700°C Power Plant Technology—
Current Status and Further Challenges

S Lockyer¹ & H Tschaffon²
¹E.ON New Build & Technology Ltd
²E.ON New Build & Technology GmbH
Development of Coal Fired 700°C Power Plant

AD700 and other Projects

COMTES700

NRWPP700

E.ON-R&D

COMTES+ FP7-Projects

Demo Plant

Experience, Know-How

1998

2005 - 2011

2006 - 2010

since 2007

2011 - 2016

>2016
COMTES700 – Project Partners

<table>
<thead>
<tr>
<th>Public funding (RFCS)</th>
<th>Host plant of the CTF</th>
<th>Coordinator</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Commission</td>
<td>e.on</td>
<td>VGB</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Suppliers</th>
</tr>
</thead>
<tbody>
<tr>
<td>EWE</td>
</tr>
<tr>
<td>ALSTOM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Utilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrabel</td>
</tr>
<tr>
<td>EnBW</td>
</tr>
<tr>
<td>WARTENFALL</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDF</td>
</tr>
<tr>
<td>DONG energy</td>
</tr>
</tbody>
</table>

E.ON New Build & Technology, 2011
COMTES700 – Evaporator and Superheater

Evaporator
Superheater
Safety Valve
Turbine Valve
By-Pass Valve
Silencer

705°C
536°C
42 bar
210 bar
538°C

Evaporator, Superheater, and Safety Valve designed by Alstom.

Headers produced by Alstom and BWE.

Designed by Hitachi.

Alloy 740

700°C
A 617

H3C/TP310N
Sanicro25

< 600°C

Designed and manufactured by Alstom.
COMTES700 – Operation Time

Operation until August 2009
22,400 hours

12,850 h
T ≥ 680°C
Circumferential cracking occurred in the weld and heat affected zone.

Cracking attributed to a combination of welding residual stress, thermal shock and thermal expansion.

Ongoing R&D to develop weld and heat treatment procedures.
## Pre-Engineering Study NRWPP700

### Project data

<table>
<thead>
<tr>
<th>Coordinator</th>
<th>Project Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>VGB PowerTech</td>
<td>Steering Committee</td>
</tr>
</tbody>
</table>

### Project partners

- **PMG** Project Management Group
- **OPL** Overall Plant Layout
- **BIG** Boiler Island Group
- **TIG** Turbine Island Group
- **MIG** Material Island Group
- **CCG** Carbon Capture Group
- **EWG** Editorial Working Group

### Suppliers

- e.on Energy
- CEPA Energy
- EnBW
- VORWEG GEHEN
- EDF
- Siemens
- Alstom
- Hitachi
- Steag

---

E.ON New Build & Technology, 2011
NRWPP700 – Pre-Engineering Design of a 550MW Demonstration Plant

**Steam generator:**
- Basic design for 3 variants of Tower Boiler
- Detail design for 1 variant with cost estimation
- Scale-up from 550 MW to 1000 MW
- Transfer of results from a coal to a lignite fired power plant

**Steam turbine:**
- Detail design for 1 variant with cost estimation
- Scale-up from 550 MW to 1000 MW

**Materials:**
- Develop sourcing concept
- Execution of several material projects

**Carbon Capture:**
- Principle design of a post combustion CO₂ capture plant (Base: MEA)
NRWPP700 – Basic Design of 3 Steam Generator Variants

Alstom Power Boiler
High Pressure (350bar, 705/720°C)

Hitachi Power Europe
Reduced Pressure (250bar, 705/720°C)

Burmeister & Wain
Master Cycle (350bar, 705/720°C)

Technological and economic evaluation
(efficiency, cost, amount of Ni-base alloys, availability)
Components with Steam Temperatures over 700°C

HP / IP pipes, valves, headers, etc.

Superheater and reheater

Efficiency 600°C Technology: 45-46%

Efficiency 700°C Technology: 50%
R&D-Projects with New Materials

HP and IP Pipes:
V&M¹, VDM²,
Wyman-Gordon, Saarschmiede,…

Valves:
Hora, Sempell,
Goodwin, VA⁷, ..

Steam generator:
Design: HPE³, Alstom, BWE⁹
Tubes: SMST, Special Metals,
Sandvik, SB⁴
Also: Gülde, BGH⁵, Meerane,
Neumark

HP and IP Turbine:
Design: Alstom, Siemens
Parts: Saarschmiede, Goodwin,
Voestalpine,…

Target: Qualify more than 1
manufacturer for each component and if
possible with different production routes

Overall (examination, bend, weld):
Instituts, TÜV, EAS⁶, BHR⁷, M&M⁸, EEN,…

¹Vallourec & Mannesmann, ²ThyssenKruppVDM, ³Hitachi Power Europe, ⁴Schöller-Bleckmann, ⁵Boschgotthardshütte,
⁶E.ON Anlagenservice, ⁷Bilfinger Hochdruck Rohrleitungsbau, ⁸Müller & Medenbach, ⁹Voestalpine & Burmeister & Wain Energy
Material selection in Steam Generator

