Application of Martensitic Steels in Power Plants – Qualification, Standardization, Quality Assurance, Experience and Operational Safety

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Application of Martensitic Steels in Power Plants – Qualification, Standardization, QA/QC, Experience and Operational Safety

Introduction – Why do we need martensitic materials? Candidates?

Application of Martensitic Steels in Power Plants
  ➤ Standardization (Europe/VGB)
  ➤ Challenges and Requirements

Introduction to the 912 MW unit RDK8
  ➤ Specifications (Components, Materials)
  ➤ QA/QC
  ➤ Experience and Operational Safety

Summary/Conclusions

Source: EnBW AG
Introduction –

Why do we need martensitic materials?

Candidates?
Martensitic Steels in Power Plants

Introduction - Why do we need martensitic materials?

- **CO₂-reduction** (Business €€€)
- **Higher efficiency**
- **Higher steam parameters**
- **New materials**

Source: GE (Alstom)
Increases in steam temperatures require the transition from previously proven to newly developed high-temperature resistant materials (or in other words: martensitic materials).
Martensitic Steels in Power Plants
Introduction – Why do we need martensitic materials?

Example for dimension comparison X20 vs. P91

Source: MPA Stuttgart

Advantages:
› Reduction of wall thickness ↓
› Reduction of weight ↓
› Reduction of material costs ↓
› Increase of temperature gradients ↑
› Increase of flexibilization ↑

Design parameters: 300 bar / 585 °C

MPA-Seminar 2019 · 01. October 2019 · EnBW AG, T-BTW: Martensitic Steels in Power Plants
Martensitic Steels in Power Plants
Introduction – Candidates? Material Development 9-11% Cr Steel

10^5h Creep Rupture Strength at 600°C

35MPa

- 2.25Cr-1Mo
- 9Cr-1Mo
- 12Cr AISI 410

60MPa

- 2.25Cr-1MoV
- 9Cr-2Mo
- 9Cr-1MoVNb
- 12Cr-0.5Mo

100MPa

- 2.25Cr-1.6MoVNb
- HCM2S (ASME T23 STBA24J1)

130MPa

- 2.4Cr-1MoVTi
- T24

150MPa

(Under Development)

- 9Cr-1MoVNbB
- EM12 (NFA 49213)
- HB91 (DIN X20CrMoV121)
- HT9 (DIN X20CrMoV121)

Source: Maile MPA 1999, after Masyama

New-built projects of USC power plants (Western EU) employing grade 92

<table>
<thead>
<tr>
<th>Operator</th>
<th>Plant</th>
<th>[MW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>EnBW</td>
<td>RDK 8</td>
<td>1 x 900</td>
</tr>
<tr>
<td>ENGIE</td>
<td>Rotterdam</td>
<td>1 x 800</td>
</tr>
<tr>
<td>ENGIE</td>
<td>Wilhelmshaven</td>
<td>1 x 800</td>
</tr>
<tr>
<td>GKM</td>
<td>GKM 9</td>
<td>1 x 900</td>
</tr>
<tr>
<td>LEAG</td>
<td>Boxberg Block R</td>
<td>1 x 675</td>
</tr>
<tr>
<td>RWE</td>
<td>Eemshaven A+B</td>
<td>2 x 800</td>
</tr>
<tr>
<td>RWE</td>
<td>Neurath F+G</td>
<td>2 x 1100</td>
</tr>
<tr>
<td>RWE</td>
<td>Westfalen E</td>
<td>1 x 800</td>
</tr>
<tr>
<td>STEAG/EVN</td>
<td>Walsum 10</td>
<td>1 x 750</td>
</tr>
<tr>
<td>Uniper</td>
<td>Datteln 4</td>
<td>1 x 1100</td>
</tr>
<tr>
<td>Uniper</td>
<td>Maasvlakte 3</td>
<td>1 x 1100</td>
</tr>
<tr>
<td>Vattenfall</td>
<td>Moorburg A+B</td>
<td>2 x 820</td>
</tr>
<tr>
<td>CEZ</td>
<td>Ledvice</td>
<td>1 x 660</td>
</tr>
</tbody>
</table>

13 sites, 16 units
installed capacity of approx. 14 GW
# Martensitic Steels in Power Plants


