Recovery Boiler Equipment and Operation

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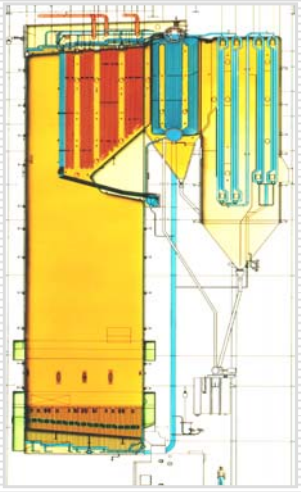
What Does The Recovery Boiler Do?

- Burns black liquor
- Recovers inorganic chemicals
- Generates superheated steam



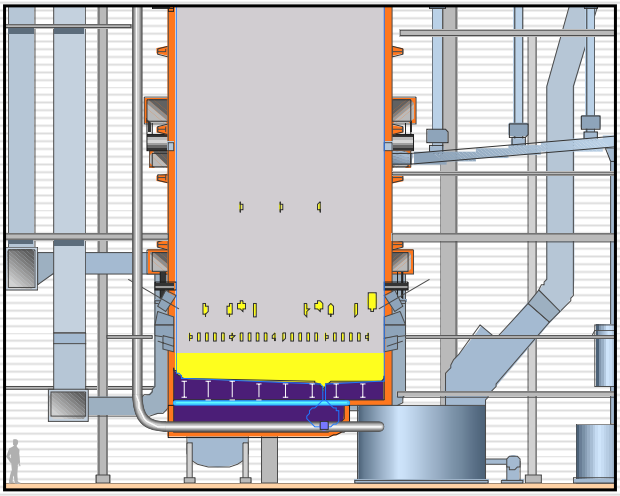
Burning Black Liquor

- Takes place in the furnace section
- Requires black liquor and air to be intermixed
  - Black liquor sprays
  - Forced air system
- Self-sustained combustion is normal
  - Use auxiliary fuel for start-up, shut-down, and to assist marginal combustion
- Combustion gas flow driven by induced draft (ID) fan

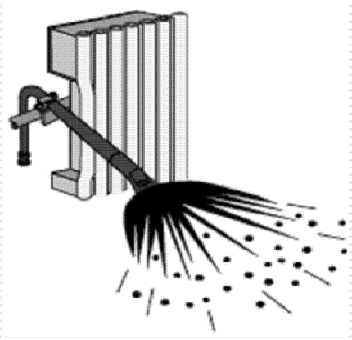
Furnace Section

- Basically a rectangular box with openings for liquor, air, etc.
- Lower Furnace
  - Liquor sprayed in
  - Combustion air enters
  - Char bed - smelt formation and drainage
- Upper Furnace
  - Residence time to complete combustion
  - Heat absorption to cool gases

Recovery Boiler Lower Furnace

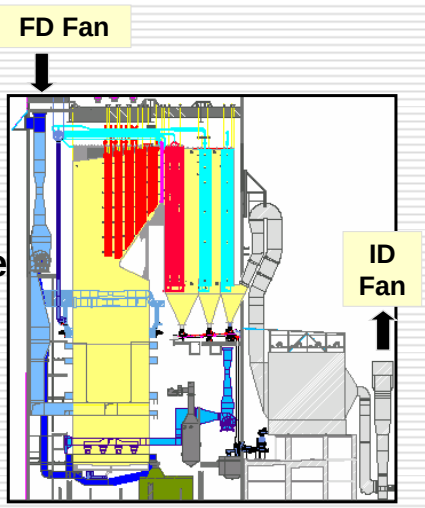


Black Liquor Sprays



Air / Flue Gas Equipment

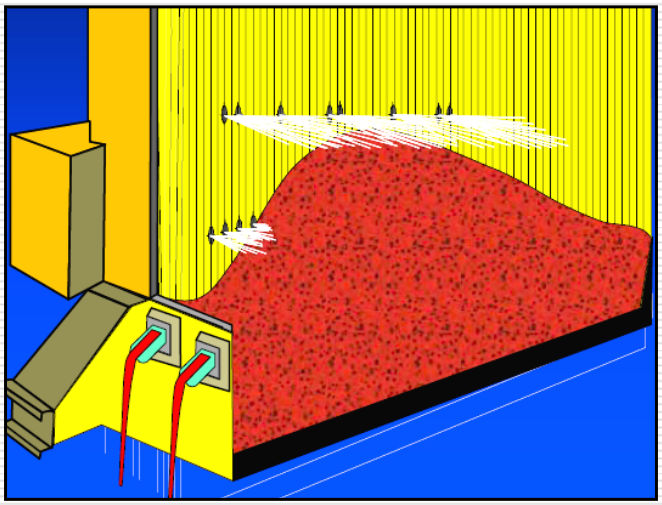
- A forced draft (FD) fan to deliver the combustion air to the boiler, typically at 3 different levels
- An ID fan to withdraw the flue gas from the boiler
- Operate on a balanced draft



