Coal Properties and its influence on Boiler

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Influence of Coal Properties

- Transportation of Coal
- Storage of Coal
- Design of Boiler
- Combustion Performance
- Mill Performance
- Performance of Boiler (losses)
- Slagging
- Performance of ESP
- Life of Boiler Components

Properties of Coal

- Coal properties are evaluated by different methods.
- The most commonly used methods are Proximate and Ultimate analysis of the coal.
- Proximate analysis gives the Moisture, Ash and Volatile matter, while the Fixed Carbon is found by difference.
- Ultimate Analysis gives the elemental composition of the coal.
- Other methods like Macarel analysis is also used for coal classification and evaluation of coal properties.
- Fusion characteristics of Ash is estimated from the Initial Deformation Temperature, Hemispherical Temperature and Fusion Temperature of the ash
- Ash oxide analysis is commonly used for analysis of ash composition.
- Ash analysis is used to characterize the slagging and fouling potential of coal in the boiler

What Boiler Engineer must always be aware of ……

- Fixed carbon
  - is the solid fuel left in the furnace after volatile matter is distilled off. It consists mostly of carbon but also contains some hydrogen, oxygen, sulphur and nitrogen not driven off with the gases. Fixed carbon gives a rough estimate of heating value of coal
- Volatile Matter
  - Volatile matters are the methane, hydrocarbons, hydrogen and carbon monoxide, and incombustible gases like carbon dioxide and nitrogen found in coal. Thus the volatile matter is an index of the gaseous fuels present. Typical range of volatile matter is 20 to 35%.
    - Proportionately **increases flame length**, and helps in easier ignition of coal.
    - Sets minimum limit on the **furnace height** and volume.
    - Influences secondary air requirement and distribution aspects.
    - Influences secondary **oil support**
- Coal Grindability
  - Affects Mill performance

Why the Boiler Engineer …… (contd)…..

- Ash Content
  - Ash is an impurity that will not burn. Typical range is 5 to 40%
    - Reduces handling and burning capacity.
    - Increases handling costs.
    - Affects combustion efficiency and boiler efficiency
    - Causes clinkering and slagging
- Moisture Content
  - Moisture in coal must be transported, handled and stored. Since it replaces combustible matter, it decreases the heat content per kg of coal. Typical range is 0.5 to 10%
    - Increases heat loss, due to evaporation and superheating of vapour
    - Helps, to a limit, in binding fines
    - Aids radiation heat transfer
- Sulphur Content (NOT IN PROXIMATE ANALYSIS)
  - Typical range is 0.5 to 0.8% normally
    - Affects clinkering and slagging tendencies
    - Corrodes chimney and other equipment such as air heaters and economisers
    - Limits exit flue gas temperature

What Indian and International Coals are like

Characteristics	Indian	Indonesian	South African
Total Moisture %	10 - 20	10-30	8
Ash %	25 - 50	10-15	15-17
Volatile Matter %	16 - 30	25-35	23
Fixed carbon %	24- 40	45	51
Carbon %	30 - 55	60	70-80
Hydrogen %	2 - 4	4.5	4-5%
Nitrogen %	0.7- 1.15	1	2-2.5%
Sulphur %	0.3 - 0.8	about 1%	Upto 1%
Oxygen %	4-8	12	8-9%
GCV kcal/kg	2800-5000	5500	6500
Abrasive index	40-60		
Ash Softening temp	Above 1300C	1350oC	13000C
HGI	50-110	About 50	About 50

How Boiler Design is affected by Coal

- Following major aspects considered for Boiler Design
  - FC / VM Ratio
  - Ash per million Kcals and
  - Initial Deformation Temperature
  - Slagging Characteristic of Ash
  - Ash Erosion Characteristic