Membrane wall

13CrMo4-5
7CrMoVTiB10-10

Alloy617 or T92

Contact heating zone

13CrMo4-5

16Mo3
13CrMo4-5
10CrMo9-10
X20CrMoV11-1

Super304H
HR3C / DMV310N
Sanicro25

Alloy617
Sanicro25

Sanicro25

A740 or Alloy617

Sanicro25

Alloy617

Alloy617 or T92

7CrMoVTiB10-10
Material selection in Steam Generator

Membrane wall

Contact heating zone

Well known materials

13CrMo4-5
7CrMoVTiB10-10

Alloy617 or T92

A lot of projects are underway or have finished
# 700°C Technology – Technical Challenges

<table>
<thead>
<tr>
<th>Supply of materials for further processing:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemistry:</strong> Purity of materials (use of scrap?)</td>
</tr>
<tr>
<td><strong>Sort of melting and remelting process:</strong> VIM, VOD, ESR, VAR</td>
</tr>
<tr>
<td><strong>Block size:</strong> Homogenity, grain size</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Processing:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Forging, pipe manufacturing:</strong> Forming, temperature, heat treatment</td>
</tr>
<tr>
<td><strong>Mechanical treatment:</strong> Hardness, selection of tools</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Welding:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Procedures:</strong> Hand/automated, wire size, velocity, temperature</td>
</tr>
<tr>
<td><strong>Filler metal:</strong> Chemistry (different from base metal?), amount</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Examination:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NDE:</strong> PT (surface); UT, X-ray, linear accelerator (volume)</td>
</tr>
</tbody>
</table>

VOD: Vacuum-Oxygen-Decarburization; ESR: Electro-Slag-Remelting; VIM: Vacuum-Induction-Melting; VAR: Vacuum-Arc-Remelting
A617 Influence of Boron content

**Boron-Content:**
- A617: 0 ppm
- A617B: 20-50 ppm

- **Base material:** Boron increases creep strength and improves hot ductility.
- **Welds:** Weldability becomes a bigger challenge with increasing boron content.

Source: TÜV Rheinland

Source: Husemann, Klöwer, Bader
A617B – Heat Treatment at 980°C for 3 hours (1)

**Target:** Avoid cracks in welds

**Application:** Welds in thick walled pipes and form parts

**Background:**
- Reduction of residual stress in the weld and heat affected zone
  Reason: Tensile strength at 980°C $\ll$ tensile strength at 700°C
- Re-resolution of $\gamma'$

![Graph showing temperature vs. time for heat treatment](image)

![Micrograph showing weld material and base material](image)
A617B – Heat Treatment at 980°C for 3 hours (2)

Crack behaviour of aged material:

[Images showing intergranular cracking]

Crack behaviour with modified heat treatment (980°C, 3 h):

[Images showing virtually no cracking]
A617B – Influence of Carbon

**Challenge:** Solidification cracking in heat affected zone at carbon segregations

**Normal carbon content in A617B:** 0.05 – 0.08 %

**Possible measures to reduce carbon segregation:**
- Modification of chemical composition
  - Reduce C content → Influence on creep data?
  - Reduce impurity levels by changing from VIM/ESR to VIM/VAR → Cost
- Influence of solution temperature (allowed range: 1160 – 1190°C)
  - Increasing solution temperature reduces carbon segregation, but → a full re-solution is not possible
  - → negative influence on grain size

Source: Husemann
700°C Technology – Challenges

Investment Cost
- Must take account of increased efficiency
- Carbon capture and storage

Operational Risk
- Must be at same level as conventional coal plant
- Must be capable of flexible operation

Therefore additional R&D required into
- Design, construction and operation of components especially thick walled
- Development and Qualification of production routes and components
- Through life management inc. weld repair, life assessment procedures, etc.
- Dynamic behaviour of components, i.e. Flexible operation
700°C Technology – Further Investigations

Necessary R&D for Nickel base alloys for 700°C power plant

• Lifetime consumption data depending on load change (ramps, time for start-ups), i.e. Flexible Operation
  → HWT II
• Development, test and qualification of cost optimised production routes (e.g. HIP)
  → ENCIO
• Production, welding and testing of thick walled cast and forged components
  → ENCIO, HWT II, MACPLUS, NEXTGENPOWER
• Optimisation of Nickel base alloys (chemical composition, heat treatment, ..)
  → ENCIO, MACPLUS
• Corrosion and oxidation behaviour (oxyfuel, air fired)
  → MACPLUS, NEXTGENPOWER
700°C Technology – Current Status

- Nickel base alloys are, in principle, suitable for 700°C power plant technology.
- Valuable operational experience with Nickel base alloys was gained with COMTES700.
- Very thick walled components have been manufactured from Nickel base alloys (cast and forged) produced. → No operational experience.
- Engineering design for a demonstration plant completed.
- Need to understand effects of flexible operation.
- Cost reduction with new manufacturing routes is necessary.

700°C technology is nearly fit for application
Many thanks for your attention