Boiler  Fuel Firing  System
• Everywhere, at all times, oxygen combines with other elements. This general process is called Oxidation.

• Burning, or Combustion, is a special form of oxidation:
  - Oxygen combines rapidly with certain types of fuels, such as coal, oil, gas or wood, and substantial amounts of heat are liberated.

• The Degree of Flammability depends on how easy it is to turn into a gas, because nothing truly burns until it is a gas. This in turn depends on the nature and quantity of the substance, compared with amount of heat available to start combustion.
The task of burning commercial fuels in actual furnaces includes:

1) Preparing the fuel and air;
2) Converting the complex fuel into elementary fuels;
3) Bringing these fuels and air together in the right propositions and at the proper temperature for ignition and combustion;
4) Transferring heat from the products of combustion to the boiler or other surfaces, while retaining enough heat in the combustion zone to maintain volatilization and ignition.

All these actions occur at the same time in any furnace, and each particle of fuel traces the entire sequence, in order, in its brief passage through the furnace.
Combustion Sequence Of Coal

Coal

Release Of Moisture

Release Of Volatiles (Devolatilisation)

Combustion Of Char (Char Oxidation)

Emissions (Flue Gas)

Fly Ash

Ash

Bottom Ash
BURNERS:

Burners undertake the task of delivering coal and air in a proper proportion, facilitate ignition energy to the coal air stream, sustain the ignition and provide a stable flame during the operation, complete the task of combustion and delivering heat to the intended purpose.

Burners are broadly classified as follows:

(1) Tangential Burners

(2) Wall Burners

(3) Down shot or fan tail burners
Burner Arrangement

In a tangentially fired boiler, four tall windboxes (combustion air boxes) are arranged, one at each corner of the furnace. The oil and gas burners are located at different levels or elevations of the wind boxes. The coal, oil and gas burners are sandwiched between air nozzles or air compartments. That is, air nozzles are arranged between gas spuds, one below the bottom gas spud and one above the top gas spud. The fuel and combustion air streams from these burners or compartments are directed tangentially to an imaginary circle at the centre of the furnace. This creates a turbulent vortex motion of the fuel, air and hot gases which promotes mixing, ignition energy availability and thus combustion efficiency.
Modern Burners are equipped with:

(a) Separate flame envelope ports for coal, oil and gas
(b) Secondary air control to adjust the flame envelopes.
(c) Ignitors.
(d) Flame Scanners to detect the distinct flames in an enclosure.
(e) Flame Stabilisers.
(f) Flame Analysers
The proportioning of air flow is done based on boiler load, individual burner load, by a series of air dampers. Each of the auxiliary and end air nozzles are provided with louver type regulating dampers, at the air entry to individual air compartment. The damper regulates on elevation basis, in unison, at all corners.

**Igniters**

Oil and gas are ignited by a pilot flame. This pilot torch may be a

Oil ignitor
Gas ignitor
High energy arc ignitor
The burners are tiltable +/- 30° about horizontal, in unison at all elevations and corners. This shifts the flame zone across the furnace height and enables control over steam temperature.

Each burner is associated with an ignitor arranged at the side.

**Combustion Air Distribution**

The Combustion air, referred to as Secondary Air, is provided from FD Fans. A portion of secondary air called `Fuel Air', is admitted immediately around the burners (annular space around the oil/gas burners) into the furnace. The rest of the secondary air, called 'Auxiliary Air', is admitted through the auxiliary air nozzles and end air nozzles. The quantity of secondary air (fuel air + auxiliary air) is dictated by boiler load and controlled by FD Fan inlet guide vane regulation.
TANGENTIAL BURNERS

- Corner 1
- Front W.W
- Burner Panel
- Corner 2
- Rear W.W
- Furnace Width
- Corner 3
- Wind Box Assembly
- Corner 4
- Wind Box Connecting Duct
TANGENTIAL BURNERS
FURNACE FIRING ANGLES AND ELEVATIONS

Corner Designation  Elevation Designation
COAL COMPARTMENT ASSEMBLY

05 ADJ. COAL NOZZLE TIP
06 SEAL PLATE
07 COAL NOZZLE CASTING

DETAILS OF COAL COMPARTMENT ASSY.
COAL COMPARTMENT ASSEMBLY
TILTING DRIVE MECHANISM

Nozzle tilting Mech. (Indirect)

Nozzle tip pin assy.