How Boiler Design is affected by Coal

- Convective section of the boiler consists of large bundles of tubes arranged inside the gas path to extract heat from the flue gases.
- Erosion due to ash is a major consideration in this section.
- The maximum permissible velocity is proportional to the ash quantity and the abrasive nature of ash.
- Silica and alumina, which are high in typical Indian coals, are highly abrasive in nature and therefore a the maximum permissible velocity is limited.
- The metal loss due to erosion is also dependent on the spatial variation of velocity.
- Coal parameters critical to maximum permissible velocity
  - Ash content
  - Ash silica (particularly alpha quartz) and alumina

How Boiler Design is affected by Coal

- Objective of the coal firing system is to enable
  - Complete combustion of the coal particles
  - Limit the formation of pollutants like NOX
- Coal Properties Affecting Combustion
  - Fuel Ratio (Fixed Carbon / Volatile Matter) is commonly used to evaluate the combustibility of coals
  - More advanced analysis rely on macarel analysis and vitrinite reflectance for evaluating combustion performance
- Firing Arrangements
  - Wall Fired
    - Front Wall
    - Front and Rear Fired
  - Tangential Fired
  - W-fired

Furnace Sizing and coal

- Volumetric Heat Release Rate
- Furnace Residence Time
- Net Heat Input per Unit Plan Area
- Burner Zone Heat Release Rate
- Furnace Cooling Factor
- Furnace Exit Gas Temperature (FEGT)

All the above parameters are affected by the coal properties especially the slagging and fouling characteristics of the coal

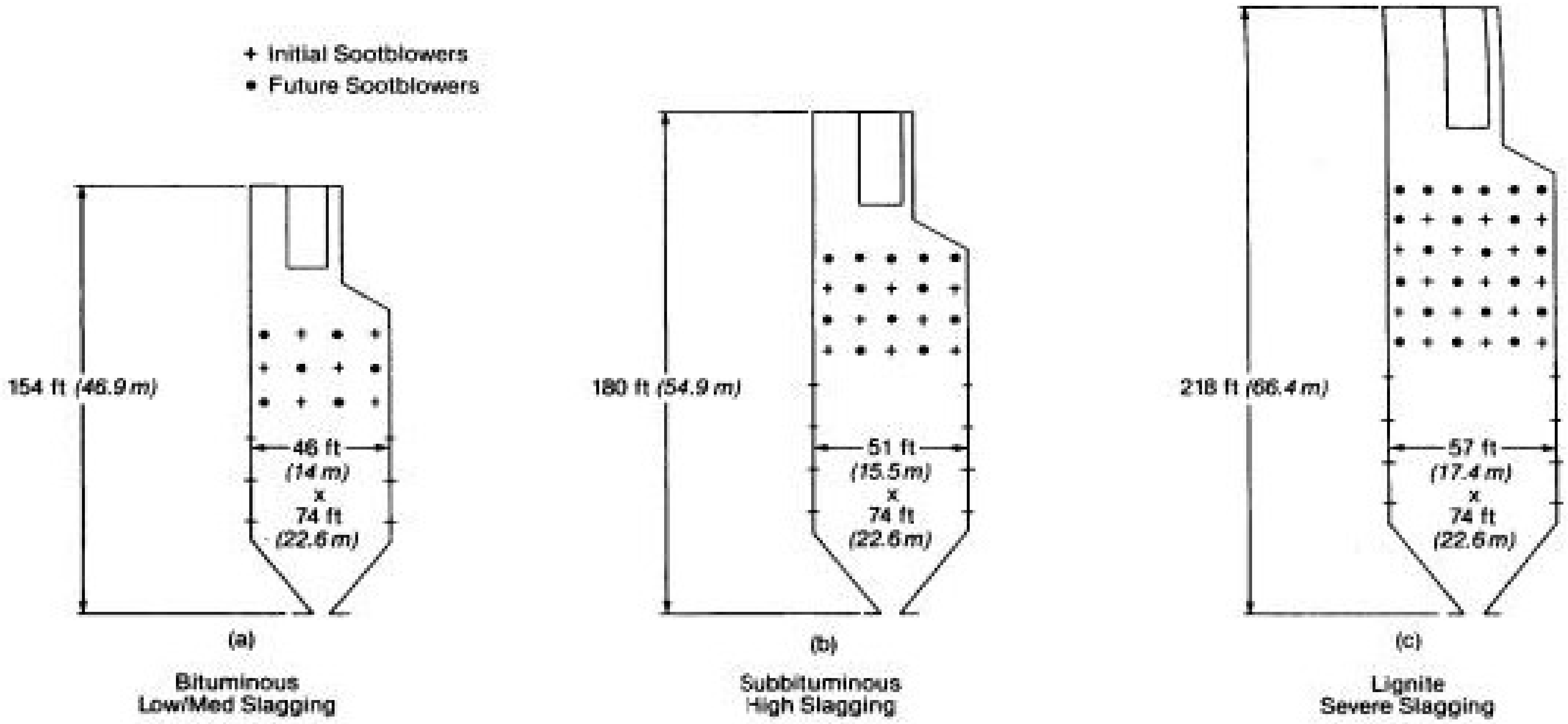
Net Heat Input (NHI) is the GCV of the fuel minus the radiation losses, loss due to unburnt combustible, moisture in air, latent heat of moisture in fuel & that formed by combustion of H2 in the fuel plus the sensible heat of combustion air (Primary plus Secondary air), all above reference temperature.

