Synthesis gas cooling
downstream pressurized gasification

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1. Introduction – Motivation

- Most gasification processes occur at temperatures >1400 °C
- Subsequent processes such as gas treatment, CO – shift or other reactions, require temperatures <300 °C

**Direct quench with water**
- low invest cost
- low technical risk
- dilution of target product
- loss of sensible heat

**Cooling by steam generation**
- makes use of the sensible heat and delivers a high value by–product
- key component in IGCC plants for the entire efficiency of the plant.
- increases invest cost

Distribution of coal's heating value
1. Introduction - Background of Steinmüller Engineering

- Legal successor for chemical plant components of the L&C Steinmüller GmbH
- Engineering services to Thyssen Krupp / Siemens / IHI for coal gasification projects
- Personal references on various coal gasification projects outside SE or LCS

<table>
<thead>
<tr>
<th>Plant / Location</th>
<th>Capacity</th>
<th>Year</th>
<th>Technology</th>
<th>Steinmüller scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gersteinwerk</td>
<td>350 t/d</td>
<td>1982</td>
<td>VEW</td>
<td>Gasifier Island + steam generators</td>
</tr>
<tr>
<td>Buggenum IGCC</td>
<td>235 MW\text{el}</td>
<td>1994</td>
<td>Shell</td>
<td>Water tube syngas cooler</td>
</tr>
<tr>
<td>Polk IGCC Tampa</td>
<td>250 MW\text{el}</td>
<td>1996</td>
<td>Texaco</td>
<td>Fire tube syngas cooler</td>
</tr>
<tr>
<td>Puertollano IGCC</td>
<td>300 MW\text{el}</td>
<td>1999</td>
<td>Krupp Koppers</td>
<td>Water tube syngas cooler</td>
</tr>
</tbody>
</table>

L&C Steinmüller references on large scale coal gasification projects
2. Challenges of syngas cooling in gasification process

<table>
<thead>
<tr>
<th></th>
<th>Conventional Power Station</th>
<th>Syngas from reformer</th>
<th>Coal Gasification</th>
</tr>
</thead>
<tbody>
<tr>
<td>High temperature</td>
<td>✓</td>
<td>---</td>
<td>✓</td>
</tr>
<tr>
<td>High pressure</td>
<td>---</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hazardous gas</td>
<td>---</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>High dust load</td>
<td>✓</td>
<td>---</td>
<td>✓</td>
</tr>
<tr>
<td>H₂S corrosion</td>
<td>---</td>
<td>---</td>
<td>✓</td>
</tr>
</tbody>
</table>

⇒ Pressurized gasification combines requirements from conventional power stations and waste heat boilers in chemical industry

⇒ The selection of the cooling system requires detailed know-how in thermal design as well as in mechanical design to avoid performance shortfalls.
3. Radiant Syngas Cooler - Concept

- Physical principle: Gas radiation
- Applicable for $T > 1350 \, ^\circ C$
- Lower end $T \approx 750 \, ^\circ C$
- Application directly downstream gasifier
- 2\textsuperscript{nd} cooler or quench required
- Slag collected in water pool
3. Radiant Syngas Cooler - Design

Heating surface:
Membrane wall separates syngas from pressure vessel
Radial arranged platen heating surface (panels)
3. Radiant Syngas Cooler - Performance

- Low fouling on gas side
- Low erosion
- Good thermal performance
- High material temperatures on central panel tubes
4. Convective water tube boiler - Concept

- Applicable for $T < 1000 \, ^\circ C$
- Gas / water quench required
- Integration of superheater and economizer
4. Convective water tube boiler - Design

- Forced circulation required
- Bundle consist of concentric membrane wall cylinders
- Area of inner cylinder closed
- Rapping devices installed for cleaning purposes

Bundle for BUGGENUM (L&C Steinmüller GmbH)
4. Convective water tube boiler - Performance

- Physical principle: Convection, $\alpha_{\text{gas}} \sim u^{0.7}$
- High fouling due to dust load and low velocities in cold areas
- Increased gas velocity enhances efficiency of heating surfaces significantly
- Rapping device increases performance

![Graph showing efficiency of convective heating surface vs. relative velocity $u/u_0$.]

![Graph showing temperature variation with time, indicating a fluctuation of approximately 25 K.]

Steinmüller Engineering

IHI Group
5. Convective fire tube boiler - Concept

- Applicable for $T < 1000 \, ^\circ\text{C}$
- Gas / water quench required
- Also applicable downstream Radiant Syngas Cooler (Polk Power Station Tampa)
5. Convective fire tube boiler - Design

- Natural circulation
- Shell and tube design with straight tubes
- Thin flexible tubesheet
- Refractory lining at gas inlet
- Downcomers / risers aligned to heat release

FEA analysis of tubesheet
5. Convective fire tube boiler - Performance

- Affected to fouling at low gas velocities
- Effective cleaning during shut down only
- On the run cleaning only possible by increasing velocity
  (blocking of a tubesheet segment)

Fire tube boiler downstream RSC, Polk PS, (L&C Steinmüller GmbH)
6. Conclusion – Properties of boiler types

<table>
<thead>
<tr>
<th></th>
<th>Radiant Syngas Cooler</th>
<th>Convective Water Tube</th>
<th>Convective Fire Tube</th>
</tr>
</thead>
<tbody>
<tr>
<td>High gas temperature</td>
<td>✓</td>
<td></td>
<td>---</td>
</tr>
<tr>
<td>Low fouling behavior</td>
<td>✓</td>
<td></td>
<td>--</td>
</tr>
<tr>
<td>Cleaning on the run</td>
<td>✓</td>
<td>✓</td>
<td>--</td>
</tr>
<tr>
<td>Superheater / Eco</td>
<td>---</td>
<td>✓</td>
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</tbody>
</table>

One boiler type does not cover the entire temperature range.
6. Conclusion

Syngas cooling

- collects up to 20% of the fuel’s HV
- is mandatory for resource-friendly plant operation
- has to be adapted to the specific fuel properties
- requires skilled and experienced engineering team

Steinmüller Engineering provides...

⇒ FEAture analysis on critical items

⇒ Thermal design with in-house tools

⇒ CFD for flow optimization