Impact of Blended Coal Firing on the Power Plant Performance

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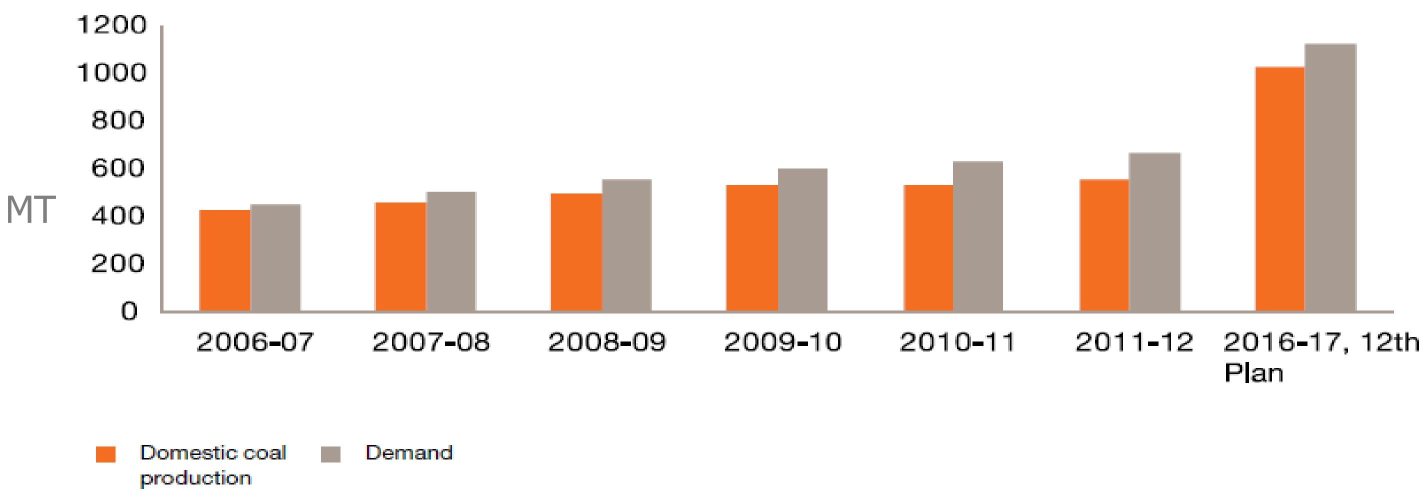
Significance of Blended Coal firing in India

- Reduction in the Power Generation Cost
- To meet the coal shortage and power demand

Demand-supply scenario



Source: India Energy Book, 2012 (World Energy Council, Indian Member Committee)

- Maintaining ash content not exceeding 34% (on quarterly averaged basis) as required by the Gazette Notification issued by MoEF for the power plants (>100MW) which are 1000km away from pit heads.

Issues related to blended coal firing

- Indian boilers are designed for Indian coals
- Imported coals are from different origin have different characteristics compared to Indian coals
- All the properties may not be "additive" and cannot be predicted from individual coal properties
- Method of blending in large scale and processing for power generation

Challenges in blended coal firing

- Burning blends in coal fired boilers is not always straightforward and may produce unanticipated and undesirable consequences.
- Clear understanding on the impact of blended coals on transportation, mill performance, combustion behavior, pollutant formation, etc. before it is introduced into a power station.
- Evaluating a method for optimizing the blend ratio specific to plant design
- Technical know-how for the large scale blending of coals to obtain required blend ratio

Additive and Non-Additive Characteristics of blended coals

Additivity:

The properties of a blend can be mathematically predicted from properties of the component coals

Non Additivity:

The properties of a blend cannot be predicted form the properties of component coals

Characterization of blended coals

The additive rule is given by,

$$M = (1\text{-}x_2)M_1 + x_2M_2$$

Where M is a blend value of any of the parameter investigated, and M_1 and M_2 are the properties of component coals 1 &2 and x_2 is the weight fraction of coal 2 in the blend.

Proximate parameters of a blend

<u>Moisture</u>

- Generally follow additive rule
- If size difference between different coals are more, blending leads to “stockpile drainage” and this reduces the moisture content of blend than the predicted value
- This is advantageous for handing coal

Proximate parameters of a blend

Volatile Matter

- Generally additive
- However in the mixture of hard and soft coals, the finest fraction contain low volatile than the course fraction.
- This variation aggravates at 50:50 composition and the reason for this is inexplicable

Proximate parameters of a blend

Ash Content

- When sub-bituminous coal and high sulphur bituminous coal are blended, the blend observed to have high dry ash content than predicted
- This is due to the absorption of sulfur oxides emitted from bituminous coals by the alkaline sub-bituminous coals as sulphate

Proximate parameters of blends

<u>Fixed Carbon</u>

- Fixed carbon is a calculated parameter and reflects all the errors from moisture, volatile and ash content

Ultimate parameters of blends

Carbon

Hydrogen

Nitrogen

Sulphur

Oxygen

All these parameters are found to be generally additive

Heating Value (Calorific Value)

- The calorific value is mostly depending on the carbon content present in the coal and alters with moisture content and ash content

- Calorific value generally found to be generally additive as it is a quantitative parameter

