Retrofit von Industriekesseln zur Brennstoffänderung und NOx-Reduzierung

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Contents

• NOx formation

• In-furnace NOx reducing measures

• Application of premixed combustion

• Experiences in Stork test facility

• Conclusions
NOx formation

Fuel NOx
Formed by the conversion of chemically bound Nitrogen with the Oxygen in the combustion air.
Formation depends on N content in the fuel and availability of Oxygen

Thermal NOx
Thermal fixation of atmospheric N2 with Oxygen at high temperatures in the combustion zone.
Formation depends on the combustion air temperature

Prompt NOx
Result of Hydrocarbon radicals reacting with Nitrogen components like HCN, NH3
NOx versus fuel type

[Graph showing NOx emissions from different fuels: Gas, Oil, Coal. The graph compares Fuel NOx, Prompt NOx, and Thermal NOx.]
Techniques for in-furnace NOx reduction

- Low NOx burners
  - Fuel staging
  - Air staging

- Flue Gas Recirculation (FGR)

- Burner staging with Over Fire Air (OFA)
Air staging

1) Fuel-rich central flame
2) Mixing zone
3) Burnout zone

Integral knowledge of water-steam systems
Fuel staging

- Fuel lean primary flame (A)
- Remainder of the fuel injected into post-flame zone (B) of primary flame (A)
- Combustion products of zone (A) and internal FGR (4) dilute post flame zone (B)

1. Combustion air
2. Secondary gas
3. Primary gas
4. Flue gas
A primary combustion zone
B secondary combustion zone
Flue gas recirculation

- Consequences for burner design and boiler performance
- Very effective NOx reduction
Burner staging with over-fire air

- Burners fire under-stoichiometric (less $O_2$ than needed for complete combustion)

- Remaining air supplied at top of furnace in burnout zone

- Specially suitable for oil combustion
Presently realized NOx values

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Retrofit</th>
<th>New build</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas firing</td>
<td>Good</td>
<td>Very good</td>
</tr>
<tr>
<td>Light fuel oil</td>
<td>Very good</td>
<td>Good</td>
</tr>
<tr>
<td>Heavy fuel oil</td>
<td>Good</td>
<td>Very good</td>
</tr>
<tr>
<td>Coal</td>
<td>Very good</td>
<td>Very good</td>
</tr>
</tbody>
</table>
Experiences in Stork Test facility

• **New firing concept for Stork ‘Impulse’ burner**

• **Center burner is premixed**
  - 9MW total firing capacity of test burner
  - Up to 4MW premixed combustion possible
Advantages of premixed combustion

- Premixed flame
  - Fuel and oxidants are perfectly mixed prior to combustion
  - Flame separates products from fresh fuel-air mixture
  - Possible to eliminate thermal NOx

- Well-known and used technique in gas turbines, household heating systems

- Not yet applied in boilers
Experiences in Stork’s test facility

- New burner concept for ‘Stork Impulse burner’

- Premixing using ejectors
  - High-quality premixing
  - No low-velocity zones in premixing duct
  - Employ gas-pressure energy as extra air pump
    - Use main air fan for remaining premix air requirement

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Air

Fuel

Mixture

Ejector

Lean premix

(A)

(B)
Fuel staging with lean premix

- Primary flame (A) is now lean, premixed flame
  → No thermal NOx formation in primary flame

- Fuel staging principle has not changed

  ⇒ Very low NOx emissions of total flame

  ⇒ Total flame principle is not changed: very little consequences for furnace

  ⇒ No enhanced risk of CO emissions in contrast to other NOx reduction measures
Experiences in Stork´s test facility

Present design (6 burner installation)
Test burner (Test rig, in full operation)
Experiences in Stork´s test facility

- Down to 0.5% O2 with negligible CO
- Ultimate performance: 9mg NOx @ 3% O2
Conclusions

• In-furnace low-NOx measures can reduce NOx emissions to below 50 mg/Nm3 when firing Natural Gas

• 10 mg/Nm3 NOx is possible with in-furnace measures, by taking advantage of premixed combustion with fuel staging
  □ Proven performance in Stork test furnace

... → 10 mg/Nm3, YES at optimal conditions
Integration of burner and combustion chamber design necessary
□ But: Ultra-low NOx design starts at the burner

□ Every installation and fuel is different; Ultimate NOx reduction is every time a challenge