<table>
<thead>
<tr>
<th>Unit</th>
<th>HKW 1</th>
<th>HKW 2</th>
<th>RDK 8</th>
<th>700 °C Power Plant [proposal from manufacturer]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commission date [COD]</td>
<td>1985</td>
<td>1997</td>
<td>2014</td>
<td>-</td>
</tr>
<tr>
<td>Gross capacity [MWel]</td>
<td>420</td>
<td>380</td>
<td>912</td>
<td>-</td>
</tr>
<tr>
<td>Net efficiency factor (el)</td>
<td>39%</td>
<td>42%</td>
<td>&gt;46%</td>
<td>&gt;50%</td>
</tr>
<tr>
<td>Steam parameters HP/Reheat [boiler outlet]</td>
<td>540 / 540 °C 196 / 40 bar</td>
<td>545 / 568 °C 249 / 59 bar</td>
<td>603 / 621 °C 285 / 59 bar</td>
<td>700 / 720 °C 350 / 70 bar</td>
</tr>
</tbody>
</table>
Martensitic Steels in Power Plants
RDK 8 – Influence of Efficiency Improving Measures

The application of optimized technology and the benefit of site conditions (cooling water from river rhine and district heating) are the supposition for the high efficency of RDK 8.

Most influence for the complete improvement come from the use of new materials!
Application of Martensitic Steels in Power Plants

- Standardization (Europe/VGB)
- Challenges & Requirements to components/materials
# Martensitic Steels in Power Plants Standardization (Europe/VGB)

## PED (Modul G)

<table>
<thead>
<tr>
<th>EN12952</th>
<th>EN 13445/AD2000</th>
<th>EN 13445</th>
</tr>
</thead>
<tbody>
<tr>
<td>VGB-Standards, FDBR-Guidelines</td>
<td>e.g. VGB-S-013 (boiler)</td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td>e.g. EN 10216-2 (seamless tubes/pipes), EN 10222 (forgings), EN 10273 (bars), EN 10028 (flar products)</td>
<td></td>
</tr>
<tr>
<td>VGB-S-109 and VdTÜV Material Sheets (e.g. 511, 552, 560)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Put into service

- Example P91 header
- Min Requirements: PED (Modul G) + EN12952 + EN10216-2
- Contract extensions: + VGB-S-109 + VdTÜV 511

## Operation

- BetrSichV
- TRBSen
- VGB-S-506 and EN 12952-4
Martensitic Steels in Power Plants
Standardization (Europe/VGB)


Structure

1. Abbreviations
2. Terminology
3. Field of application
4. Basis of the material acceptance
5. Requirements on the Material Manufacturers or Suppliers
6. Requirements on the materials for pressure equipment
7. Further processing within the component Manufacturer
8. Test activities within the material Inspection
9. Occurrences, deviations
10. Order placed with the Material Manufacturers or Suppliers
11. Additional regulations
12. Castings
13. List of material data sheet
   13.1 til 13.12 separately shown materials
14. Requirements on filler material

http://www.vgb.org

Ongoing activity:
A working group at the association VGB is still in the process of establishing a standard for the application of martensitic steels

Working title:
"Martensitic materials – guideline for design, manufacture and safety concept"
**List of material data sheet:**
- 15NiCuMoNb5-6-4 (WB36)
- 7CrMoVTiB10-10 (T24)
- X20CrMoV11-1 (X20)
- X10CrMoVNb9-1 (T/P91)
- X11CrMoVNb9-1-1 (E911)
- X10CrWMoVNb9-2 (P/T92)
- VM12-SHC
- X3CrNiMoBN17-13-3
- Super 304 H or DMV 304 H Cu
- TP 347 HFG or DMV 347 HFG
- HR 3 C or DMV 310 N
- NiCr23Co12Mo mod. (Alloy 617 mod.)

**Following topics were considered:**
- material expert opinion (PMA)
- manufacturing processes, quenching and tempering treatment
- heat analysis, parts analysis
- mechanical-technological properties
- microstructure verification
- hardness testing, surface examinations
- acceptance test certificates

**Topic: Requirements for separately listed materials respectively types of products which exceed the applicable standards**

E.g. P91 (extract of requirements only):

- **Chemical composition:**
  - Al <= 0.03, S <= 0.006%, N 0.04 – 0.06%, Cu <= 0.3%, P<=0.020% (forgings)

- **Austenitizing temperature:** >=1050°C

- **Charpy notch test with 41/68J** (transvers/longitudinal direction)

- **Hardness 200-260 HV10**

- ...
Martensitic Steels in Power Plants
Standardization (Europe/VGB)