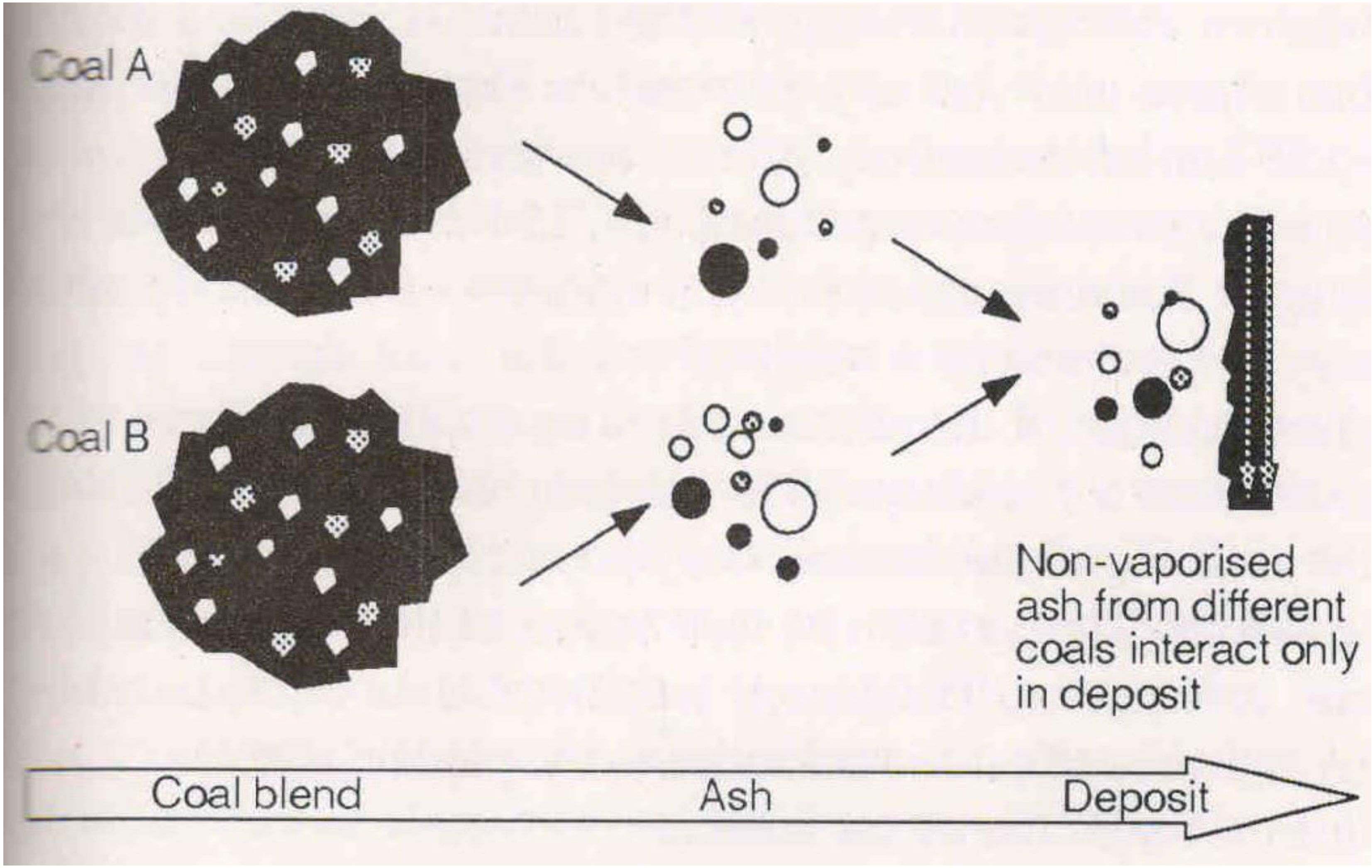
Ash Fusion Temperature

- Ash Fusion Temperature is a Qualitative parameter, found to be generally non-additive

- The reason for non-additivity is the interaction between the mineral constituents with in the blend

- Fluxing action of the iron and the smaller molecules like Na, Ca, and Mg from one coal may influence the other coal to decrease the fusion temperature less than component the coals

Ash Fusion Temperature (Clinker formation in the boiler)



Ash Fusion Temperature (Clinker formation in the boiler)

- Slagging

  Refers to the deposits within the furnace, in areas directly exposed to flame radiation such as the furnace walls

- Fouling

  Refers to the deposits in the areas not directly exposed to the flame radiation (convective passes)

Ash Fusion Temperature (Clinker formation in the boiler)

- Studies on the blending of UK power grade coals indicates that the blend has shown more slagging propensity than componet coals

1:10 (Slagging:Non-slagging)

- Reason is the excess presence of iron content from the slagging coal

Ash Fusion Temperature (Clinker formation in the boiler)

- Studies on blending sub bituminous coals with bituminous coals indicates more fouling characteristics than component coals

  - Bituminous contains more sulphur content
  - Sub-bituminous coals contains more alkali elements
  - SOx from bituminous coals are captured by alkali elements to form sulfates and coated on the convective passes (fouling)

Grindability of blended coal

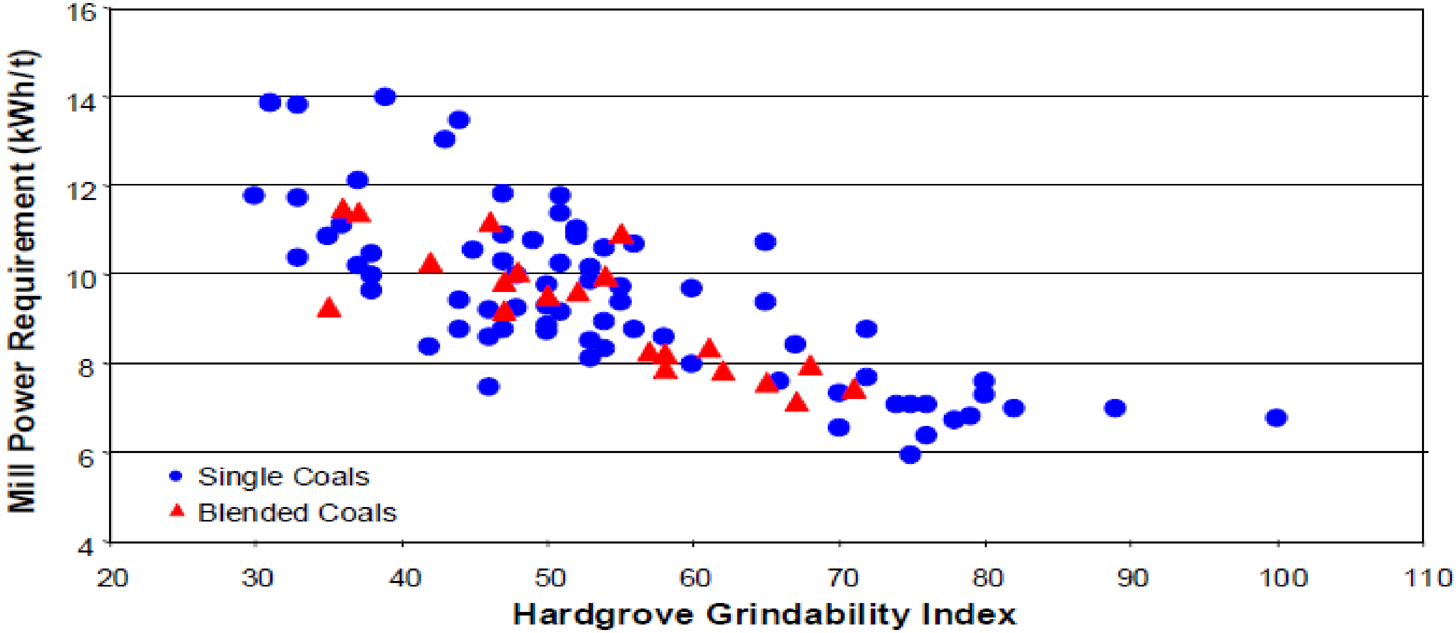
- HGI values increases from low rank sub-bituminous to medium rank bituminous coals, attain maximum and decreases with increase in rank till anthracite

- HGI is found to be additive for iso-rank coals and non-additive for coals with different ranks

- Non-Additive HGI values lead to disproportionation of particle sizes (particles burning in the boiler may not have targeted blend composition)

Grindability of blended coal

The pilot scale studies by Australian Coal Research program on blending of iso-rank bituminous coals indicates;



Power = 95 (HGI)-0.58 (R^2 = 0.63) (Unblended coal)
Power = 89 (HGI)-0.57 (R^2 = 0.65) (Blended coal)

Abrasion Index

- The abrasion index is mainly due to free silica (alpha quartz) and pyrites and these are quantitative
- Abrasion index is generally additive