Nozzle tilting Mech. (Direct)
OIL FIRING SYSTEM

Fuel Oil Preparation

Filtering the oil, Pumping the oil and heating it are the major preparatory functions.

Filtration of oil in one or more stages to remove any dust, dirt, sediments, sledge etc. also forms part of preparation.

This renders long trouble free service life to pumps, valves and oil gun atomiser nozzles.

Pumping the oil to overcome pressure drop in the long oil supply lines and deliver the oil at required pressure at oil gun tips.
Fuel Oil Atomisation

Atomisation is the process of spraying the fuel oil into fine mist, for better mixing of the fuel with the combustion air. While passing through the spray nozzles of the oil gun, the pressure energy of the steam converts into velocity energy, which breaks up the oil stream into fine particles.

Poorly atomised fuel oil would mean bigger spray particles, which takes longer burning time, results in carryovers and makes the flame unstable due to low rate of heat liberation and incomplete combustion.

Other than pressure, viscosity of the oil is the major parameter which decides upon the atomisation level. For satisfactory atomisation the viscosity shall be 15 to 20 centistokes.
Oil Recirculation

Before putting in the first burner into service, it is necessary to warm up the long oil supply lines to the burners, so that the oil does not get cooled in the colder pipings and that the oil at correct atomising temperature becomes available at the burners. To achieve this the heated oil is circulated up to the burners and back to the oil tank through oil return lines till adequate oil temperature is reached near the burners.

System Vents

Fuel oil heaters, strainers and lines are provided with vent cocks or valves on oil and steam sides to get rid of air locks while charging system.
System Drains

All oil lines are run with a slope of about 0.3 to 0.5% towards drain. Each section of oil line is provided with a drain valve at the lowest point. All drain valves are normally kept closed during operation.

Oil Temperature Control

The result of inadequate heating of oil is "higher oil viscosity" which impairs atomisation at the oil gun, leading to poor flames, sooting, increased carbon loss and finally flame failures. Over heating the oil is also not desirable from the point of thermal cracking of oil. The formed solid carbon particles build up over the heater tubes, and plug up the strainer, intricate passages of control and shut off valves and atomisers. The carbon particles also cause faster atomiser wear out and sparklings in the flame.
Combustion generated Pollutants

1. Nox emission
2. Sox emission
3. CO$_2$ emission (green house gases)
4. CO emission
5. Particulate emission
NOx Formation
and
Control Strategies
NO\textsubscript{x} FORMATION AND REDUCTION

THE FORMATION OF NITROGEN OXIDES WITH THE COMBUSTION OF FOSSIL FUELS MAY RESULT FROM THREE DIFFERENT REACTION MECHANISMS

• THERMAL NO\textsubscript{x} FORMATION

• PROMPT NO\textsubscript{x} FORMATION

• NO\textsubscript{x} FORMATION FROM FUEL NITROGEN
Tangential Firing System and NOx

- The swirling motion, which creates an aerodynamics in the entire belt of the array of burners enabling the segregation of air and fuel around the central vortex.
- This increase the residence time and delay the combustion process and hence the NOx formation, which is the inherent advantage of tangential firing system.
<table>
<thead>
<tr>
<th>NOX Type:</th>
<th>Fuel NOx</th>
<th>Thermal NOx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source:</td>
<td>Nox formed from Nitrogen in the Volatile Matter and Fixed Carbon in the Fuel</td>
<td>Nox formed from N2 in the Combustion Air.</td>
</tr>
</tbody>
</table>
| Formation Sensitive to: | • Oxygen Availability  
  • Fuel Nitrogen Content  
  • Kinetics | • Furnace Temperature  
  • Oxygen Availability |
| Proportion | 60 – 80% | 20 – 40% |
Nox FORMATION MECHANISMS

Nitrogen Sources
- Fuel
- Volatile Matter Nitrogen
- Hydrocarbon Fragments
- Char Nitrogen

Mechanisms
- Fuel NOx
- Heterocyclic Nitrogen Compounds
- Nitrogen Intermediates: HCN, CN, OCN, HNCO, NH3, NH2, HN, N

Products
- Molecular Nitrogen
- Total NOx

Thermal NOx
Prompt NOx

Air
BASIC Nox REDUCTION STRATEGIES

Staging of the Combustion Process

- Vertically and Horizontally
- Fuel Rich / Air Lean Zones
  - Minimize Air at Early Stages of Combustion (< Fuel NOx);
- Fuel Lean / Air Rich Zones
  - Minimize Gas Temperatures in Furnace (< Thermal NOx).
AIR STAGING

• TO REDUCE NO\textsubscript{x} FORMATION DURING COMBUSTION, THE TWO MAJOR NO\textsubscript{x}- GENERATION MECHANISMS - CONVERSION OF FUEL BOUND NITROGEN AND HIGH-TEMPERATURE FORMATION OF THERMAL NO\textsubscript{x} - MUST BE CURTAILED.

