

Steinmüller Engineering Conference 2016

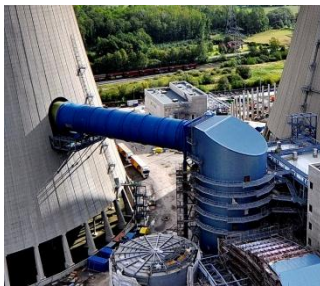
Customized Process Gas Coolers and Waste Heat Boilers for various Applications

Speaker: Dr. Ralph Ernst (Department Manager Steam Generation)

&

Analysis, Optimization and Improvement of Utility Boilers with In-house Design Tool

Speaker: Lutz Brandau (Head of Marketing & Proposals)



Employment Record Dr. Ralph Ernst

Since 02/2013	Steinmüller Engineering GmbH; Gummersbach, Department Manager Steam Generation
Since 10/2010	Steinmüller Engineering GmbH; Gummersbach, Department Manager Chemical Plant Components
04/2009 – 09/2010	Steinmüller Engineering GmbH; Gummersbach, Process Engineer Chemical Plant Components
01/2008 – 03/2009	Steinmüller Engineering GmbH; Gummersbach, Process Engineer Flue Gas Treatment
07/2005 – 12/2007	Fisia Babcock Environment GmbH; Gummersbach, Process Engineer Electrostatic Precipitator / Fabric Filter
08/2002 – 05/2005	University of Technology Darmstadt, Scientific Assistant BMBF key project Homogenous Multi-Phase Catalysis Parallel screening of Heterogeneous Catalysts
06/2002	PhD Thesis, „Simultaneous adsorption and desorption of sulfur dioxide and hydrogen chloride on magnesia supported activated carbon“
03/1998 – 06/2002	University of Technology Darmstadt, Scientific Assistant in research and student education



Employment Record Lutz Brandau

since 03/2016	Steinmüller Engineering GmbH, Gummersbach, Germany Head of Marketing & Proposals act. Department Manager Proposals Steam Generation
06/2015-02/2016	Steinmüller Engineering GmbH, Gummersbach, Germany Department Manager Proposals Steam Generation <ul style="list-style-type: none">• Utility boiler• WHB, PGC for Chemical Process Industry
2000 – 2015	ONI-Wärmetrafo GmbH, Lindlar, Germany Heat Recovery and Energy Saving Systems <ul style="list-style-type: none">• Area Sales Manager• Key Account international• Project Manager
1999 – 2000	Babcock Borsig Power Energy GmbH, Oberhausen, Germany Thermal Power Plant / Project Engineering <ul style="list-style-type: none">• Process Engineer / Team Leader
1992 – 1999	L.&C. Steinmüller GmbH, Gummersbach, Germany Thermal Power Plant / Utility Boiler / Industrial Boiler <ul style="list-style-type: none">• Process Engineer



Agenda

1

Product Overview

2

Design Tools

3

References

4

Case Study I

5

Case Study II

6

Summary

Engineering and supply for *Critical Static Equipment*

- Process gas coolers (downstream secondary reformer)
- Syngas coolers for gasification plants
- Waste heat boilers for catalytic processes (nitric acid plants and similar)

Motivation

- Increase of plant capacity
- Optimization of thermal and mechanical design

Technologies

- Natural circulation
 - horizontal fire tube boilers
 - vertical fire tube boilers
 - Texaco boilers
- Forced circulation – water tube boilers incl. superheater
- Radiant syngas coolers

2 Design Tools

IN - HOUSE

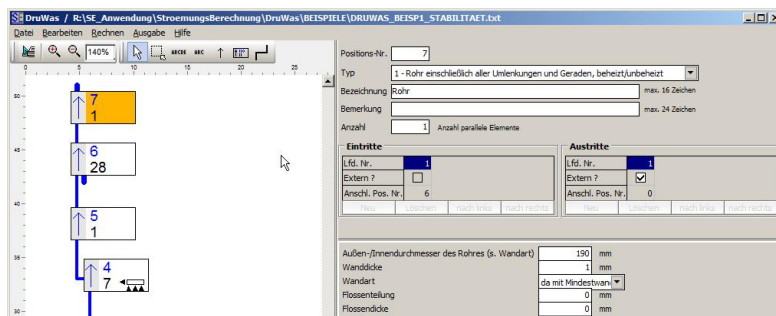
DIMBO

⇒ Thermal design



DRUWAS

⇒ Water circulation

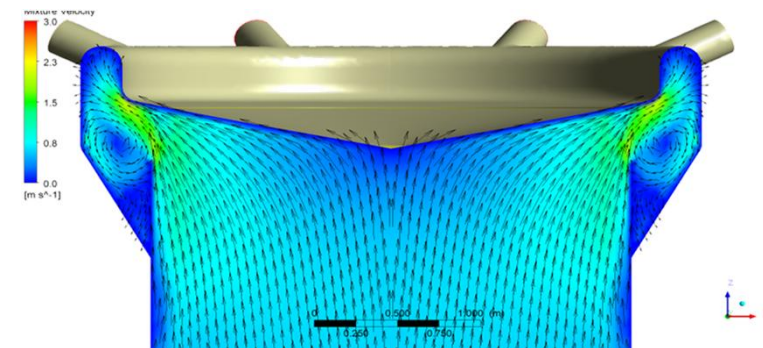


COMMERCIAL

⇒ Flow Optimization

⇒ Computational Fluid Dynamics

ANSYS Fluent

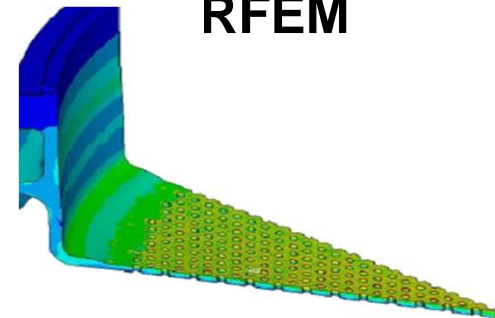


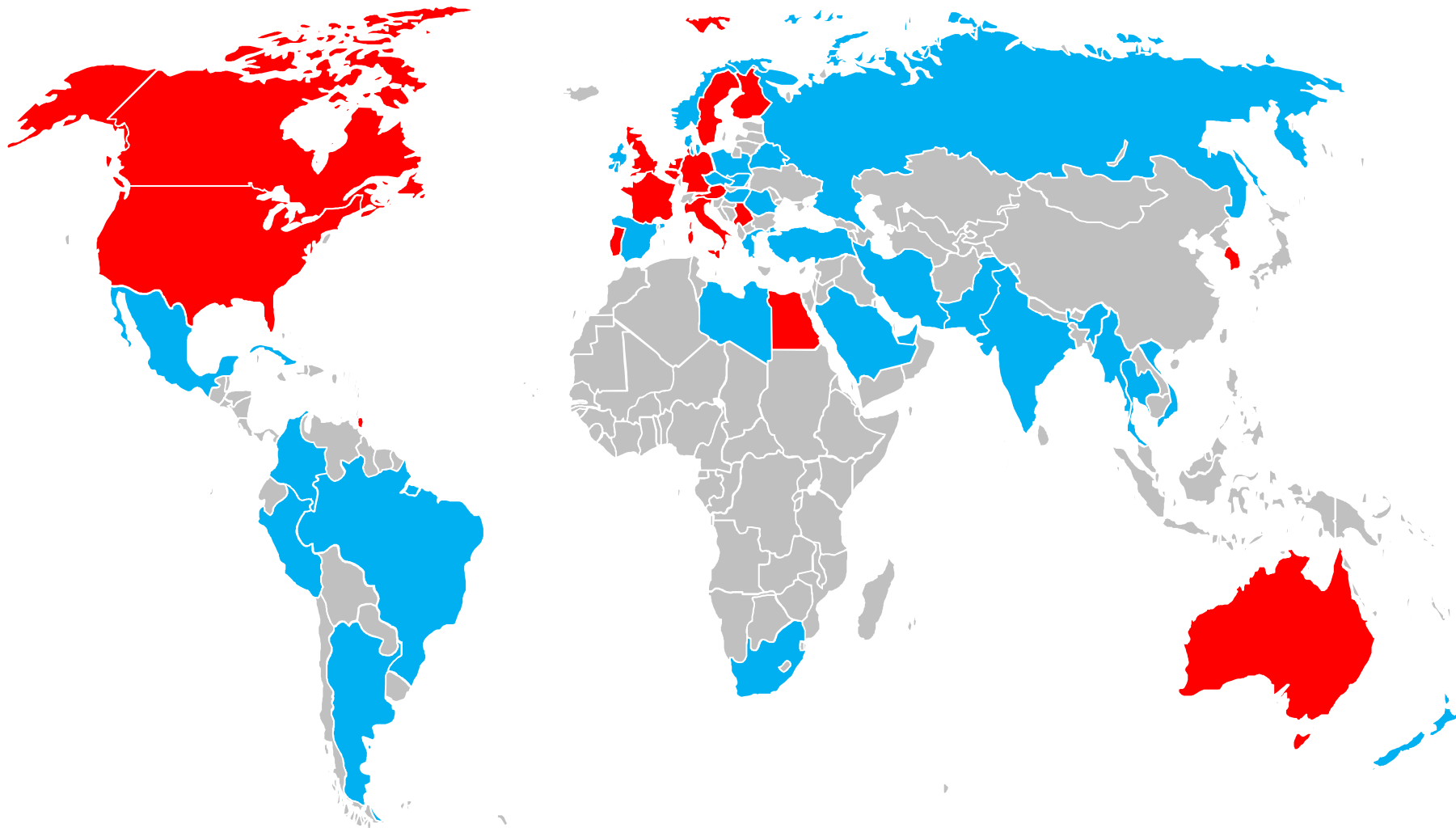
⇒ Stress analysis on critical items

⇒ Finite Element Method

ANSYS Mechanical

RFEM





SE holds the rights for all *Chemical Plant Component* products
of the former L&C Steinmüller company.