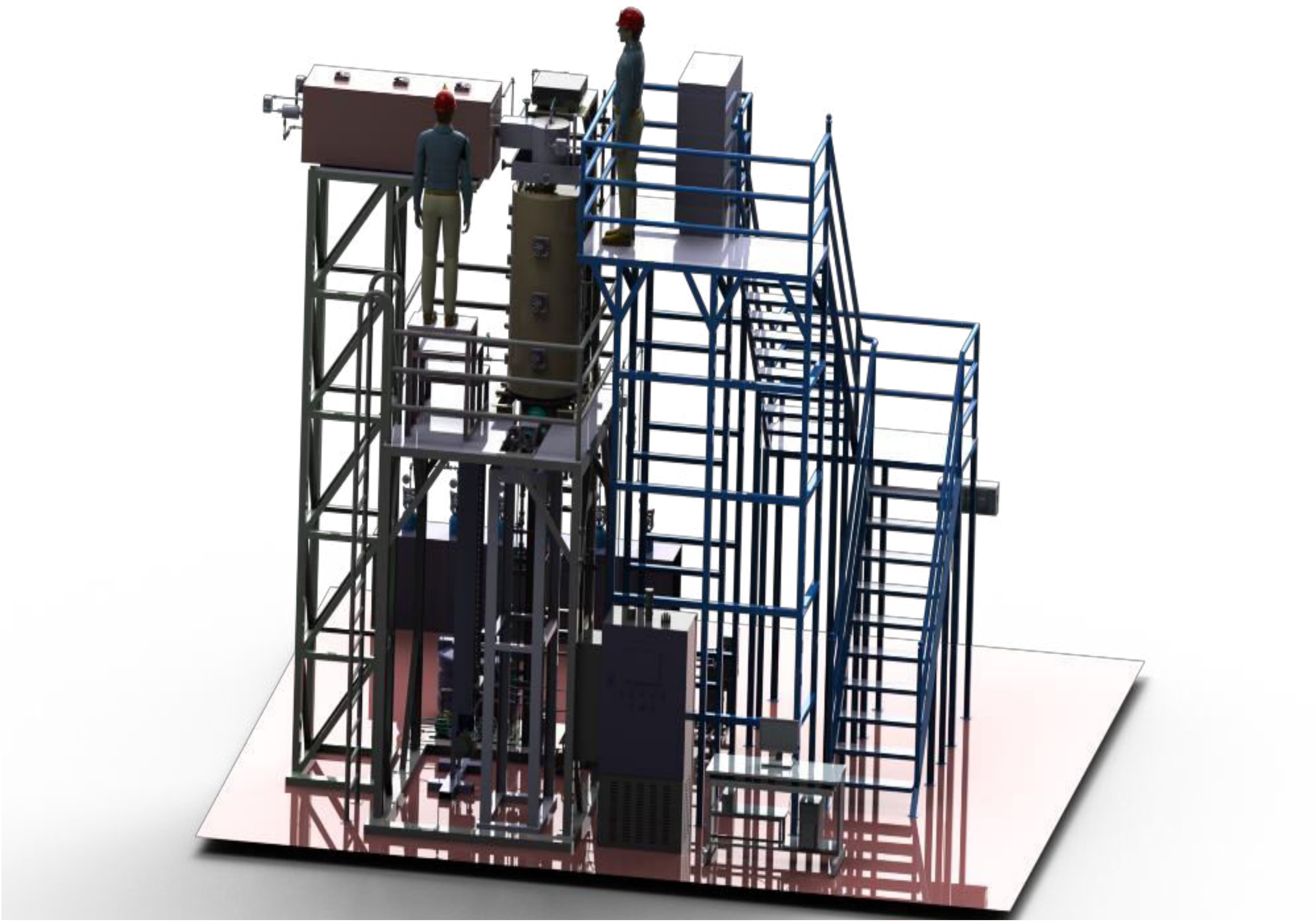
Combustion reactivity or burn out

- Depends completely on the rate at which the devolatilisation and char combustion takes place
- Coal particles in blend have larger burnout times leads to high unburnt losses in the ash
- The particle dynamics should be customized for the low reactive coals through burner/furnace modifications
- The interaction during combustion may improve the combustion reaction of low grade coals

Assessment of Blended coal combustion reactivity through Drop Tube Furnace at CPRI

Reaction Tube Dia	: 65mm
Reaction Zone length	: 100-400 mm (variable distance)
Maximum Gas Temperature	: 1000^{o}C
Maximum Wall Temperature	: 1200^{o}C
Coal quantity	: 6g/hr
Primary air	: 5 LPM
Secondary air	: 50 LPM
Particle size	: <38 Microns
Axial gas velocity	: 2.15m/s (at 1000^{o}C)
Particle velocity	: Assumed equal to gas velocity
Isokinetic suction	: 20 LPM

Drop Tube Furnace for Combustion Studies



Global practices for blending coals

Some Terminologies

- Homogenization

  Processing of one type material so that the inherent fluctuations in respect of quality and/or size distributions are evened out

- Blending

  Aims to achieve a final product from two or three coal types that has a well defined chemical composition where the elements will be very evenly distributed and no large pockets of one type is identified

- Mixing

  The traces of Individual components can still be located with in a small quantity of the mixed material of two or more coal types

Global practices for blending coals

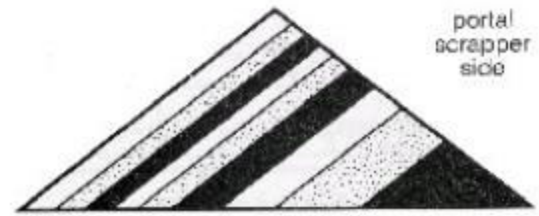
- Stockpile blending (Blending during stacking)
- Belt Conveyor blending (Blending at conveyors meet at single silo)
- Blending at Bins/Bunkers
- Tier Blending (Indian practice)

Stockpile Blending

Layers of coal are stacked in a pile with triangular cross section to give the average chemical composition of desired blend

Methods of stockpile blending

Strata



Strata or skewed chevron

Chevron

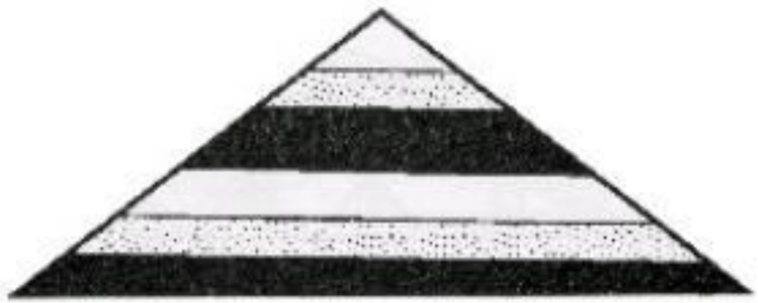
Windrow

Chevron - windrow

Stockpile blending (Stacking method)

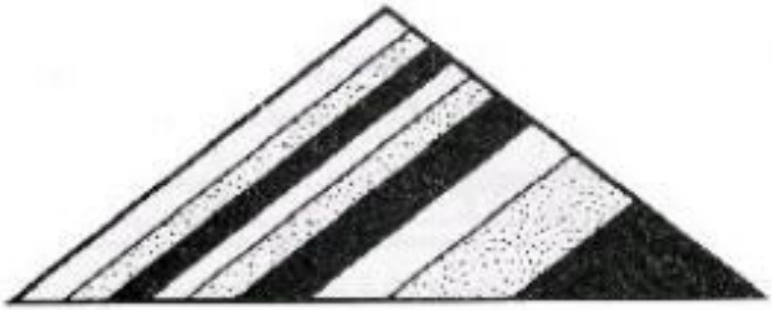
- <u>Strata</u>

  Different coal types are laid in horizontal layers



- <u>Skewed strata</u>

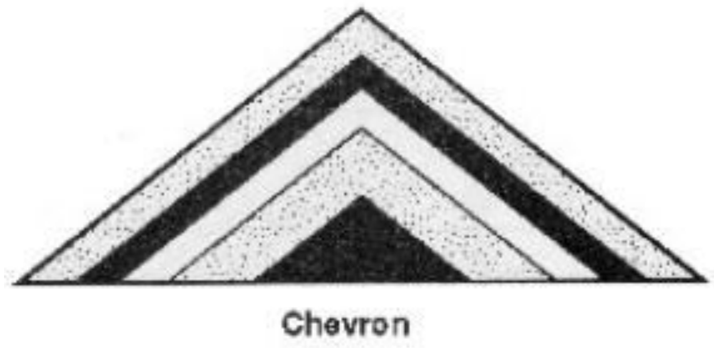
  Different coal types are laid in inclined layers



Stockpile blending (Stacking method)