Topic: Order
Requirements for not separately listed materials
Martensitic Steels in Power Plants
Example headers, pipework, fittings

Challenges/requirements to materials/components:
› Workability of high wall thickness
› High mechanical strength/creep rupture strength
› Ductility
› Oxidation resistance

Usual dimensions, design of components:
› Outer diameter øD 300...700 mm
› Wall thickness Wd 40...105 mm
› Design pressure 70 (RH), 300 (SH) up to 350 bar (ECO),
› Design temperature 400 (ECO) up to 620 (SH), 650°C (RH)

Safety issues must be taken into account!
Martensitic Steels in Power Plants
Example heating surfaces

Challenges/requirements to materials/components:
- Sufficient mechanical strength/creep rupture strenght
- Corrosion (flue gas side) and oxidation resistance (steam side)

Usual dimensions, design of components:
- Outer diameter äD 31,8...44.5 mm
- Wall thickness Wd 5.6...8.8 mm (supporting pipes up to 10 mm)
- Design pressure 70 (RH), 300 (SH) up to 350 bar (ECO),
- Design temperature 400 (ECO) up to 660(Ü), 700°C (ZÜ)

No operational safety issues!
Damage tolerant systems, only relevant for availability [business].
Quality problems
- Heat treatment errors due to lack of experience with martensitic steels
- HRSG in CCGT plants particularly affected different quality tradition
- Heat treatment after hot bending
- On site heat treatment of welds

Type IV cracking damage evolution
- Replacement headers in UK particularly affected (high Al materials
- Welded bends in Japan, and other places have leaked
- Creep damage evolution in martensitic steels different to low alloy steels

Reduction of allowable stresses
ECCC: Minor strength reduction of 8-10% for both steels based on more available longterm data; Current new assessment:

- ASME (Grade 91): 10-15% reduction of allowable stresses;
- Japan (Grade 91): Reduction based on poor long-term creep (tube/plate). Pipe data more stable;
- China: National data indicate better stability.

**P91 and P92 – Previous ECCC evaluations**, ECCC WG3A (Source: J. Hald/ECCC WG3A Convenor)

- P91: 1995 and 2008
- P92: 1999 and 2005

Validated extrapolations to 200,000 hours for P91 and 100,000 hours for P92 at application temperatures -> Basis for EN standards
P91 – **New ECCC assessment**, ECCC WG3A *(Source: J. Hald/ECCC WG3A Convenor)*

- Data from multiple sources worldwide (Europe, Japan (NIMS and others), US);
- Significant increase of long-term data since 2009:
  - 2009: 125 tests (broken and unbroken) with durations >30,000 hours, 3 tests broken with durations >100,000 hours,
  - 2017: 304 tests (broken and unbroken) with durations >30,000 hours, 15 tests broken and 16 unbroken with durations >100,000 hours;

Reduction of 5-10% as compared to ECCC datasheet!
P92 – **New ECCC assessment**, ECCC WG3A  *(Source: J. Hald/ECCC WG3A Convenor)*

- Global data collation 2017 (10M testing hours, 7 tests > 100 kh);
- Preliminary assessments show similar strength values as for the 2005 assessment;
- ePATs carried out on new database with old model equation -> result: passed
  *(ePAT = electronic post assessment tests: Predicted rupture times compared with measured times both for complete dataset, for most tested temperatures and for individual heats. Only limited deviations are allowed to pass the test)*

<table>
<thead>
<tr>
<th>Temps</th>
<th>10,000h</th>
<th>200,000h</th>
<th>250,000h</th>
</tr>
</thead>
<tbody>
<tr>
<td>520°C</td>
<td>272*</td>
<td>255*</td>
<td>235*</td>
</tr>
<tr>
<td>530°C</td>
<td>256</td>
<td>238</td>
<td>218</td>
</tr>
<tr>
<td>540°C</td>
<td>240</td>
<td>222</td>
<td>202</td>
</tr>
<tr>
<td>550°C</td>
<td>225</td>
<td>207</td>
<td>187</td>
</tr>
<tr>
<td>560°C</td>
<td>210</td>
<td>192</td>
<td>172</td>
</tr>
<tr>
<td>570°C</td>
<td>195</td>
<td>177</td>
<td>157</td>
</tr>
<tr>
<td>580°C</td>
<td>181</td>
<td>163</td>
<td>142</td>
</tr>
<tr>
<td>590°C</td>
<td>167</td>
<td>148</td>
<td>127</td>
</tr>
<tr>
<td>600°C</td>
<td>153</td>
<td>134</td>
<td>113</td>
</tr>
<tr>
<td>610°C</td>
<td>139</td>
<td>121</td>
<td>100</td>
</tr>
<tr>
<td>620°C</td>
<td>126</td>
<td>107</td>
<td>87</td>
</tr>
<tr>
<td>630°C</td>
<td>113</td>
<td>95</td>
<td>75</td>
</tr>
<tr>
<td>640°C</td>
<td>100</td>
<td>83</td>
<td>65</td>
</tr>
<tr>
<td>650°C</td>
<td>88</td>
<td>72</td>
<td>56</td>
</tr>
</tbody>
</table>