Recover Inorganic Chemicals

- Recover the inorganic chemicals as a molten smelt of Na_2S and Na_2CO_3
  - Na_2S requires a local reducing (oxygen deficient) environment
  - Some S leaves as Na_2SO_4 – incomplete reduction measured by reduction efficiency
- Runs out of the furnace through spouts into the dissolving tank to form green liquor

Recovery Furnace Char Bed



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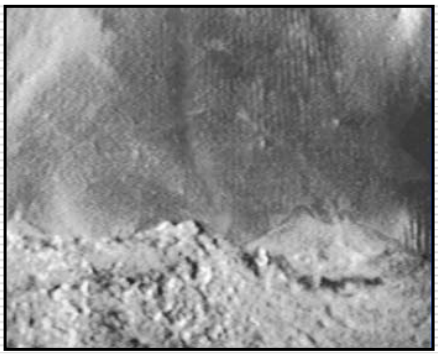
Char Bed Shapes



Low Bed

High Bed

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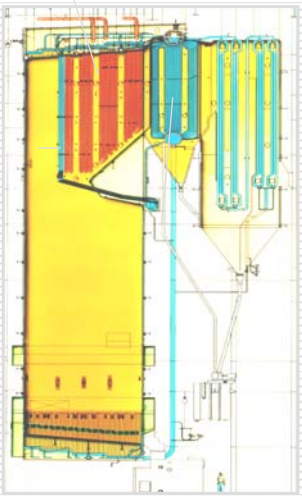
Chemicals Recycled to Furnace

- Dust (Na_2SO_4 and Na_2CO_3) collected in electrostatic precipitator and returned to the black liquor being fired
- Inorganic that collects on heat transfer surface is removed with sootblowers and either falls directly to the hearth or is collected in ash hoppers and returned to the black liquor being fired

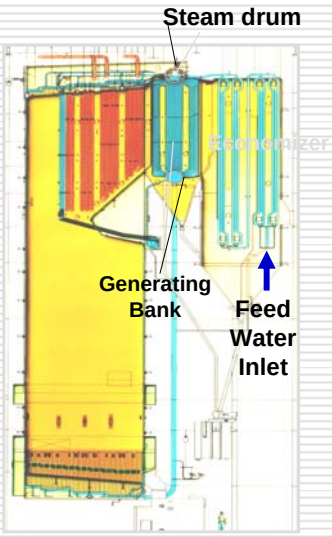
Steam Generation

- Feedwater heating in economizer
- Natural circulation steam generation
  - Waterwalls, floor, roof
  - Screen, if used
  - Generating bank
- Raise steam temperature in superheater



Water/Steam Circuits

- Feed water enters the boiler through economizer lower headers
- Water/vapor separation occurs in the steam drum of the generating bank
- Generating bank is natural circulation loop
  - Water flows down backside
  - Steam/water flows up front

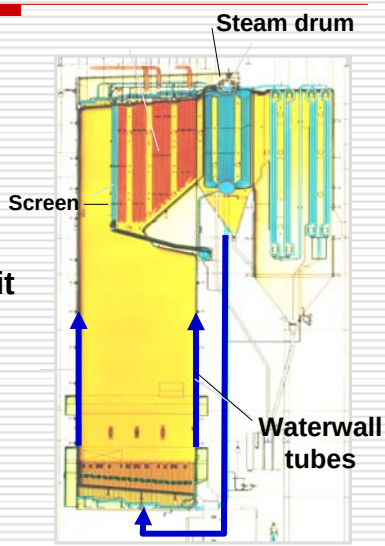


Circulation in Two-Drum Boiler

- Top drum is a steam-water separator
  - Hot feedwater enters – steam leaves
  - Generating bank is its own natural circulation loop
    - Rear tubes act as downcomers
    - Forward tubes act as risers
- Mud drum is source of water to all other loops
  - Floor and waterwall headers
  - Furnace screen headers