- <u>Chevron</u>

  Layers of coal deposited by moving the stacker to and fro along the central axis



- <u>Windrow</u>

  Coal is stacked in triangular rows using multiple discharge peaks (since several layers, compaction by bulldozer is easier)

Stockpile blending (Stacking method)

- <u>Chevron-Windrow</u>

  Combination of Chevron and Windrow methods

Chevron - windrow

Stockpile blending (Stacking method)

- Some degree of particle segregation occurs in all stock piles

- Segregation is minimized in Windrow and Chevron-Windrow method which are found to be most efficient methods compared to other methods

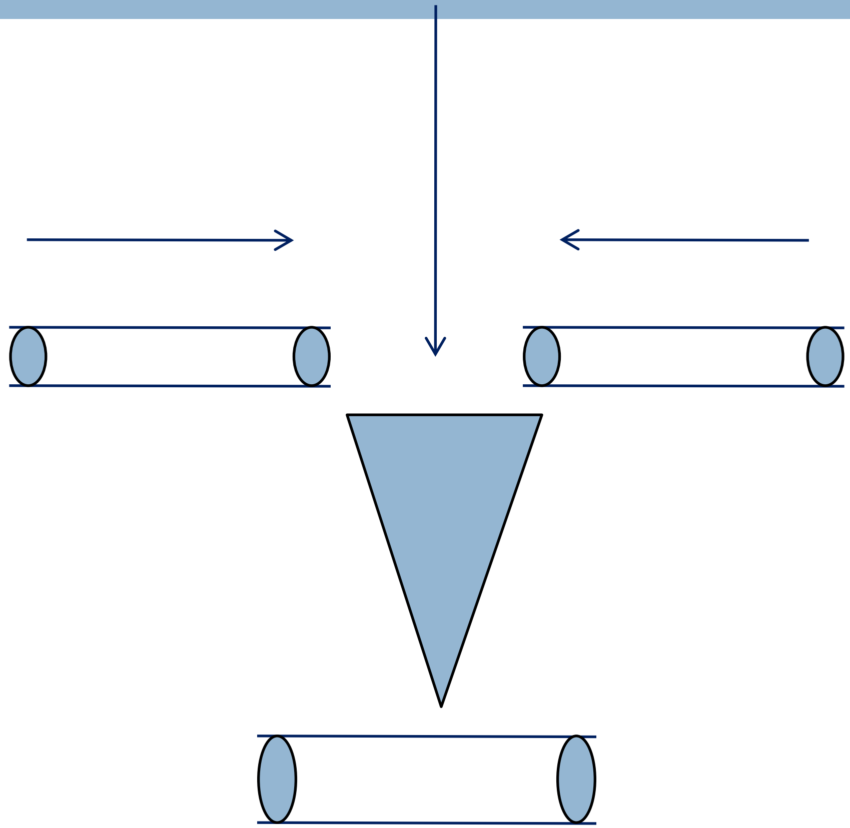
Stockpile Blending

Blending efficiency

=Variation of individual components before stacking/Variation of the components after reclaiming

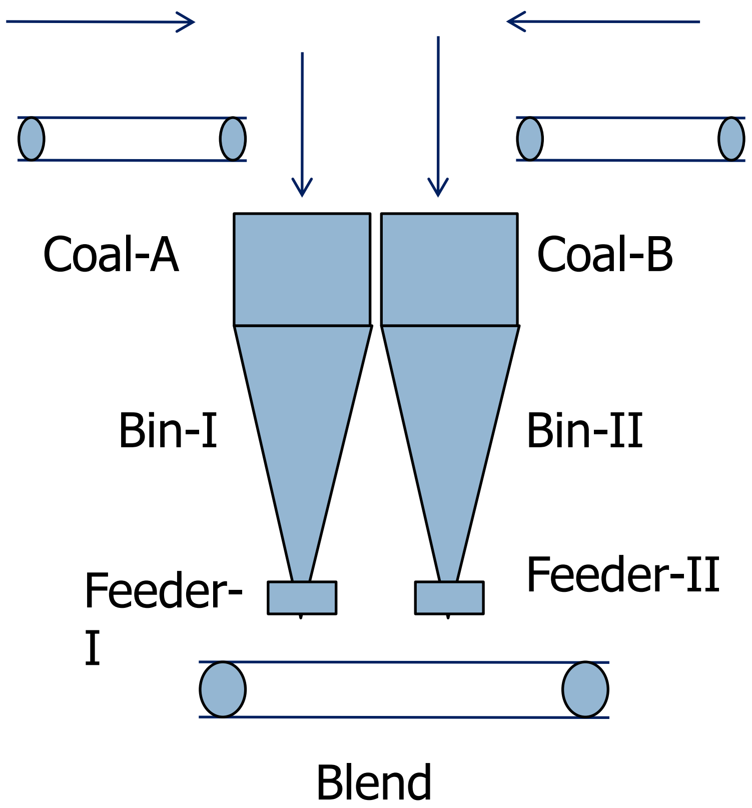
Belt Conveyor blending Blending

- Different coals are placed in different stock piles and reclaimed in belt conveyors
- The multi conveyors meet at single point silos and blended to fall on single conveyor
- Conveyors should have accurate weighing facility and speed control system which will give precise mass flow rate
- Multi weighing scales are used to get more reliable data



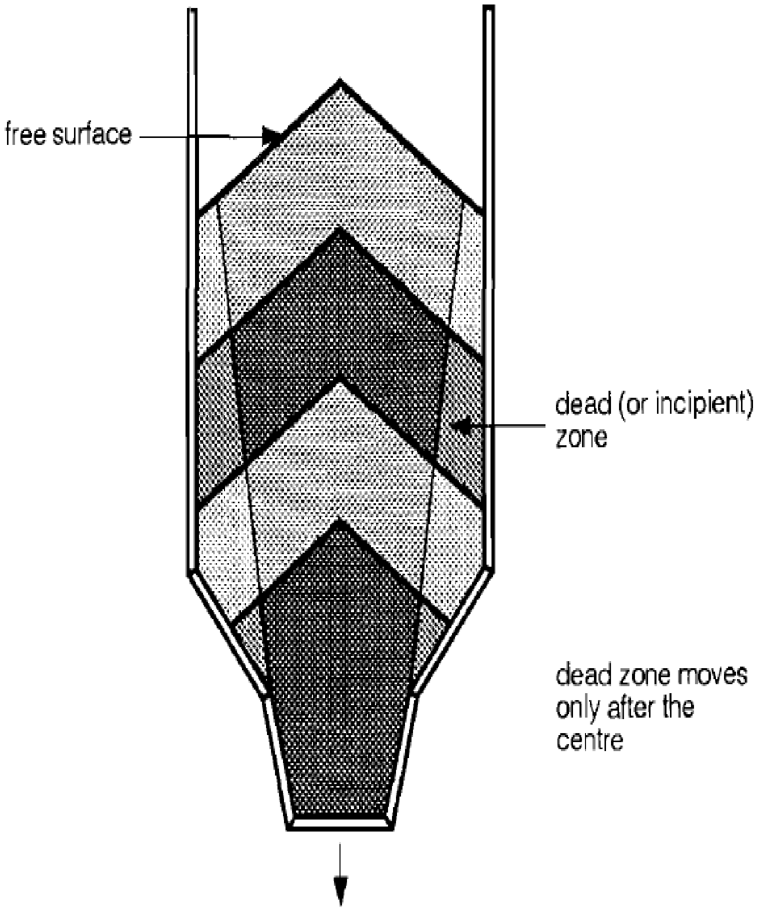
Bin System Blending

- Bins are either silos (cylindrical storage unit) or bunkers (rectangular storage unit with multiple outlets at the bottom)
- Bins in series loaded with different coals and are fed to the conveyor running under the bins.
- The feed rates are adjusted to get the proper blend proportion