**Analysis of Grade 92 indicate more stable behavior; ECCC provisional data sheet for steel92 in 2018:**
- ✔ Strength values from 2005!
- ✔ Data extrapolations to 200,000 hours at 580-650°C allowed!
Introduction to the 912 MW unit

- Specifications (Components/Materials)
- QA/QC
- Experience and Operational Safety
Martensitic Steels in Power Plants
Introduction - USC Power Plant RDK8

| Source: GE (former: Alstom)/EnBW |

Gross capacity: 919 MW_{el}
District heating: max. 220 MW_{th}
Fuel: Hard coal
Net efficiency factor (electr.): > 46%

Steam parameters [HP/reheat]: 600/620 °C; 275/58,4 bar [turbine inlet]
COD: 2014

Material concept:

- T24 (7CrMoVTiB10-10) for membrane wall (evaporator, superheater 1 stage)
- P92 (X10CrMoVNb9-2) for HP steam line and reheat line

Source: GE (former: Alstom)/EnBW
Martensitic Steels in Power Plants
QA/QC @EnBW AG - Skills/Fields of Competence & References

- Regulations, codes and standards, materials technology
- Welding technology, (Welding engineers IWE, EWE)
- Destructive and Non-destructive Testing (NDT Level 2 für RT, MT, UT und VT)
- QA/QC techniques, damage analysis, project management
- Calculation /Design of components [PED]
- Lifetime calculation, fracture mechanics, FEM
- Networking/VGB association
  TC Materials and Quality Assurance;
  TG Supervision; TG Piping & Fittings;
  PG T24/HR3C; PG BCWP; PG Condition Monitoring

RDK8 Karlsruhe (hard coal-fired PP)
912 MW_{el}, 220MW_{th}, IBN 2014

HKW3, Stuttgart-Gaisburg (gas engines)
30 MW_{el}, 210MW_{th}, IBN 2018

GuD F, KW Lausward Düsseldorf (CCGT)
595 MW_{el}, 300MW_{th}, IBN 2016

- Participation tender / set up of specifications and contractual documents
- QA/QC prefabrication and assembly
- Checking the inspection and test / quality documentation
- Control of external inspectors/experts
Other applicable specifications and regulations (EN 12952, EN 13480, VGB-Standards, AD2000, VdTÜV material data sheets, ...);
Certifications and qualifications;
Requirements for process tests and production samples before production (welding, bending processes);
Personnel qualifications (welders, operators, NDT examiners and supervisors);
Instructions / factory codes for the heat treatment, cold / warm straightening, forming and re-stamping processes;
Requirements for incoming inspection / provision of material, mechanical processing, welding and bending work, heat treatment, NDT tests (execution, evaluation, mandatory scopes) and dimensional checks;
Identification/marking;
Scope of the monitoring of the test steps by the supplier, system manufacturer, the notified body (NoBo) and the customer’s construction supervision, type and scope of the documentation;
Preservation, storage, packaging, transport.
Martensitic Steels in Power Plants
USC Power Plant RDK8 - Scope of Material Specifications

- Test and delivery conditions;
- Dimensional / tolerance standard;
- Requirements for material manufacturers / material dealers;
- Binding tests according to harmonized standard;
- Supplementary checks and requirements (options), such as:
  - Steelmaking,
  - chemical composition,
  - delivery condition,
  - checking unit / sampling,
  - mechanical-technological tests (hot tensile test, impact test, ring trial),
  - microsection,
  - longitudinal error, transverse error and double test,
  - surface cracks,
  - hardness testing,
  - dimensional check, actual measurement of the wall thickness, and finish;
- Identification/marking;
- Scope of the monitoring of the test steps by the notified body / manufacturer, type and scope of the acceptance test certificate;
- Storage, packaging, transport.