Furnace

- **Volumetric Heat Release Rate**
  - Volumetric Heat Release Rate is the Heat liberated per unit volume in the furnace zone (upto FEGT plane)
  - Maximum value depends on the fuel and ash characteristic.
  - However, for large units, this is not a limiting criteria.
- **Furnace Residence Time**
  - A minimum furnace residence time is necessary to ensure complete combustion of fuel particles.
  - Furnace residence time is calculated from the top burner to furnace exit (inlet of Platen Heat Exchangers)
  - The choice of furnace residence time depends on fuel ignition characteristic and reactivity.
  - Fuel ratio gives a good indication of the fuel reactivity.

Furnace

- Although particle ignition and combustion characteristic of coal is a major design criterion, the primary design consideration for furnace sizing and convective section design is to minimize problems due to ash slagging, fouling and erosion.



Furnace Sizing

- **Net Heat Input (NHI) per unit Plan area of furnace**
  - Net Heat Input (NHI) per unit Plan area of furnace or Plan Area Loading is the amount of heat released per unit cross section of the furnace.
  - Net Heat Input (NHI) per unit Plan area of furnace reflects the temperature level in the furnace. A high NHI per plan area increases flame stability but also increases the possibility of slagging in the furnace.
  - The allowable Plan Area Loading depends on the capacity of boilers and the softening temperature (ST) and composition of the ash in coal.
  - The plan area loading is generally kept in the range of 3.9 to 4.9 Mkcal/m2-hr.
  - High silica and alumina content of the ash in Indian coals reduce the chance of slagging. However, the high ash content poses a possible risk during operation.
  - A conservative approach is necessary to avoid any chance of slag build up as it may prove catastrophic.
- **Burner Zone Heat Release Rate (BZHRR)**
  - BZHRR is the ratio of the Heat supplied to the furnace to the burner zone surface area between top and bottom burners.
  - The BZHRR represents the temperature level and peak heat flux in the burner region.
  - The choice of BZHRR depends largely on the slagging characteristic of the coal.
  - BZHRR also affects the thermal NOx formation in the furnace.

Pressure Parts

- Material
  - Fuel side corrosion of the pressure parts is major concern with coals having high sulphur or sodium and chlorine in ash.
  - Fuel side corrosion is not a major concern with Indian coals.
- Arrangement
  - Above IDT slag deposits bridging across the tubes is the major constraint
  - Below IDT fouling of tubes and ease of cleaning decides the minimum pitching between assemblies
  - Ash slagging and fouling characteristics are largely dependent on ash composition

Coal Quality and Boiler Efficiency

- Losses from Boiler
  - Dry Gas Loss depends on
    - Exit Gas Temperature
    - Excess Air
  - Loss due to Moisture and Hydrogen in coal
    - Moisture in coal
      - Every 1% increase in moisture decreases the Boiler Efficiency by 0.1-0.2%
    - Hydrogen in Coal
      - Every 1% increase in hydrogen content decreases the boiler efficiency by 1.5-2%
  - Sensible heat due to ash
    - Every 1% increase in ash content decreases the boiler efficiency by 0.02% approx.

