Lessons-learnt during construction, commissioning and start of operation

Delhi, Mumbai, Hyderabad, August/September 2015

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Agenda

Introduction: Overview of the new built plants in Europe

Project Management: key to success
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- Planning
- Scheduling
- Quality Management

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- HR3C
- P92

During commissioning: one exampe seawater ingress

First operating experiences: heat recovery concepts

Summary

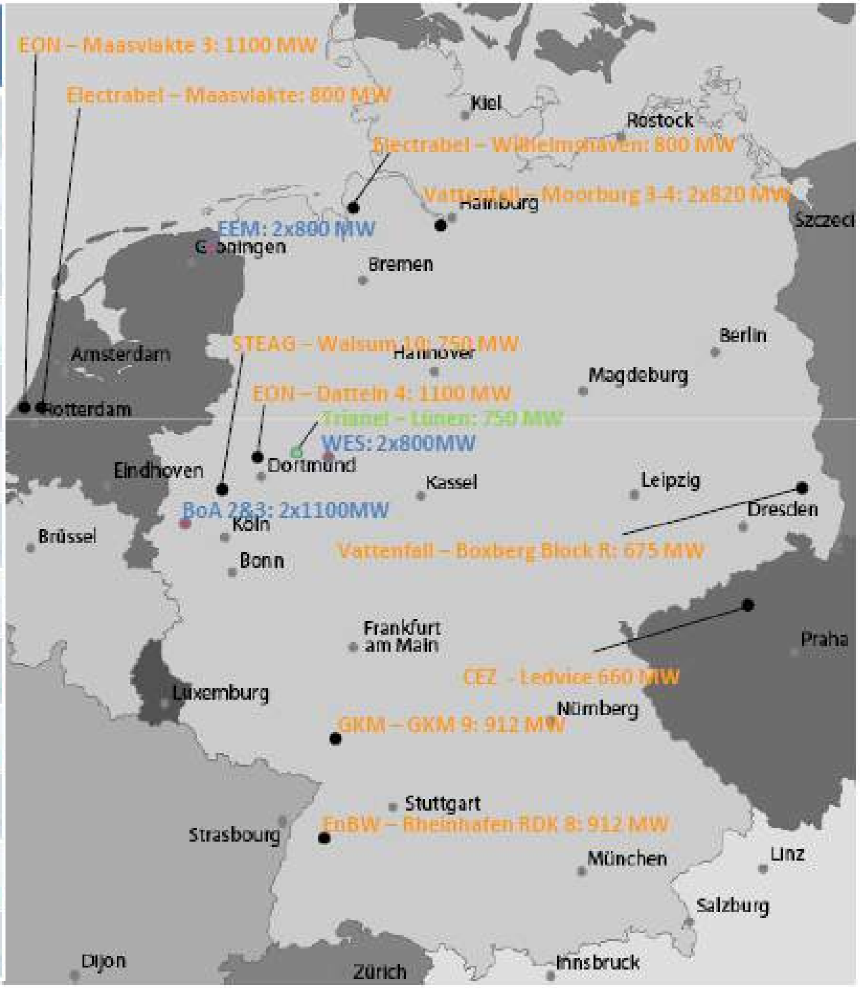
Reference Power Plant NRW

Gross output	600 MW
Net output	556 MW
Net efficiency (cooling tower mode)	ca. 46 %
Net efficiency (river cooling)	ca. 47 %
Main steam parameters	285 bar/600°C/620°C
Feed water end temperature	303,4 °C
Condenser pressure	45 mbar, wet closed cooling via natural-draft cooling tower
Boiler type	Benson tower boiler with vertical tubes
Boiler efficiency	95 %
Mills	3 mill-concept with 6 burners each
Economizer stages	Eight economizer + external desulpher-heater
Feed water pump concept	3 x 50 % electric motor driven feed water pumps, variable speed drive with planetary gearing
Utilization of waste heat	Use of mill air heat
Flue gas cleaning	SCT-DENOX with ammonia, four-grade electrostatic precipitator, flue gas desulphurization using limestone-gypsum method
Flue gas discharge	Discharge via cooling tower
Steam turbine	Three-casing steam turbine with simple intermediate heating and low-pressure stages made of titanium alloy (reheating after high pressure turbine)
Generator	Water-/hydrogen cooled
Operating personnel	70

The concept study for the Reference Power Plant NRW served as a blue print for the European new build program initiated in the late 90s.

Overview of new built projects in Europe

Plant	Operator	Site	Number of units	MW
Datteln 4	E.ON	Datteln	1	1100
Walsum 10	STEAG/EVN	Walsum	1	750
Moorburg	Vattenfall	Moorburg	2	820
Westfalen D-E	RWE Power	Hamm	2	800
Rheinhafen RDK 8	EnBW	Karlsruhe	1	911
GKM 9	GKM	Mannheim	1	911
Wilhelmshaven	GDF SUEZ	Wilhelmshaven	1	800
Boxberg Block R	Vattenfall	Boxberg	1	675
Neurath G-F	RWE Power	Neurath	2	1100
Eemshaven A-B	RWE Power	Eemshaven	2	800
Rotterdam	GDF SUEZ	Rotterdam	1	800
Maasvlakte 3	E.ON	Rotterdam	1	1100
Ledvice	CEZ	Ledvice	1	660



Overview of new built projects in Europe

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Country	Name of Plant	Name of Company	Site of Plant	No. Units	Unit Cap. MW (gr.)	Tot. Cap. MW (el.)	Main Fuel	Life/RH Steam Temp. (°C)	start erection (Y)	COD (Y)	Delay (Y) estimated
Czech Republic	Ledvice 4	CEZ AS	Ledvice	1	660	660	LIG	600/610	2008	2014	1,5
Germany	Neurath F&G	RWE Power	Neurath	2	1100	2.200	LIG	595/605	2005	Jul 12	2,5
Germany	Datteln 4	E.ON	Datteln	1	1100	1.100	HC	600/620	2007	?	> 4
Germany	Moorburg A-B	Vattenfall Europe	Hamburg-Moorburg	2	820	1.640	HC	600/610	Okt 07	2015	2
Germany	Boxberg R	Vattenfall Europe	Boxberg	1	675	675	LIG	600/605	Okt 06	Okt 12	2
Germany	GKM 9	Grosskraftwerk Mannheim AG	Mannheim	1	911	911	HC	600/610	2007	2015	2
Germany	RDK8	EnBW	Karlsruhe	1	912	912	HC	600/620	2008	2014	2
Germany	Walsum 10	STEAG/EVN	Duisburg	1	725	725	HC	610/620	2006	Nov 13	3
Germany	Lünen	Trianel	Lünen	1	750	750	HC	600/610	Sep 08	Jan 14	0,5
Germany	Wilhelmshaven	GDF Suez	Wilhelmshaven	1	800	800	HC	600/610	Sep 08	Apr 14	1,5
Germany	Westfalen D&E	RWE Generation	Hamm	2	800	1600	HC	600/610	Feb 08	Sept 14 (E)	2
Netherlands	Eemshaven	RWE Power	Eemshaven	2	800	1.600	HC	600/610	Sep 08	Jan 15 (A)	1,5
Netherlands	Maasvlakte	Electrabel	Rotterdam	1	750	750	HC	600/610	2009	2013	1
Netherlands	Maasvlakte 3	E.ON Benelux	Maasvlakte	1	1100	1.100	HC	600/620	Feb 08	2015	2,5

The T24 material is used in European power plant projects with a capacity of 14.8 GW.

