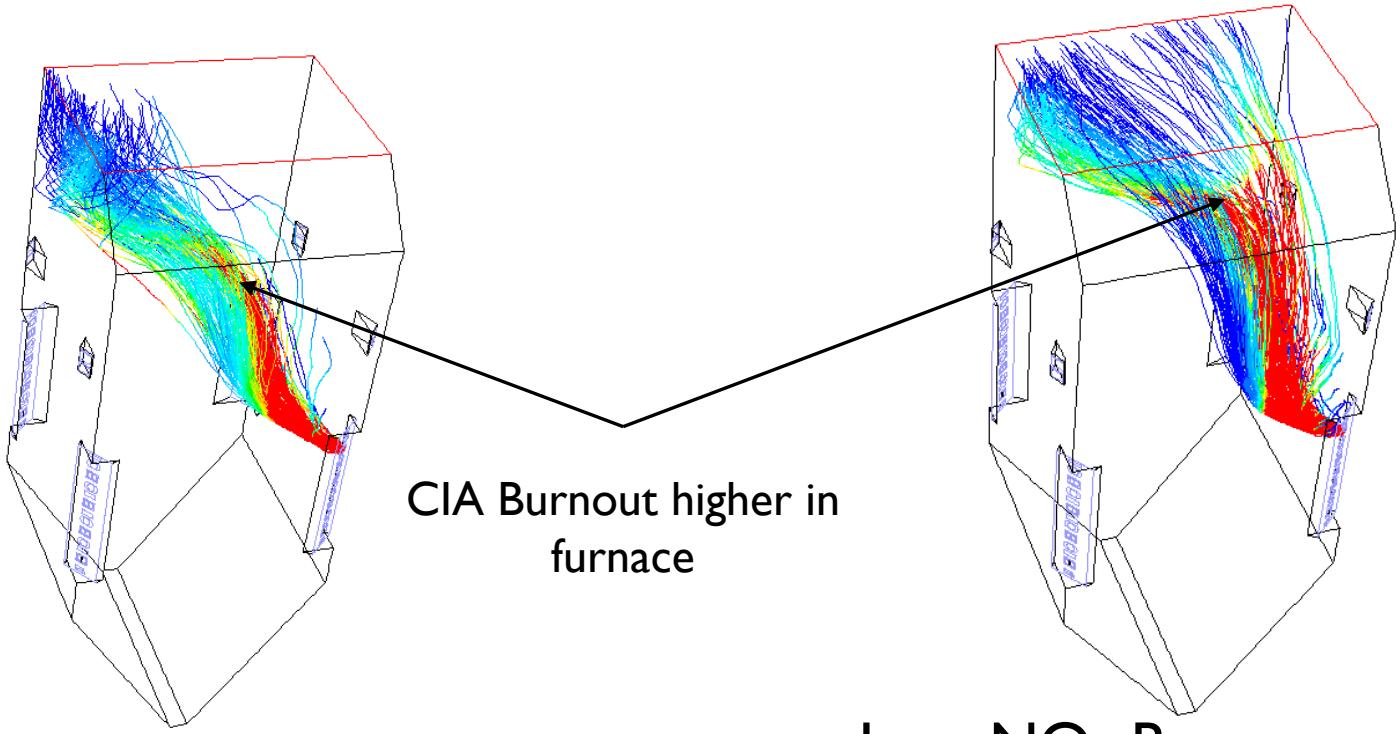
Blue is 100% char Oxidation

Red is no char Oxidation



Low NOx Burners & CIA Minimization

Upper Mill Operation – Optimization of SOFA's



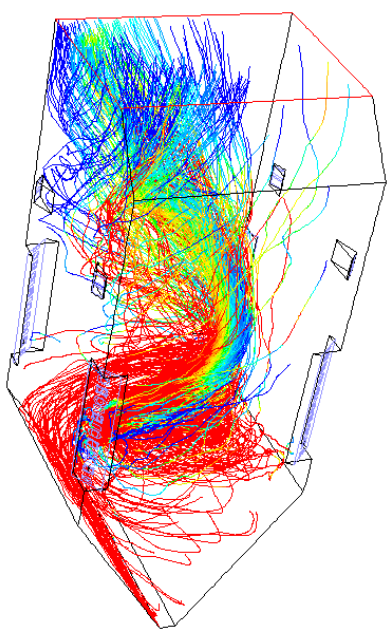
CIA Burnout higher in furnace

Existing Operation

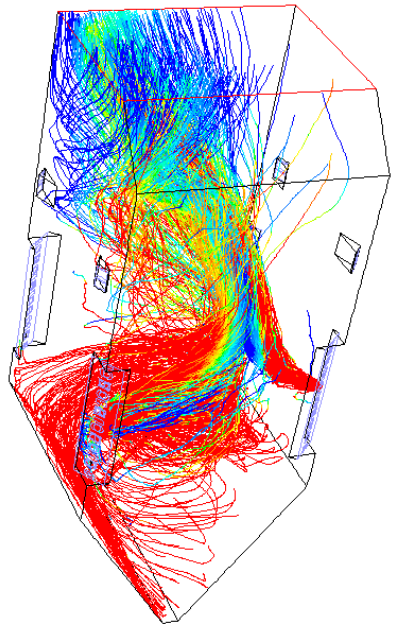
Low NO_x Burner Operation

Low NOx Burners & CIA Minimization

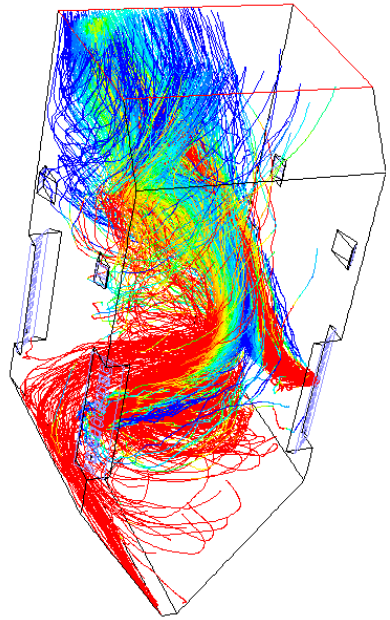
Upper Mill Operation – Combination of CIA Sources



