Status of VGB high temperature projects

Dr. Herbert Urban
VGB PowerTech e.V., Essen, Germany
General Assembly

Scientific Advisory Board  |  Board of Directors  |  Technical Advisory Board

Executive Managing Director

Competence Centres for Heat and Power Generation

- Nuclear Power Plants
- Power Plant Technologies
- Renewables and Distributed Generation
- Environmental Technology, Chemistry, Safety and Health
- Operational Services

Teams

- Research
- IT
- Marketing
- Administration

VGB Committees
**VGB Power Tech Committees**

### Nuclear Power Plants
- GC: Nuclear Power Plants
  - SC: Plant Engineering
  - WP: Nuclear Engineering Standards
- TC: Nuclear Power Plant Operation
  - WP: PWR
  - WP: BWR
  - WP: Practical Radiation Protection
  - WP: Nuclear Engineering Training
  - WP: Maintenance Manager Workshop
  - WP: Nuclear Safety Officers and Human Factors
  - WP: Crisis Staff Coordinators
- TC: Nuclear Fuel Cycle
  - WP: Waste Management
  - WP: Cask Handling and Storage
  - WP: Safeguards
  - WP: Decommissioning

### Power Plant Technologies
- GC: Combustion Power Plants
- TC: Power Plant Concepts
- SC: Hydro Power
- TC: Steam Generation Plants
  - WP: Steam Generators
  - WP: Fuel Technology/Firing Systems
  - WP: Fluidised Bed Firing Systems
  - WP: Thermal Waste Utilisation
  - WP: Industrial and Cogeneration Stations
- TC: Machines
- SC: Emax Technology
- SC: Emax CCS

### Renewables, Distributed Generation
- SC: Hydro Power
- TC: Hydro Power Plants
- ETC: Use of Renewables and Distributed Generation
  - EWT: Wind Energy
  - EWB: Biomass
  - EWB: Biogas

### Environmental Technology, Chemistry, Safety and Health
- GC: Environmental Technology, Chemistry, Safety and Health
  - TC: Emissions/Immissions
  - TC: Noise Control
  - TC: Operational Water Management
  - TC: Power Plant Byproducts
  - TC: By-products of Waste Incineration
  - TC: Chemistry
    - WP: Chemistry of Water Treatment
    - WP: Chemistry of Flue Gas Cleaning Plants
    - WP: Analytics
    - WP: PWR Chemistry
    - WP: BWR Chemistry
  - ETC: Health and Safety (Coordination)
  - EWG: Fire Protection
  - EWG: Safety & Health at Work
  - EWG: Industrial and Environmental Medicine/Health Management
  - WP: Medical Scientists in Nuclear Power Plants
  - EWG: Environment
    - EWG: Emissions Monitoring
    - EWG: EPRTR
    - EWG: Safety & Health at Work
    - EWG: EGHSE for Offshore Wind Parks
  - TC: Chemistry
  - IC: Climate Protection
  - IC: Immission Control
  - IC: Licensing
  - IC: Water and Soil Conservation
  - IC: Waste and Byproducts
  - IC: Dangerous Goods/Hazardous Materials

---

In more than 90 Committees about 1,600 experts meet regularly for Information Exchange on all technical Power Plant Issues.
- Introduction
- Research Activities 700°C/720°C Technology in Europe
  - COMTES700
  - HWT II
  - ENCIO
  \[ \text{Comtes+} \]
- Summary
CO₂ Reduction Potential

Average worldwide

30%
1.116 g CO₂/kWh
480 g Coal/kWh

EU

38%
881 g CO₂/kWh
379 g Coal/kWh

State-of-the-art Technology

45%
743 g CO₂/kWh
320 g Coal/kWh

Steam Power Plant
700°C-Technology

rd. 50%
669 g CO₂/kWh
288 g Coal/kWh

CCS-Technology

But: Efficiency Losses 7%-12%

1) Average data for hard coal fired power plants
Measures for Efficiency Enhancement for hard coal fired PP

Increasing pressure and temperature can enhance efficiency by 3%
Introduction

Research Activities 700°C/720°C Technology in Europe

- COMTES700
- HWT II
- ENCIO

Comtes+

Summary
700°C Research Activities in Europe

600°C Power Plant ~ 46%

Esbjerg Test Rig ............... 720°C
COMTES700 Test Facility .... 700°C

725 HWT GKM I - Test Rig.... 725°C

NextGenPower .......................... Material Test
MACPLUS ................................. Material Test