• ONE SUCCESSFUL TECHNIQUE INVOLVES WITHHOLDING SOME O\textsubscript{2} FROM PRIMARY FLAME ZONE AND INTRODUCING IT GRADUALLY THEREAFTER TO ENSURE SMOOTH, COMPLETE COMBUSTION AT RELATIVELY LOW TEMPERATURES. THIS METHOD IS KNOWN AS AIR STAGING, IS USED IN SOME FORM FOR VIRTUALLY ALL LOW -NO\textsubscript{x} WALL AND TANGENTIALLY FIRED BURNERS.
Close Coupled Over Fire Air System

- Overfire air is introduced into the furnace tangentially through two additional air compartments, termed as overfire air ports, designed as vertical extensions of the corner windboxes.

- The overfire air ports are sized to handle 15 percent of total windbox air flow.

- At design levels of overfire, a 20 to 30% reduction in NOx formation is achieved.
NOX DEPENDENCE ON OVERFIRE AIR FLOW

- OFA VS NO
- EXCESS O2 (%) VS NO

Graph showing the relationship between NO (PPM @ 3% O2) and Overfire Air (%) for OFA and Excess O2 (%).
Over Fire Air Vs NOx

- The previous chart indicates the need for care in identifying optimum NOx control methods. While NOx emission decrease linearly with increasing overfire air, excess air rises (i.e., more air is needed to complete the combustion).

- If overfire air is increased beyond 15%, this decreases boiler efficiency due to the heating of extra air.
Separated Over Fire Air System (SOFA)

- In the current units CCOFA (close coupled overfire air) feature is incorporated in the windbox itself.

- To meet the latest trends in the NOx control measures, provision of a separate over fire air (SOFA) is being developed.

- The SOFA developed was tested at Suratgarh Site yielded good results in reduction of Nox.
VERTICAL STAGED COMBUSTION FOR NOx REDUCTION

- Air staged Low Nox Firing Approach.
- Utilizes a flexible, multipoint air injection design.
- Controls build-up of lower furnace stoichiometry.
Low Nox Firing System (with SOFA)

- Close Coupled Over Fire Air (CCOFA)

- Single level Separated Over Fire Air (SOFA)
Emerging trends in Fuel firing system Design
COAL - AIR BALANCING IN FUEL PIPING

Un balance in Coal- air flow in to the furnace results in uneven heat release, uneven distribution of excess air and unpredictable Nox formation.

1. Selection of Orifices for Coal air two phase flow regime.

2. Provision of on-line adjustment dampers in coal air flow path.

3. On-line measurement of coal -air flow using microwave techniques.

Emerging trends in Fuel firing system Design

1. Burners shall be designed to operate on multiple fuels from LCV gases, Liquid fuels to solid fuel or in combination of these fuels.

2. Less polluting burners - Technology development

3. Larger guarantee periods for high ash coals - Material selection, Improved design features

4. New gadgets like thermal analysers, on line coal flow measurement and control thro coal air dampers etc.,

5. Micro processor based on line measurement and control of secondary air admission to individual burners.

6. Computer simulations using software tools viz., ANSYS, CAEPIPE, STADD and CFD.

7. Virtual assembly using CAD tools in design office before
Separated Overfire Air

SOFA on Walls

Tilt +/-20°

Yaw +/-20°
Vertically and Horizontally Adjustable Air Nozzle

Secondary Air from Windbox Dampers

Adjustable Air Nozzle Tip

15°

Vertical Tilt Drive Mechanism

Horizontal Adjustment Mechanism
Tilt Drive Linkage Improvements

External Direct Drive

Shear / Locking Mechanism

Direct Drive Mechanism

Carbon Graphite Bushings

1.75” Accurloy Shaft

Drive Cylinder