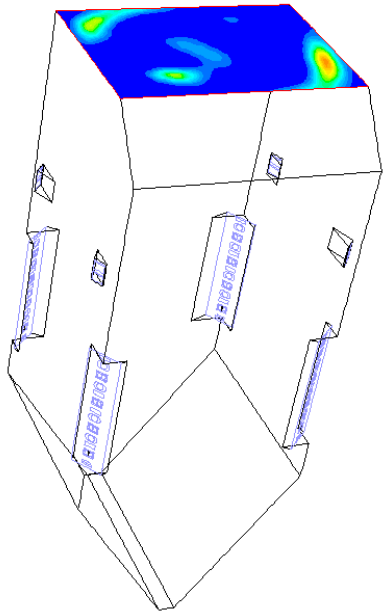
Coal Inj. C



Coal Inj. C & B



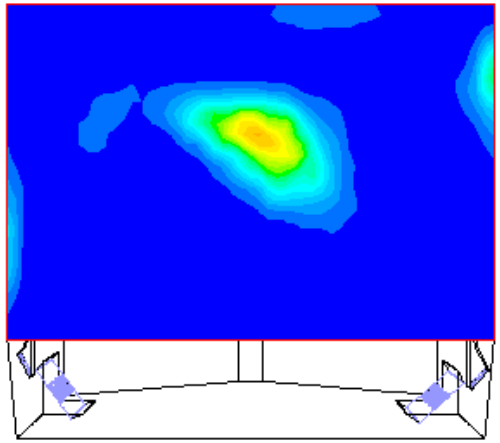
Coal Inj. C & B & A



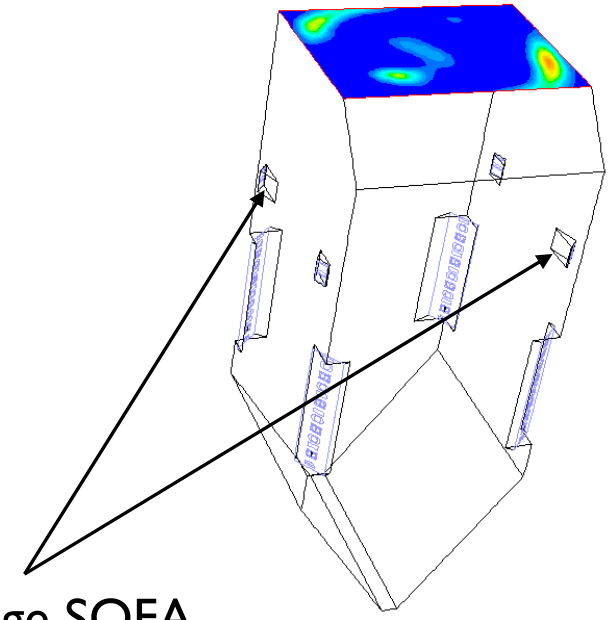
Exit "C" Concentration

Low NOx Burners & CIA Minimization

Upper Mill Operation – Change of SOFA "Yaw"



Reduction and Concentration of CIA

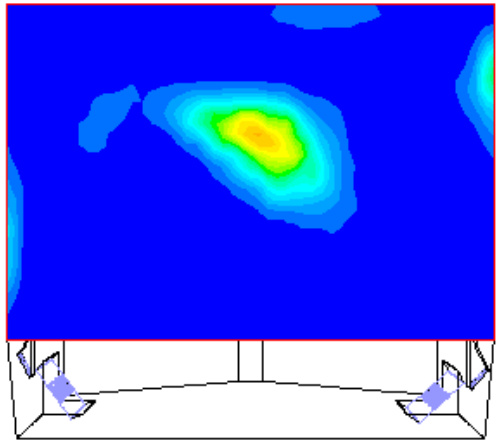


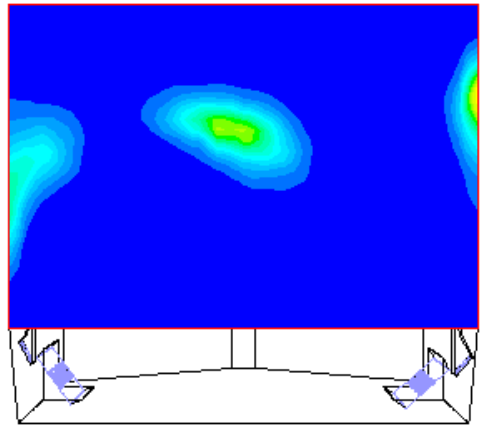
Change SOFA

"Yaw" angle

Low NOx Burners & CIA Minimization

Upper Mill Operation – Change of SOFA "Yaw"





Final angle change:

Predicted CIA 4.7% !

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Low NOx Burners & CIA Minimization

Lower Mill Operation – CIA sources

- Wanted to maintain upper mill Yaw angles
- Upper mill “Yaw”, lower mill operation CIA: 7.5%
- Good value, but too high

Low NOx Burners & CIA Minimization

Lower Mill Operation – CIA sources

Injection	Mass Flow	% of CIA
d4	0.0672	26.6%
d3	0.0272	10.8%
d2	0.0575	22.8%
d1	0.0226	8.9%
c4	0.0083	3.3%
c3	0.00766	3.0%
c2	0.0131	5.2%
c1	0.0323	12.8%
b4	0.00025	0.1%
b3	0.0055	2.2%
b2	0.0048	1.9%
b1	0.00616	2.4%

69% of CIA is from "d" level

Low NOx Burners & CIA Minimization

Lower Mill Operation – CIA sources

- Modification to lower secondary air supply
- CIA Prediction: **3.45%**

AES Kilroot – CFD vs RJM PGT, South African

	CFD Upper Mills	RJM PGT Upper Mills	CFD Lower Mills	RJM PGT Lower Mills
NOx mg/m_0^3 @ 6% O_2 dry	418	444	416	418
CIA %	4.65%	5.5%	3.45%	4.5%

AES Kilroot – Final Performance, Upper Mills

	Baseline - SA	RJM - SA	Baseline - Colombian	RJM - Colombian
NOx mg/Nm^3 @ 6% O_2 dry	648	444 **31% Redn**	638	339 **47% Redn**
CIA %	8.0%	5.5% **31% Redn**	4.1%	1.25% **69% Redn**

Kilroot – Low NOx Coal Injection – 110MWe

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Conclusions

- Carbon in Ash (CIA) model predicted trends from field
- Model estimated CIA increases due to low NO_x burners
- Model identified reduction strategies
- Model identified additional equipment modification requirements
- Final field results showed very close agreement with the Model

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