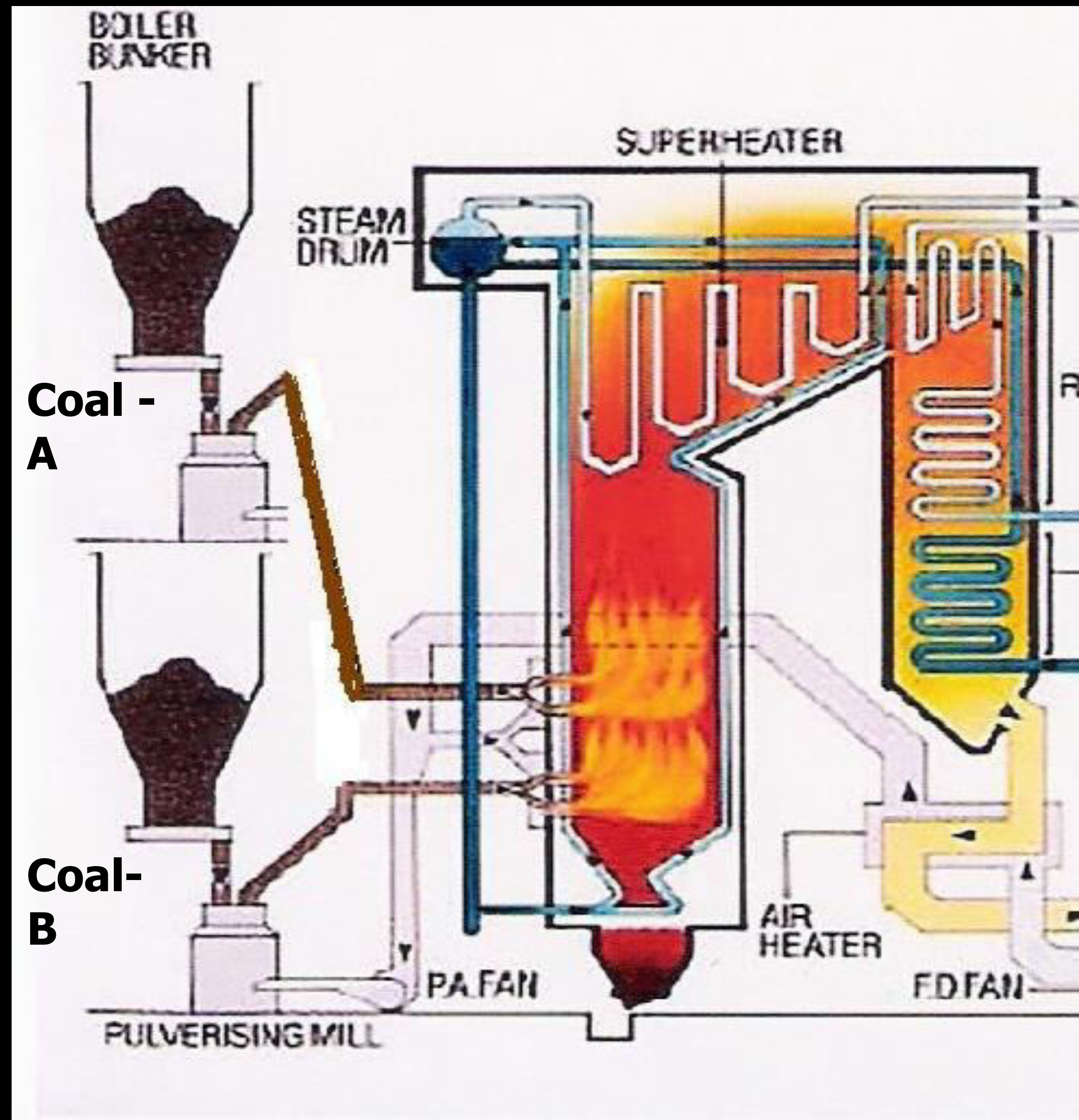
Bin system (Problems with bins)

- In a same bin if batches of coals of varying quality are added, the knowledge of the quality of the output stream is lost
- Bins does not allow first-in-first out concept as centre part falls first then "dead" zone falls down
- Proper design of bins may avoid this problem



Tier Blending

- Coals are put in different bunkers and pulverized separately and mixed in the boiler during the combustion
- Convenient method of blending
- Possibility of heterogeneous combustion