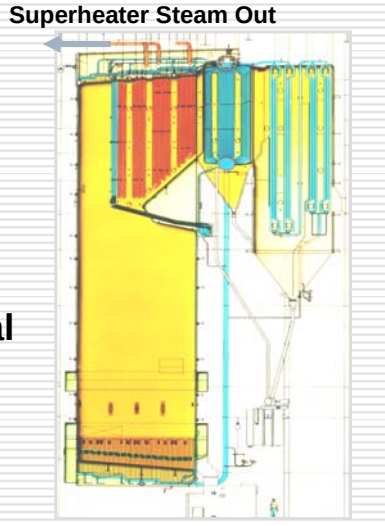
Water / Steam Circuits

- Hot water then
  - follows the down comer to lower furnace headers and is distributed evenly to waterwall tubes
  - rises in waterwall tubes as it is heated and enters the steam drum
- A separate loop feeds the screen tubes

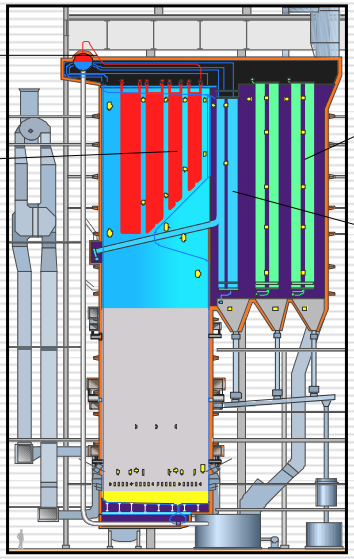


Water / Steam Circuits

- The separated vapor (saturated steam) is further heated in the superheater to produce superheated steam
- Superheated steam exits the boiler through the final superheater outlet



Single Drum Recovery Boiler



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Circulation in One-Drum Boiler

- Everything goes to and comes from the drum
  - External downcomers take water to floor and lower wall headers
  - External downcomers feed bottom generating bank header
  - Crossover tubes take water from economizer outlet header to drum
  - Supply tubes take steam to superheater inlet header

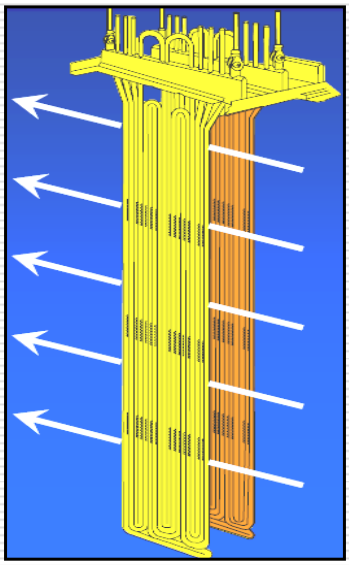
One Drum vs. Two Drum

- All recoveries used to be two-drum
- First one-drum in 1984 at Leaf River
- Increasing size and pressure favors one-drum design
- Except for very small units, all new modern recovery boilers are single-drum design

Superheater

- Usually several banks with various arrangements of steam flow vs. gas flow
  - May have interstage attemporation
- Tube backspacing in bank may be tangent or spaced
- Various support arrangements at roof or headers

Superheater Gas Flows



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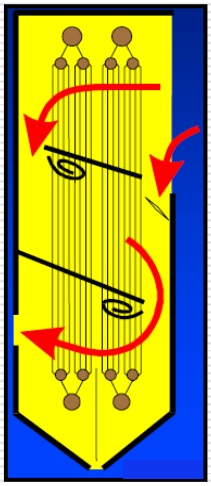
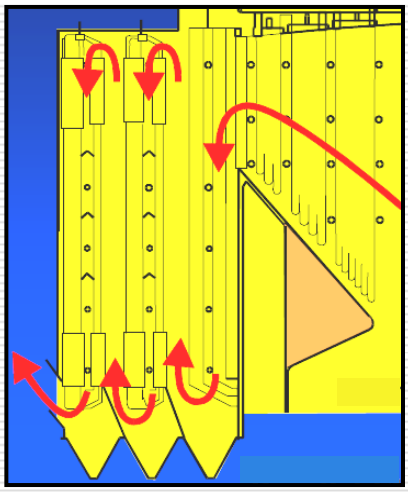
Generating Bank

- Hot gas leaves furnace through a generating bank screen above arch
  - Rear wall tubes bent out of plane to form opening for gas to flow through
- Single-drum boiler
  - Gas flow parallel to boiler bank tubes
- Two-drum boiler
  - Gas flows across tubes