4 Case Study I – Process Gas Cooler in an Ammonia Plant

Revamp of a waste heat boiler downstream secondary reformer

Client: Yara Trinidad Limited

Location: Point Lisas / Trinidad

Process: Syngas for Ammonia plant



4 Case Study I – Process Gas Cooler in an Ammonia Plant

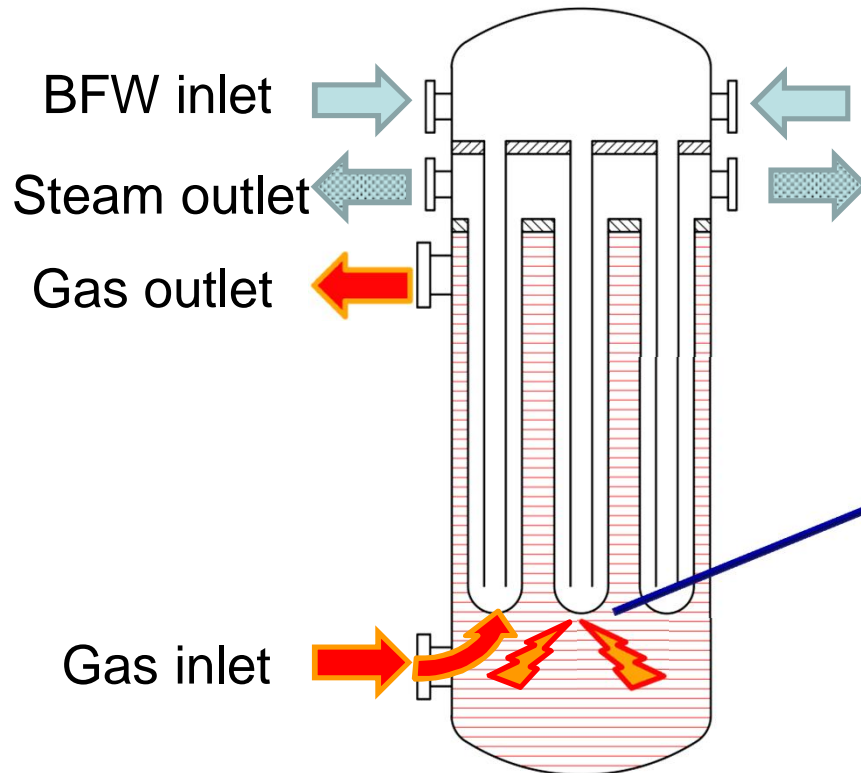
Scope split and technical data

Steinmüller Engineering	Client (Yara Trinidad Limited)	
▪ basic and detail engineering	▪ transport	
▪ supply of waste heat boiler	▪ erection	
▪ installation of refractory	▪ installation	
	▪ commissioning (with SE support)	
Project design data	Gas side	Water / Steam
Temperature @ inlet	980 °C	313 °C
Temperature @ outlet	471 °C	313 °C
Pressure	31,8 bar	103 bar
Mass flow	208.000 kg/h	200.000 kg / h

4 Case Study I – Process Gas Cooler in an Ammonia Plant

Existing Process Gas Cooler

- Forced circulation system
- Original WHB: Bayonet design (tube-in-tube), built 1975
- Frequent damages in return caps
- Regular exchange of bundle required

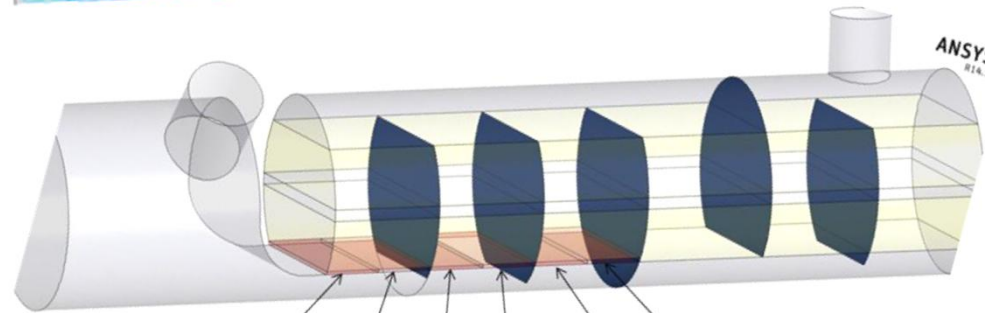
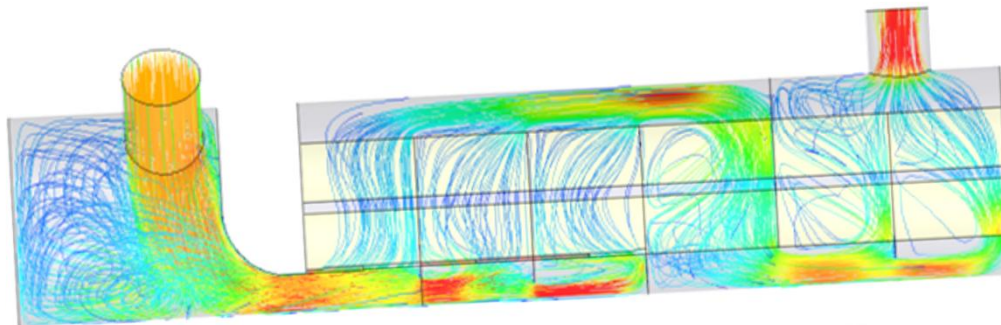


Area with high heat flux

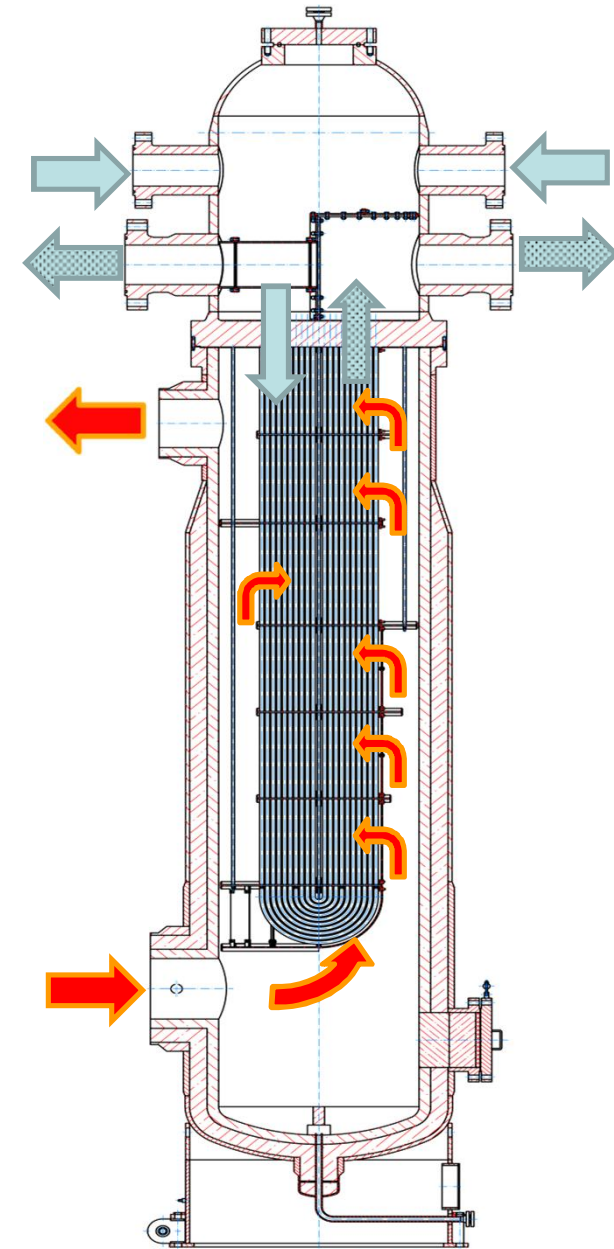
4 Case Study I – Process Gas Cooler in an Ammonia Plant

New Waste Heat Boiler

- U – Tube bundle, vertically arranged
- CFD – optimised design (in-house)
- Unchanged footprint
- Connection to existing piping



Perforated plates &
baffle extensions



4 Case Study I – Process Gas Cooler in an Ammonia Plant



Impressions from workshops in
Germany and Austria



4 Case Study I – Process Gas Cooler in an Ammonia Plant

Order entry: Dec 20th 2013

Delivery date: July 21st 2014

Bundle:	10,3 x 1,7 m	40,2 t
Shell:	9,5 m x 2,3 m	30,1 t
Refractory:		31,0 t
Assembled:	13,6 m	101,3 t



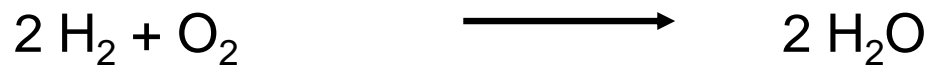
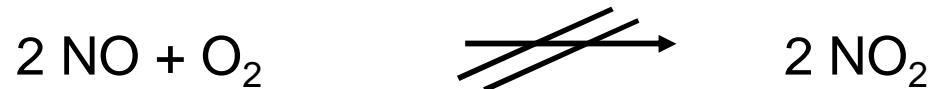
5 Case Study II – WHB downstream Ammonia Burner

Upgrade of a reactor / waste heat boiler for Caprolactam plant

Client: Domo Caproleuna

Location: Leuna, Germany

Process: Catalytic Ammonia Oxidation



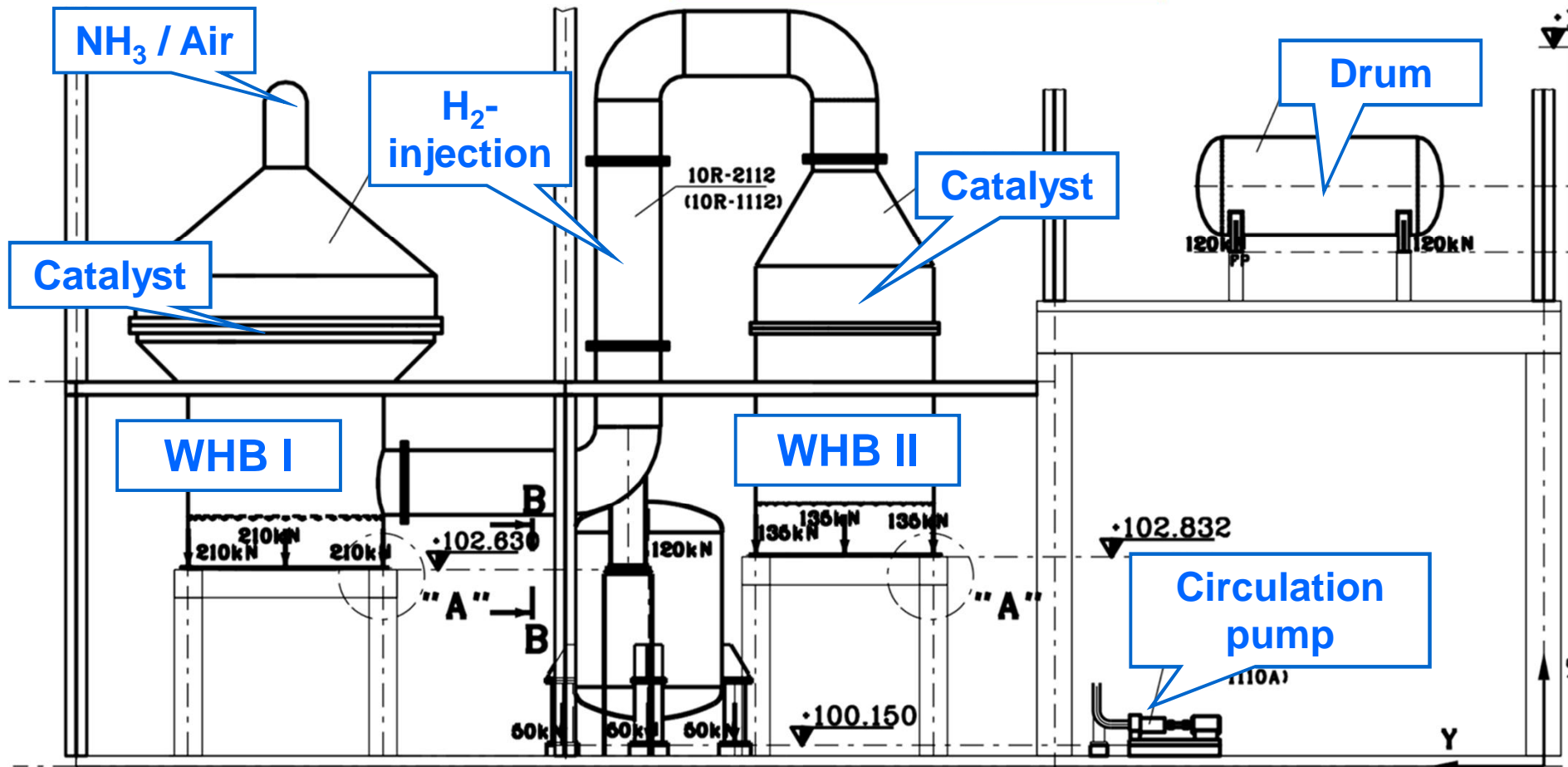
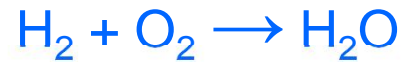
- NH_3 Reactor & O_2 Reactor built in 1995 by former L&C Steinmüller
- Enhanced catalyst enables higher production rate
- SE engineered and delivered new heating surfaces for increased plant load (100 % \rightarrow 170 %)

