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Boiler Design of innovative 600 °C- and 700 °C- Power Plants

Power Plants – Technology in Dialogue

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Boiler Design of innovative 600 °C- and 700 °C- Power Plants

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Introduction

600 °C - and 700 °C - Technology

Design Aspects

Material selection

Conclusion

CO_2 Emissions of Power Plants with different Fuels

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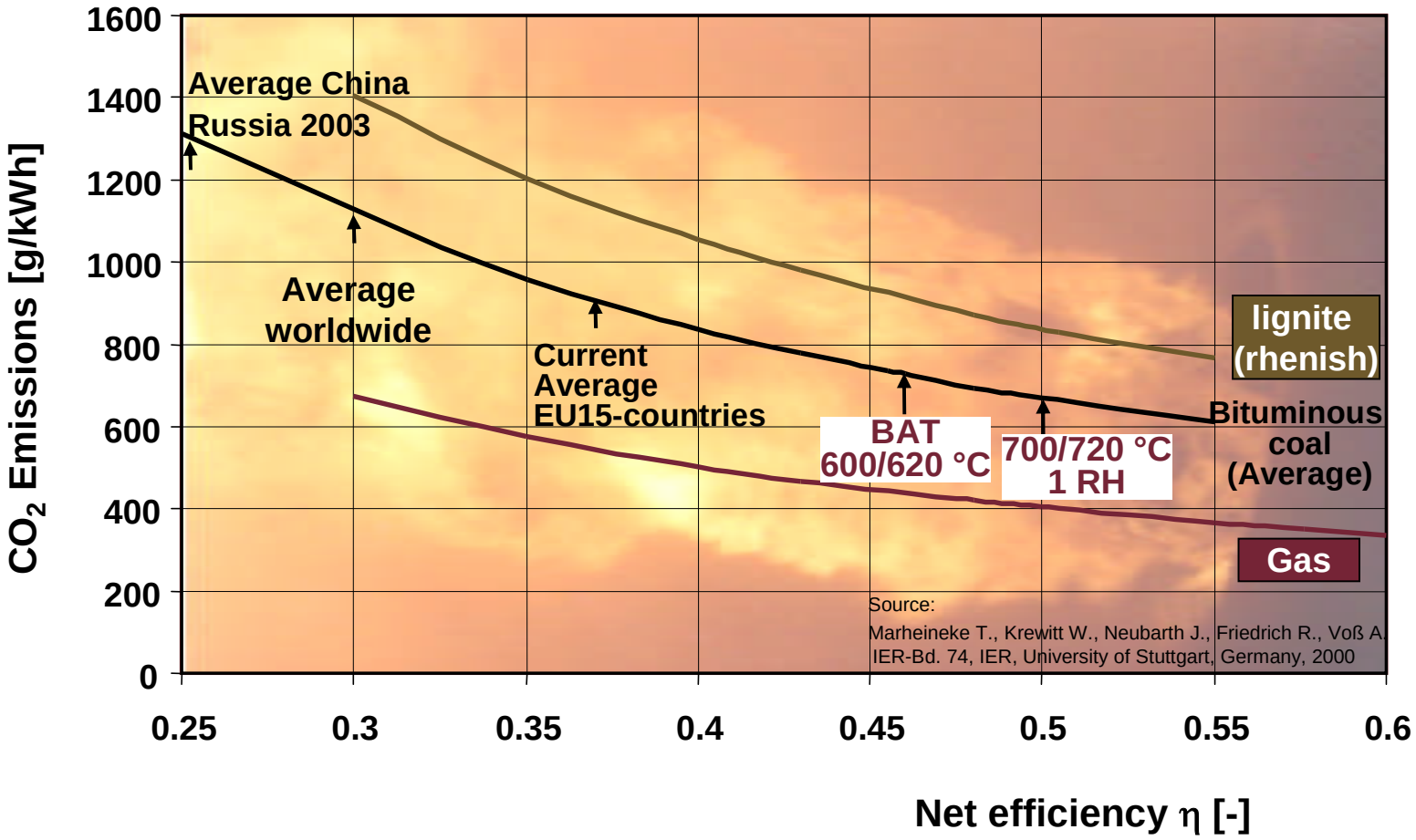
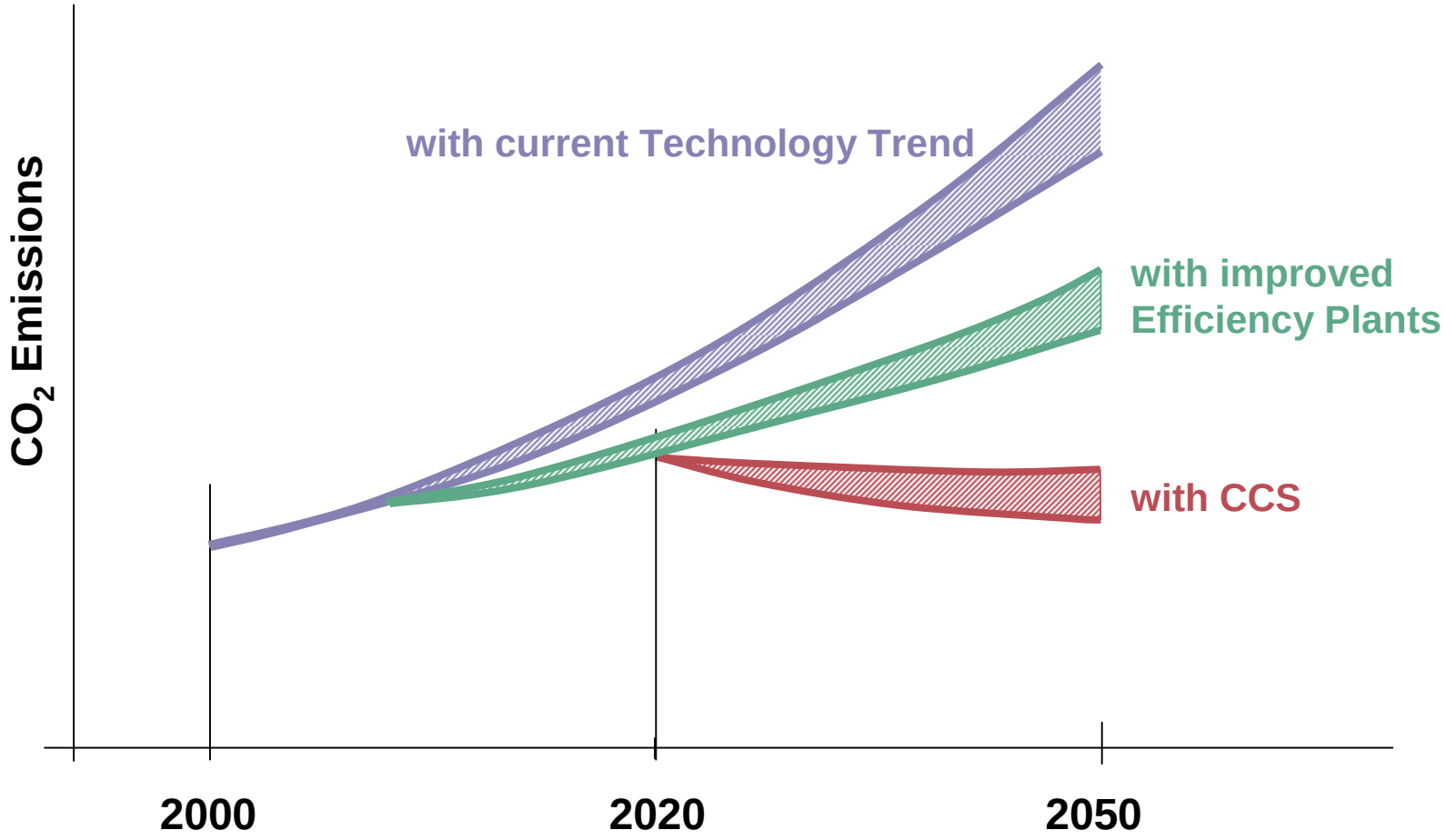