Project Management is key to success

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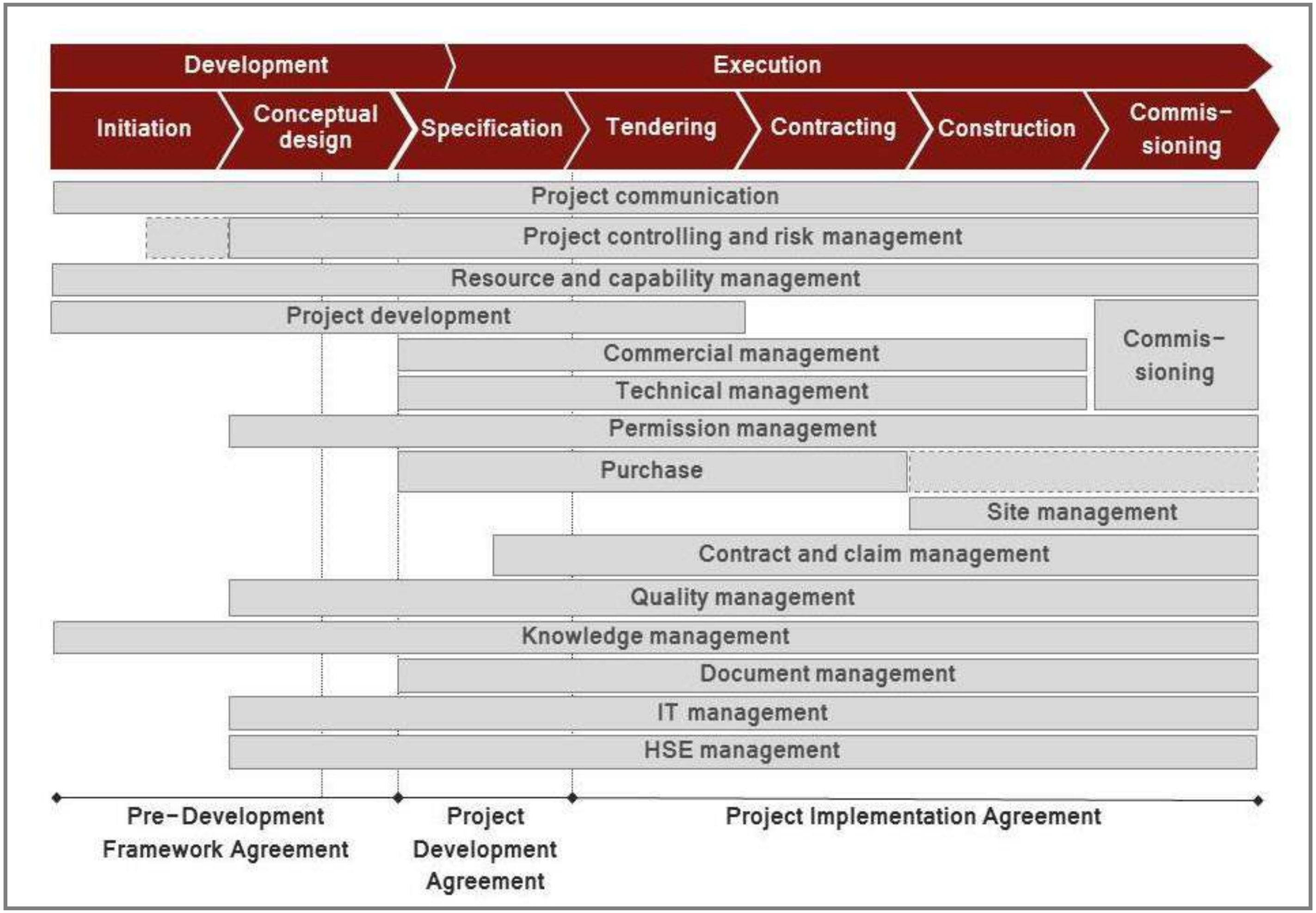

There are 16 processes covering all tasks that need to be managed for a successful new build project These processes run within a phase or across phases.

Project Management: Organization

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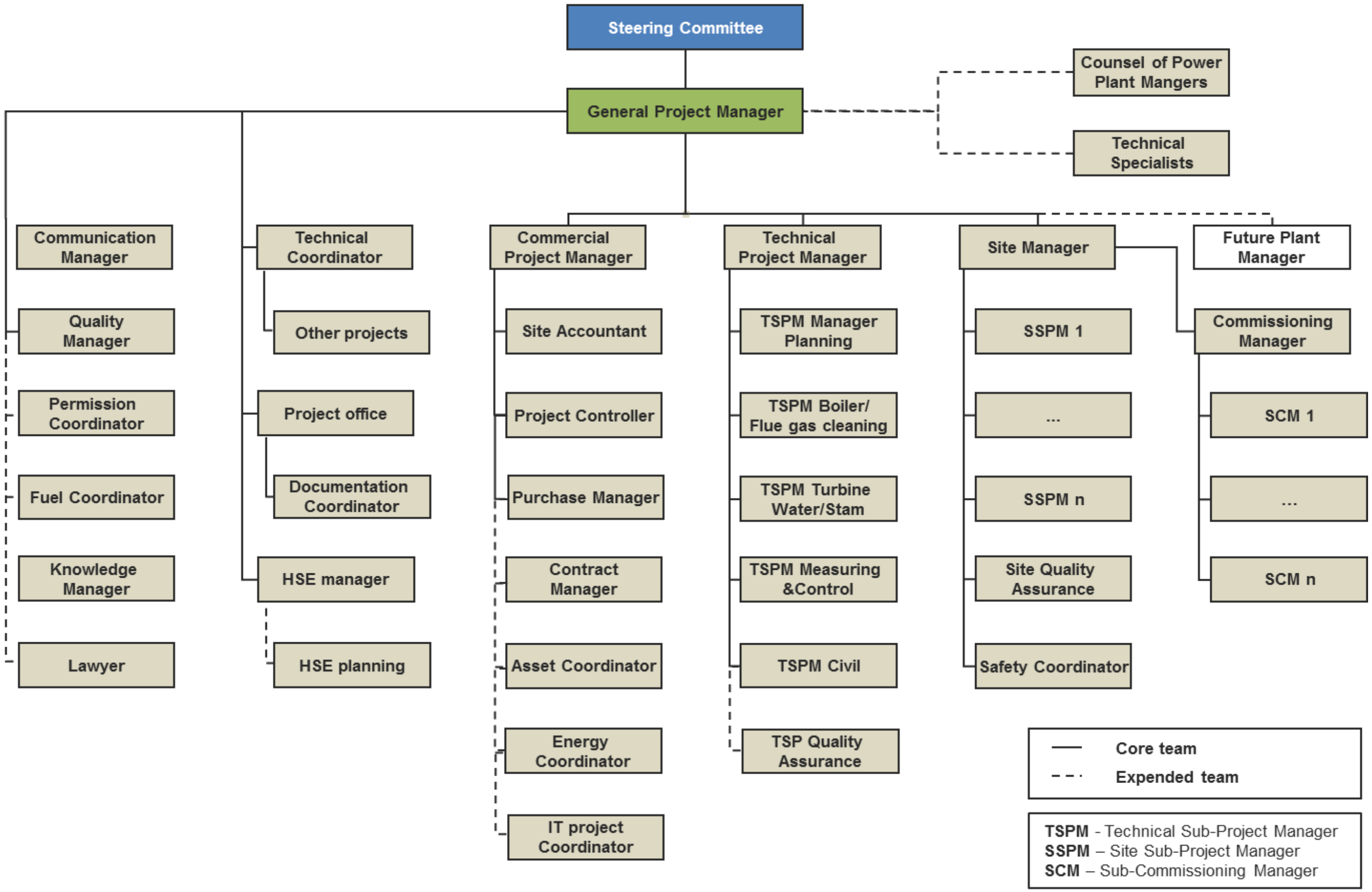
Project Organisation (typical)