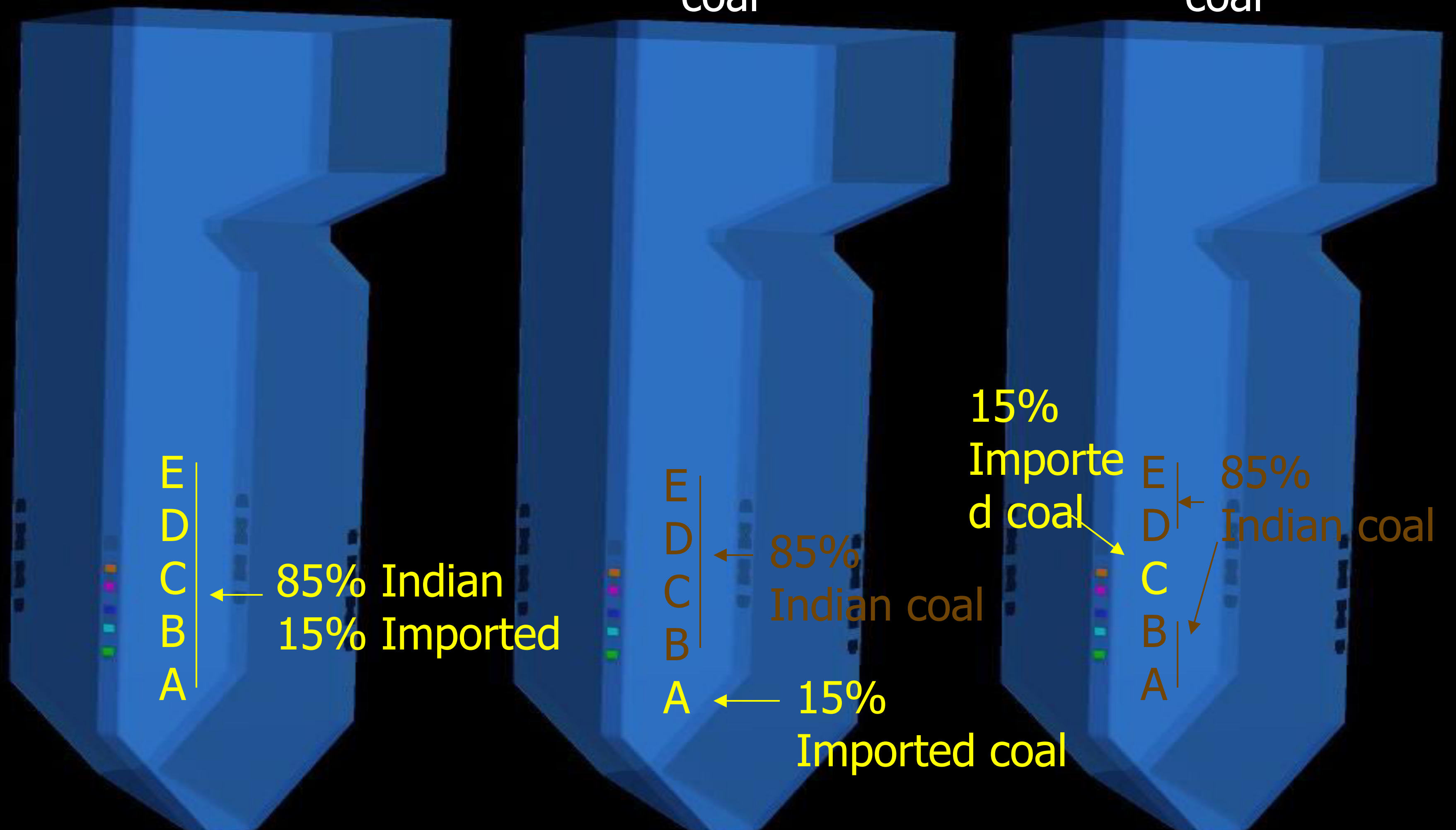


Tier Blending CFD simulations

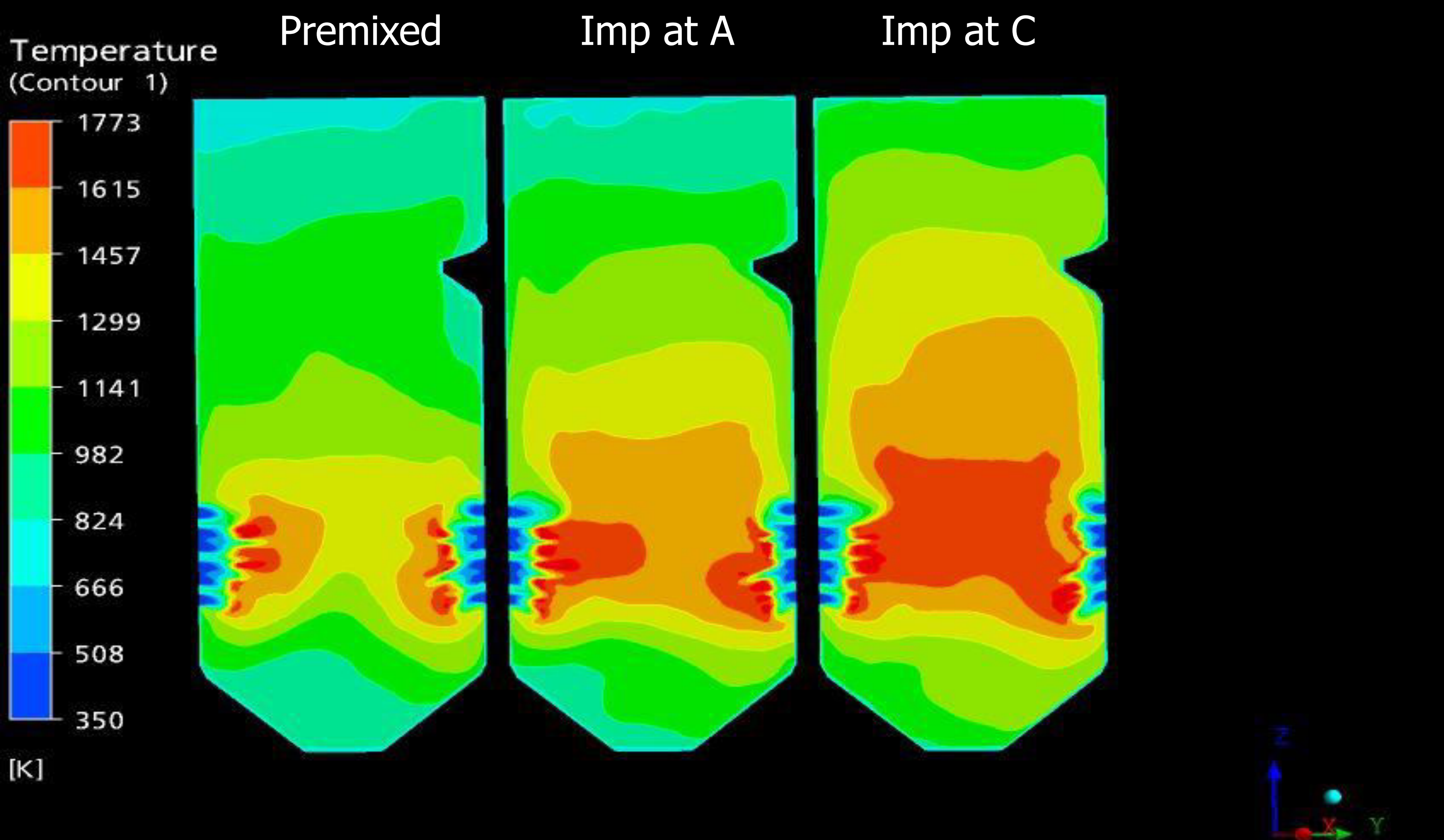
(I) Premixed coal blend in all burners

(II) Tier blending Imported coal in burners at A elevation Remaining all Indian coal

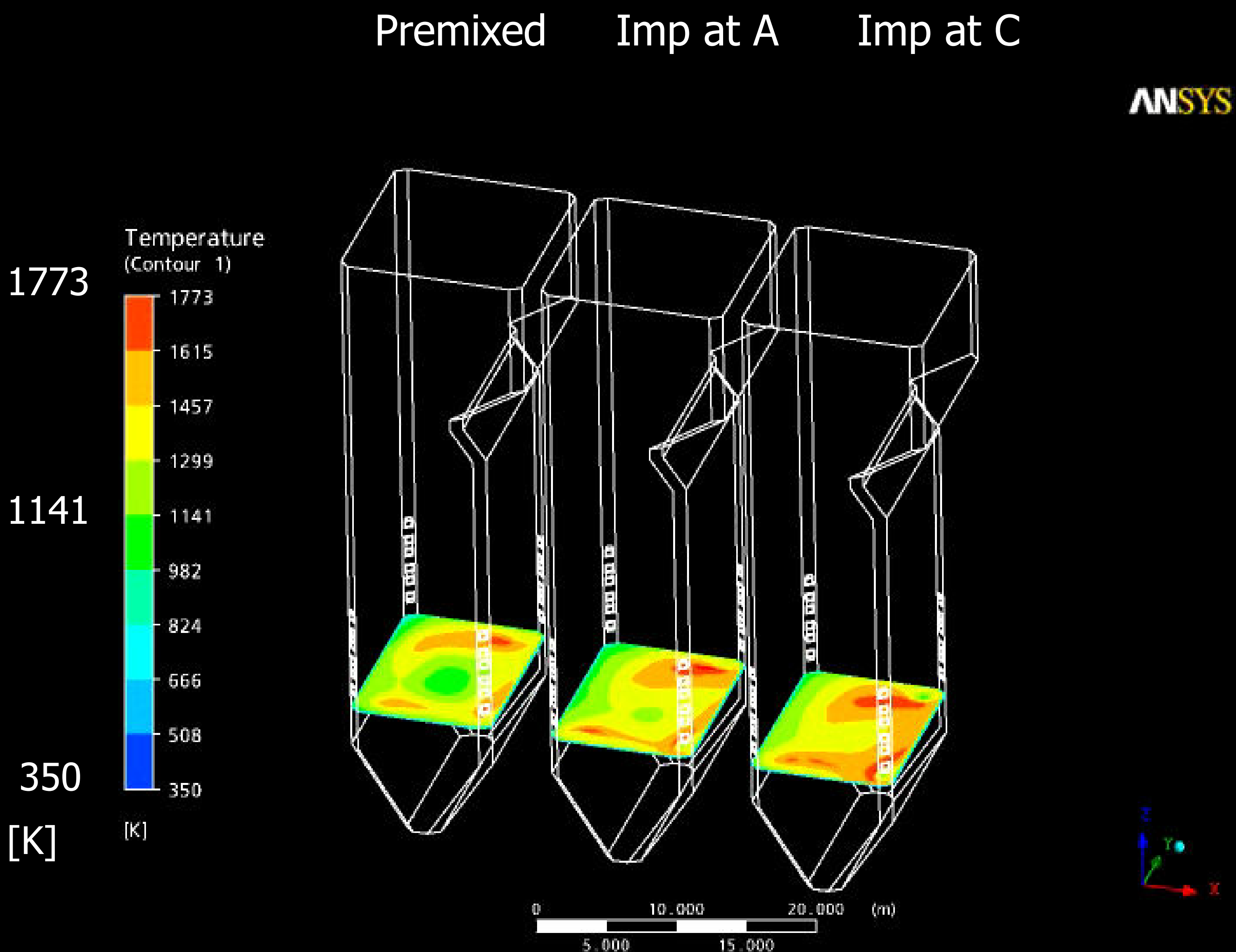
(III) Tier blending Imported coal in burners at C elevation Remaining all Indian coal