725 HWT GKM II Test Rig ...... 725°C
ENCIO Test Rig ........................ COMTES+

700°C Power Plant ≥ 50% .......................... Expected operation beyond 2020

700°C Power Plant ≥ 50% .......................... Expected operation beyond 2020
- Introduction

- **Research Activities 700°C/720°C Technology in Europe**
  - COMTES700
    - HWT II
    - ENCIO
  - Comtes+

- Summary
COMTES700 Component Test Facility for a 700°C Power Plant
The COMTES700-project was financed by industrial and public funds. The project receives funding from the European Community's Research Fund for Coal and Steel (RFCS)

**Project Budget: 26.1 m €**

- 23% - (EC) RFCS 6.1 m €
- 4% - Industrial Partners 0.9 m €
- 73% - Generators 19.1 m €

**Generators**
- DONG Energy
- E.ON
- EdF
- Electrabel
- EnBW
- Enel
- PPC
- RWE
- Vattenfall Europe
- Vattenfall Nordic
- EVN
- Evonik Energie
- GKM

**Industrial Partners**
- Alstom
- BWE
- HPE
- Siemens

**Co-ordination VGB**
Objectives

- Manufacturing, bending and welding of the components in real plant dimensions for a power plant with efficiency higher than 50%,

- Operational behaviour of all components especially operational testing of Ni-based alloys for tubes, pipes and valves,

- Flue gas corrosion and steam oxidation behaviour of the materials and erosion effects due to sootblowing,

- Operation started in summer 2005

- Approximately min. 20,000 operation hours, end of operation 2011
Implementation in host boiler

Host Plant - Scholven F, Germany, E.ON

- **Net output**
  - 676 MW

- **Live-steam**
  - 220 bar
  - 540 °C
  - 2,250 t/h

- **Reheater-steam**
  - 44 bar
  - 540 °C
  - 2,044 t/h

- **Fuel**
  - Hard coal

Flow scheme of COMTES700

Aerial view of Scholven
Materials in membrane wall and superheater

Membrane Wall (33.7 x 7.1 mm)

- 44 parallel tubes
- 8,800 mm
- 13 CrMo44

Superheater 1 & 2 (44.5 x 10 mm)

- Bank 1:
  - 7 CrMoVTiB 10 10/T24
  - P 92
  - Alloy 617 (2 Tubes)
  - Sanicro 25 (16 Tubes)
  - Protection tube against sootblower erosion

- Bank 2:
  - Alloy 617 (8 Tubes)
  - HR3C (8 Tubes)
  - DMV310N (8 Tubes)
Reasons for damages: Mainly stress relaxation cracking in weld seam through residual stress, high heat input and high hardness

⇒ Development of a repair concept for Alloy 617 is necessary
Results

- All three tested materials of the **membrane wall** (T24, HCM12, Alloy 617B), erected without Post-weld heat treatment (PWHT), have shown failings. Further tests of materials for membrane walls are needed.

- The austenitic **superheater** material performed reasonable. Alloy 740 showed internal oxidation along grain boundaries and Alloy 617 showed local corrosion rates resulting in life estimation lower than 200,000 h.

- Post-weld heat treatment is mandatory for **thick-walled** weld sections due to stress relaxation cracking. Developed repair technologies must be tested.

- **Non-destructive testing (NDT)** has to be developed further. Thermal stress have to be avoided as well two-phase flow.

- **Valves** showed in general good results.

---

**Open issues from COMTES700 to use as input for COMTES+:**
- Continuation of further material tests for membrane walls
- Developing and testing of repair technologies
- Developing of Non-destructive testing (NDT)
➤ Introduction

➤ Research Activities 700°C/720°C Technology in Europe

➤ COMTES700

➤ HWT II

➤ ENCIO

➤ Summary

Comtes+
COMTES+ umbrella for HWT II and ENCIO

**COMTES+ Overall Budget**

<table>
<thead>
<tr>
<th></th>
<th>Amount (Mio €)</th>
<th>Funding Percentage</th>
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<tbody>
<tr>
<td>ENCIO</td>
<td>23,3</td>
<td>58% Generators</td>
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<tr>
<td>HWT II</td>
<td>17,6</td>
<td>30% Generators</td>
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<tr>
<td>Risk Fund</td>
<td>2,6</td>
<td>control of COMTES+</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>43,5</strong></td>
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</table>