Economizer Gas Flows





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Cross Flow

Parallel Flow

Superheaters and Economizers

- Both have a significant increase in the fluid (steam or water) temperature as it flows within the tubes
- Both are subject to thermally induced stresses
- Differences in flow or heat pickup in parallel tubes cause different amounts of expansion

Peripheral Equipment

- Fans
- Liquor system
- Auxiliary fuel system
- Spouts and dissolving tank
- Sootblowers
- Precipitator
- Direct contact evaporator

Liquor System

- Liquor guns
- Pumps and piping
- Mix tank for dust addition
- Liquor heaters
- Solids monitoring and automatic diversion system

Auxiliary Fuel System

- Burners and ignitors
- Fuel piping and controls
  - oil and/or gas
- Flame safety system
  - Monitors
  - Interlocks

Burner Locations

- Hearth burners
  - Use for startup and shutdown
  - Assist in unstable firing conditions
- Load burners
  - Usually above liquor guns
  - Used for extra steam generation

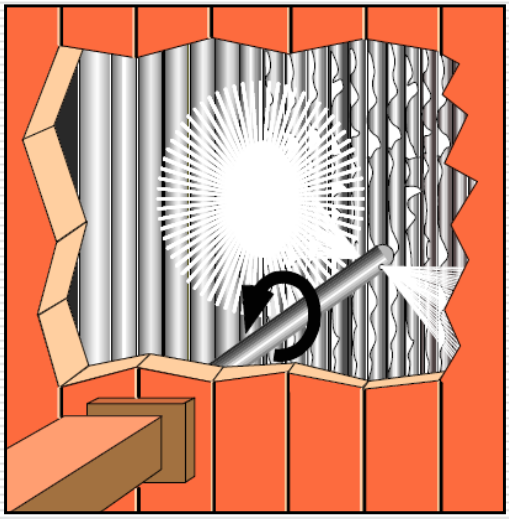
Spouts and Dissolving Tank

- Spouts – water-cooled troughs mounted in or on furnace at spout openings near hearth
- Spout cooling water system
- Agitated tank to dissolve smelt and make green liquor
- Shatter jets or other means to break up smelt stream as it enters the tank

Sootblowers

- Use a steam jet to remove deposits
  - Superheater
  - Generating bank
  - Economizer
- Large number mounted external to boiler – when activated they go in and then retract

Deposit Removal with Sootblowers



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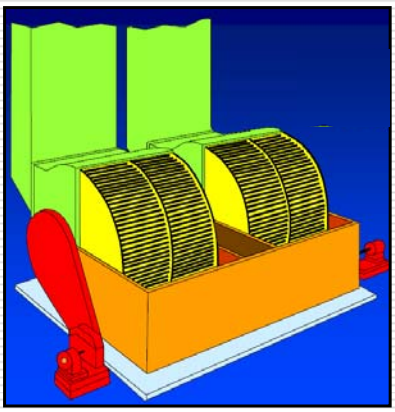
Electrostatic Precipitator

- Removes dust from the flue gas
  - Recovered dust is recycled to black liquor
- Precipitator efficiency determines dust load and opacity out the stack

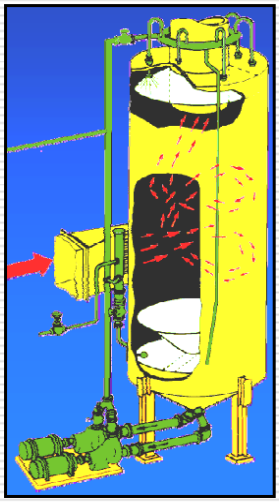
Direct Contact Evaporator

- Final black liquor concentration step on many older recovery boilers
  - Hot flue gas brought into direct contact with black liquor
  - Raises solids from 50% to 65% solids
  - Cools flue gas – need a smaller economizer
- Two types in use
  - Cascade evaporator
  - Cyclone evaporator

Direct Contact Evaporators



Cascade Evaporator



Cyclone Evaporator

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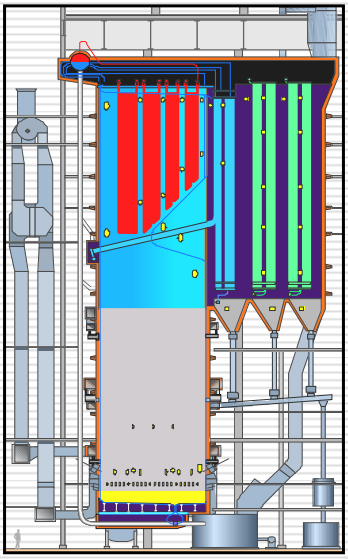
Modern Recovery Boiler



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