Source: EnBW AG

PMA Certification (Particular Material Appraisal)
Martensitic Steels in Power Plants
USC Power Plant RDK8 – Quality Engineering Documents

Quality Engineering Documents

PED
✓ Headers/Pipes
✓ injection coolers
✓ tube panels
✓ bank tubes, supporting / connecting tubes
✓ cyclone
✓ black-white connectors
✓ eco-fin tubes
✓ ...
Non-PED
✓ Steel structure
✓ pulverized coal burners/lines
✓ expansion joints
✓ steel plate constructions (ducts, casings, ...)
✓ ...

Material Specifications for each material grade and product forms
✓ tubes/pipes
✓ open-die/drop forgings
✓ bars
✓ flat products
✓ products for steel structure
✓ ...

... includes parameters:
✓ weld preparation,
✓ welding process,
✓ filler material,
✓ processing and parameter for preheating and interpass temperature, heat treatment and
✓ kind & scope of NDT
More than 500 NCRs from prefabrication and assembly of boiler parts were to be evaluated, some of them were on quality issues with martensitic steels.

Example: Unsatisfying storage / transport
Saltwater attack on the material VM12-SHC

Chemical composition [%]
(with Na, Cl, S und Ca)

<table>
<thead>
<tr>
<th>O</th>
<th>Na</th>
<th>Al</th>
<th>Si</th>
<th>S</th>
<th>Cl</th>
<th>K</th>
<th>Ca</th>
<th>Cr</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.8</td>
<td>0.5</td>
<td>5.8</td>
<td>0.5</td>
<td>0.2</td>
<td>0.6</td>
<td>0.1</td>
<td>2.1</td>
<td>1.1</td>
<td>89.9</td>
</tr>
<tr>
<td>13.1</td>
<td>0.1</td>
<td>0.3</td>
<td>0.5</td>
<td>0.3</td>
<td>0.6</td>
<td>0.6</td>
<td>1.0</td>
<td>0.9</td>
<td>92.6</td>
</tr>
<tr>
<td>14.2</td>
<td>0.1</td>
<td>0.5</td>
<td>0.4</td>
<td>0.2</td>
<td>0.5</td>
<td>0.8</td>
<td>0.7</td>
<td>1.6</td>
<td>91.0</td>
</tr>
</tbody>
</table>

Corrosion layer inner surface 50-120 μm
Local attack on grain boundary up to 160 μm

Example: Missing hand skills of welders
Slag inclusions, header nozzels material P92

-> New production

-> Remove all nozzels
-> New welding/other production site
Design of components grade 91 was carried out with values of creep strength from VdTÜV (2001)

- Header superheater stages 2 and 3
- HP steam gate
- Cyclone separator
- Range 481 to 559°C

Deviation (reserve) between used Design data for these components is more than 2.5% to the data from ECCC 2018
Special case “Reduction of strength parameters of materials”
see VGB-S-506 3rd revision 05/2019

Therefore, the following alternative approaches are:

- Verification of the material (utilisation of calculation reserves);
- Use of material of a higher quality;
- Wall thickness increase;
- Reduction of operating temperature and, where necessary, operating pressure;
- Shortening of the operating time compared to its calculated value;
- Shortening of inspection periods;
- Increase of the extent of tests and examinations.
The following measures were implemented for grade 92 in RDK8-project:

- Material specification for semi-finished products, which i.a. contains the following special requirements:
  - Austenitizing temperature with lower limit 1050°C;
  - Tempering temperature with lower limit 760°C;
  - Impact test with a required energy absorption of 41J/68J (transverse/longitudinal direction);
  - Micro section (magnification 200:1 and 500:1) to prove a pure martensitic structure;
  - Hardness test in the range 200 HV10 to 260HV10;
- Specifications and requirements for further processing such as bending, welding and heat treatment;
- Creep tests with planned running times in the range up to 70,000 h for pipe and forged material for header;
- For the high-stressed components in the creep-fatigue area, replicas were prepared as a zero test. Likewise, there are wall thicknesses and ovalities for individual cross sections measured;
- Monitoring of the high-stressed components in the creep-fatigue area and calculation of life consumption or exhaustion factor to creep and fatigue according DIN EN 12952-4 (linear damage accumulation);
- To recognize temperature imbalance additional operational temperature measurements were applied on individual header tubes of final superheater and reheater stage.
Creep rupture tests at 600°C and 650°C

One test is still running with more than 61,000 hours at 650°C for each type of material.