**Involved Parties of COMTES+**

1) CEZ a.s. *
2) EDF Electricité de France *
3) EnBW Kraftwerke AG *
4) ENEL Produzione S.p.A. *
5) E.ON New Build & Technologie GmbH *
6) ESKOM Holdings SOC Ltd. *
7) EVN AG *
8) STEAG GmbH *
9) GDF Suez *
10) GKM Großkraftwerk Mannheim AG *
11) RWE Power AG *
12) Vattenfall AB *
13) Vattenfall Europe Generation AG *
14) ENEL Ingegneria e Innovazione S.p.A. 
15) VGB PowerTech e.V. – Coordinator

**Focus on Ni-Based Materials**

- **Scientific Approach:** Validation of the material and component behaviour supported by computer modelling
- **Test start from ~ 2012**
- **Location:** GKM / Germany
- **Funded by BMWi (PTJ)**
- **29 Partners**

**Focus on Ni-Based Components**

- **Pragmatic Approach:** Investigations for qualification of components, suppliers and repair concept
- **Test start from ~ 2013**
- **Location:** Fusina / Italy
- **Funded by RFCS**
- **26 Partners**

---

*Note: The asterisks (*) indicate the status or role of the partners.*
“Examination of In-Service and Damage Behaviour of Thick-Walled Components for High Efficient Power Plants“

HWT II
Objectives

- Impact of **non stationary load** (thermal flexibility, fatigue) on base metal and weld on thick-walled components up to 50 mm at **725°C Steam**, 
- Development of Ni-base control **valves** - Design, Optimization of gaskets, Coatings and material compounds,
- Basic examinations at probes of **thick-walled components**,
- **Optimization of design calculation** of thick-walled austenitic components under operational conditions,
- Influence of **welding conditions** and **heat treatment** on crack sensibility, determination of internal stresses,
- **Metallurgical description** of crack initiation and growth mechanism,
Facility in GKM

Unit 6, boiler 17
Flow Chart HWT II

1. Pipe + bend + weld
   Prim. Stresses from inner pressure
   Sec. cycl. Stresses from hangers
   **Steam extraction**
   530 °C
   2.5 kg/s from BÜ 4

2. Pipe + weld
   Prim. Stress from inner pressure
   Therm. gradient from simul. start-up and shut-down (injection ΔT ≈ 300 °C steam)
   **PRDS* functionality**
   D_a = 219.1 x 50 mm
   Thick walled pipe „Cyclic Load“

3. HT-conditioning valves
   Design, reliable longtime operation
   Mass flow control
   Set to 725°C/162 bar
   KZÜ steam < 400 °C

4. PRDS* functionality
   530°C, 170 bar
   Bypass with PRDS*

5. Bypass
   Hangers, insulation

Combustion chamber
1200°C „Superheater Pipes“

* Pressure Reducing Desuperheating
Arrangement of Components in Unit 6

Key Components:
- High-Pressure Steam Conditioning Valve by E.ON
- Pipe Bend (static load)
- Injection Valves (Steam / Feedwater)
- 725°C Header
- 725°C Superheater in BÜ 4

- Thick Walled Test Track (cyclic load)
- High Temperature Pressure Conditioning Valves
# 725 HWT II – Time Schedule

Successfully executed on 1st of October

<table>
<thead>
<tr>
<th>Workpackages</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
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<td>1 2 3 4</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
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<tr>
<td>WP 1: Planning and erection of test rig</td>
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<tr>
<td>WP 2: Set into operation and test operation</td>
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<tr>
<td>WP 3: Test rig operation</td>
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<tr>
<td>WP 4: Material qualification and characterisation</td>
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<tr>
<td>WP 4.1: Lab tests</td>
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<td>WP 4.2: Identification and description of damage mechanisms</td>
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<tr>
<td>WP 4.3: Numerical calculation of stress/strain and damage</td>
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<td></td>
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<tr>
<td>WP 5: Monitoring and optimization concepts</td>
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<tr>
<td>WP 6: Project coordination and reporting</td>
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</tbody>
</table>
Project Partners of Research Group HWT II