Ammonia Oxidation



O₂ – Reduction

(avoid NO₂ formation)



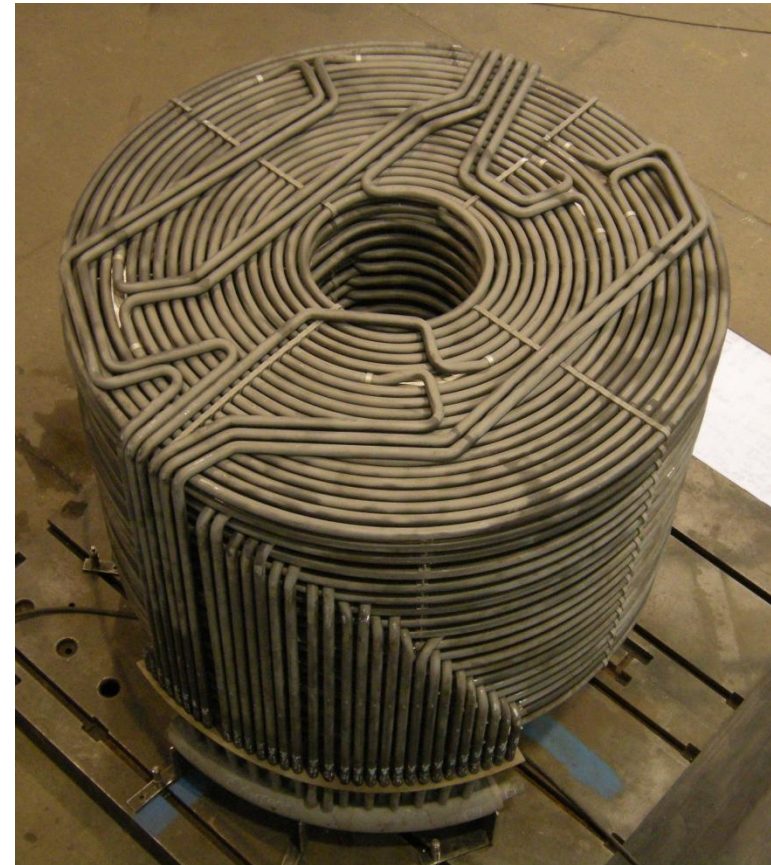
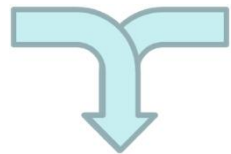
5 Case Study II – WHB downstream Ammonia Burner

Scope split and technical data

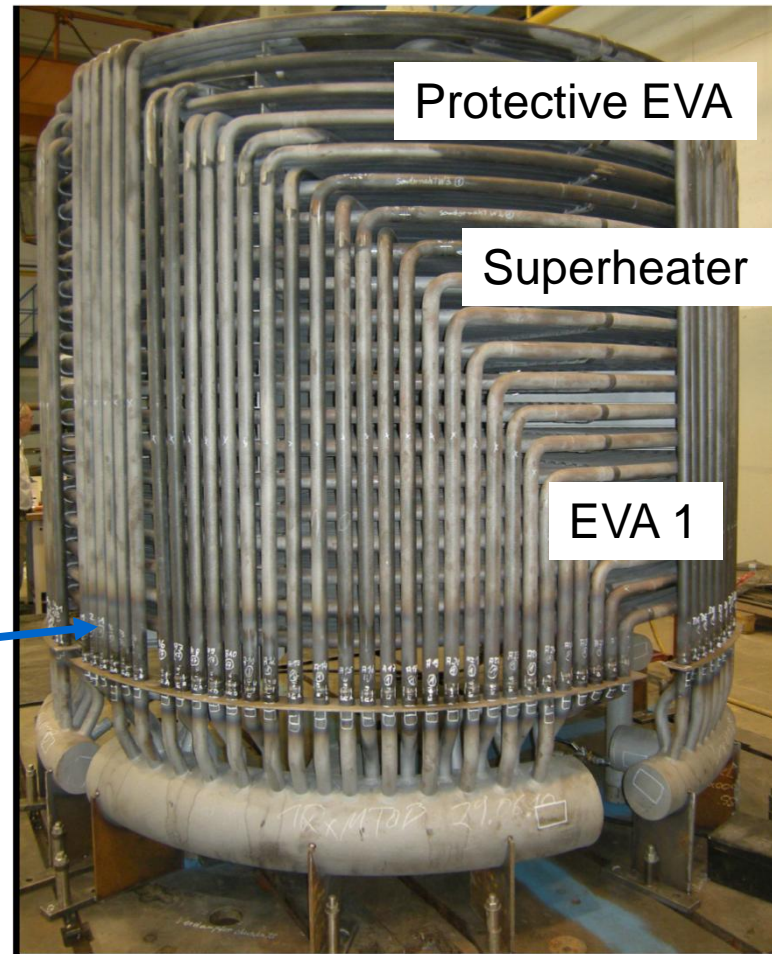
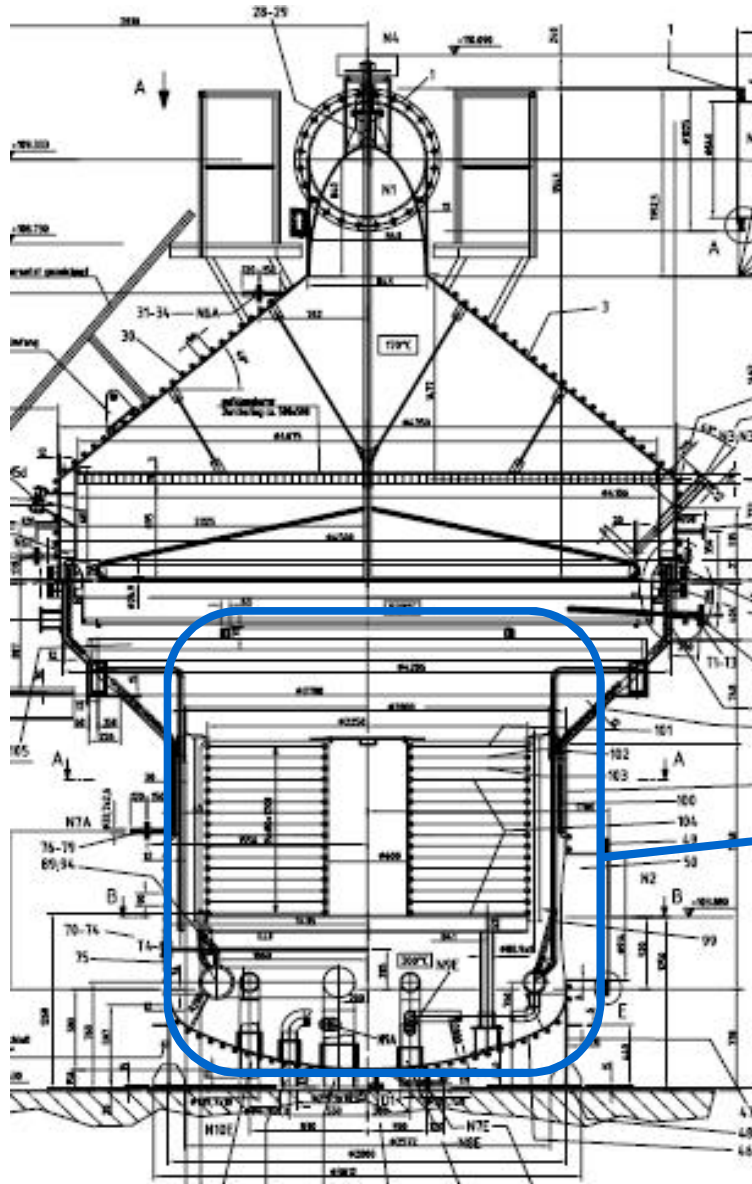
Steinmüller Engineering		Client (Domo Caproleuna)			
▪ basic and detail engineering		▪ installation			
▪ supply of heating surfaces in NH ₃ – reactor and O ₂ - reactor		▪ new catalyst (Pt – gauze)			
Project design data		Gas side		Water / Steam	
		100 %	170 %	100 %	170 %
Temperature @ inlet	°C	915	915	226	226
Temperature @ outlet	°C	300	335	297	300
Pressure	bar(a)	1,27	1,27	23,5	21,5
Mass flow	kg/h	15.400	26.100	8.300	13.400