The organization structure is usually based on the model of a hybrid project organization. It combines the advantages of a line and a matrix approach.

Project Management: Scheduling

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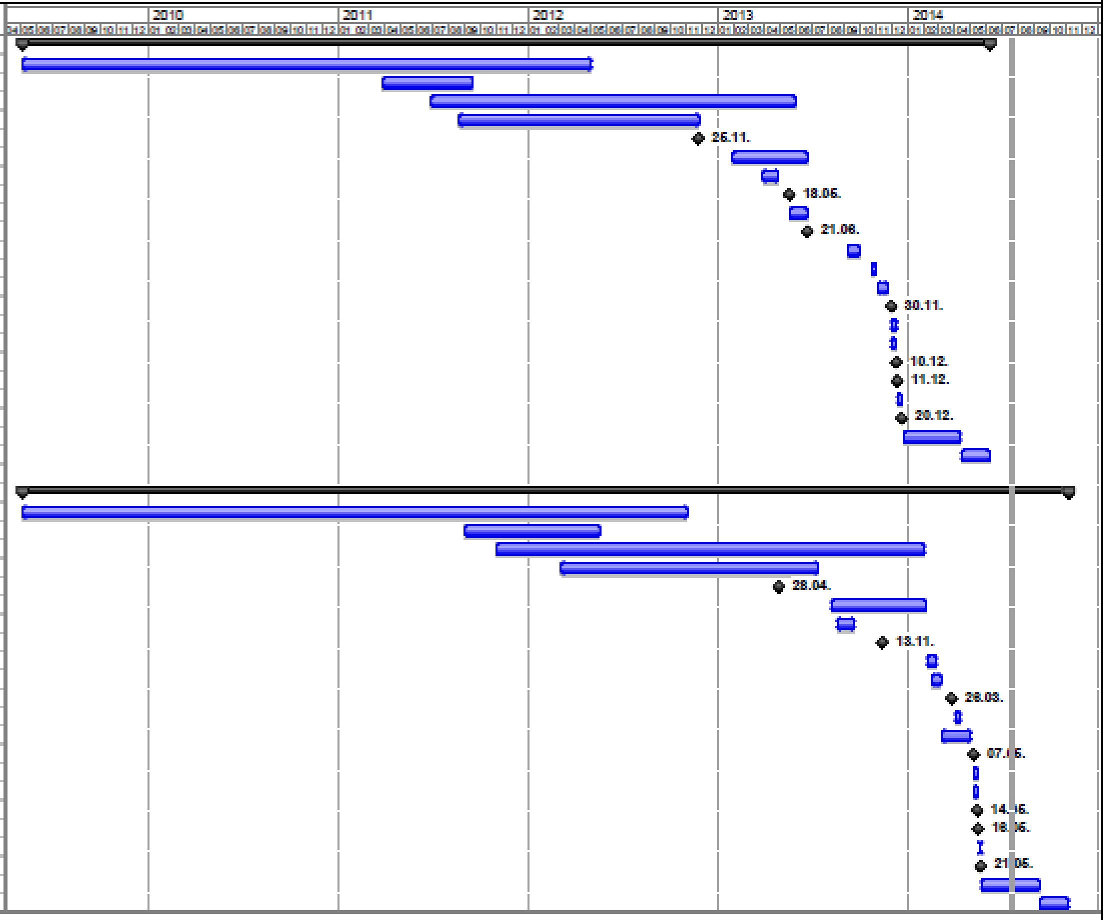
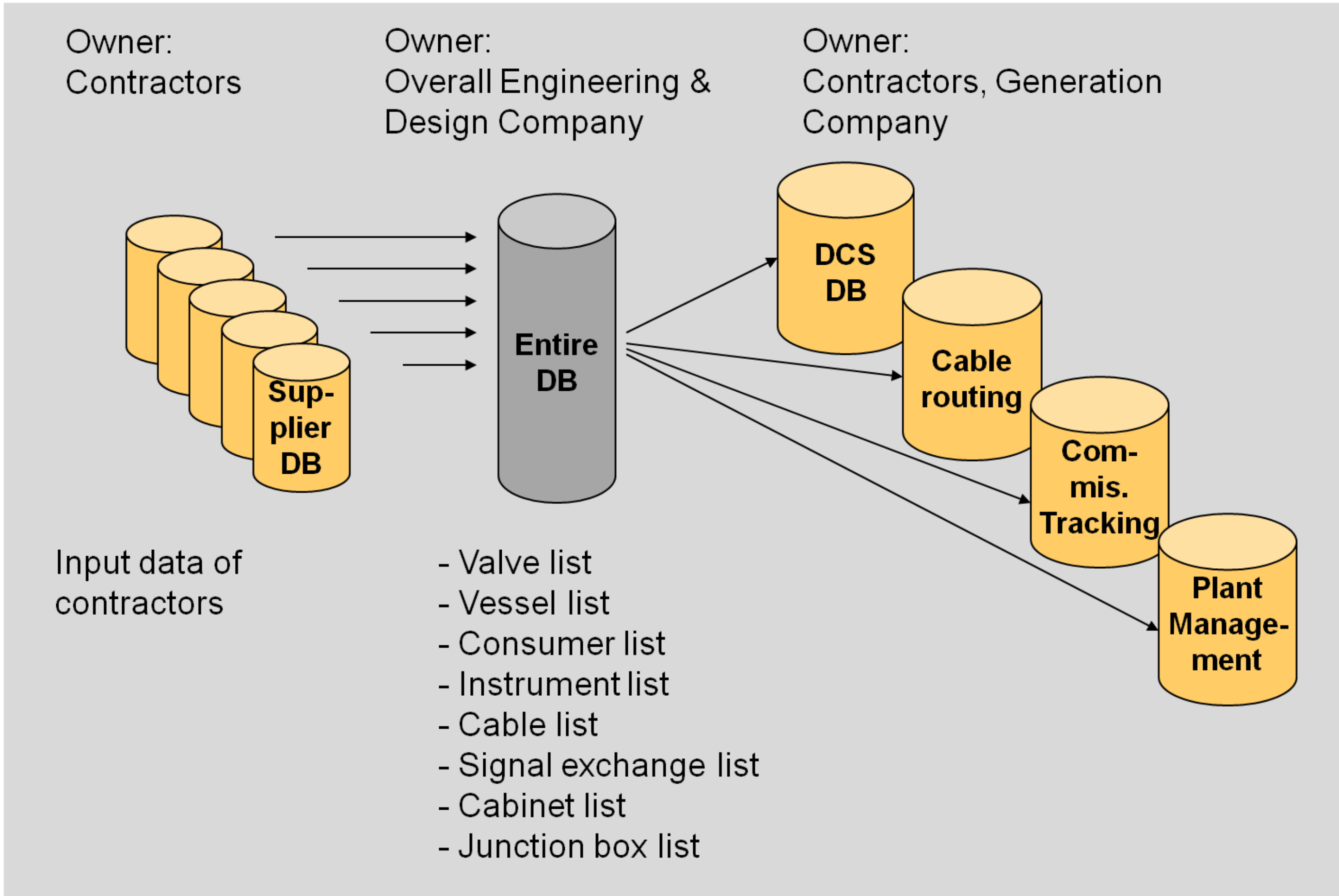
Commissioning
Hard Coal Plant 2x800MW