Kraftanlagen München

Babcock Borsig Steinmüller

MVV Energie

e.on

Wrede & Niedecken

Bopp & Reuther Gruppe

MVV Energie

EagleBurgmann

Bundesministerium für Wirtschaft und Technologie

Schweiztechnische Lehr- und Versuchsanstalt Mannheim GmbH

Fraunhofer IWM

IKD Instut für Kraftwerkstechnik, Dampf- und Gasturbinen

Welland & Tuxhorn AG Armaturen- und Maschinenfabrik

VGB PowerTech e.V. | H. Urban | Slide 25
Introduction

Research Activities 700°C/720°C Technology in Europe

- COMTES700
- HWT II
- ENCIO

Comtes+

Summary
Successful deployment of 700°C technology
Objectives

- Provide proof of design and material behavior of **thick-walled components** (<140mm) under real operating conditions

- Solve main technical open items derived out of the comprehensive analysis of COMTES700 (**Repair technologies**),

- Test **new developed materials** and **manufacturing options** (e.g. post weld heat treatments) to improve the reliability of weldments made out of Ni-based alloys,

- Develop a **life-time** monitoring concept for pipes made out of Ni-based alloys,

- Explore materials and manufacturing options having the potential to reduce the investment cost of 700°C technology and improve the **load change behavior**, 

- Verify the technical conditions for achieving **high efficiency** and better environmental figures (lower emissions).
Unit 4 of “Andrea Palladio” Power Station located in Fusina (Italy); operated and owned by ENEL

Technical Data of the HostPlant

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Data</th>
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<tbody>
<tr>
<td>Boiler type:</td>
<td>two pass boiler</td>
</tr>
<tr>
<td>Burner configuration:</td>
<td>tangential</td>
</tr>
<tr>
<td>Steam capacity:</td>
<td>1.050 t/h</td>
</tr>
<tr>
<td>Production capacity:</td>
<td>320 MWe</td>
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<tr>
<td>Fuel:</td>
<td>hard coal + RDF (Residual Derived Fuel)</td>
</tr>
<tr>
<td>Superheater steam temperature:</td>
<td>540 °C</td>
</tr>
<tr>
<td>Superheater steam pressure:</td>
<td>177 bar</td>
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</table>
### Technical Concept

#### P&I Diagramm

![P&I Diagramm](image)

#### 3D-View of the Test Facility

![3D-View](image)

<table>
<thead>
<tr>
<th>Test Loop</th>
<th>Scope</th>
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<tbody>
<tr>
<td>TL1</td>
<td>Development of pipe repair concept</td>
</tr>
<tr>
<td>TL2</td>
<td>Test of Hot Isostatic Pressing (HIP) parts and weldments as well as life-time monitoring</td>
</tr>
<tr>
<td>TL3</td>
<td>Test of different Ni-based alloys and weldments</td>
</tr>
<tr>
<td>TL4</td>
<td>Test of turbine cast material and weldments</td>
</tr>
</tbody>
</table>
Organisation and Funding

The ENCIO-project will be financed by industrial and public funds. The project receives funding from the European Community's Research Fund for Coal and Steel (RFCS) under grant agreement n° RFCPCT-2011-00003.

The ENCIO started on 1 July 2011.

The overall project duration is six years (72 months), to allow enough operating hours, as well as related data collection, investigations and evaluation of results.
The leading ENCIO partners are:

The ENCIO partnership comprises the following companies, which are co-funding and supporting the project:
- Introduction
- Research Activities 700°C/720°C Technology in Europe
  - COMTES700
  - HWT II
  - ENCIO
- Summary
Summary

**Today**

**600/620°C Power Plant Concepts**
- Reference efficiency > 45%
- Material concept realized
- High production requirements especially on site
- Intensive quality checks
- Investment ~ 1.200 €/kW

**Tomorrow**

**700/720°C Power Plant Concepts**
- Reference efficiency > 50%
- Material concept under develop.
- High specific costs for Ni alloys.
- High machinery time
- Further material development and component tests necessary
- Investment >> 1.200 €/kW

---

**Material mix in modern power plants**

- **250 bar / 540°C / 560°C**
  - Ferrite/Martensite 100%

- **280 bar / 600°C / 620°C**
  - Ferrite/Martensite 80%
  - Austenite 20%

- **360 bar / 700°C / 720°C**
  - Ferrite/Martensite 56%
  - Ni-Basis 29%
  - Austenite 15%
Thank you for your attention!

Web page: www.vgb.org

E-mail address: herbert.urban@vgb.org
Back-up 1
Source: World Coal Institute: Coal meeting the climate challenge
VGB offers a neutral platform for joint research of the member companies.

R&D-projects are steered by the experts organised in the VGB Committees.

VGB Committees define the need for research in the respective fields of activity and supervise the project and the transfer of results.

About 90% of the R&D projects are relevant for all member companies.