NEW WAYS TO SAVE CHEMICAL COSTS

- Dry
- Reduce
- Utilize
Early flame oven from late 1800 (Edling, 1981)

Early Tampella rotary furnace from about 1925
Ideas behind first recovery boilers

- All processes happen in a single vessel, drying, combustion and subsequent reactions of black liquor occur inside a cooled furnace. This is the main idea in Tomlinson's work.
- The combustion is aided by spraying the black liquor into small droplets. Spraying was used in early rotary furnaces and with some success adapted to stationary furnace by H. K. Moore.
- Controlling the char bed by having primary air level at char bed surface and more levels above. Multiple level air system was introduced by C. L. Wagner
- Smelt removal directly from the furnace through smelt spouts into a dissolving tank.
- Use of Cottrell's precipitator for dust recovery

First Tomlinson Kraft recovery boiler from Babcock & Wilcox in 1934 (Steam, 1992)
The first CE recovery boiler 1938 (Combustion Engineering, 1949)

The time was right

- Using fibers from annual plants had been superseded by production of pulp from wood
- In 1879 C.F. Dahl discovered that the addition of sodium sulfide to cooking liquor improved the pulping process and the properties of final product.
- The Kraft mill was born when 1885 the Munksjö mill in Sweden started using this process.
- Kraft mills had economic advantage as Kraft recovery boilers decreased chemical costs substantially
Two drum recovery boiler

- Main steam pressure typically 85 bar(a) and temperature 480 °C
- The maximum design solids handling capacity about 1700 tds/d.
- Three level air
- Stationary firing
- Screen
- Vertical boiler bank

Modern recovery boiler

- Main steam pressure up to 90 bar(a) and temperature 490 °C
- The maximum design solids handling capacity about 3000 tds/d.
- Multiple level air
- Single drum construction
- Vertical steam generating bank
**Current recovery boiler**

- Main steam pressure up to 13 bar(a) and temperature 520 °C
- The maximum design solids handling capacity about 5000 tds/d.
- Advanced air system
- Utility boiler features
- Reheater?

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**State of the art and current trends**

- One drum boiler with 3-part superheater and optional water screen
- Steam design data 9.2 MPa / 490 °C
- Design for high solids 80+ %DS with pressurized heavy liquor storage tank
- Liquor temperature control with flash tank, indirect liquor heaters eliminated
- CNCG and DNCG are introduced to the boiler
- Low emissions of TRS, SO₂ and particulates
- Flue gas cleaning with ESP (no scrubbers)
**Ongoing design changes**

- Higher design pressure and temperature due to increasing demands of power generation
- Superheater materials of high-grade alloys
- Further increase in black liquor solids towards 90%
- Burning of biological effluent treatment sludge
- Dissolving tank vent gases returned to the boiler
- Chloride and potassium removal from fly ash when recovering bleaching filtrates
- Many air levels for NOx control

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**Main steam temperature**

![Graph showing main steam temperature over time](image)
Virgin black liquor dry solids as a function of purchase year of the recovery boiler

Virgin black liquor capacity as a function of purchase year of the recovery boiler
Main steam pressure (design) as a function of purchase year of the recovery boiler

![Graph showing main steam pressure over time]

Gasification increases electricity generation?

Effectiveness of converting black liquor HHV into fuel value in net product gas (Grace and Timmer, 1995).

<table>
<thead>
<tr>
<th>Original HHV, MJ/kg bl</th>
<th>HHV in net gas</th>
<th>HHV in net gas</th>
<th>Commercial processes</th>
<th>HHV in net gas</th>
<th>HHV in net gas</th>
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Newest recovery plants can increase electricity generation significantly

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<th>Old</th>
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<th>Modern+</th>
<th>Utility</th>
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<td>Own consumption</td>
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<td>-500</td>
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<td>Pressure</td>
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<td>Temperature</td>
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<td>490</td>
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<td>505</td>
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<tr>
<td>Dry solids</td>
<td>65 %</td>
<td>78 %</td>
<td>85 %</td>
<td>85 %</td>
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Size of lines increases. Utility sized power production (>100 MWe).
Economics of scale means new possibilities to increase the yield of bioenergy.
New concepts for connection of recovery boiler and turbine (=utility).
Up-coming Scandinavian lines will have main steam values around 100 bar and 505 °C.
Potassium and chlorine removal equipment are needed.
Example modern Scandinavian mill produces more than 30 MWe for sale with annual pulp capacity of about 600 000 t/a.
Increase in net revenue of around 10 % can be achieved with surplus electricity, bark and wood residue sales.