Lecture 2.16

Plant Auxiliary Systems and Circuits

Agenda

- Overview of Plant Auxiliary Systems
- Fuel and Ash Handling Systems
- Air Supply and Flue Gas Systems
- Feedwater and Steam Circuits
- Condenser and Cooling Water Systems
- Steam Turbine Lubrication System

Overview of Auxiliary Systems

Key Characteristics

- Auxiliary systems consume approximately 5% to 8% of the total gross power generated by the plant.
- They form closed-loop circuits for fluids (water, air, oil) and open-loop paths for consumables (coal, ash).
- Reliability of auxiliaries directly dictates the overall plant availability and load-following capability.
- Categorized primarily into mass-transport circuits (fuel/ash) and thermodynamic-transport circuits (water/steam, air/gas).

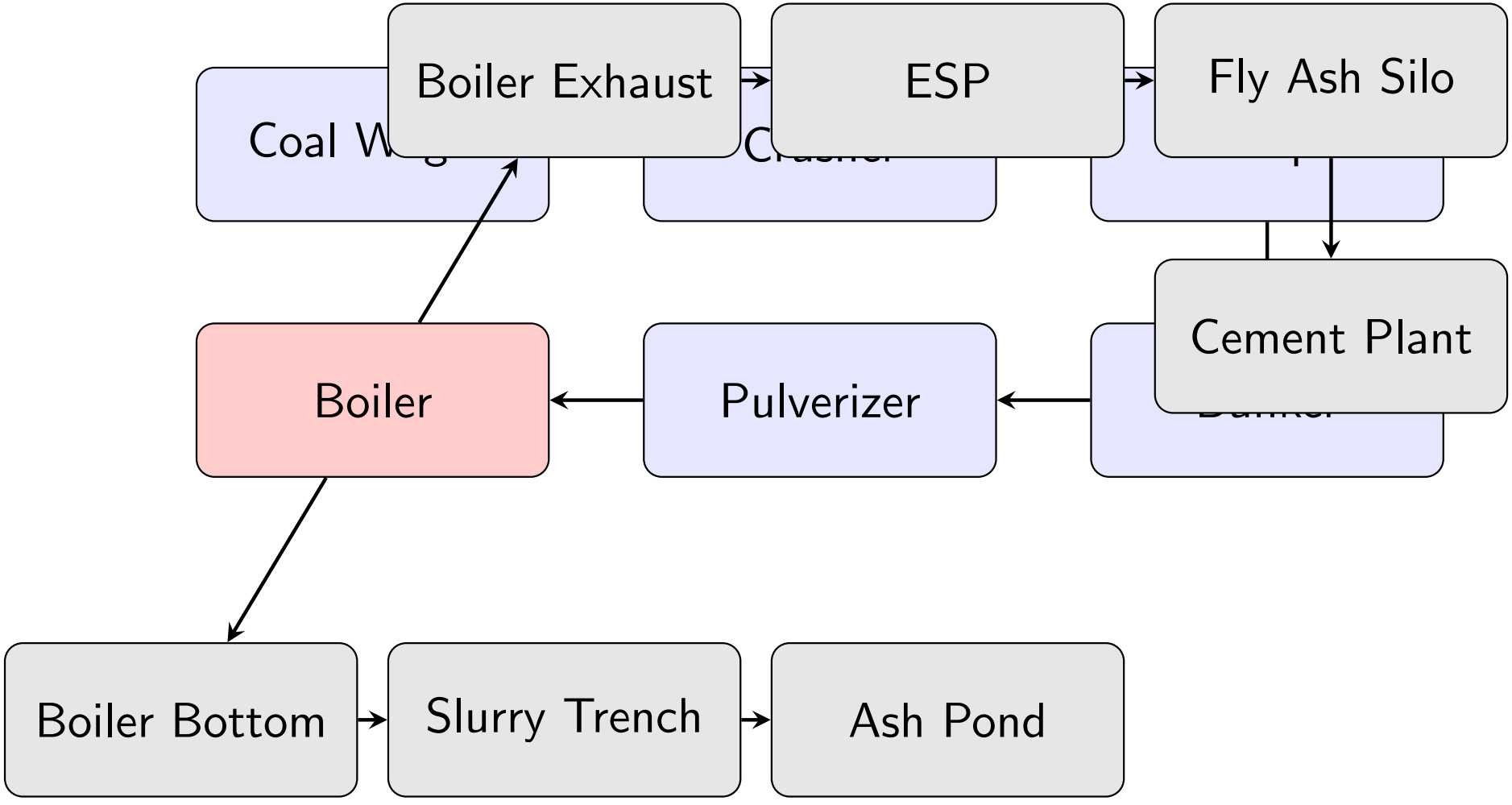
Fuel Handling System

- **Coal Unloading:** Rotary car dumpers and track hoppers handle bulk rakes arriving at the plant.
- **Coal Preparation:** Crushers reduce run-of-mine coal to < 20 mm size; magnetic separators remove tramp iron.
- **Storage & Reclaiming:** Stackers and reclaimers manage active (live) and dead coal storage piles.
- **Conveying:** Belt conveyors transport crushed coal to the boiler bunker, monitored by belt weighers for fuel accounting.
- **Milling Plant:** Coal feeders control the feed rate to pulverizers (mills) which grind coal to 70% passing through 200 mesh.

Ash Handling System

- **Ash Generation:** Coal combustion produces 15-20% bottom ash and 80-85% fly ash.
- **Bottom Ash Handling:** Heavy clinkers fall into water-impounded hoppers, are crushed, and sluiced as slurry to ash ponds.
- **Fly Ash Collection:** Electrostatic Precipitators (ESPs) capture fine particulate matter from flue gas with $>$99.8% efficiency.
- **Pneumatic Transport:** Dry fly ash is pneumatically conveyed via pressure or vacuum systems to storage silos.