Nr.	Vorgangsname	Start	End
1	**Unit A**	**08.05.09**	**08.08.14**
2	Civil Works	06.05.09	01.05.12
3	Main Steel Structure Boiler	29.03.11	16.09.11
4	Machinery Equipment	29.06.11	29.05.13
5	Start Pressure Part Boiler	22.08.11	25.11.12
6	Completion of Boiler Hydrotest	25.11.12	25.11.12
7	Electrical Equipment/C&I Systems	29.01.13	21.06.13
8	Boiler Heat Treatment	28.03.13	26.04.13
9	Air/Flue Gas System Unit A ready for test runs	18.05.13	18.05.13
10	Boiler Air System Test Run Phase	19.05.13	21.06.13
11	1st Oil Firing (Oil Burners)	21.06.13	21.06.13
12	Chemical Cleaning / Flushing	07.09.13	29.09.13
13	Commissioning of Boiler Circulation System	25.10.13	29.10.13
14	Commissining of Water- Steam System	04.11.13	22.11.13
15	1st Oil Fire	30.11.13	30.11.13
16	Bypass operation for steam cleanliness	30.11.13	10.12.13
17	Establishment of protection layer (oil fire)	30.11.13	07.12.13
18	1st coal fire	10.12.13	10.12.13
19	1st steam on Turbine	11.12.13	11.12.13
20	Check of generator protection	12.12.13	19.12.13
21	1st Synchronisation	20.12.13	20.12.13
22	Optimisation	24.12.13	11.04.14
23	Test Runs / Reliability Run	14.04.14	06.06.14
24			
25	**Unit B**	**08.05.09**	**05.11.14**
26	Civil Works	06.05.09	02.11.12
27	Main Steel Structure Boiler	02.09.11	17.05.12
28	Machinery Equipment	01.11.11	01.02.14
29	Start Pressure Part Boiler	05.03.12	11.07.13
30	Completion of Boiler Hydrotest	28.04.13	28.04.13
31	Electrical Equipment/C&I Systems	07.08.13	04.02.14
32	Boiler Heat Treatment	18.08.13	19.09.13
33	Air/Flue Gas System Unit B ready for test runs	13.11.13	13.11.13
34	Boiler Air System Test Run Phase	07.02.14	24.02.14
35	Chemical Cleaning / Flushing	17.02.14	05.03.14
36	1st Oil Firing (Oil Burners)	26.03.14	26.03.14
37	Commissioning of Boiler Circulation System	02.04.14	11.04.14
38	Commissining of Water- Steam System	08.03.14	01.05.14
39	1st Oil Fire	07.05.14	07.05.14
40	Bypass operation for steam cleanliness	07.05.14	14.05.14
41	Establishment of protection layer (oil fire)	07.05.14	14.05.14
42	1st steam on Turbine	14.05.14	14.05.14
43	1st Coal fire	16.05.14	16.05.14
44	Check of generator protection	19.05.14	20.05.14
45	1st Synchronisation	21.05.14	21.05.14
46	Optimisation	22.05.14	10.09.14
47	Test Runs / Reliability Run	11.09.14	05.11.14



The project schedule is of utmost importance for an efficient project management. The activities are based on a functional breakdown of the power plant.

Integrated planning is the basis for efficient operation



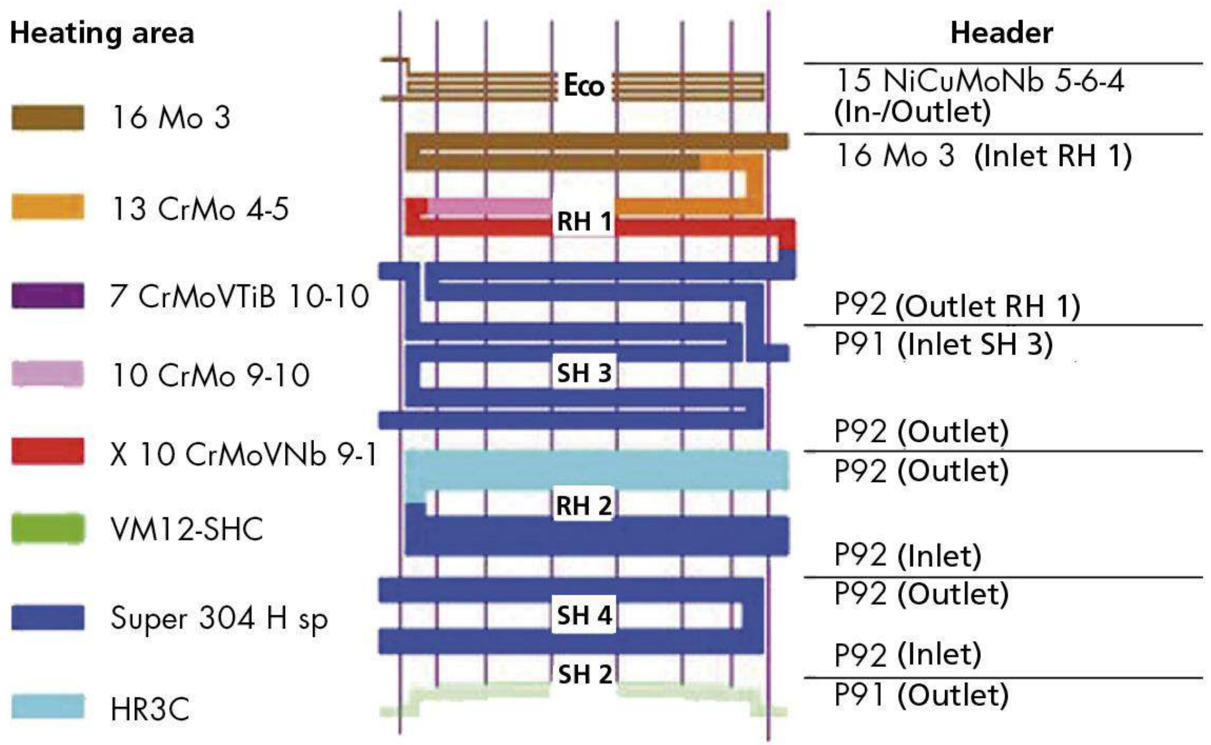
The essential tool for data management is the plant master database. It contains all C&I equipment, vessels, consumers, valves, actuators, motors, pumps.