Further CO_2 Reduction: Carbon Capture



Efficiency is the fast track – CCS achieves near Zero-Emission

CO_2 Emissions Increase of Power Plants with Bituminous coal by applying CCS

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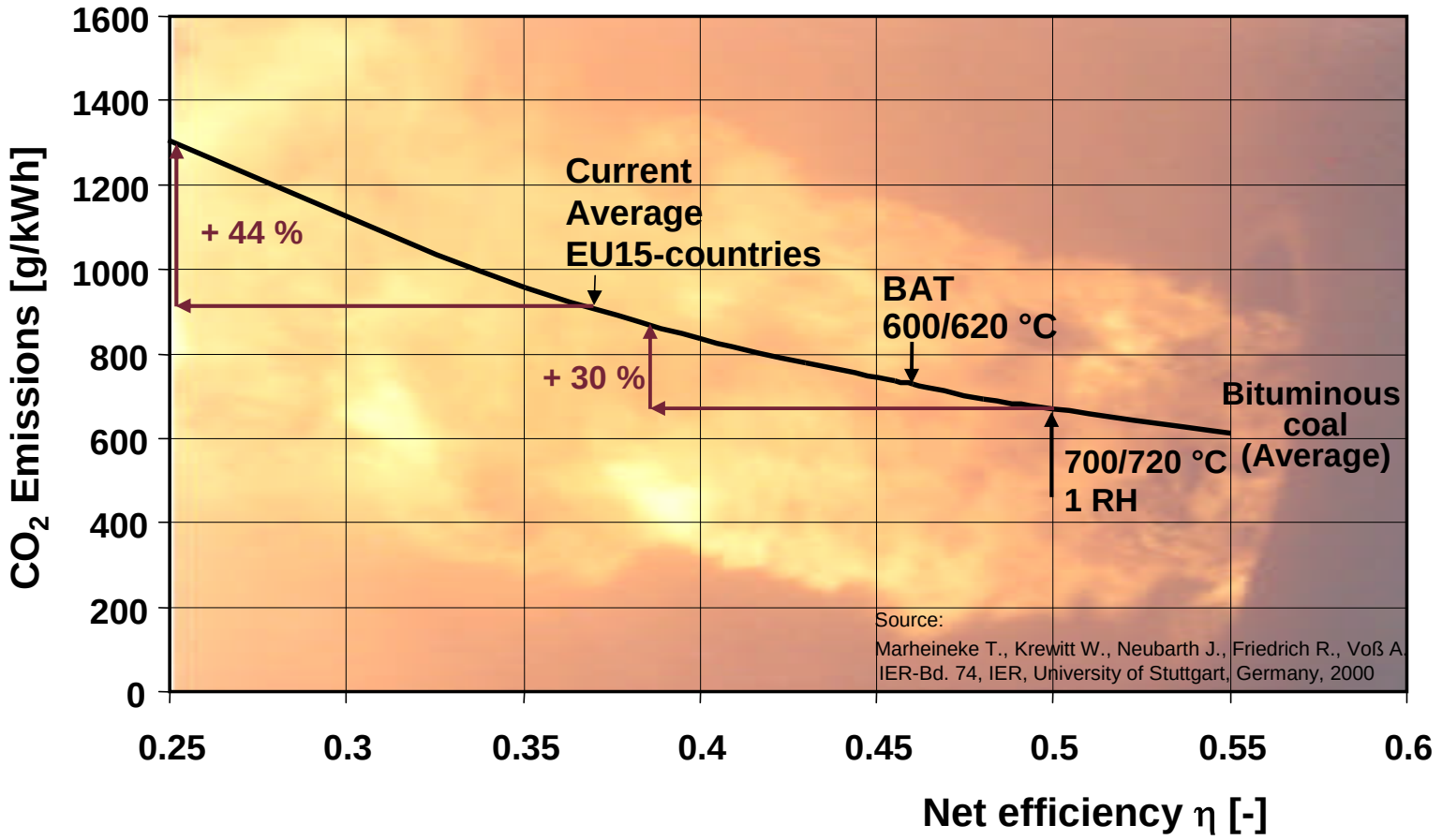

Loss of efficiency is derived by Power demand for ASU and compression of CO_2 for Oxyfuel

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Introduction

600 °C - and 700 °C - Technology

Design Aspects

Material selection

Conclusion

600 °C - Technology: NRW Power Plant Study

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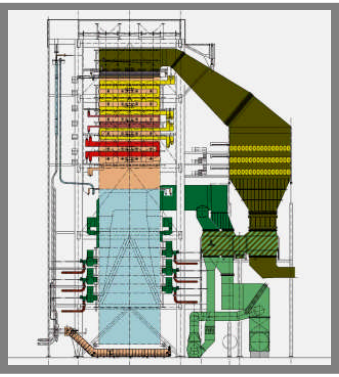
Tower type boiler „Preferred Boiler Design 600 MW“

Plant power output (gross)	500 - 600 MW
Efficiency (target)	45 – 47 % (el, net)
Steam conditions	
➢ HP Turbine inlet	285 bar / 600 °C
➢ IP Turbine inlet	60 bar / 620 °C

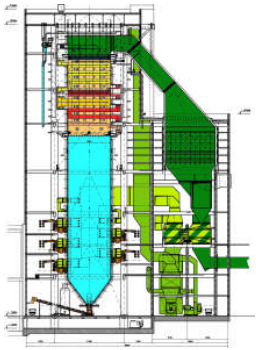


PS Moorburg A/B

2 x 820 MWel / 2 x 2088 t/h
HP: 600 ºC / 276 bar a
RH: 610 ºC / 51 bar a
Time of commissioning: 2011/2012

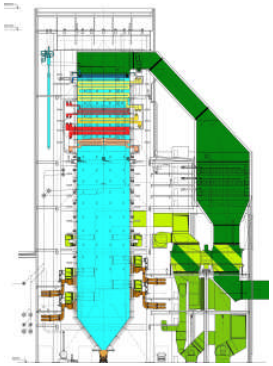
PS Datteln

1100 MWel / 2939 t/h
HP: 600 ºC / 285 bar
RH : 620 ºC / 58 bar
Time of commissioning : 2011



Walsum K. 10

1 x 790 MWel / 1 x 2143 t/h
HP : 603 ºC / 290 bar a
RH : 621 ºC / 75 bar a
Time of commissioning : 2009



600 °C - Technology: PS Datteln (1100 MW)

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1100 MWel / 2939 t/h

Benson® steam generator

Bituminous coal

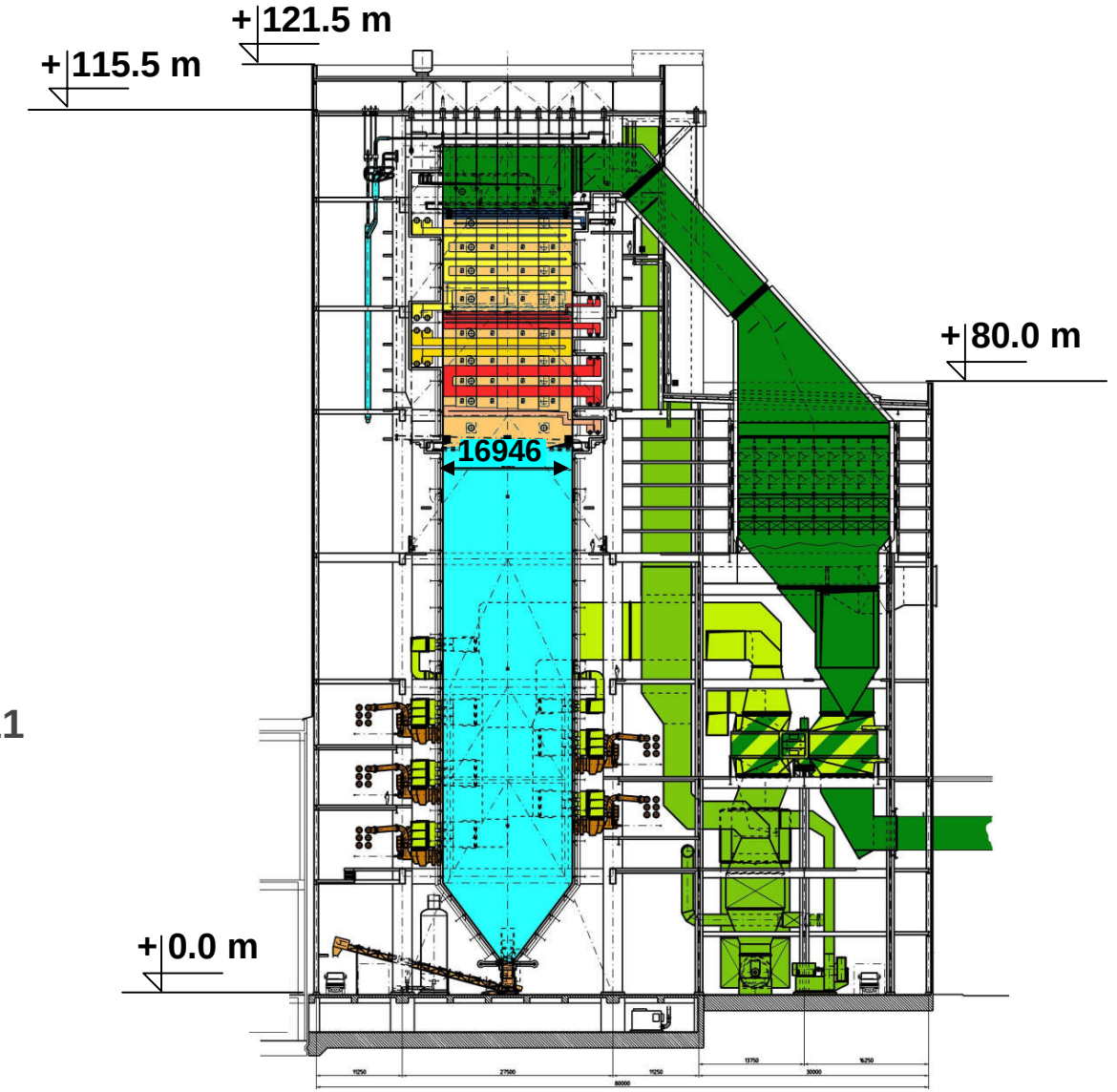
Design parameters:

HP: 600 ºC / 285 bar

RH: 620 ºC / 58 bar

Time of commissioning: 2011

Efficiency: > 45.5 % (el, net)



600 °C - Technology: Boiler materials

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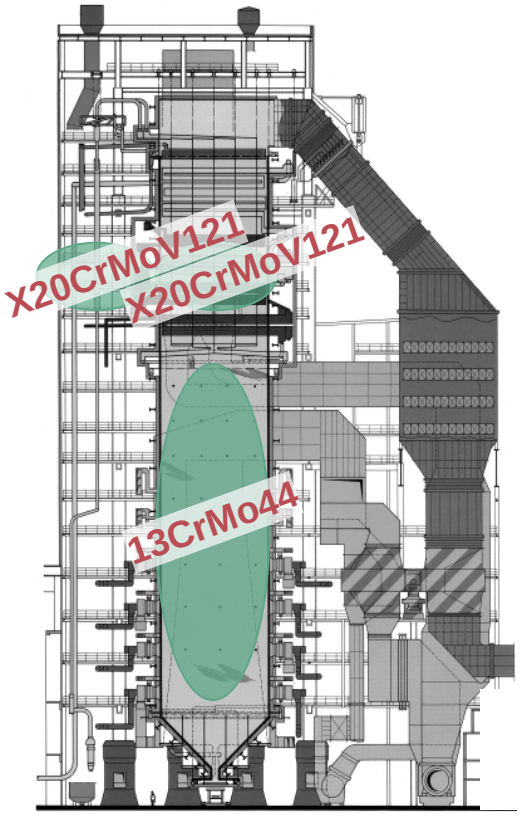
Existing PP

η = 43 %

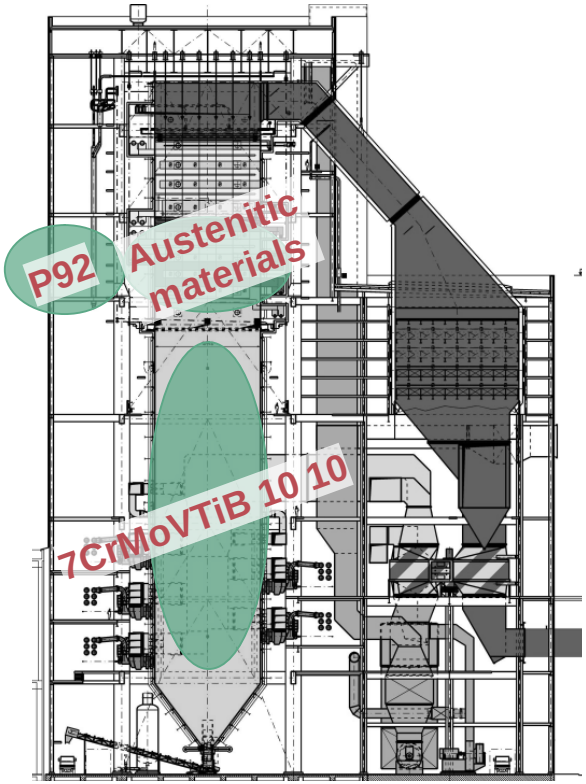
262 bar / 545 °C / 562 °C



Today

η = 45 – 47 %

285 bar / 600 °C / 620 °C



700 °C - Technology:
Power Plant Study NRWPP700

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Power Plant Study NRWPP700
500 MW_{el}

Efficiency (target) 50 % (el, net)

Three different versions for boiler design:

- **365 bar / 705 °C / 720 °C, single reheat**
- **260 bar / 705 °C / 720 °C, single reheat**
- **365 bar / 702 °C / 720 °C / 720 °C, double reheat**

Preferred boiler design:

365 bar / 705 °C / 720 °C single reheat

Base for current design of first 700 °C – boiler.

Source: NRW Power Plant 700°C (NRWPP700)

700 °C - Technology: steam generator for 500 MW_{el}

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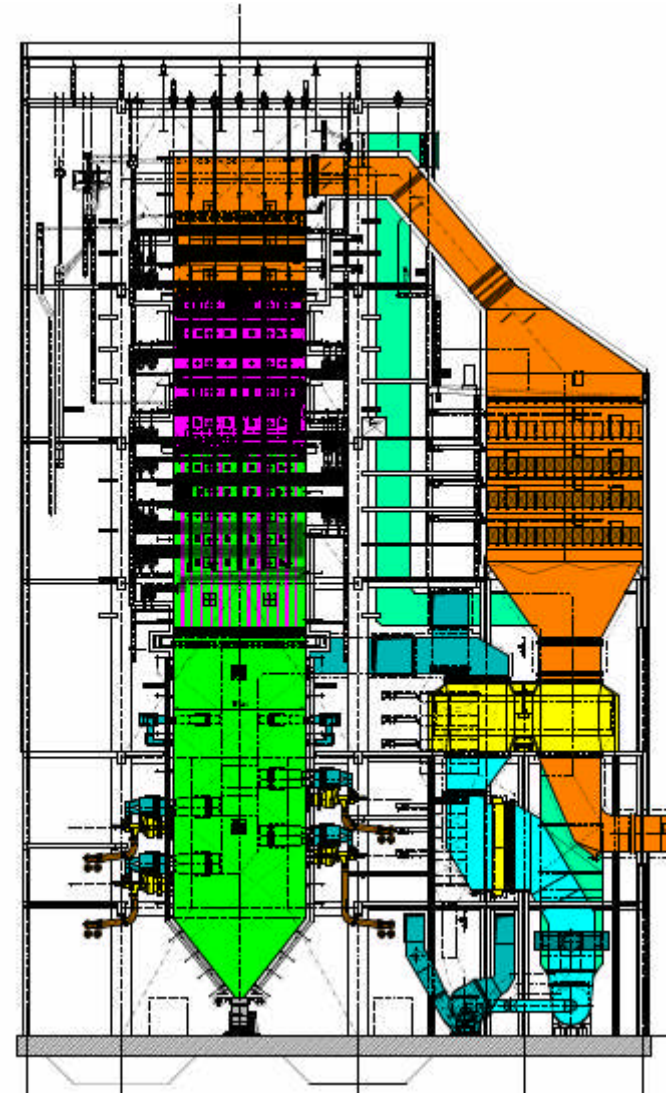

HP-Part:

Life steam pressure	365	bar
Life steam temperature	705	°C

RH-Part:

Inlet pressure	74	bar
Outlet temperature	720	°C

Bituminous coal
Benson® steam generator

First 700 °C - Power Plant scheduled for: 2014 (E.ON)

700 °C - Technology: Boiler materials

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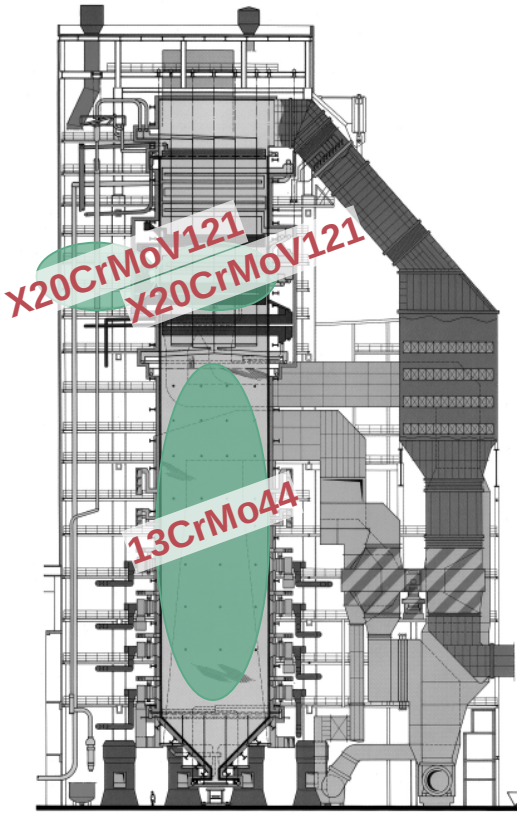
Existing PP