- **Utilization:** Dry fly ash is increasingly collected for use in the cement and construction industries.

Circuit Diagram: Fuel and Ash Flow



Air Supply System

- **Forced Draft (FD) Fans:** Supply ambient secondary air to the furnace via the air preheater to support complete combustion.
- **Primary Air (PA) Fans:** Supply high-pressure hot air to the pulverizers to dry the coal and transport pulverized coal to the burners.
- **Air Preheater (APH):** Recovers residual heat from flue gases to preheat incoming combustion air, improving boiler efficiency by $\sim$10%.
- **Windbox:** Distributes the preheated secondary air uniformly to the boiler burners.

Flue Gas System

- **Induced Draft (ID) Fans:** Draw flue gases out of the furnace, maintaining a slight negative pressure (-10 to -20 mmWC) to prevent flame blowout.
- **Gas Path Components:** Furnace $\rightarrow$ Superheaters $\rightarrow$ Economizer $\rightarrow$ Air Preheater $\rightarrow$ ESP $\rightarrow$ ID Fan $\rightarrow$ Chimney.
- **Flue Gas Desulfurization (FGD):** Scrubbers installed before the stack to remove SOx emissions using a limestone slurry.
- **Stack (Chimney):** Designed with adequate height ($>$200m) to ensure atmospheric dispersion of treated flue gases.

Feedwater and Steam Circuit

- **Condensate Extraction Pumps (CEP):** Pump water from the condenser hotwell through low-pressure heaters to the deaerator.
- **Deaerator:** Removes dissolved oxygen and non-condensable gases via direct contact steam heating, preventing boiler tube corrosion.
- **Boiler Feed Pumps (BFP):** The highest power-consuming auxiliaries; pump deaerated water at supercritical pressures ($>$250 bar) to the boiler.
- **High-Pressure Heaters:** Utilize extraction steam from the turbine to preheat feedwater before entering the economizer.
- **Main Steam Path:** Superheated steam to HP turbine $\rightarrow$ Reheater $\rightarrow$ IP turbine $\rightarrow$ LP turbine.