Quality Assurance & Control are very important

- High time pressure and cost pressure on suppliers has a negative impact on the quality assurance & control necessary on the part of suppliers
- Work is subcontracted (or even sub-subcontracted) to manufacturers lacking relevant experience
- Work packages are divided up and allocated to a large number of different manufacturing sites
- Staff numbers have been cut in many manufacturing areas
- In terms of a high quality product, the earliest possible implementation of quality management is required

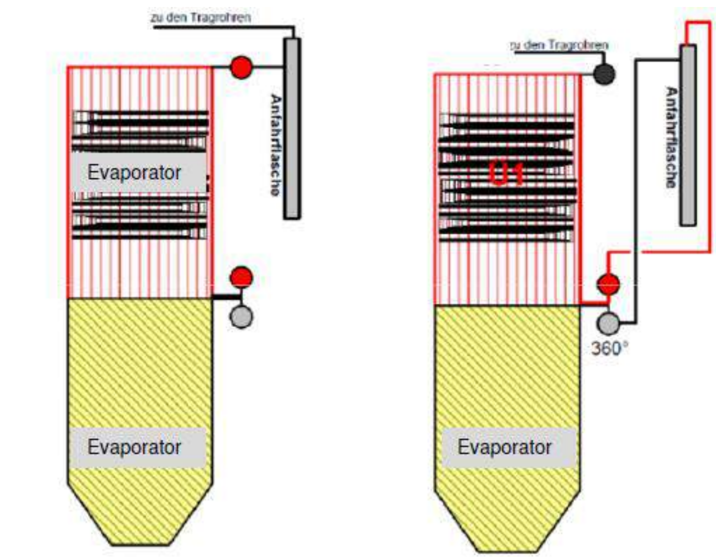
Use of new materials

European projects differ in size and steam parameters, therefore varying material concepts and boiler designs are used.



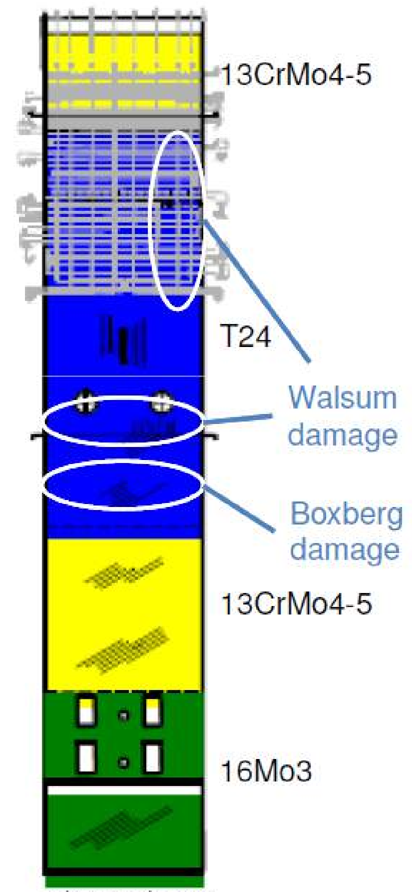
Source: GKM

Use of T24



Circuit variant A

Circuit variant B



Schematic diagram

The T24 material was chosen as material in different parts, e.g. membran tube wall, superheater and reheater bundles and supporting tubes.

Qualification of the T24 material

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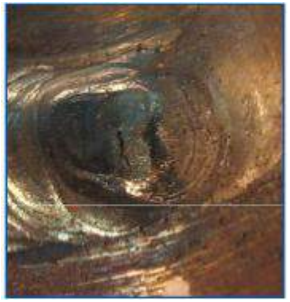
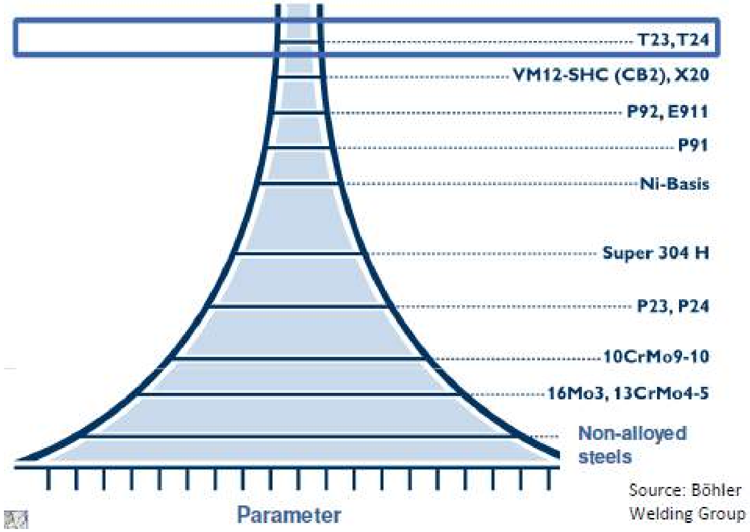
Qualification of the material 7CrMoVTiB10-10 in AVIF research projects:

- FDBR-/VGB research project „Qualification of materials for the use in steam generators with high temperature levels“ (A77, duration: 1994-1998)
- Research project „Demonstration of long-term properties of weld joints of modern steels for the use in steam generators at temperatures of up to 620 °C“ (A129, duration: 1998-2001)
- Fitness for use established in accordance with VdTÜV materials data sheets 533
- Technical supply conditions pursuant to DIN EN 10216-2 and VGB-R 109

Qualification process revealed small processing window:

- Accurate adherence to manufacturing prodecures
- Stringent craftsmanship of welders

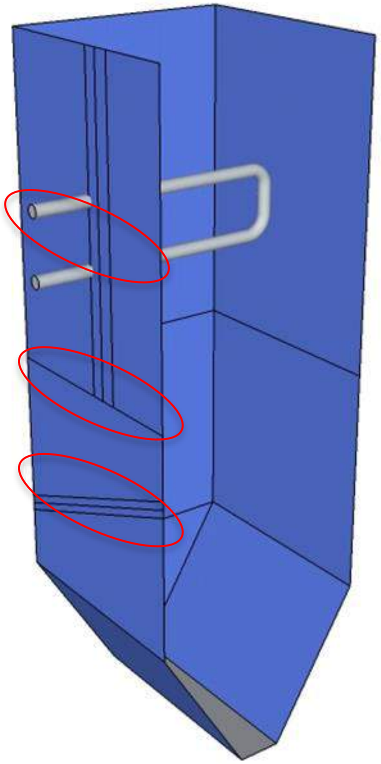




The T24 material was qualified but it places high demands on processing.