η = 43 %

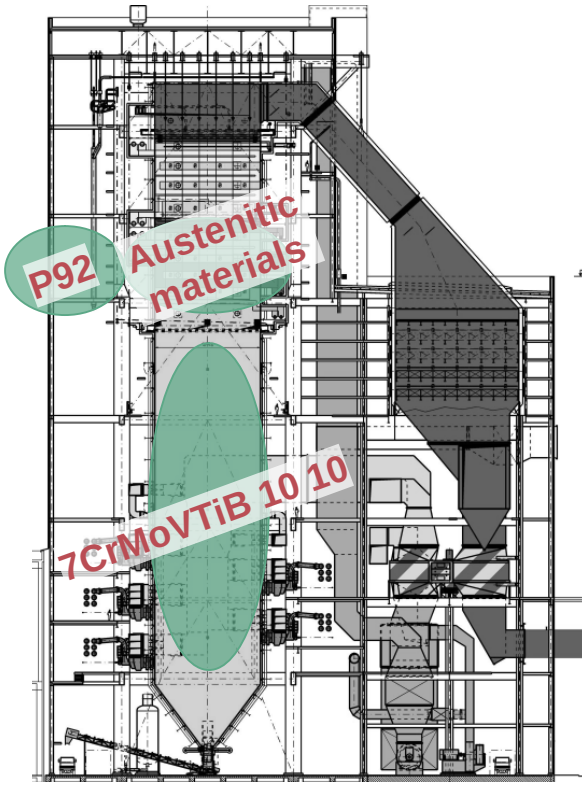
262 bar / 545 °C / 562 °C



Today

η = 45 – 47 %

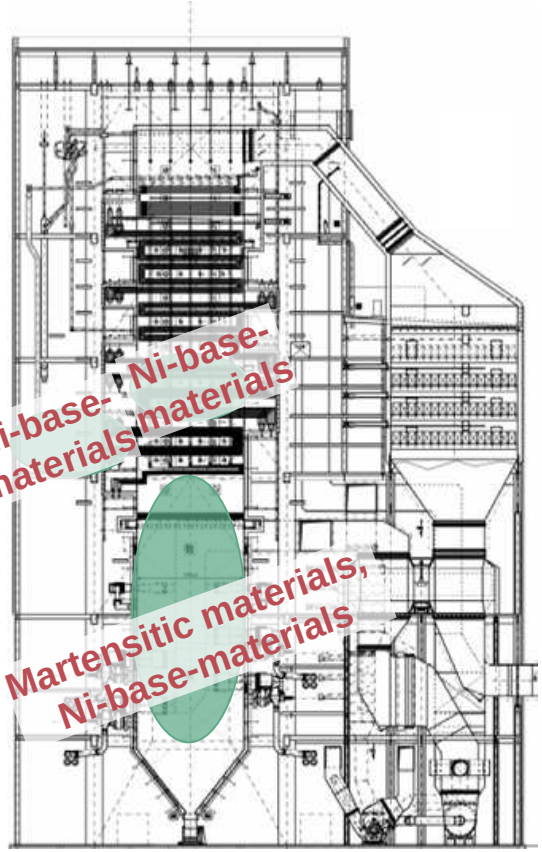
285 bar / 600 °C / 620 °C



2014

η = 50 %

365 bar / 705 °C / 720 °C



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Introduction

600 °C - and 700 °C - Technology

Design Aspects

Material selection

Conclusion

Component design in the creep regime
Tools / Methods

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Current-State

Design based on formula which are being defined by empirical knowledge

$$S_{erf} = \frac{p \cdot d_i}{2 \cdot \sigma_{zul} - p}$$

Demand for 700 °C - Technology cannot be satisfied using the existing design methods.

Perspectives

New methods for the design of high temperature components: European Pressure Equipment Directive (PED) allows the use of Design by Analysis (DBA)-Methods.

For components operating in the creep regime the inelastic Finite Element Analyses have to be applied. Appropriate inelastic constitutive equations are necessary.

Required research projects concerning inelastic constitutive equations have started.

HPE – FEM Calculation of thick walled components

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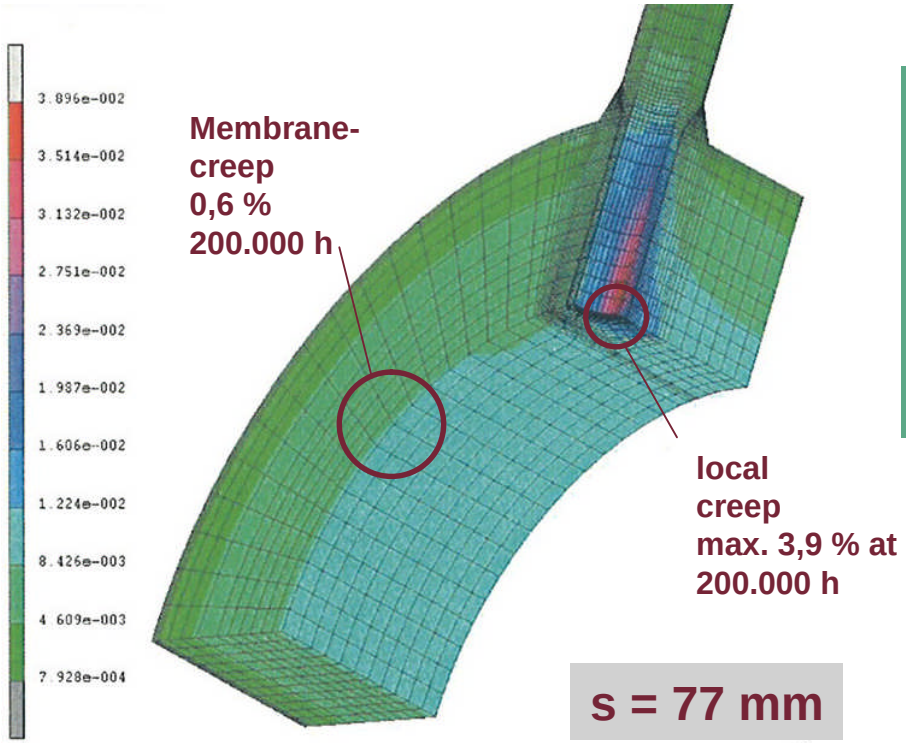
Example HP-Outlet header



Wall thickness:
Calculation acc. EN 12952-3:
➔ s=100 mm

FEM:
➔ s= 77 mm

Life time expectancy of superheater tubes

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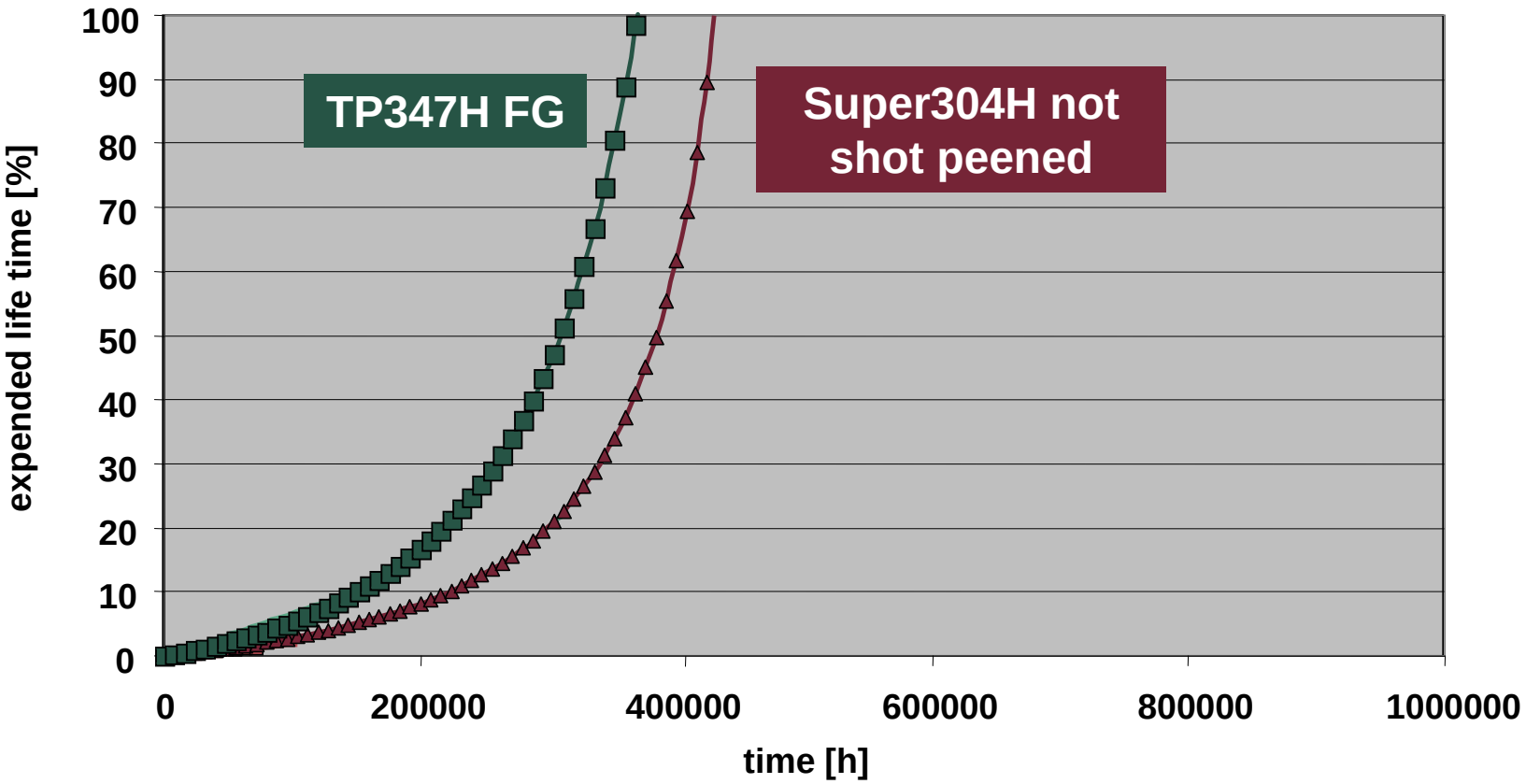
Reduction of life time of superheater tubes by:
- creep
- fire side corrosion
- steam side oxidation

Each of the three mechanisms affects the others.