5 Case Study II – WHB downstream Ammonia Burner

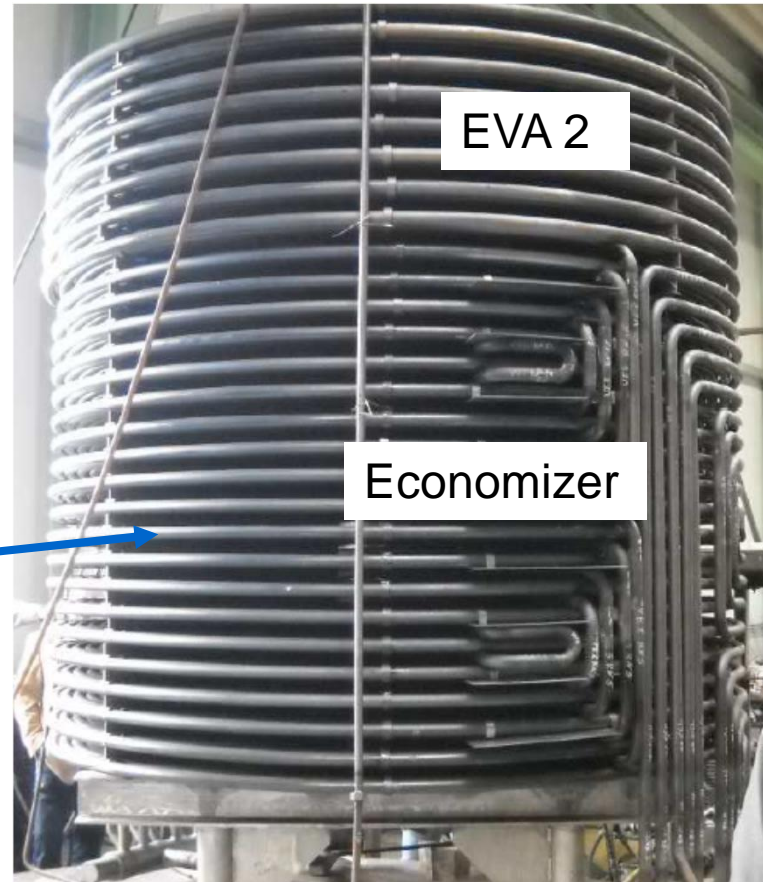
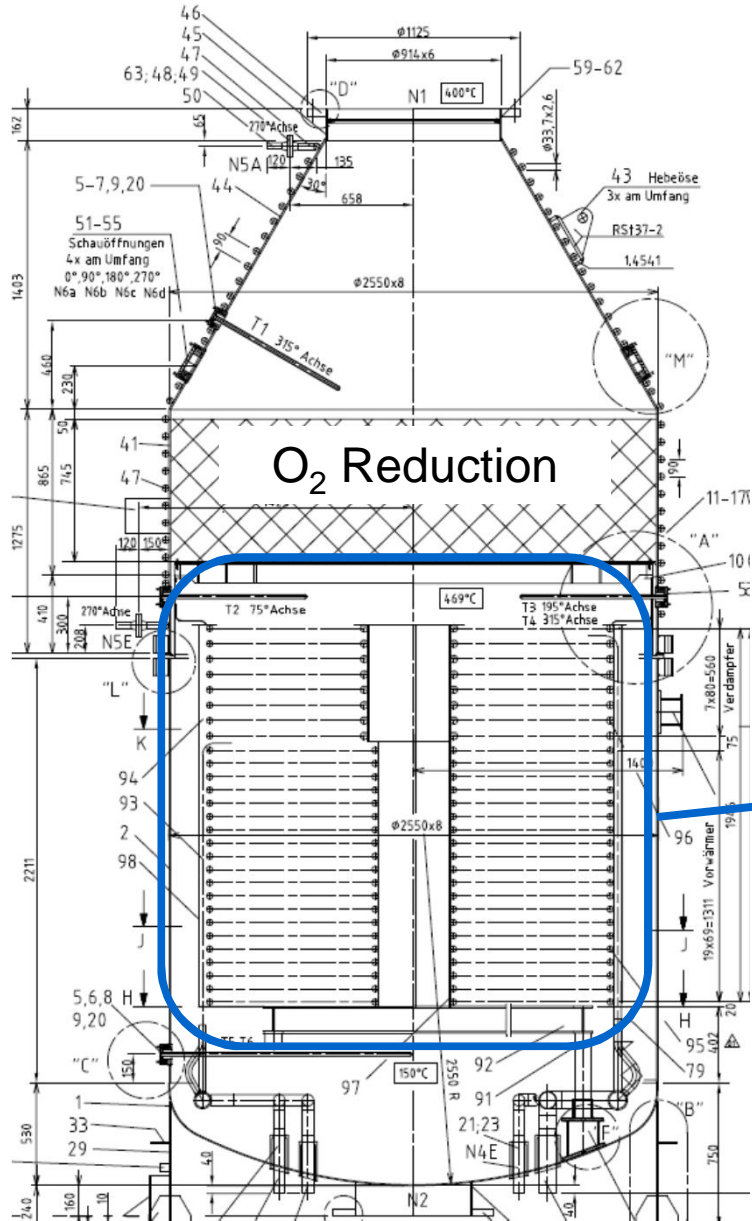
Manufacturing in German workshop



5 Case Study II – WHB downstream Ammonia Burner



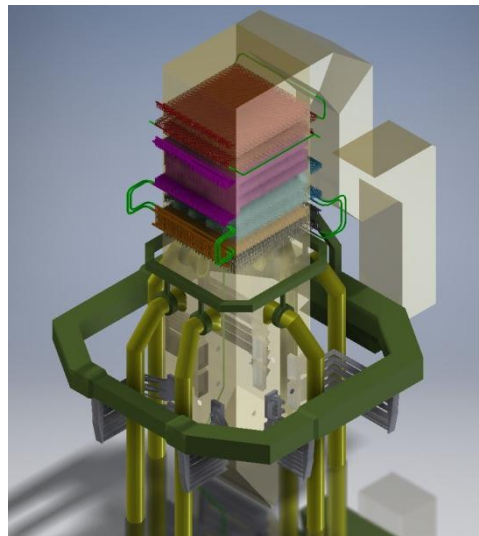
5 Case Study II – WHB downstream Ammonia Burner



6 Summary

- Steinmüller Engineering is the legal successor of L&C Steinmüller related to *Chemical Plant Components*
- SE operates successfully as supplier of engineering and hardware for challenging environments
- Supply from qualified and skilled manufacturers in Germany/Austria
- As an independent supplier SE operates in various contract configurations
- Our motivated crew is a competent partner for
 - Process engineering
 - Mechanical design
 - Hardware supply

Analysis, Optimization and Improvement of Utility Boilers with In-house Design Tool



Agenda

1

Motivation

2

Inhouse Design Tool  DimBo[®]

3

Executed References

4

Additional Services

5

Customers Benefit

1 Motivation

- **Boiler design review for replacement or new construction project**
- Capacity increase
- **Efficiency improvement**
- Increase in availability
- **Firing system conversion (e.g. LowNOx)**
- Changing fuel range
- **Problems with wear, fouling, corrosion**
- Improvement in partial load behavior
- **Expanded flexibility (e.g., co-fired plants)**
- Adaptation for S(N)CR retrofit
- **Shorter start-up times**
- ...

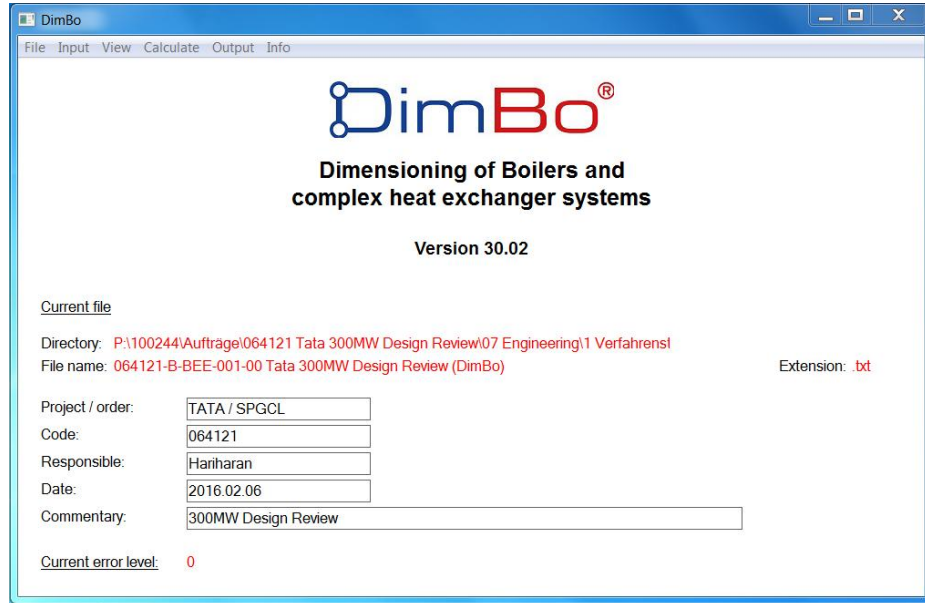


2 Inhouse Design Tool DimBo®

DimBo® is capable of handling complex systems of components for heat exchange and media conversion.

Amongst others the following parameters can be determined by DimBo® in detail:

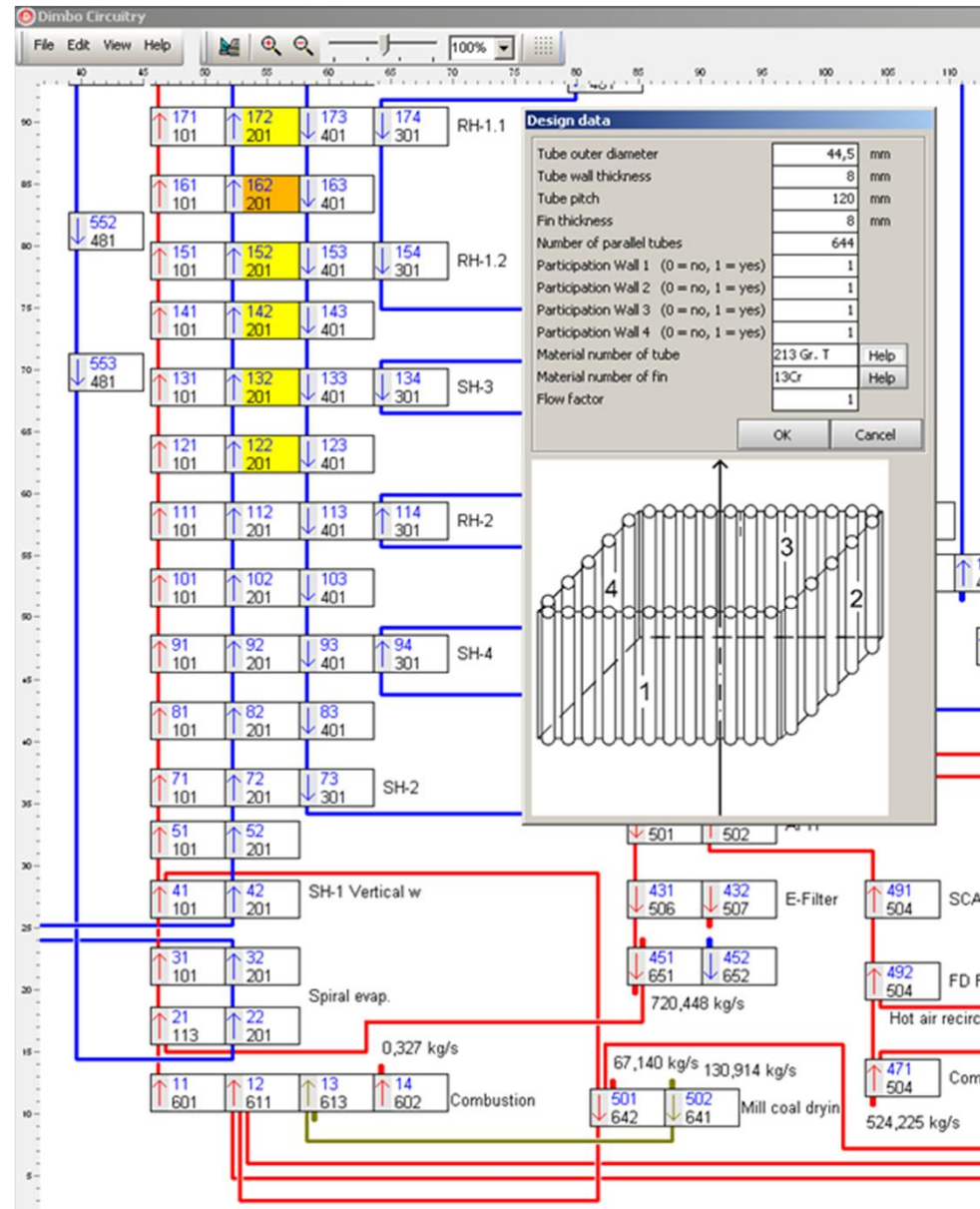
- Process parameters
- Medium flows (flow rates / analyses)
- Temperatures / specific enthalpies
- Heating surfaces
- Heat transfer
- Medium velocities
- Medium pressure loss
- Mass and energy balances
- Dynamic calculations