Temperature profile in diagonal plane



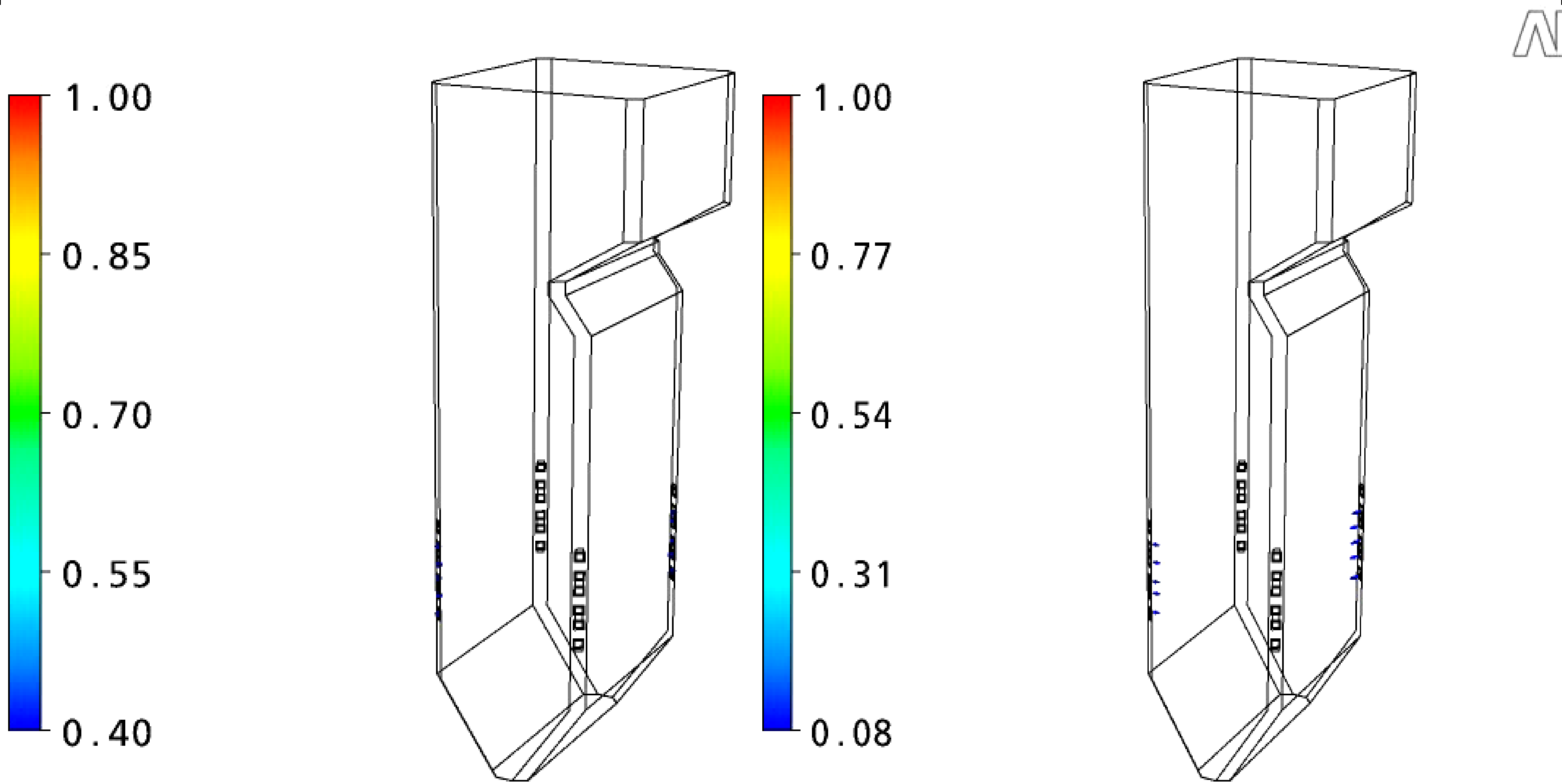
Temperature profile in horizontal plane



Combustion of Indian and imported coal (Premixed blend)