⇨ Isolated consideration is not possible.

Calculation program to estimate the life time of superheater tubes considering all three influencing factors.

Examples – Different materials



Examples – Different materials

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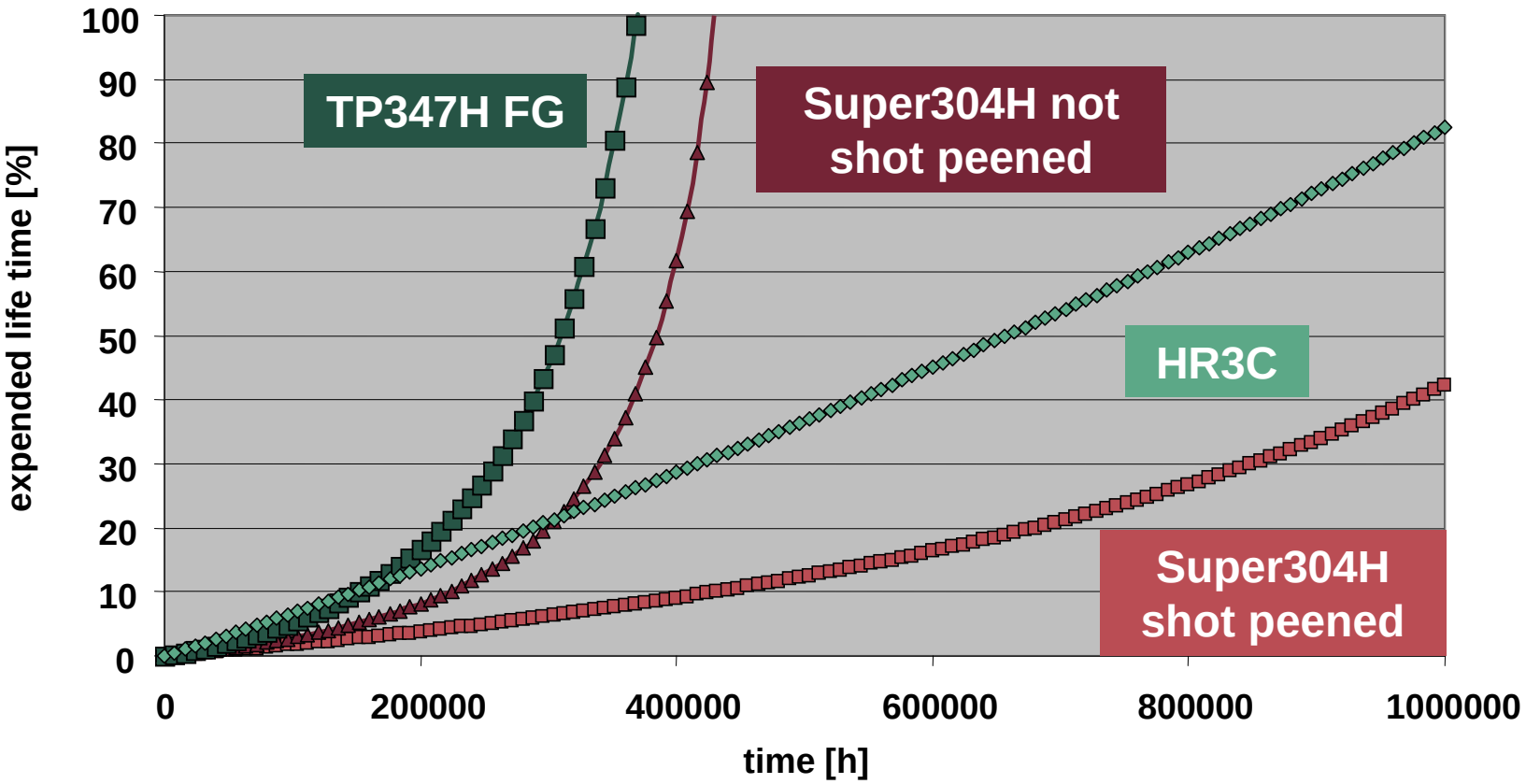
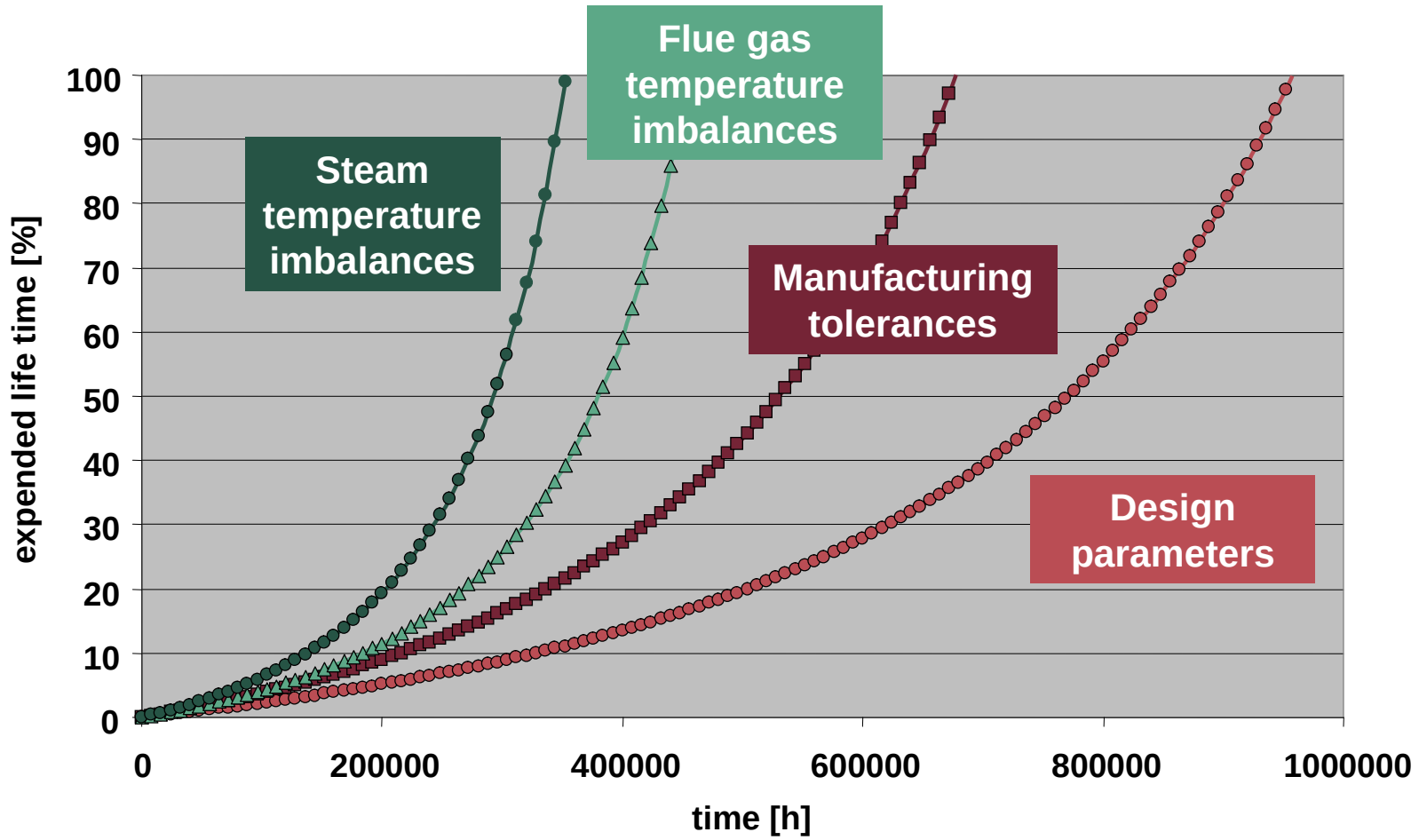