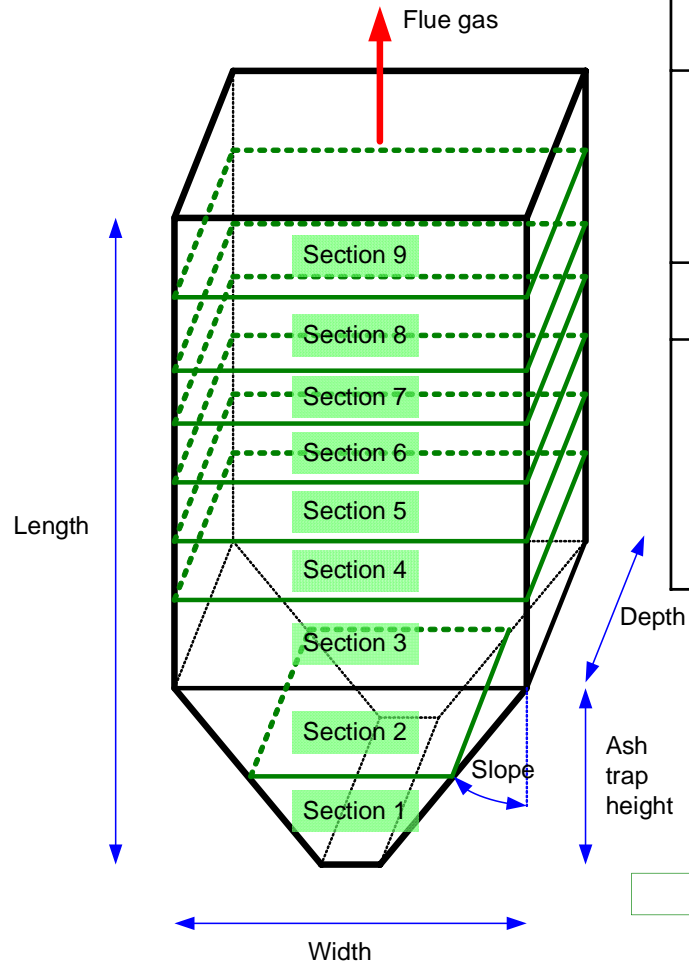


2 Characteristics of DimBo®

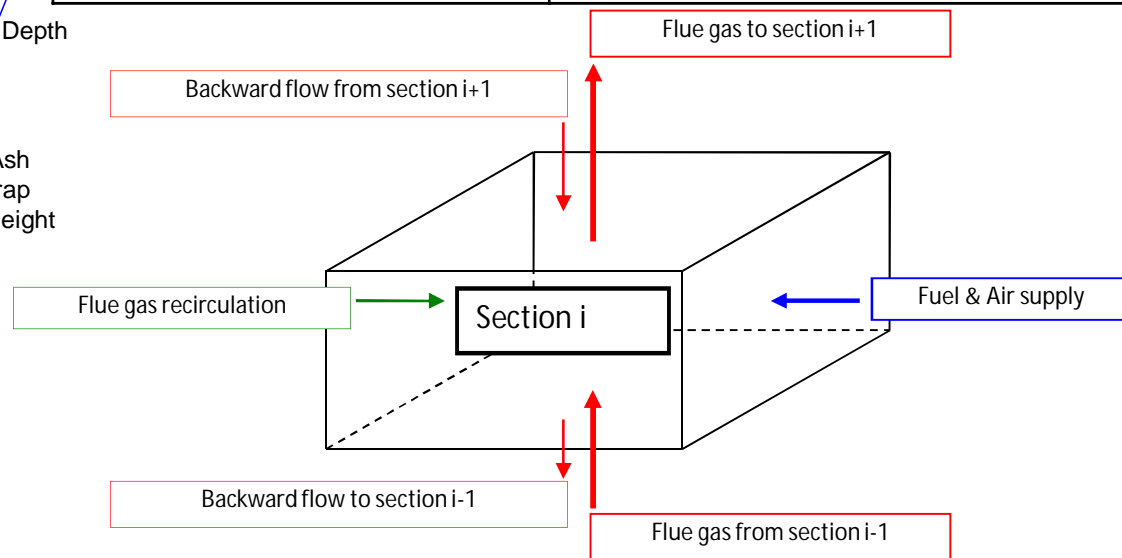
DimBo® (Dimensioning of Boilers)

- Balancing and simulation of sophisticated steam generators
- Modular design
- Mutable level of detail
- Grafical interface
- Interface to Excel
- Continuous inhouse development

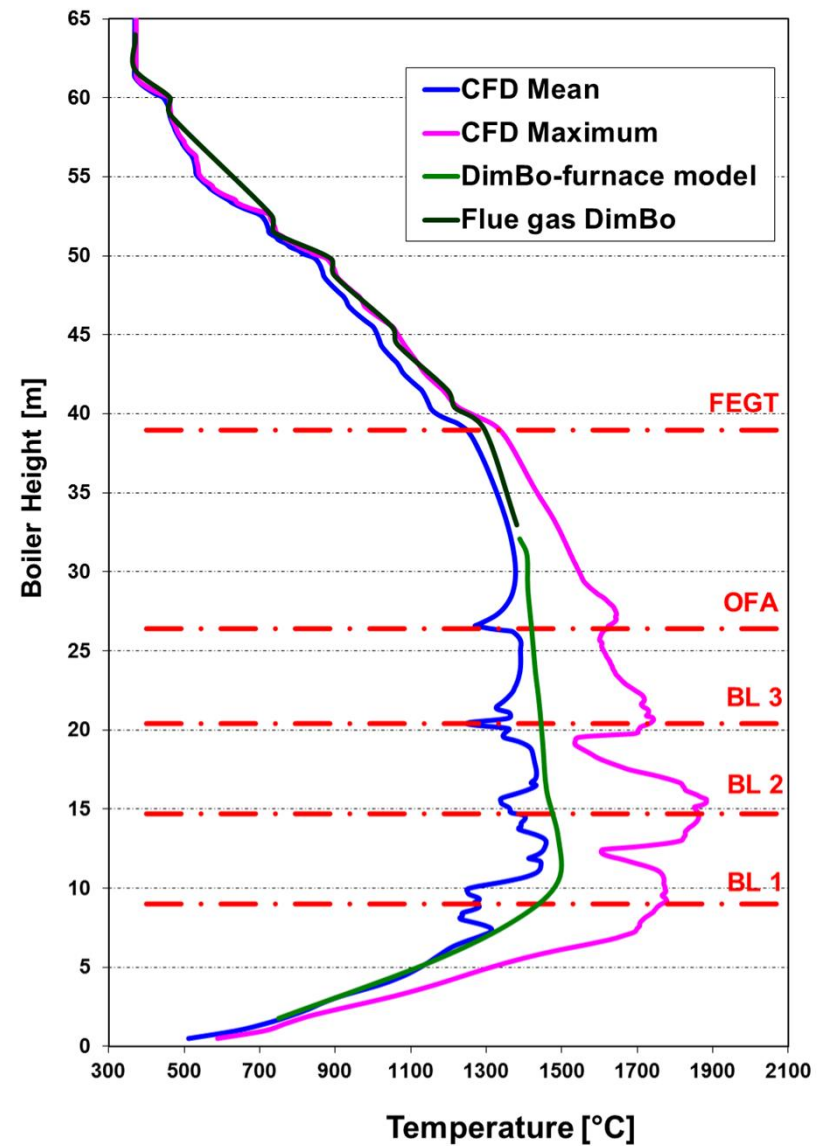
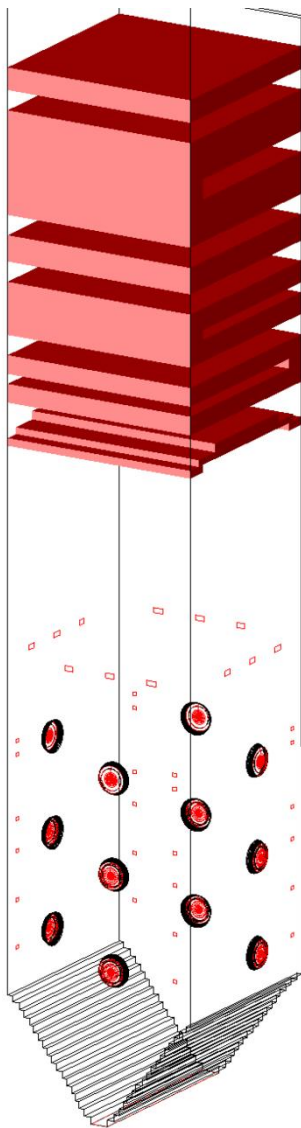




Description	No. of sections
<ul style="list-style-type: none"> Hopper 	<ul style="list-style-type: none"> 1-2
<ul style="list-style-type: none"> Section between hopper and 1st burner level 	<ul style="list-style-type: none"> 1, in case of large distance between hopper and 1st burner level
<ul style="list-style-type: none"> Burner levels 	<ul style="list-style-type: none"> 1 (at least, each)
<ul style="list-style-type: none"> Burn-out area 	<ul style="list-style-type: none"> As many as required to get heights which do not significantly exceed the burner level heights