Indian coal

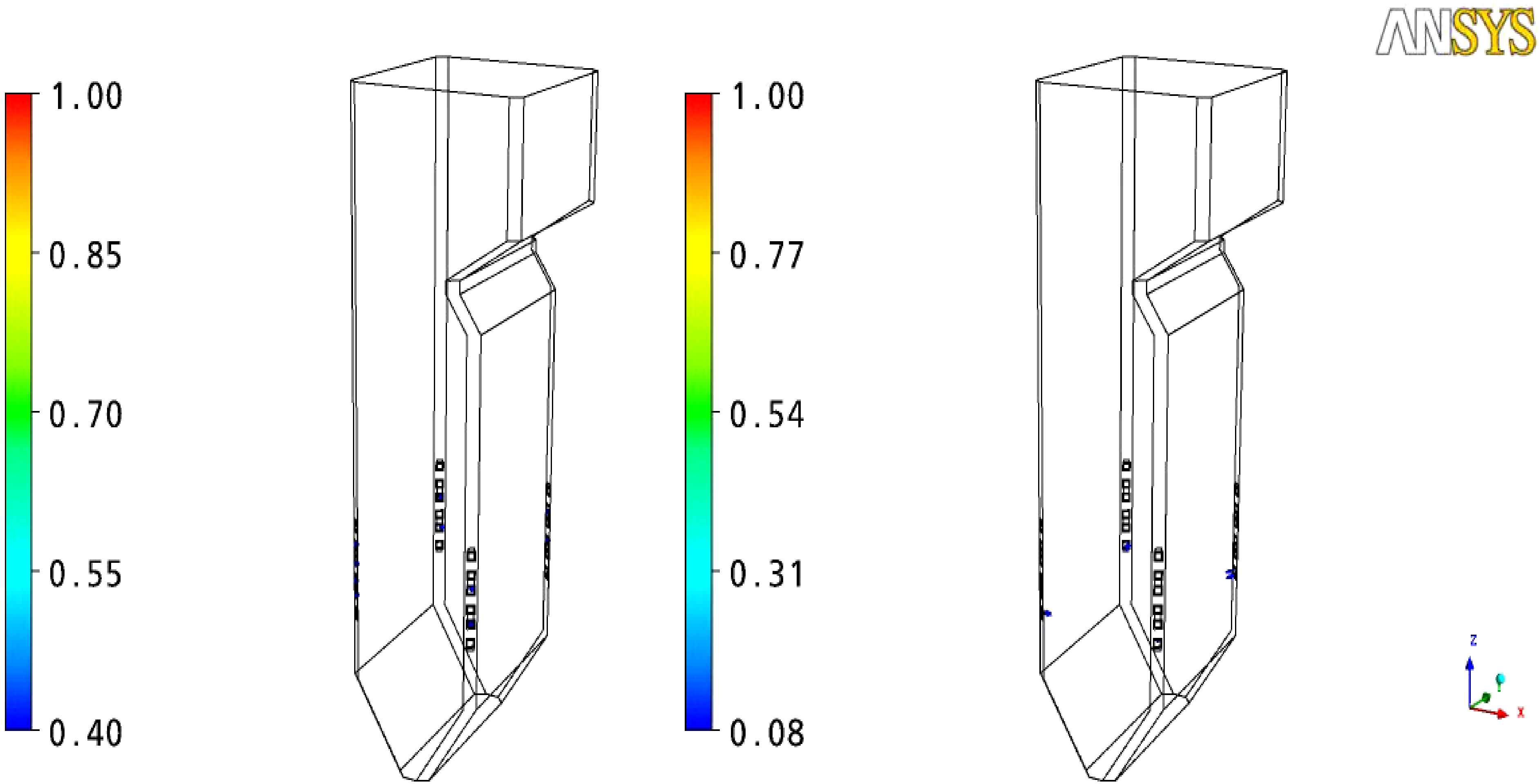
Imported coal



Combustion of Indian and imported coal (Imported coal fired at Elevation A)

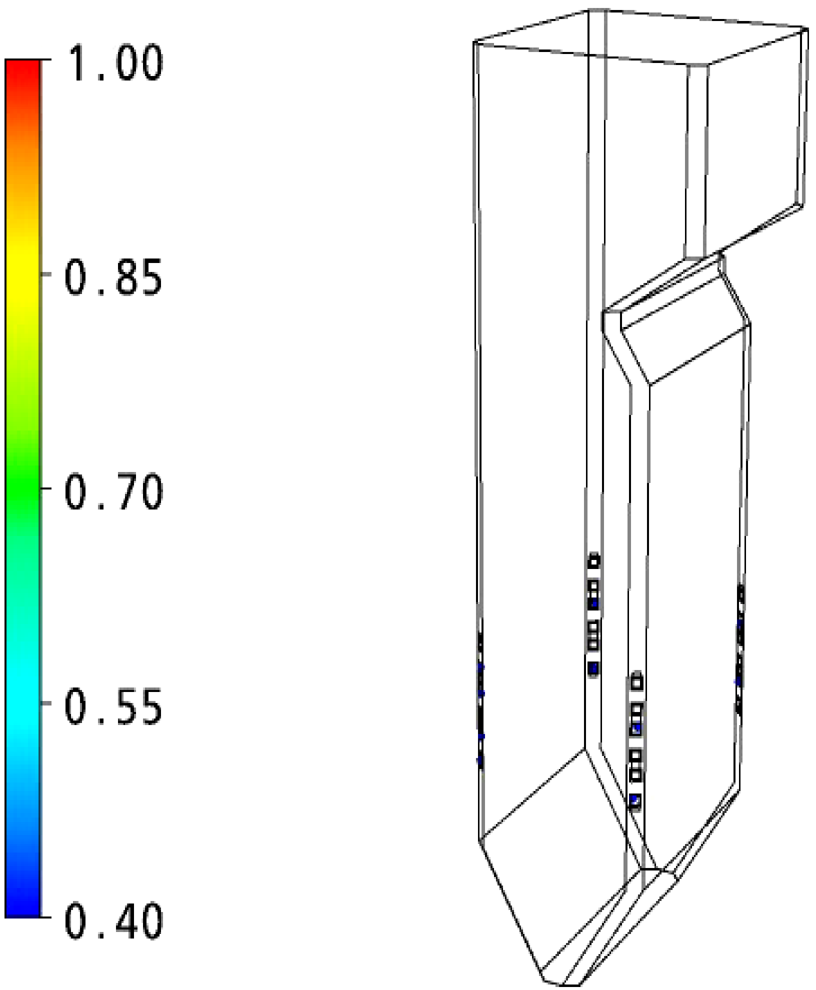
Indian coal

Imported coal

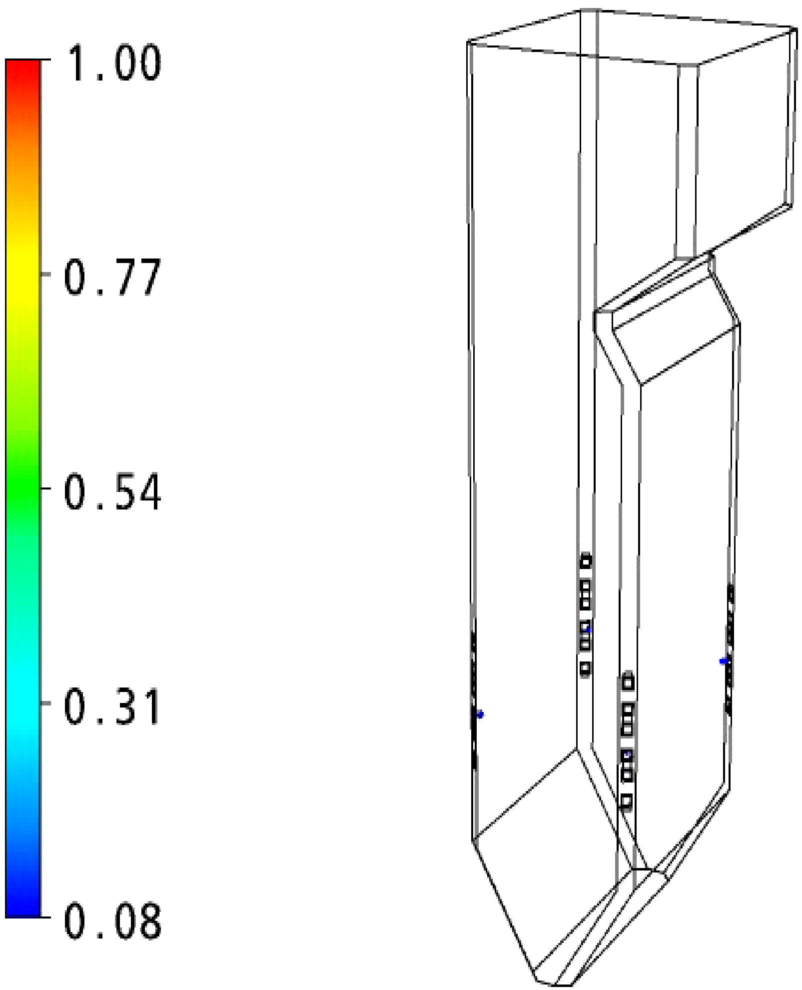


Combustion of Indian and imported coal (Imported coal fired at Elevation C)

Indian coal



Imported coal



Temperature and Carbon conversion

Cases	Carbon Conversion, %		Average Furnace exit gas temperature near gooseneck, °C
	Indian coal	Imported coal	
Premixed combustion	100	100	826
Tier combustion (Imported coal at A)	100	99.5	910
Tier combustion (Imported coal at C)	100	96.5	1037

Summary

- Blending coals have significant impact on the performance of the power plants originally designed for single coal
- The performance of every blend to be assessed before introducing to the power plant as it forms altogether a new fuel
- The qualitative properties of coal viz. AFT, HGI and Combustion reactivity are generally non-additive with few exceptions
- Large scale blending methodology to be scientifically addressed for its effect on plant performance
- Coal blending is an excellent, efficiency enhancing, environment friendly technology-Need to be implemented more scientifically to get the complete benefits

Thank you