Examples – Variations for design of superheater tubes



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Introduction

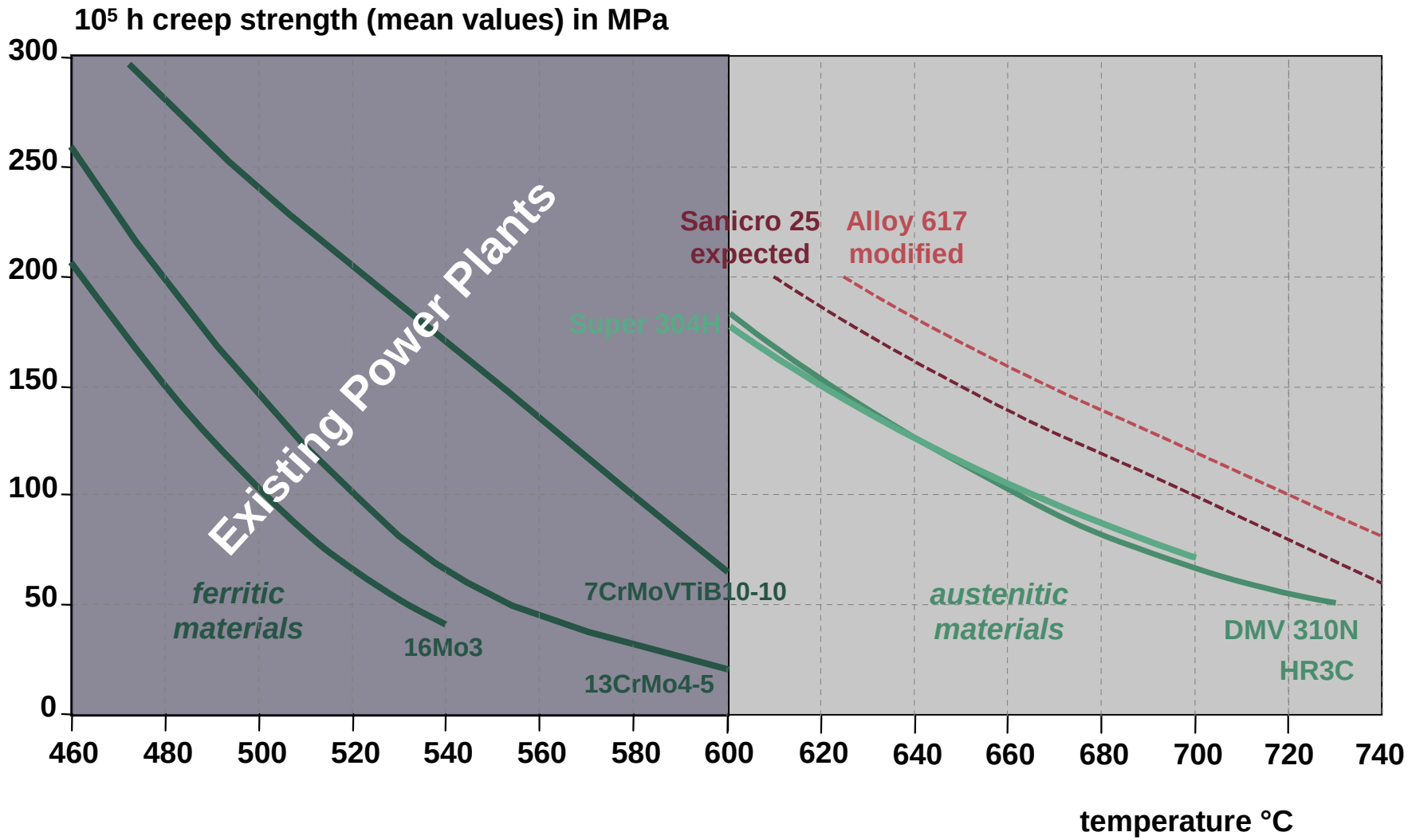
600 °C - and 700 °C - Technology

Design Aspects

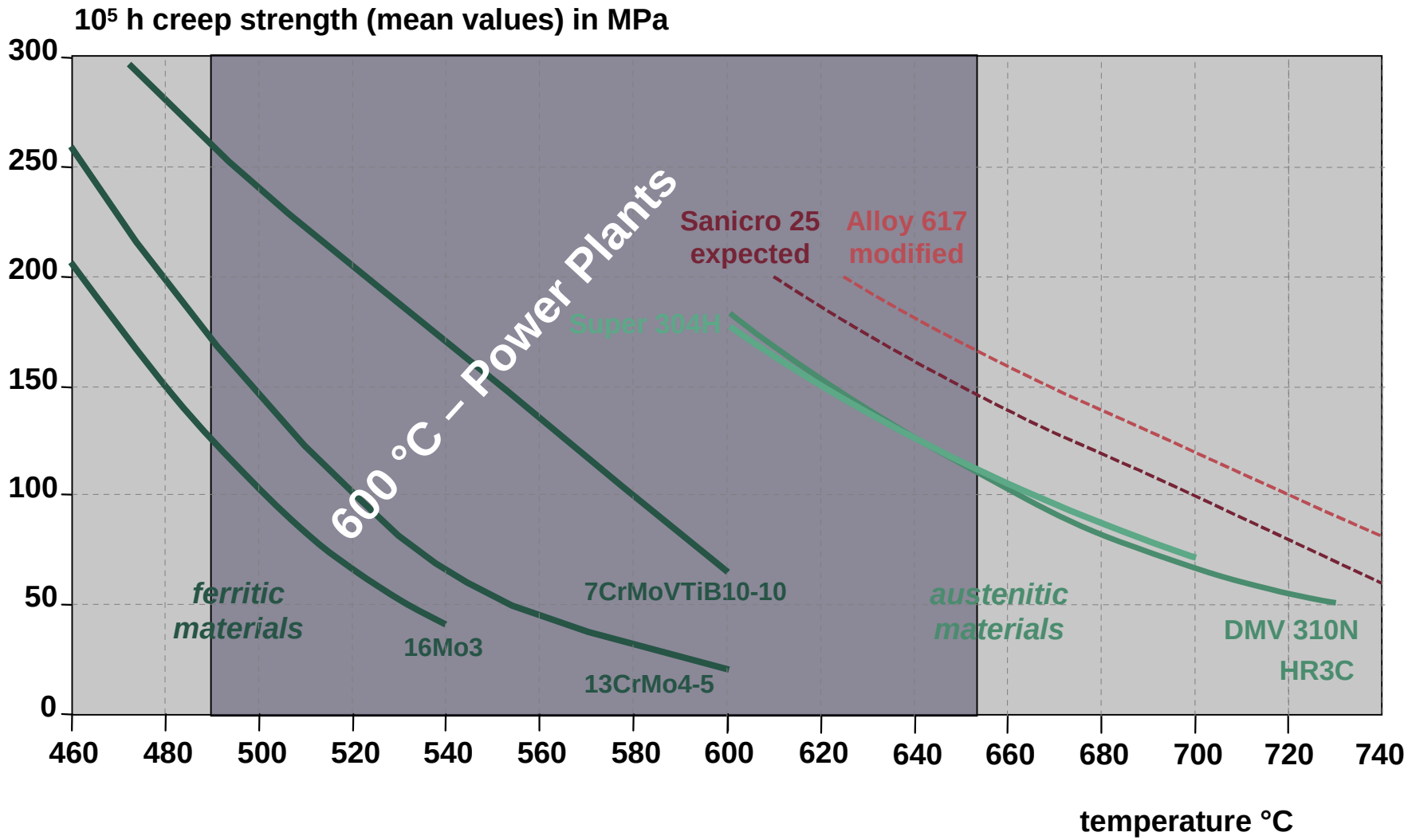
Material selection

Conclusion

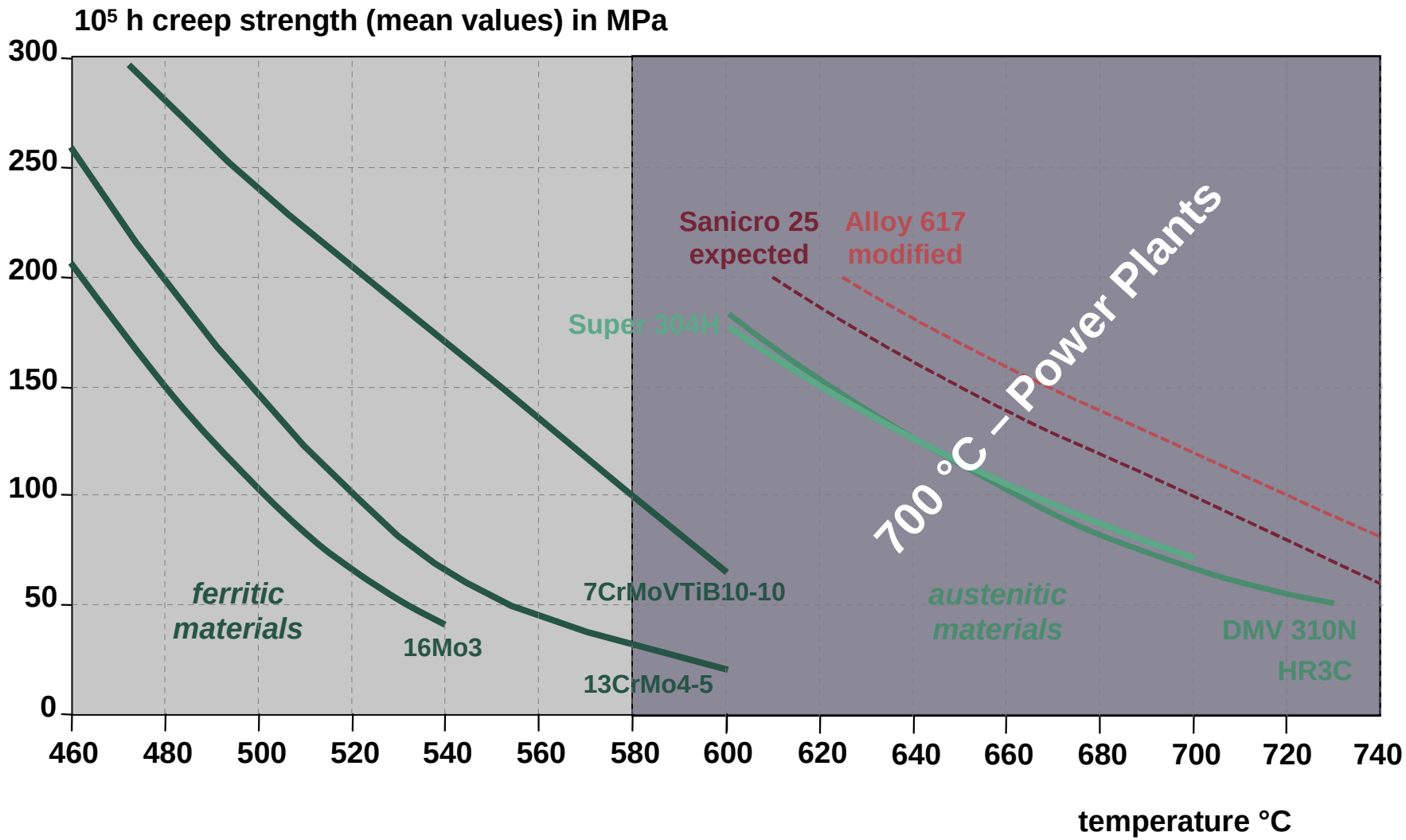
Material selection – superheater and reheater tubes