Other Component Design

- **ESP**
  - Sizing of ESP is dependent primarily on the ash content of the coal
  - Moisture and Hydrogen in coal also play a role in the size of ESP, as they tend to increase the gas volume.
  - Moisture in flue gas decreases the dust resistivity thereby improving collection.
  - Ash constituents like Na and sulphur in coal reduce the resistivity of ash thereby improving collection
- **FGD**
  - Indian coals are generally low in sulphur
  - However, owing to the low GCV, the SO2 emissions from Indian Power stations is 1500-1800 mg/Nm3, which is well above the prevalent norms in Europe, Japan and USA
  - FGD may be required in case of high sulphur coals

Influence on Coal Mill

- **MILL OUTLET TEMPERATURE**
- **MILL MOTOR AMPERES**
- **MILL AIR FLOW**
- **WEAR PART LIFE**
- **MILL PRESSURE DROP**
- **MILL OUT PUT**
- **MILL FINENESS FRACTIONS**
- **MILL REJECT RATE**

LACK OF CAPACITY OR HIGH POWER CONSUMPTION

- HIGH MOISTURE
- LOW GCV
- INCREASED RAW COAL SIZE.
- GRINDING TOO FINE
- EXCESSIVE BED DEPTH
- INSTRUMENT ERROR

EXCESSIVE MILL REJECTS

- CHANGE IN COAL GRINDABILITY, SULFUR & ASH.
- IMPROPER COAL/AIR RATIO
- THROAT GAP WEAR.

COARSE GRIND

- CHANGE IN COAL GRINDABILITY
- HIGH MOISTURE
- INCREASED THROUGH PUT.
- CLASSIFIER SETTING
- MILL WEAR.

LOW COAL \AIR TEMPERATURE

- HIGH MOISTURE
- LOW PA INLET TEMPERATURE
- PASSING OF COLD AIR.
- LOW A.H INLET TEMPERATURE
- NON AVAILABILITY OF SCAPH