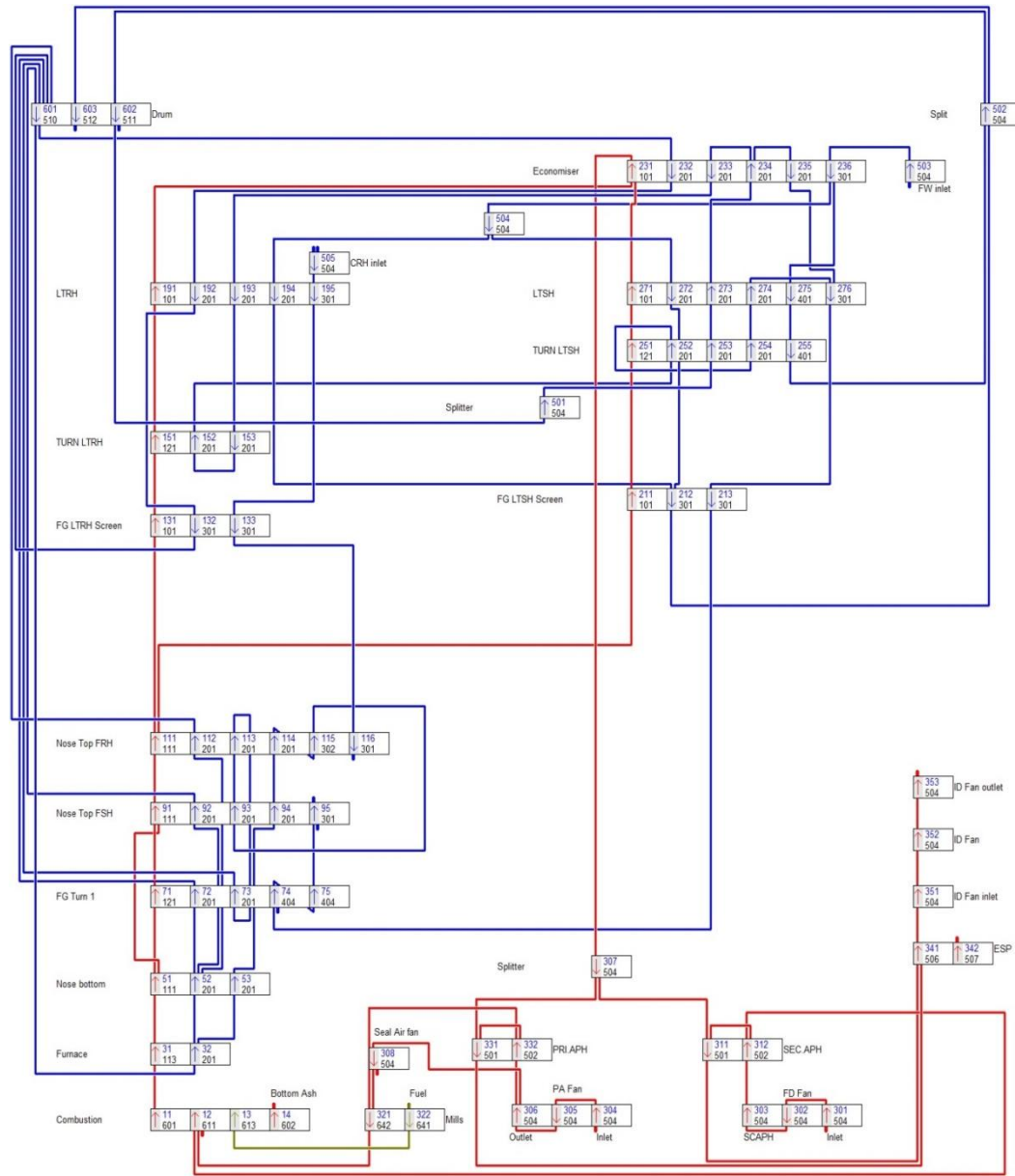
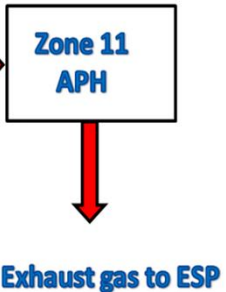
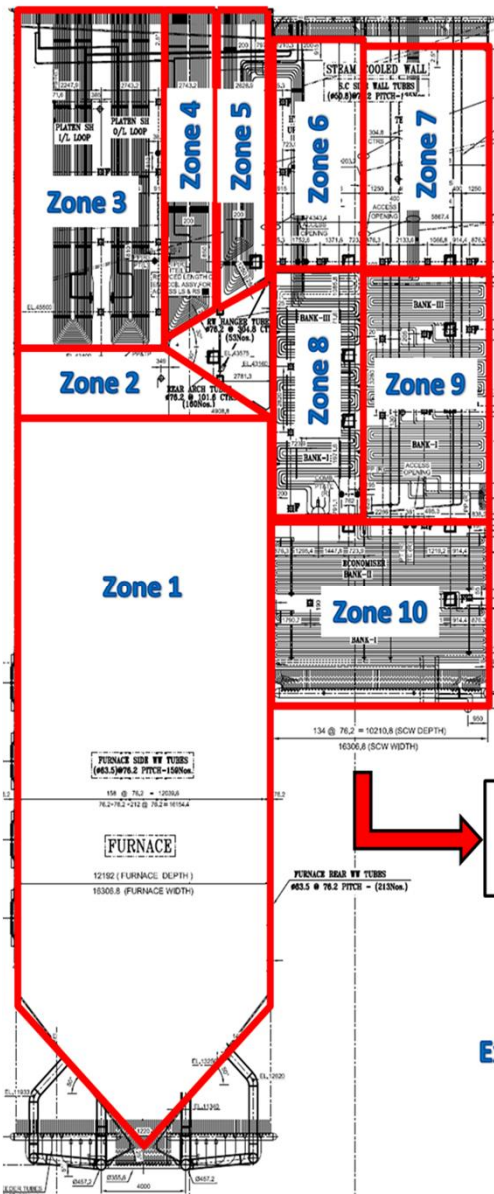
2 Characteristics of DimBo®

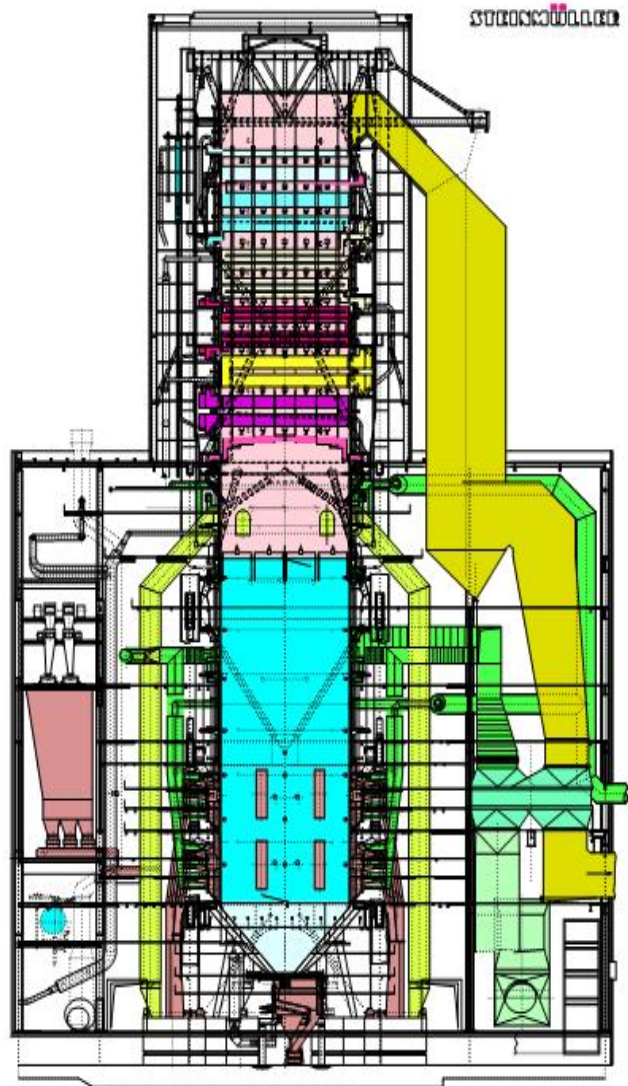


2 Characteristics of DimBo®

Software	DimBo®	for comparison: CFD
Model Size	<ul style="list-style-type: none"> Entire Boiler 	<ul style="list-style-type: none"> Focus on: Furnace
Level of Detail	<ul style="list-style-type: none"> 1D ~100 Elements 	<ul style="list-style-type: none"> 3D > 5 Million cells
Modeling Type	<ul style="list-style-type: none"> Heat Transfer Pressure Loss Material Selection 	<ul style="list-style-type: none"> Fluid Flow Combustion Pollutants
Model Structure	<ul style="list-style-type: none"> Simulation Entire Process 	<ul style="list-style-type: none"> Cross-linkage of Reaction Chamber
Requirements	<ul style="list-style-type: none"> 1 PC 	<ul style="list-style-type: none"> HPC (>100 cores)
Computation Time	<ul style="list-style-type: none"> 1...10 s 	<ul style="list-style-type: none"> $10^4 \dots 10^6$ s (3 h – 12 days)
Results	<ul style="list-style-type: none"> Mass Balance Water/Steam - Circuit 	<ul style="list-style-type: none"> Emissions and Temperature inside Furnace (FEGT)

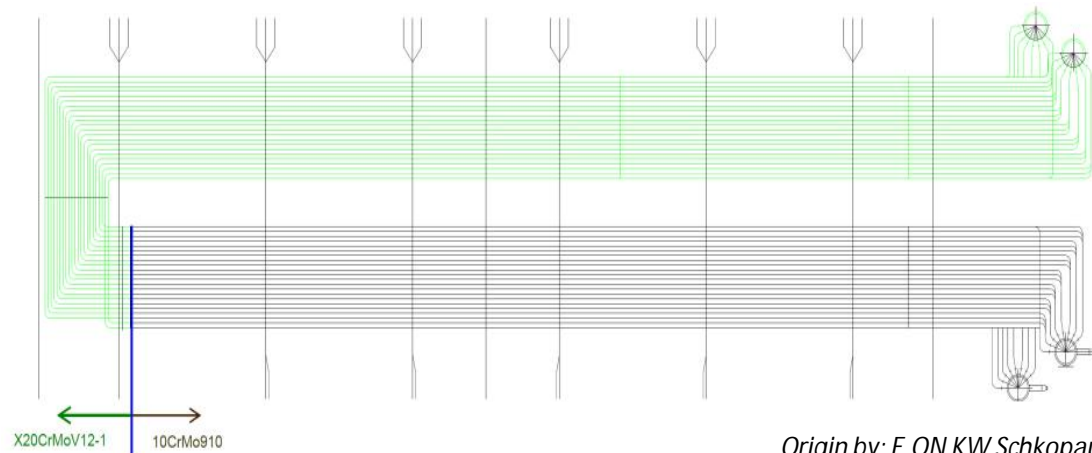
3 Executed References #1 Design Review PF Boiler 300 MW_{el}





Origin by: L.&C. Steinmüller GmbH

REHEATER 2
792 Tubes 48.3 x 4.5 / 5.0



Origin by: E.ON KW Schkopau

Motivation

- Replacement of 2nd reheater through wear
- Evaluate use of various material
- Usage of material on stock

3 Executed References #2

Replacement 2nd Reheater (2)

TubeSelect - Material selection and material properties

Info

- EN/DIN**
 - 1.0305 P235G1TH
 - 1.0345 P235GH
 - 1.0405 P255G1TH
 - 1.0425 P265GH
 - 1.0473 P355GH
 - 1.0481 P295GH
 - 1.4301 X5CrNi18-10
 - 1.4306 X2CrNi19-11
 - 1.4401 X5CrNiMo17-12-2
 - 1.4541 X6CrNiTi18-10
 - 1.4558 X2NiCrAlTi32-20
 - 1.4563 X1NiCrMoCu31-27-4
 - 1.4571 X6CrNiMoTi17-12-2
 - 1.4571 X6CrNiMoTi17-12-2
 - 1.4762 X10CrAlSi25
- ASTM**
 - SA-106 Grade A
 - SA-106 Grade B
 - SA-106 Grade C
 - SA-178 Grade A
 - SA-178 Grade C
 - SA-178 Grade D
 - SA-192
 - SA-209 Grade T1
 - SA-210 Grade A-1
 - SA-210 Grade C
 - SA-213 Grade S304H
 - SA-213 Grade T11**
 - SA-213 Grade T12
 - SA-213 Grade T22
 - SA-213 Grade T23
- Fin/Rib (ASTM)**
 - Carbon steel
 - 2.25Cr-1Mo
 - 9Cr-1Mo-V
 - 13Cr
 - 18Cr-8Ni
 - 25Cr-20Ni
- Miscellaneous**
 - 1.0038 RST37-2
 - 1.0315 ST37.8
 - 1.0460 C22.8
 - 1.0482 19MN5
 - 1.0485 21MN6
 - 1.0498 ST42.8
 - 1.3051 ST35.8I
 - 1.4406 X2CRNIMON17122
 - 1.4550 X6CRNINB1810
 - 1.4663 NICR23CO12MO
 - 1.4713 X10CRAL7(SICR08)
 - 1.4724 X10CRAL13(SICR09)
 - 1.4742 X10CRAL18(SICR010)
 - 1.4816 NICR15FE
 - 1.4817 NICR15FE

Selection Number SA-213 Designation/Alternative Grade T11 13CrMo4.5 Delivery Condition/Commentary ferritic, seamless tube, conventional boiler steel

Thermal conditions
 Temperature 450 °C
 Pressure (abs.) 185 bar

Physical properties
 Lambda 35.8 W/(m.K)
 Rho 7750 kg/m³
 Beta (diff) 0.0141 mm/(m.K)
 Beta (mean) 0.0164 mm/(m.K)
 C (diff) 657 J/(kg.K)
 C (mean) 531 J/(kg.K)
 E Modulus 174000 N/mm²
 TMax 649 °C