T24: series of damage events

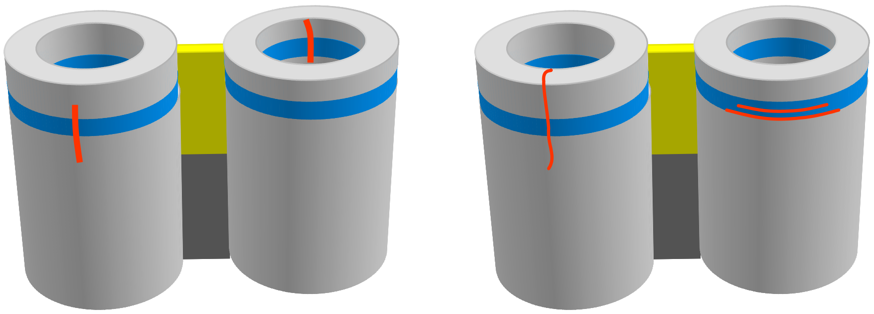
Starting March 2010 – hard coal fired power plants in Europe



in the area of superheater and reheater tube penetration

transition pieces

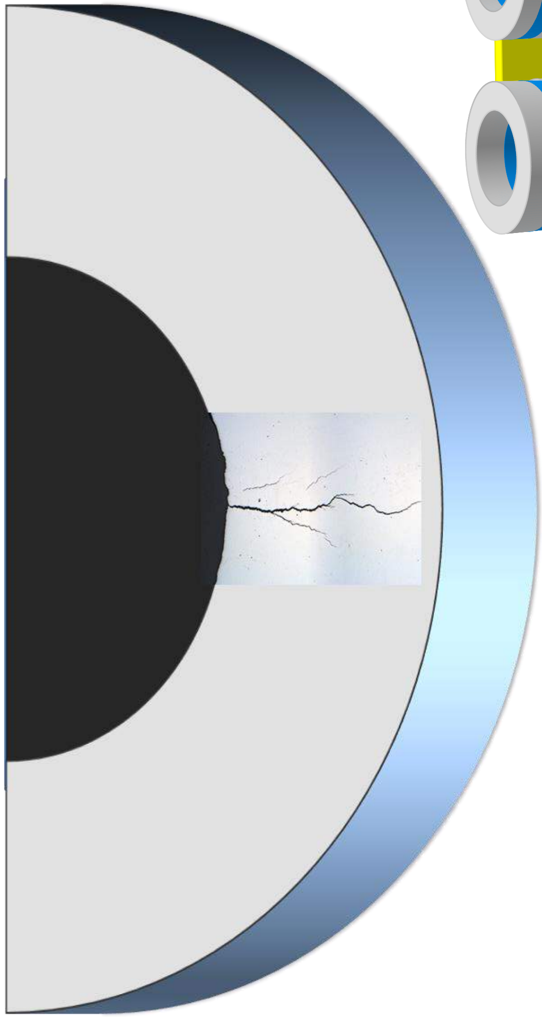
upper part of spiral wall

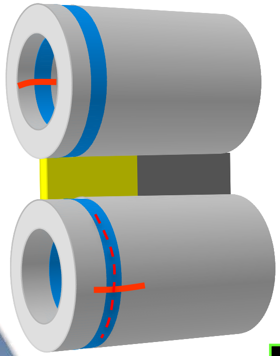


Quelle: Dr. Benesch, Herausforderungen an Werkstoffe durch den zukünftigen Kraftwerksbetrieb, Ge, 13.09.2012

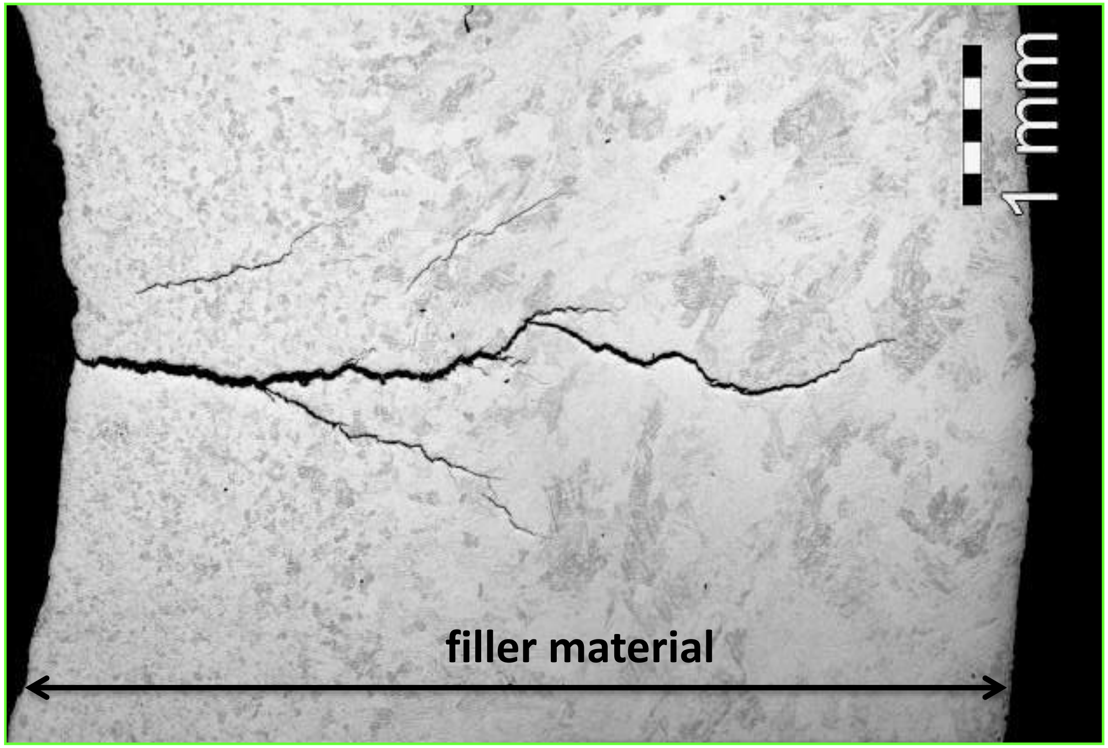
T24: failure characteristics

March 2010 – hard coal fired power plants in Europe





- crack initiation purely at the inner surface
- branched structure
- trans- and intergranular crack propagation
- nearly without any deformation