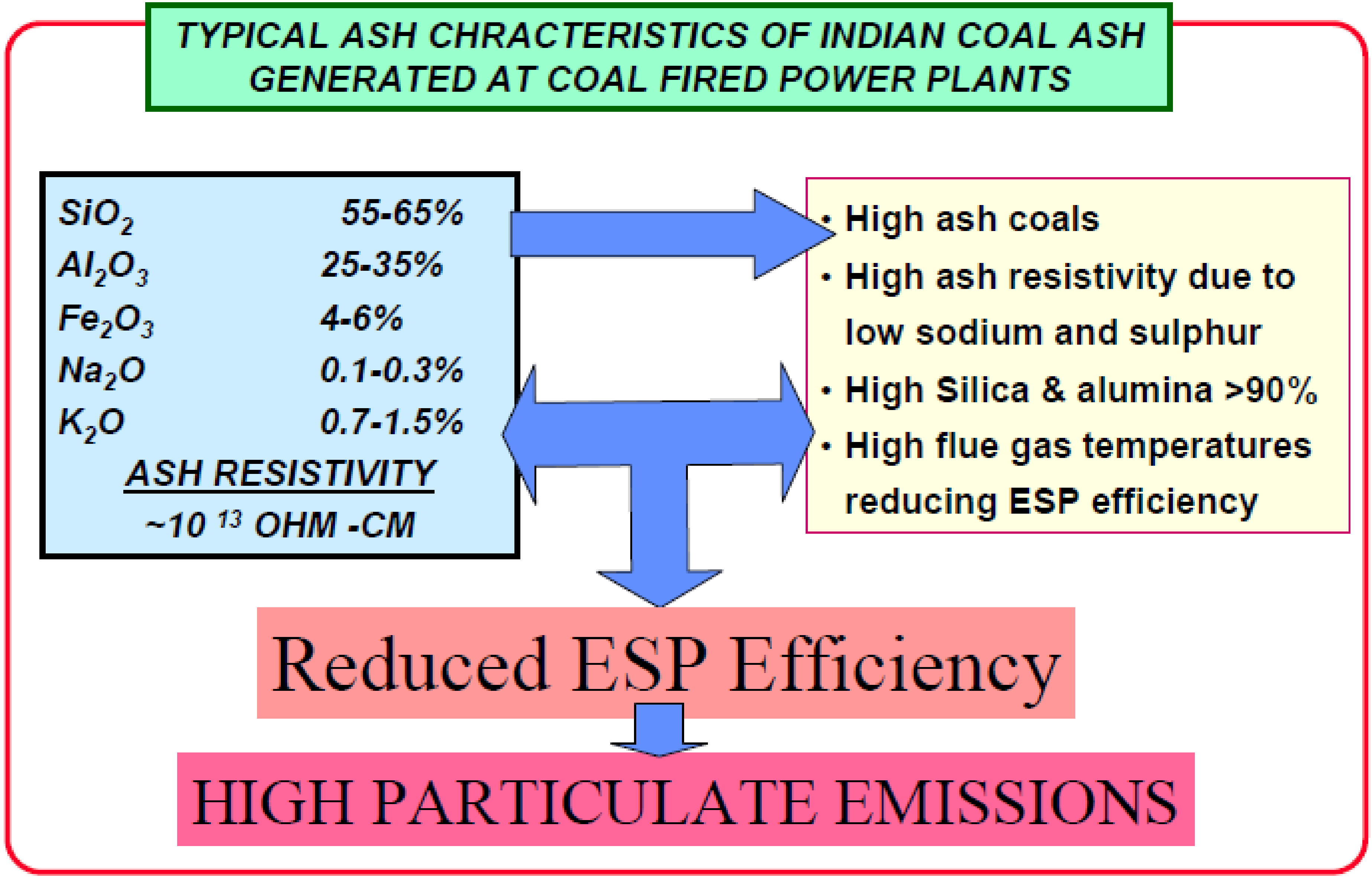
MILL FIRES

- HIGH VOLATILES
- MOISTURE
- LOW COAL\ AIR TEMPERATURE.
- BURNER LINE BALANCE

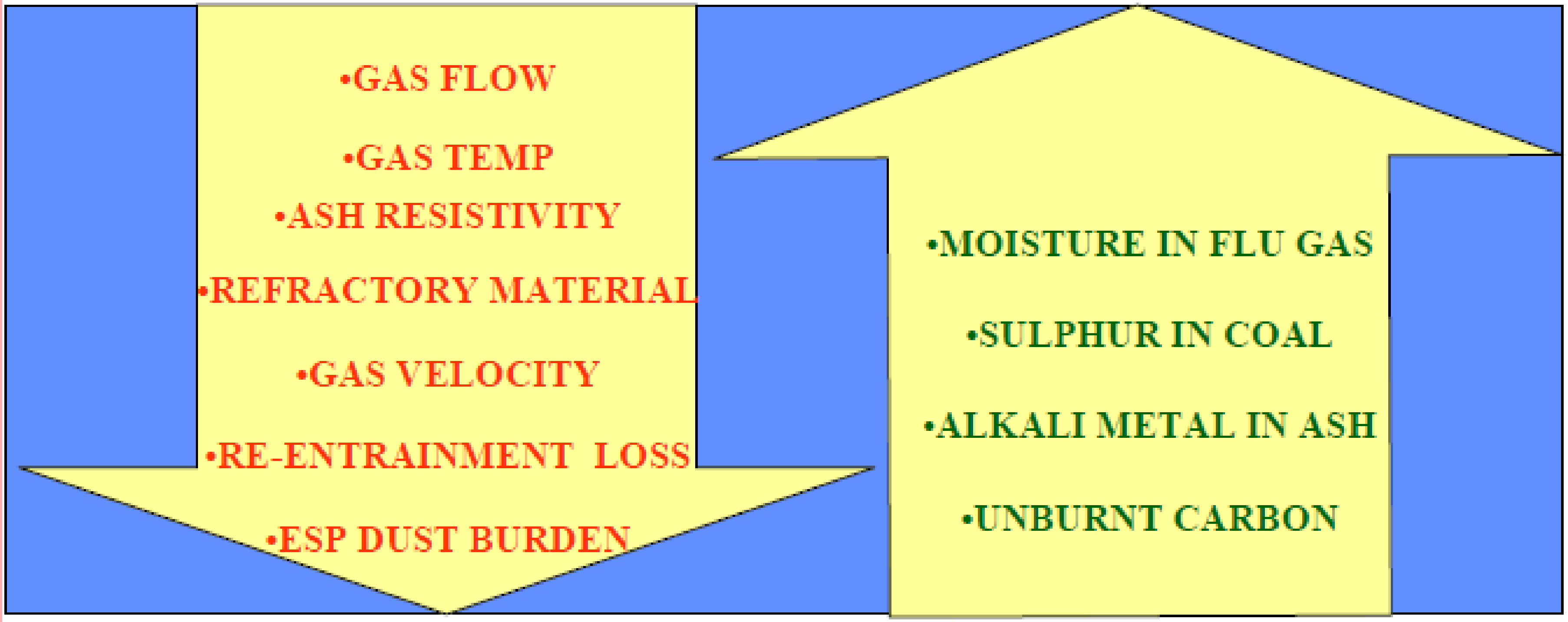
ESP

- **For a given collection efficiency, ESP size increases with increase in coal ash due to the increase in inlet dust burden.**
- **Precipitability of fly ash improves with increase in flue gas moisture content.**
- **Precipitability of fly ash improves with increase in coal sulfur content.**
- **Precipitability of fly ash improves with increase in fly ash base/acid ratio and increase in Na2O and Li2O in the ash.**
- **Precipitator efficiency increases with increase in fly ash particle size which is affected by PF size, the fusibility characteristics of the coal ash and combustion conditions.**
- **Coarser PF tends to yield a larger average fly ash particle size (or mass median diameter).**

COAL PROPERTY	EFFECT ON PARTICULATE EMISSION
Dust Burden (ash content)	1% increase in dust burden will increase emission by 1%
Gas Flow (heat value, ultimate analysis, C/H ratio, moisture level)	1 % increase in gas flow per unit heat release will increase emission by 1.5%
Ash resistivity	A resistivity change of 1 order of magnitude would suggest an increase in emissions by a factor of 2
Sulphur	General trend for reducing resistivity as sulphur increases, possibly one order of magnitude per 1 % sulphur change. Below 1 % sulphur, resistivity is dominated by other factors.


TYPICAL ASH CHRACTERISTICS OF INDIAN COAL ASH GENERATED AT COAL FIRED POWER PLANTS
SiO_2 55-65%
Al_2O_3 25-35%
Fe_2O_3 4-6%
Na_2O 0.1-0.3%
K_2O 0.7-1.5%
ASH RESISTIVITY
~10^{13} OHM -CM
• High ash coals
• High ash resistivity due to low sodium and sulphur
• High Silica & alumina >90%
• High flue gas temperatures reducing ESP efficiency
Reduced ESP Efficiency
HIGH PARTICULATE EMISSIONS

EFFECT on ESP PERFORMANCE with INCREASE in VARIOUS PARAMETERS



Particle size & Gas Distribution also play important role on ESP performance

Thanks