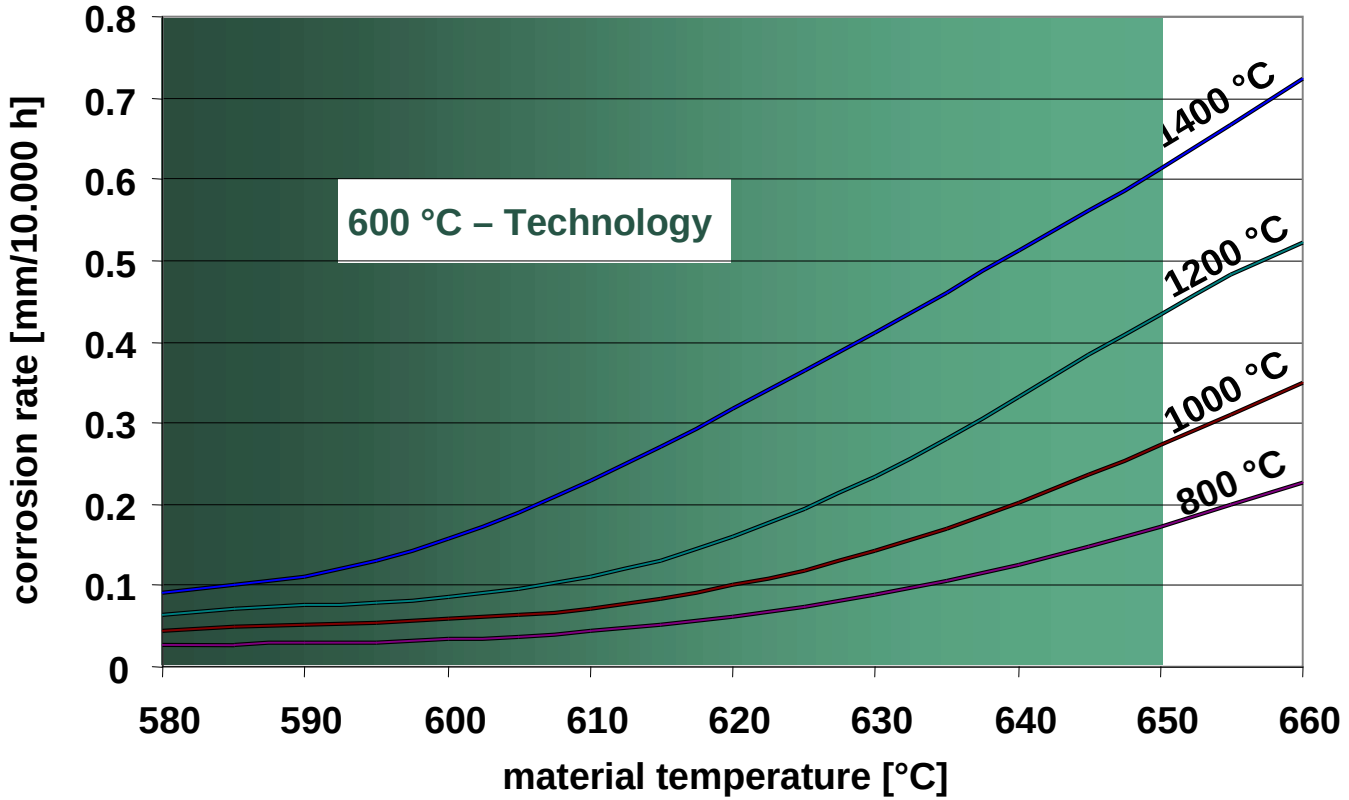
Material selection – superheater and reheater tubes



Material selection – superheater and reheater tubes



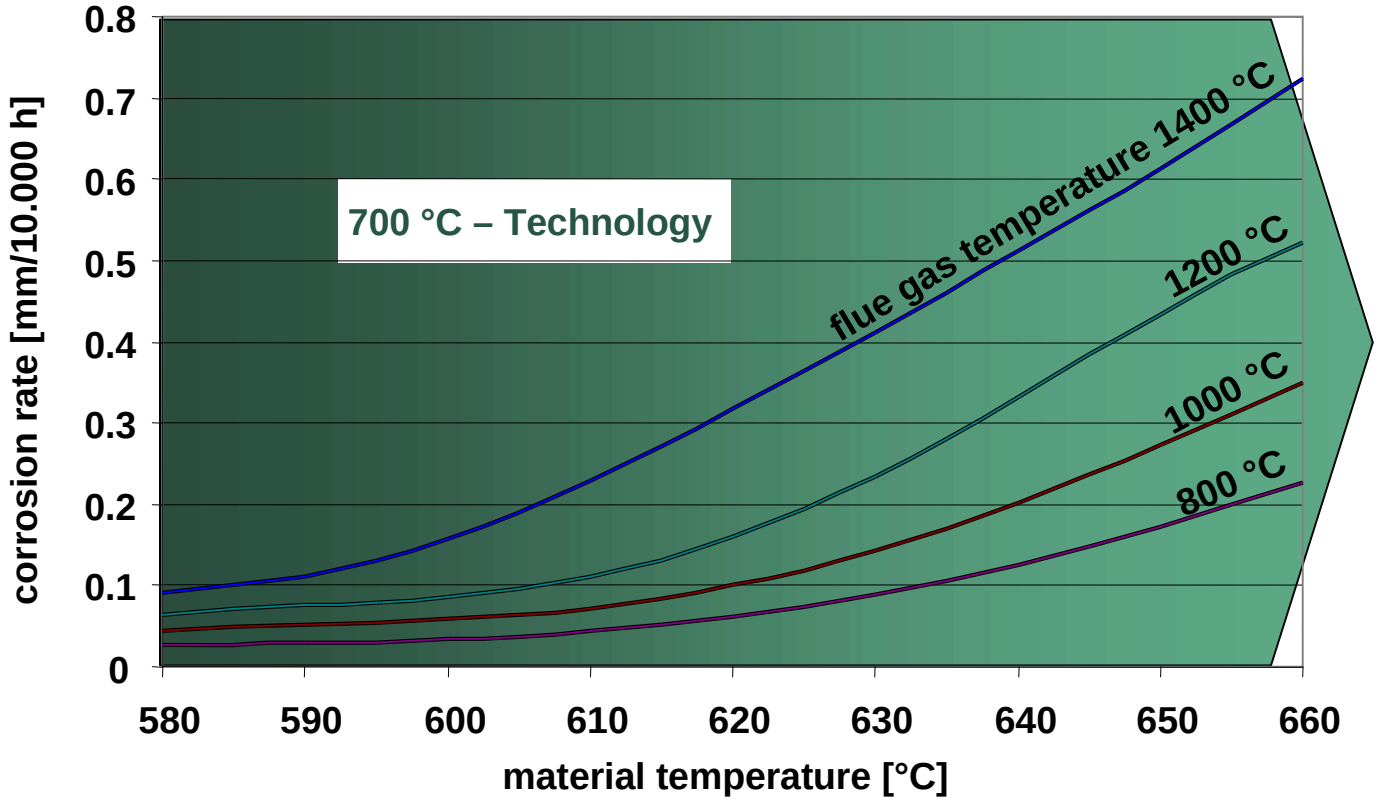
Material selection – fire side corrosion