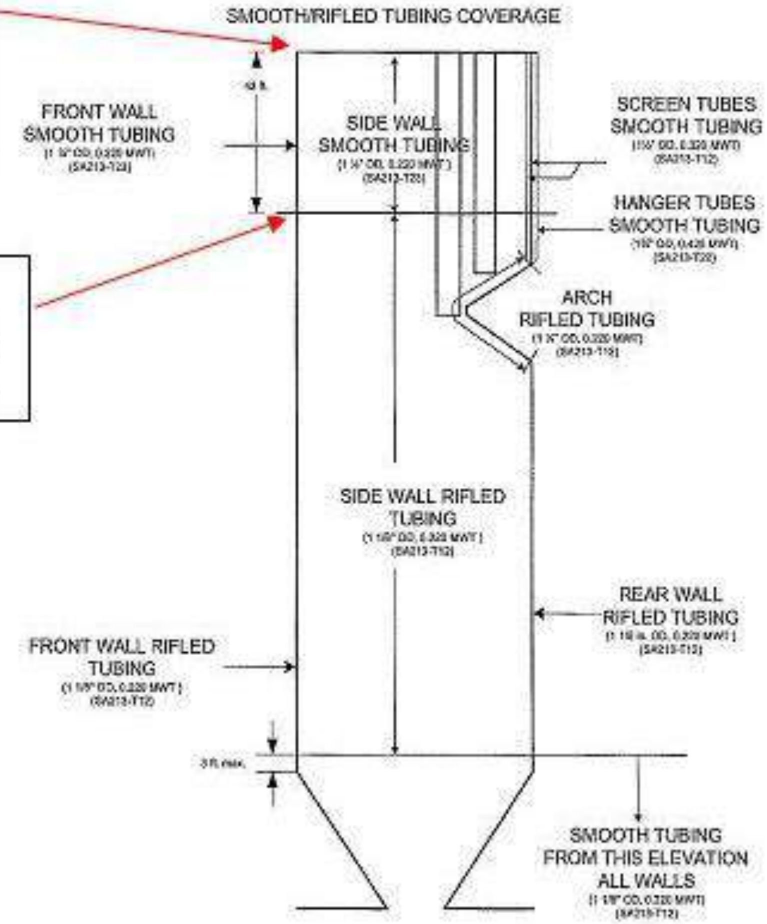
2009 – hard coal fired power plants in USA

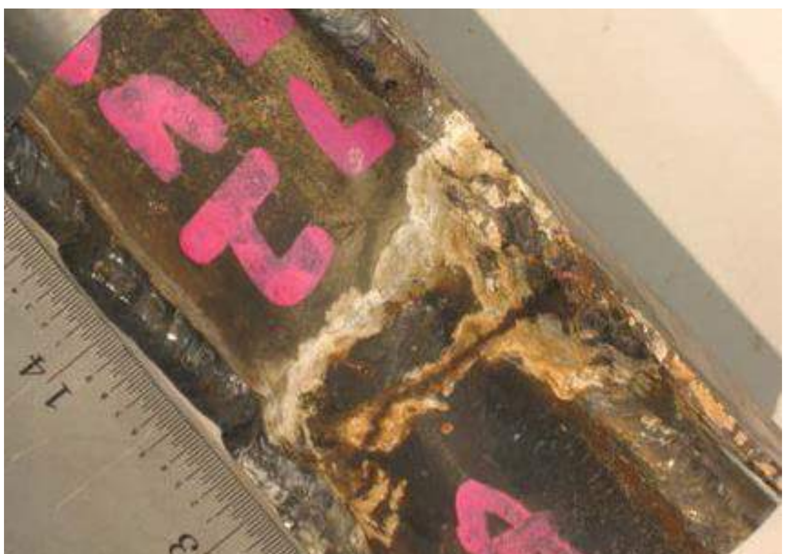
T23 only at the top of the boiler

water chemistry was not controlled in respect to oxygen

T23 Roofline Failure Location, elevation 5065'.

T23 Shop Weld Failure Location, elevation 5022'.





Quelle: **SUPERCRITICAL UNIT EXPERIENCE WITH GRADE T23 EVAPORATOR TUBE; Eric Dupont, 2013**

T24: damage investigations

Preconditions for SCC

- sensitive condition of base material and/or weld joint due to chemical composition, structure, surface condition, etc.)
- critical stresses resulting from external impact, welding stresses and exceeding a system specific threshold of stress
- presence of a fluid promoting SCC (e.g. H)

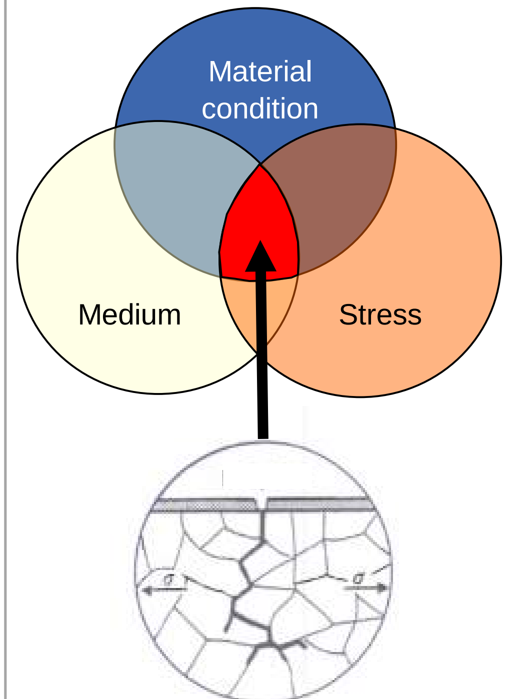
→ Appearance of SCC

Circumferential cracking

Cracking rectangular to weld

Quelle: Dr. Benesch, Herausforderungen an Werkstoffe durch den zukünftigen Kraftwerksbetrieb, Ge, 13.09.2012

SCC

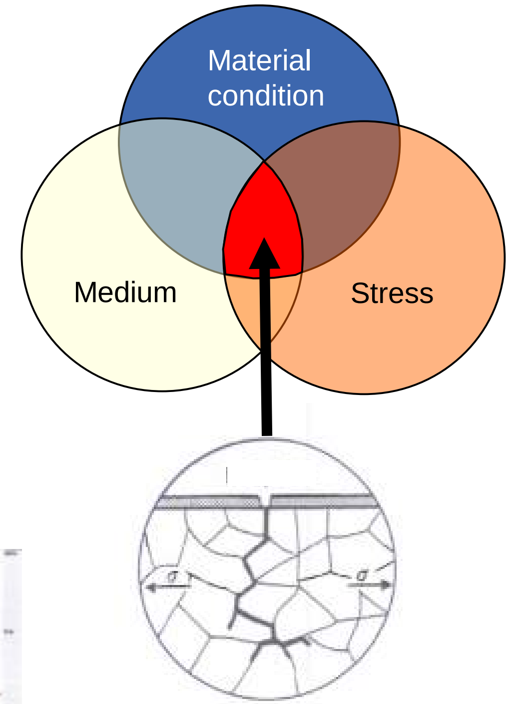


Hydrogen-induced stress corrosion cracking (SCC) was identified as a damage mechanism.