Tube dimensions
 Tube outer diameter 44.5 mm
 Corrosion allowance outer 0 mm inner 0 mm
 Production tolerance 0 %

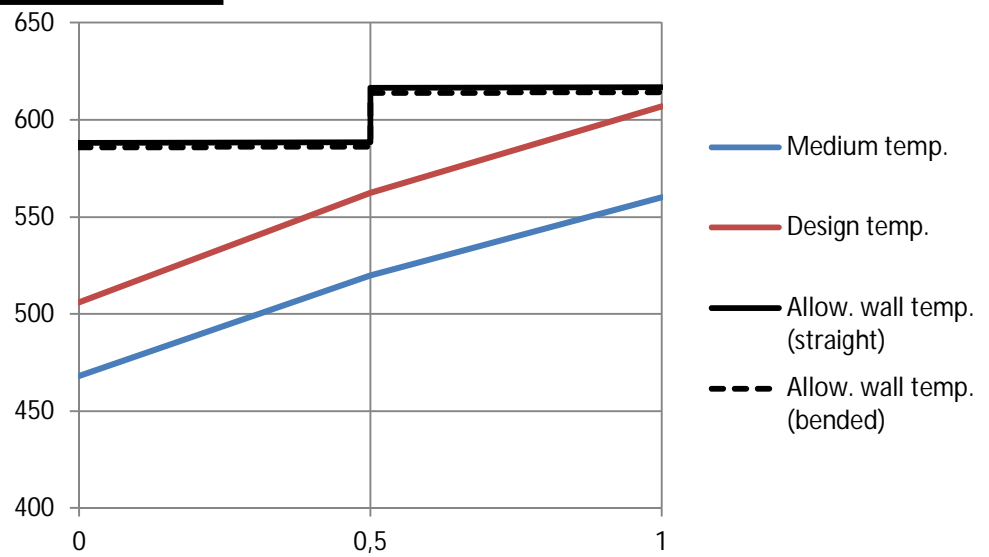
Wall thickness design
 ASME I 4.08 mm
 ASME VIII 1 3.93 mm
 ASME B31.1 3.92 mm
 ASME B31.3 0 mm
 API530 3.8 mm

Buttons: OK, Abort, Print

- Modelling with operating data (actual status)
- Recalculation with different material varieties
- Recalculation with different wall thicknesses

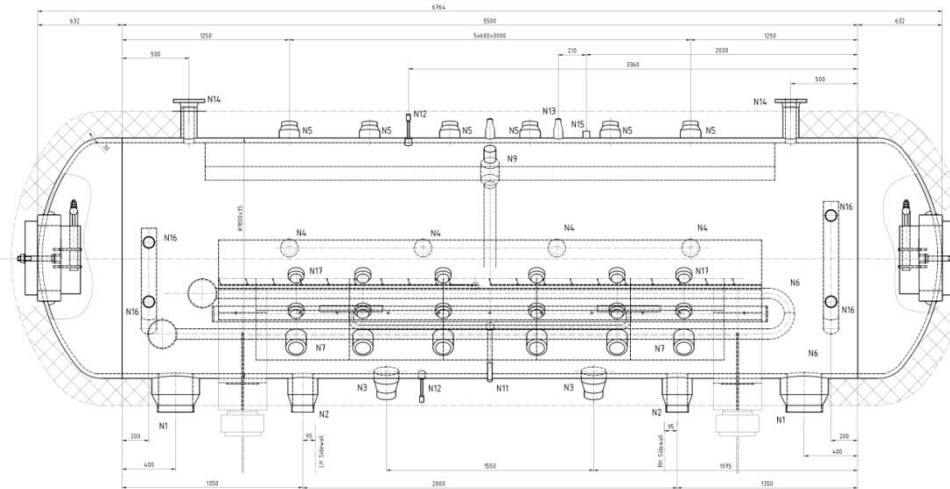
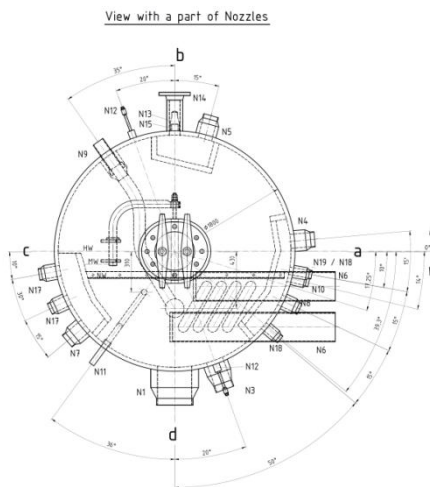
Variety D

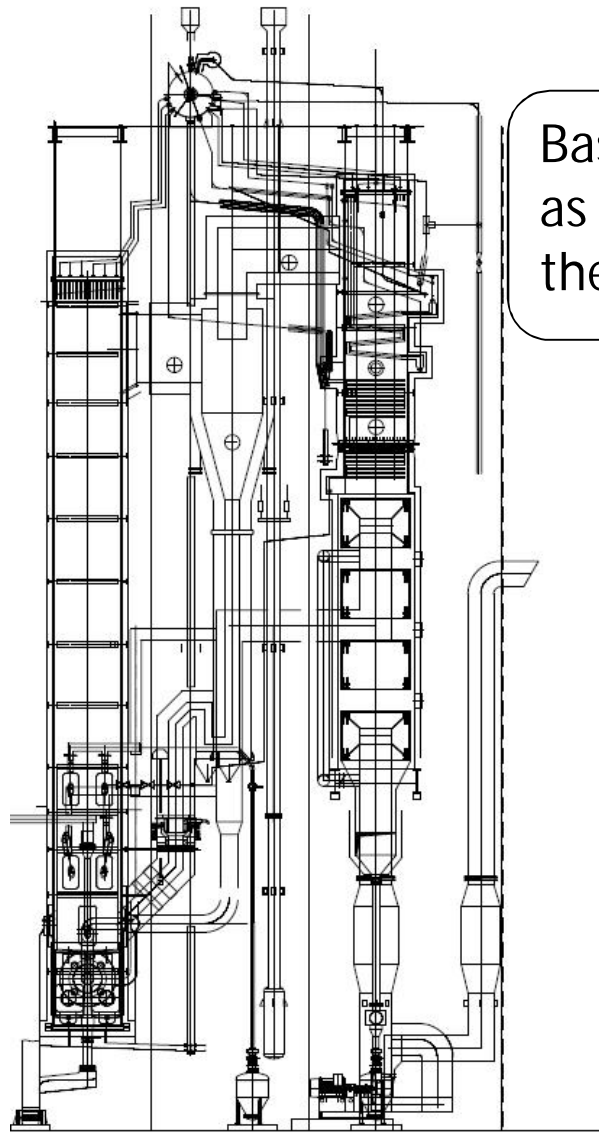
- Material diagram for different concepts
- Decision on most reliable and economic solution



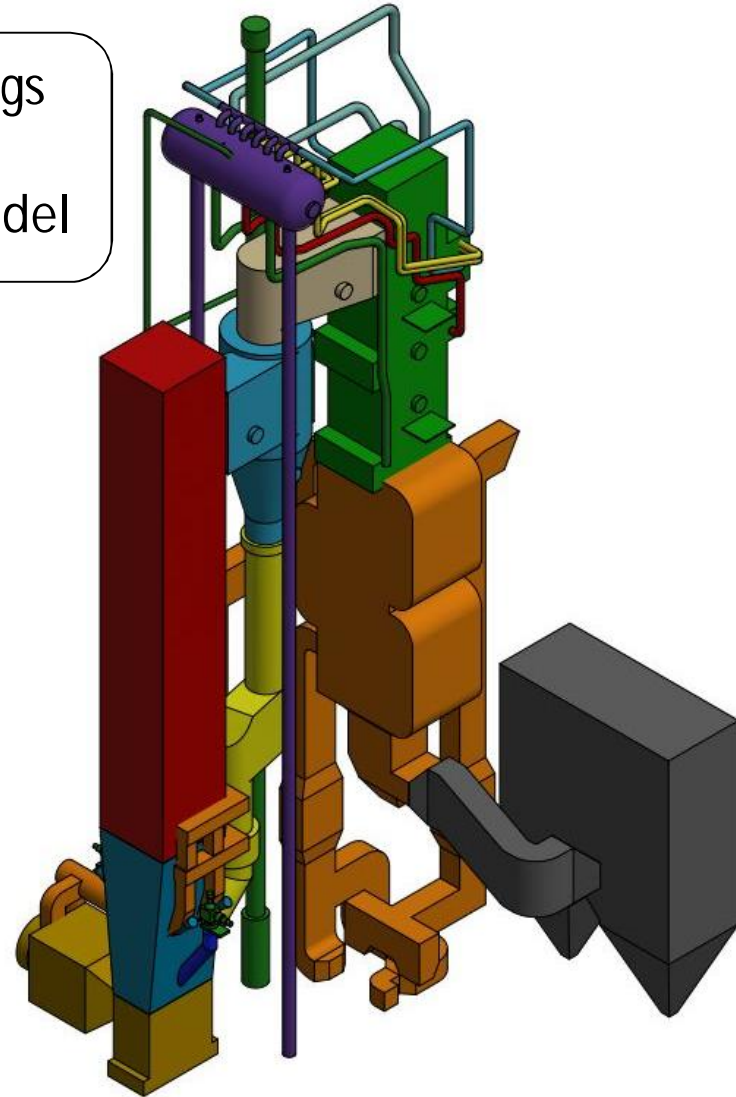
Boiler Type: CFB			
	Unit	BMCR (100%)	30% Load
Maximum Steam Flow	t/h	35	10.5
Superheat Steam Outlet Temperature	°C	241.1	240
Superheat Steam Outlet Pressure	MPa	2.7	2.7
Feed water Temperature	°C	105	105
Feed water Flow	kg/s	9.9	3.0