Corrosion rate of austenitic materials with 18 % chromium

Source: Cutler, A.J.B., Flatley, T and Hay, K.A.: Fire-side corrosion in power-station boilers. Combustion (Dez. 1980) S. 17-25

Material selection – fire side corrosion



Corrosion rate of austenitic materials with 18 % chromium

Source: Cutler, A.J.B., Flatley, T and Hay, K.A.: Fire-side corrosion in power-station boilers. Combustion (Dez. 1980) S. 17-25

Material selection - membrane walls

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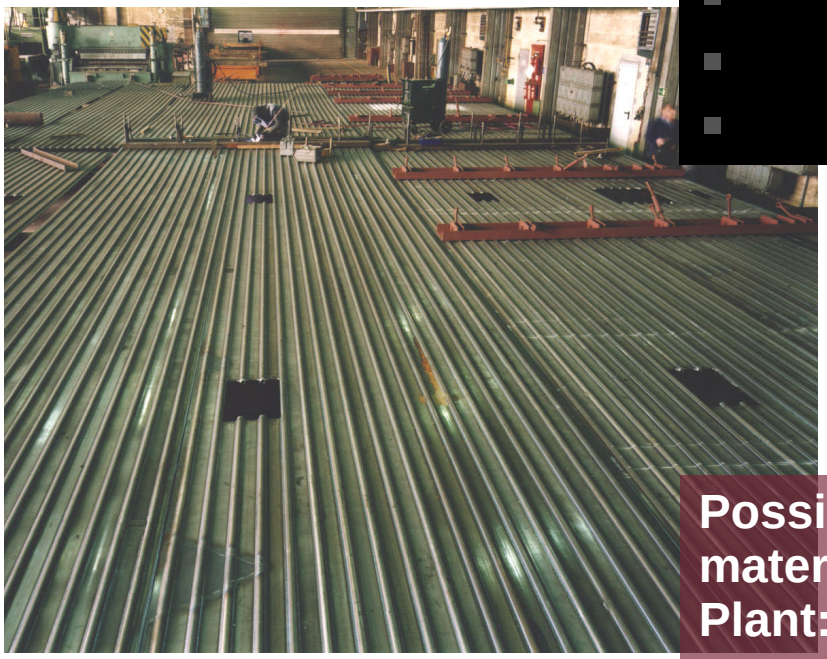

[redacted]

Ferritic

Possible additional materials for 700°C - Power Plant:

- VM12-SHC
- X10CrWMoVNb9-2 (T92)

Martensitic

- Alloy 617 (modified)

Nickel base alloy

Material selection – superheater and reheater

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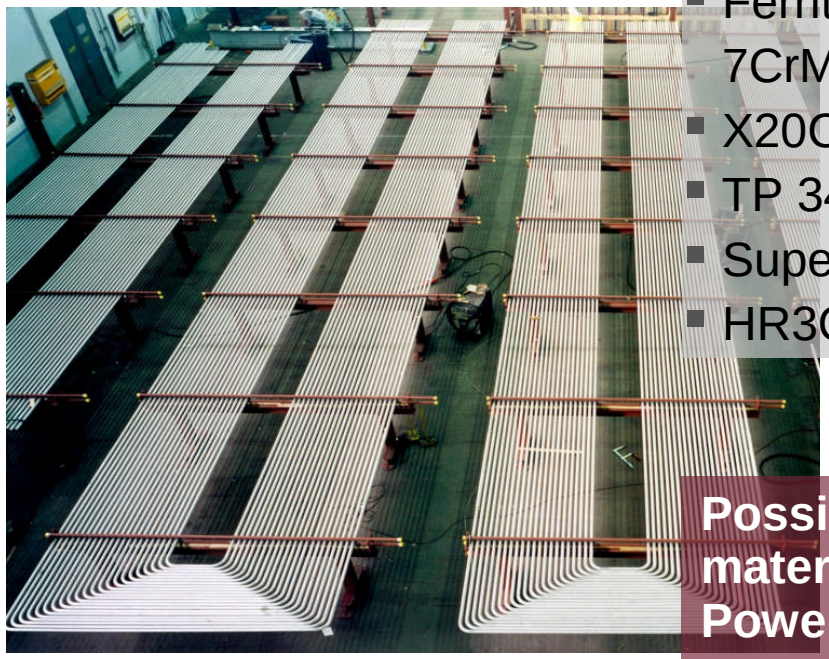

Materials for 600°C - Power Plant:

- Ferritic materials like 7CrMoVTiB10-10 (T24)
- X20CrMoV12-1, VM12-SHC
- TP 347H FG SP
- Super 304 H SP
- HR3C

Martensitic

Austenitic

Possible additional materials for 700°C - Power Plant:

Sanicro 25
HR6W
Alloy 617 (modified)
Alloy 740, Alloy 263

Austenitic

Nickel base alloys

Material selection - headers and pipes

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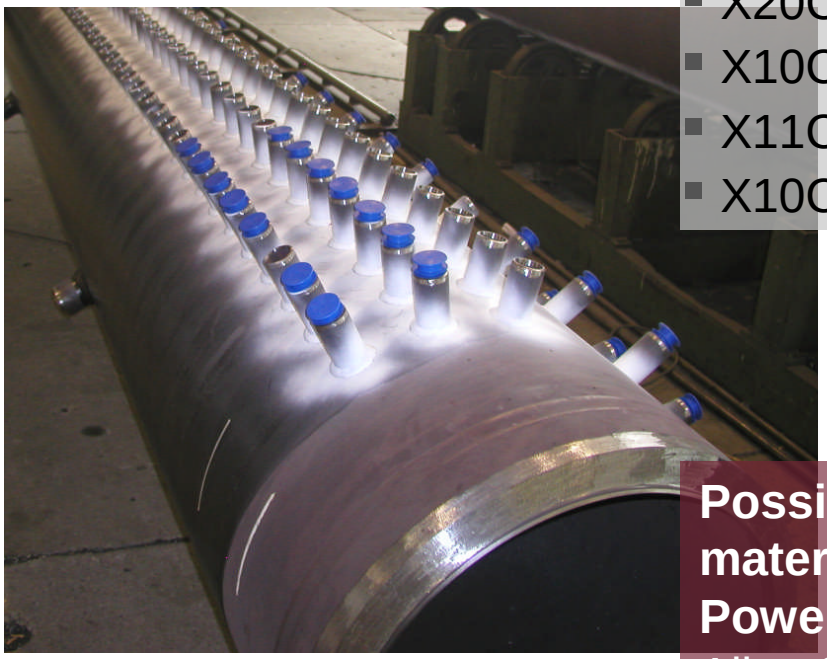

Materials for 600°C - Power Plant:

- X20CrMoV12-1
- X10CrMoVNb9-1 (P91)
- X11CrMoWVNb9-1-1 (E911)
- X10CrWMoVNb9-2 (P92)

Martensitic

Possible additional materials for 700°C - Power Plant:

Alloy 617 (modified)

Alloy 263

HR6W

Nickel base alloys

Austenitic

Boiler Design of innovative 600 °C- and 700 °C- Power Plants

HITACHI
Inspire the Next

Introduction

600 °C - and 700 °C - Technology

Design Aspects

Material selection

Conclusion

Conclusion

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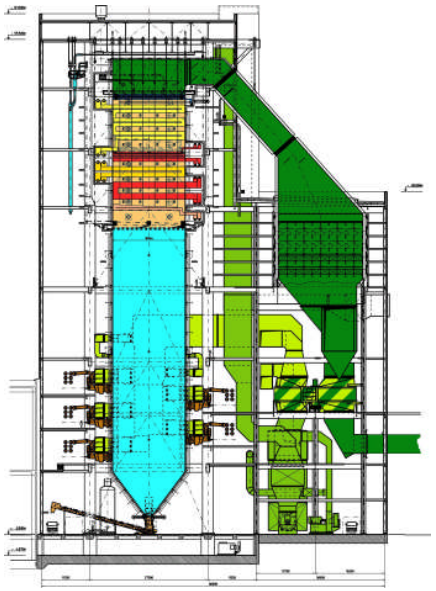
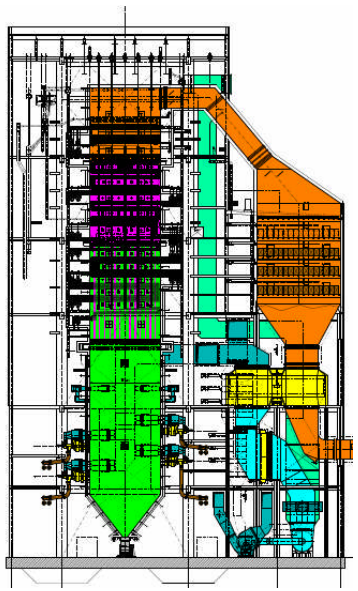
600 °C - boiler



700 °C - boiler



Biggest innovation of 700 °C - boiler lies in the materials !

New materials with higher strength and corrosion/ oxidation resistance needed.

Highest grade for materials are the nickel base alloys.

Common for both boilers:

FEM-Calculations for thick walled components

Calculation program for life time expectancy of superheater tubes

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