T24: preventive actions in three areas

Influencing the medium:

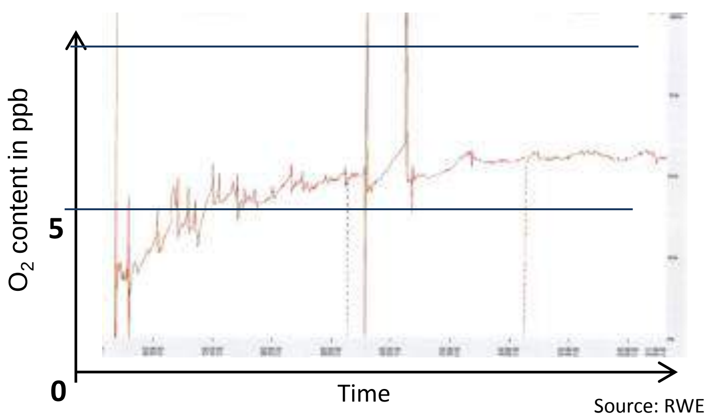
- Optimised chemical cleaning (pickling)
- Optimised water chemistry of boiler water
- Optimised start-up procedure



Influencing stresses:

- Heat treatment at 450°C-520°C of the complete boiler with external burners

Source: Vesta

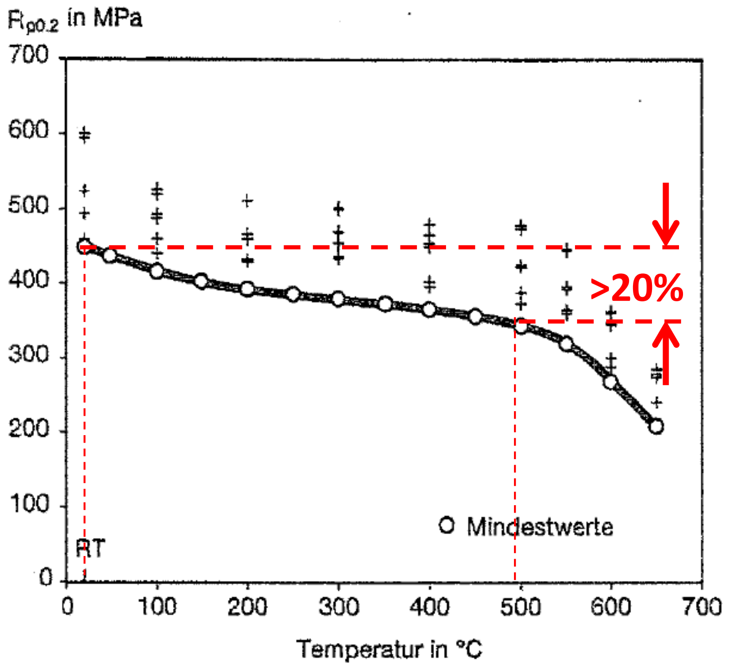


O_2 content during start-up

Influencing material condition:

- Local heat treatment at temperatures in the range of 600°C in highly stressed area

T24: influencing the stresses by the boiler heating



0,2%-yield strength versus test temperature

FDBR-/VGB-Forschungsvorhaben A77: „Qualifizierung von Werkstoffen zum Einsatz in Dampferzeugeranlagen mit erhöhten Temperaturen“

„Boiler heating“ before first commissioning at 480-520°C leads to:

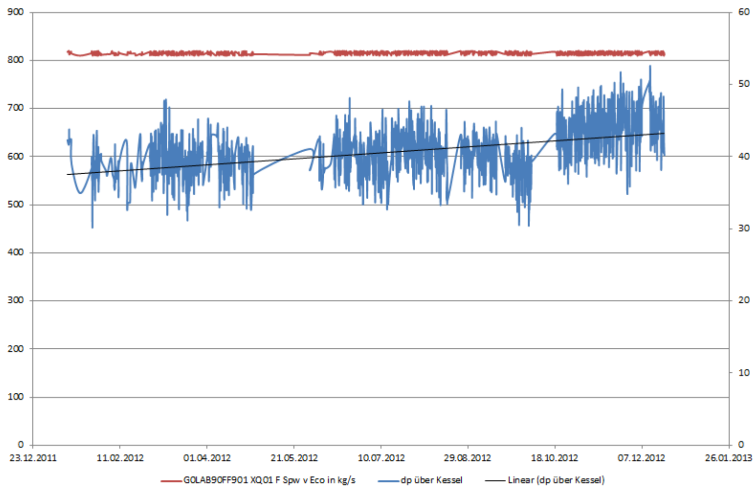
⇒ reduction of lokal stresses (appr. 20%) ✓

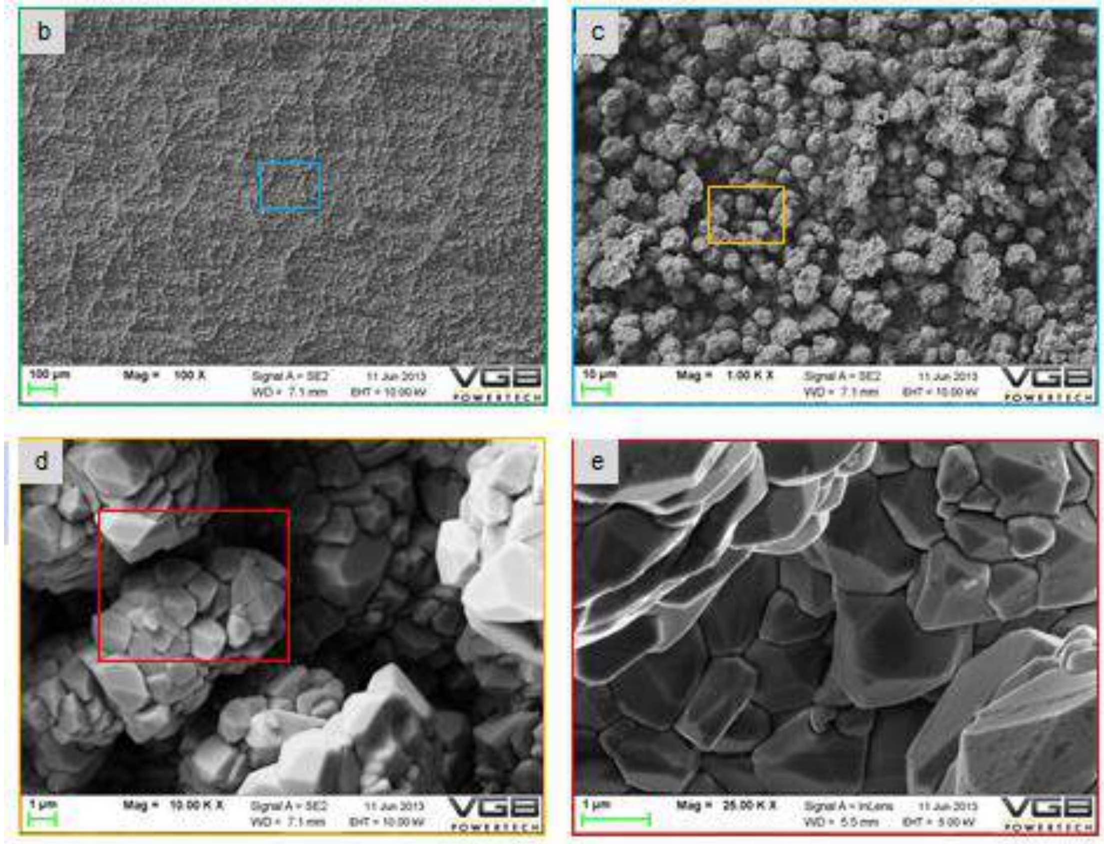
⇒ lower sensitivity against HSCC ✓

⇒ increase sensitization of austenitic materials ?

T24: influencing the medium

Reduction of oxygen content





- Increase of pressure loss during the period of low oxygen operation
- Beginning of ripples formation was identified after approx. 1,5 years of operation