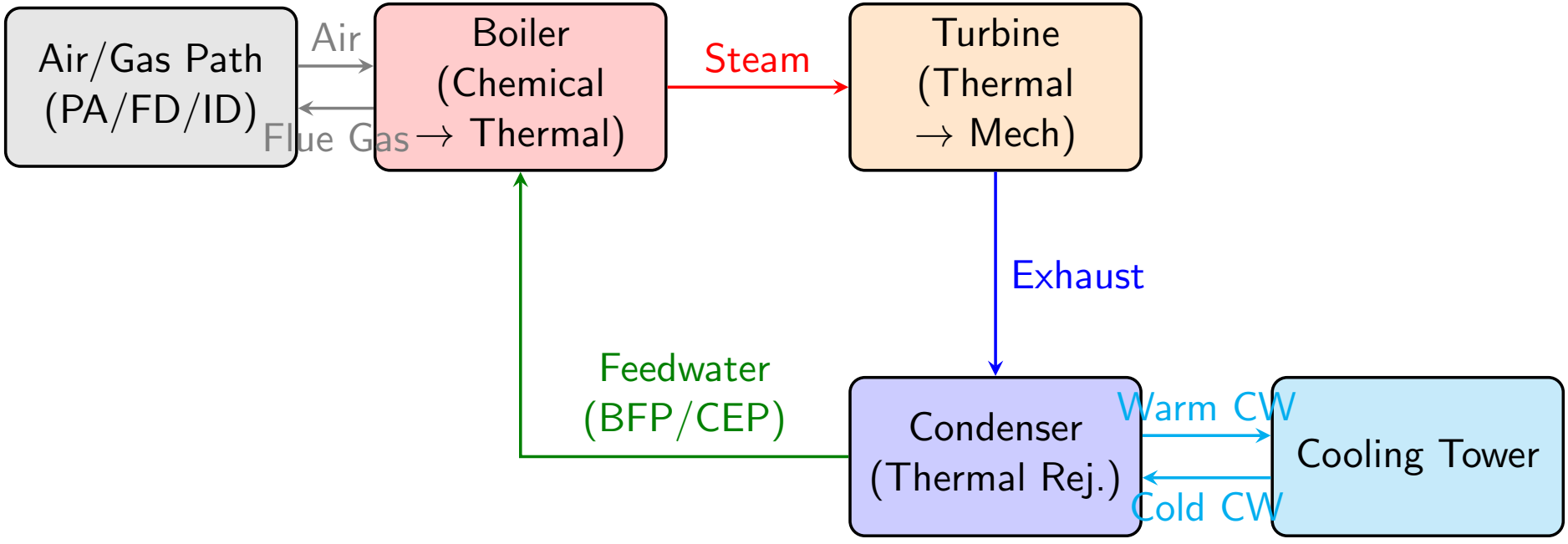
Condenser and Cooling Water System

- **Surface Condenser:** Creates maximum possible vacuum at turbine exhaust to maximize work output; transfers latent heat to cooling water.
- **Cooling Water (CW) Pumps:** Circulate massive volumes of cooling water (often $>$50,000 m^3/hr per unit) through condenser tubes.
- **Cooling Towers:** Natural draft or induced draft towers cool the warm circulating water via evaporation to ambient wet-bulb temperature.
- **Makeup Water:** Compensates for evaporation, drift, and blowdown losses in the cooling tower circuit.
- **Bio-fouling Control:** Chlorination systems prevent algae and scaling inside condenser tubes, maintaining heat transfer efficiency.

Steam Turbine Lubrication System

- **Main Oil Pump (MOP):** Driven directly by the turbine shaft; supplies high-pressure oil for governing and low-pressure oil for lubrication during normal operation.
- **Auxiliary Oil Pump (AOP):** AC motor-driven pump used during start-up, shutdown, and emergencies if MOP pressure fails.
- **Jacking Oil Pump (JOP):** Ultra-high pressure pump to lift the turbine rotor off the bearings during turning gear operation at low speeds.
- **Lube Oil Coolers:** Shell-and-tube heat exchangers that maintain oil viscosity by removing frictional heat from bearings.
- **Centrifuge/Purifier:** Continuously removes water moisture and particulate debris from the lubricating oil.

Diagram: Plant Fluid Circuits Integration



Summary

Key Takeaways

- Auxiliary systems handle mass (fuel/ash) and working fluids (water/steam/air), consuming ~5-8% of total power.
- Fuel and Ash systems must operate continuously to manage high volumes of solids and ensure environmental compliance.
- Balanced draft (FD/ID/PA fans) is critical for optimal combustion and furnace safety.
- Feedwater circuits utilize regenerative heating (Deaerator, HP/LP heaters) and high-pressure pumping (BFP) to maximize cycle efficiency.
- The Condenser creates necessary vacuum, while turbine lube oil systems protect the high-speed rotating machinery.

Next Lecture Preview

Lecture 17: Turbine Generator and Electrical Evacuation

- Coupling of the Steam Turbine to the Synchronous Generator.
- Excitation systems, synchronization, and active/reactive power control.
- Transformers and switchyard integration.