The meaningful long-term creep rupture data are well above the lower scatter band limit, in the case of 650°C almost on the middle value curve.

The deformation values are with total creep rupture strain between 12 and 16% for the long-term creep tests within the expected range.
Martensitic Steels in Power Plants
QA/QC – Examples for NDT (zero tests) for repeated tests

Documentation of location of tests

Measurements (wall thickness, ovality,...)

<table>
<thead>
<tr>
<th>Material</th>
<th>Ø A + C (mm)</th>
<th>Ø D - B (mm)</th>
<th>Wall thickness (mm)</th>
<th>Ovality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material 1</td>
<td>492.7</td>
<td>492.1</td>
<td>112.0</td>
<td>112.1</td>
</tr>
<tr>
<td>Material 2</td>
<td>421.0</td>
<td>409.5</td>
<td>112.2</td>
<td>111.8</td>
</tr>
</tbody>
</table>

Replication BM – HAZ – WM (- HAZ - BM)
To monitor the planned behaviour of steam and hot reheat pipeline force and displacement measurement were implemented for an advanced evaluation.

Example cable pull sensor (potentiometric measurement)

Example of force measurement on joint strut (strain gauge full bridge, bending-/ temperature compensated)
Especially for grade 91 and 92 applications following items beyond the scope of the technical code or relevant rules should be examined for implementation:

- **Set additional requirements for semi-finished products**, e.g. material specification according to the VGB Standard VGB-S-109. For RDK8 project >35 individual material specifications were used for the products for boiler;

- **Set additional requirements for manufacturing the components**, especially further processing such as bending, welding and heat treatment, e.g. VGB Standard VGB-S-013 for steam boiler, VGB Guidelines VGB-R-507L and VGB-R-508L for pipelines. For RDK8 project more than 35 individual inspection test plans were used for the different component types (fin tubes, supporting/connecting tubes, tube panels, headers, injection coolers, separating vessels, etc.);

- **Prepare replicas and measurement protocols** (wall thickness, ovality) on selected components as a zero test before start of operation, see VGB Guideline VGB-R-509. For RDK8 the scope includes approximately 60 positions on boiler and piping components;

- Ensuring the creep properties by **performing some creep tests** on selected material batches. For RDK8 some creep tests for pipe and forged material of the header of final superheater stage were done with planned running times in the range up to 70,000 h. In addition, unpublished extensive creep-fatigue investigations on P92 welds were performed to provide a database for possible future FEM-calculations;

- **Monitor the exhaustion due to creep and fatigue** on selected components of boiler and pipelines according to the calculation rules of DIN EN 12952-4. For RDK8 project more than 30 components will be monitored;

- **Monitor the temperature on individual header tubes of final superheater and reheater stage** to recognize temp. imbalance of header;

- **Monitor the planned behaviour of steam and hot reheat pipeline**. For RDK8 in total 24 force and 47 displacement measurements were implemented for an advanced evaluation.

- **Restoring samples of zero state used as comparative material for later material investigations on service material.**
Martensitic Steels in Power Plants

Summary/Conclusions
Martensitic Steels in Power Plants

- The use of martensitic steels allows safe operation of USC power plant up to 620 °C so far.
- The candidate X20CrMoV12-1 has meanwhile an operating experience of approximately 70 years. At the same time, extensive studies on workability and behavior under creep, fatigue, corrosion or oxidation conditions have taken place for continuous improvement of the material specification and to define safe application limits.
- For the martensitic steel grade 91 and 92 used since the nineties also extensive results from qualification and research are available. The “younger” candidate P92 – currently used in 16 USC Power Plants in Western Europe with operating experience up to 55,000 hours – has reached for the latest creep assessment 10 million testing hours and 7 tests with more than 100,000 hours. This allows data extrapolation to 200,000 hours at 580 to 650 °C.
- Thanks to the international research teams who have created this database for martensites and provide us with extensive insights to martensitic steels important for safe operation.
- Further effort is necessary. @VGB we have ongoing activities in the 2 working groups “Martensitic Steels” (together with manufacturers, research centers) and “Calculation methods” (R&D project together with manufacturers, research centers)
Thank you for your attention!