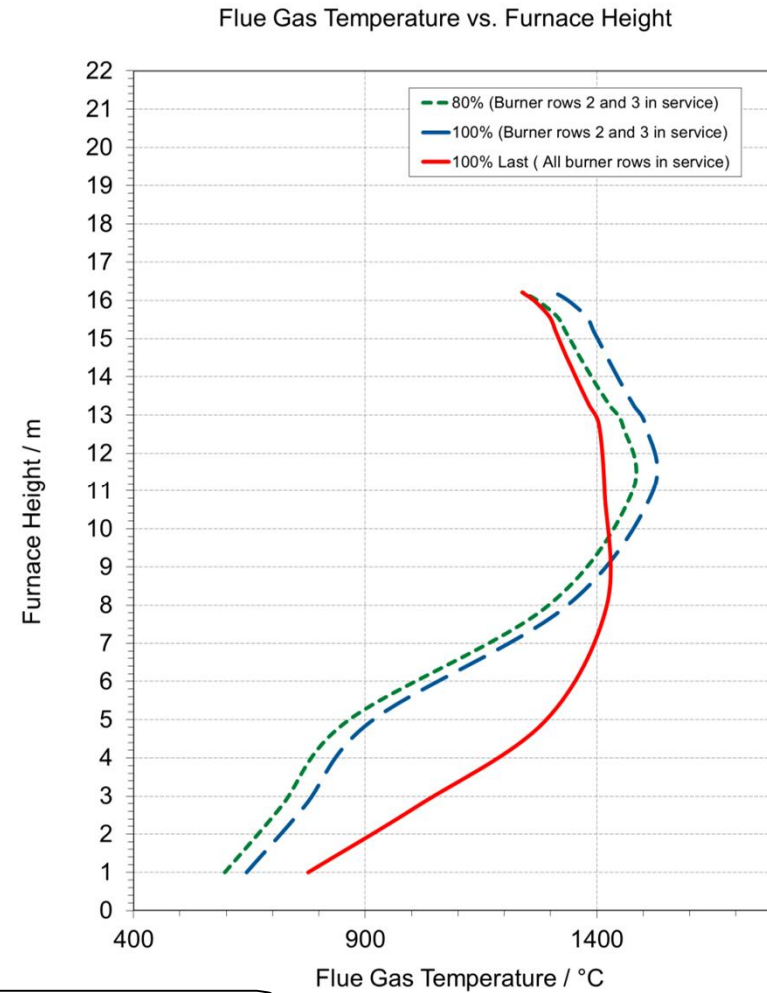
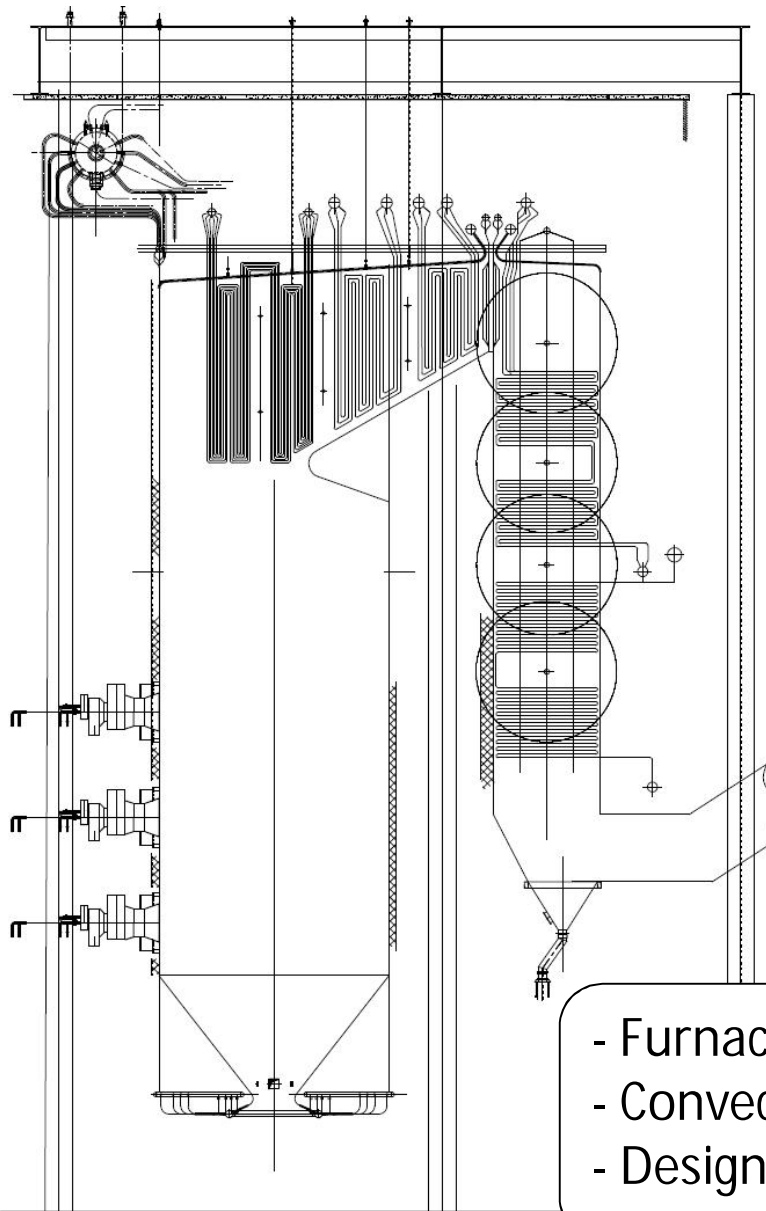
Thermodynamic model with drum cooler instead of spray attemperator





Basic design drawings
as a result of the
thermodynamic model





- Furnace dimensioning
- Convective pass design
- Design review & support

MATERIAL TEMPERATURES, HEATING SURFACE MASSES, OPERATING CONTENT								
	Temperatures at medium inlet			Temperatures at medium outlet			Heating surface masses (kg)	Content volume Absolute (l)
	Fin/Rib (°C)	Medium (°C)	Tubewall (°C)	Fin/Rib (°C)				
				Base	Peak			
		318.1					46542	11101
	346.1	318.1	332.5	329.7	346.1		2901	692
	343.7	318.1	331.4	328.7	343.7		454	108
	335.0	318.1	328.0	325.5	335.0		13918	3320
	514.8	486.9	492.3	496.5	514.8		7330	778
	545.8	520.7	525.3	529.2	545.8		7330	778
		318.1	327.1				1810	489
	379.5	335.7	347.2	349.5	379.5		7808	839
		323.4	336.2				4147	350
	339.4	328.2	349.6	353.3	401.9		10399	1118
213 SH1	335.7	342.4					71708	10837
214 Sling SH1	323.4	338.1					5787	489

List of (EXCEL interface)

- Material temperatures
- Heating surfaces masses
- Operating content

MATERIAL UTILISATION											
	MSTA Description	Material	Diameter (mm)	Wall Thickness		Temperature		Pressure (abs.)		Utilisation (%)	Remark
				Provided (mm)	Required (mm)	Operating (°C)	Design (°C)	Operating (bar)	Design (bar)		
492 wall	32 Spiral 42.4 mm	213 T22	42,4	6,7	5,3	388,6	388,6	202,0	212,1	78,90	Adequately dimensioned
502 wall SH	42 SH1 vertical wal	213 T22	33,6	6,7	4,3	407,5	407,5	197,3	207,2	64,46	Adequately dimensioned
503 SH3	52 SH-1 Verticalwa2	213 T22	33,6	6,7	4,5	459,5	459,5	196,9	206,8	66,36	Adequately dimensioned
	53 Evap. -> Sep.3rd	213 T22	323,9	40,0	32,3	374,5	374,5	198,5	208,5	80,86	Adequately dimensioned
	72 Wall SH-2	213 T22	33,6	6,7	4,6	468,4	468,4	196,7	206,5	68,35	Adequately dimensioned
	73 SH-2	213/347H	44,5	8,8	5,3	548,3	564,1	187,4	196,8	60,04	Adequately dimensioned
	74 SH2 outlet heade	213 T23	406,4	45,0	36,5	505,4	516,4	187,0	196,3	81,00	Adequately dimensioned
	75 Separator -> SH1	213 T22	406,4	45,0	40,3	374,2	374,2	198,1	208,0	89,45	Adequately dimensioned
	82 Wall	213 T22	33,6	6,7	4,5	464,9					
	83 Sling tube	213 T22	42,4	8,0	6,1	492,0					
	84 HP steam pipe	335 P91	406,4	40,5	37,5	540,0					
	85 SH2 -> SH3	213 T23	406,4	40,5	33,9	478,0					
	92 Wall SH-4	213 T22	33,6	6,7	4,6	466,0					
	93 Slings SH-4	213 T22	42,4	8,0	6,0	490,0					
	94 SH-4	213/347H	44,5	7,1	5,1	563,0					
	95 SH4 inlet header	213 T23	406,4	45,0	34,4	501,0					
	96 SH4 outlet heade	335 P91	406,4	40,5	37,8	540,0					
	102 Wall	213 T22	33,6	6,7	4,5	463,0					
	103 Sling tube	213 T22	42,4	8,0	5,7	480,0					
	104 RH steam pipe	335 P91	813,0	30,0	26,8	568,0					

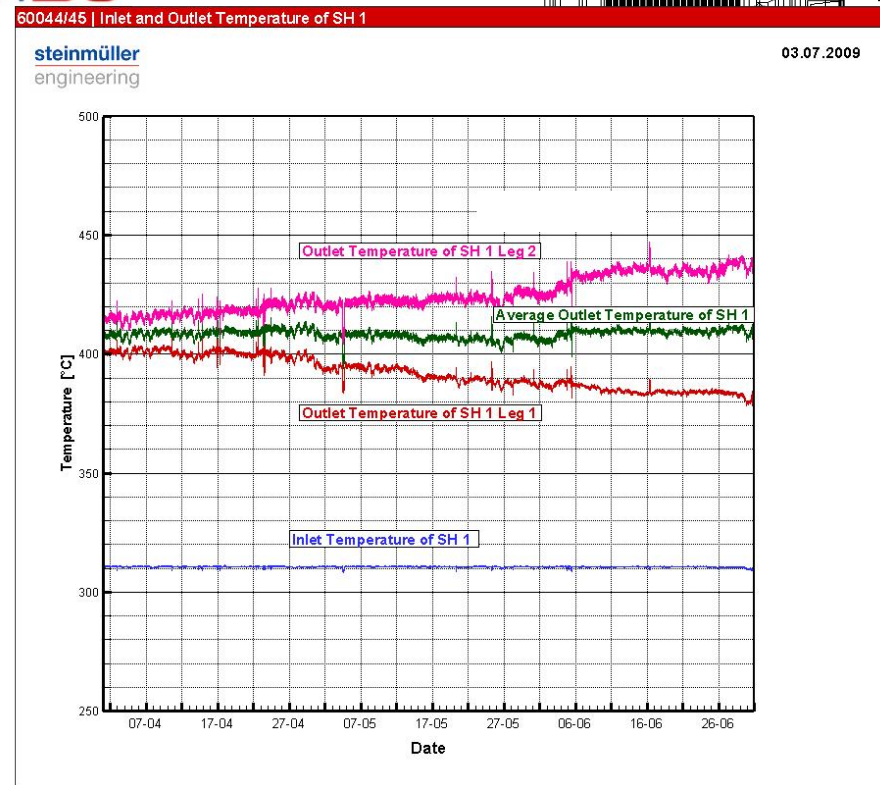
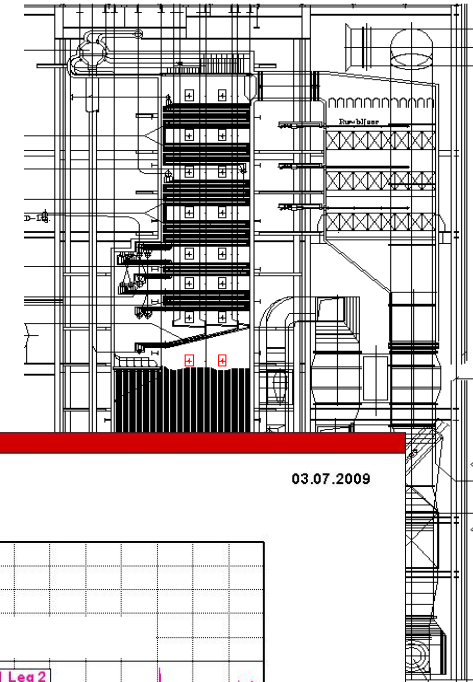
List of (EXCEL interface)

- Material dimensions
- Type of material
- Design pressure & temperature
- Utilisation

Scope of monitoring (750 t/h drum boiler):

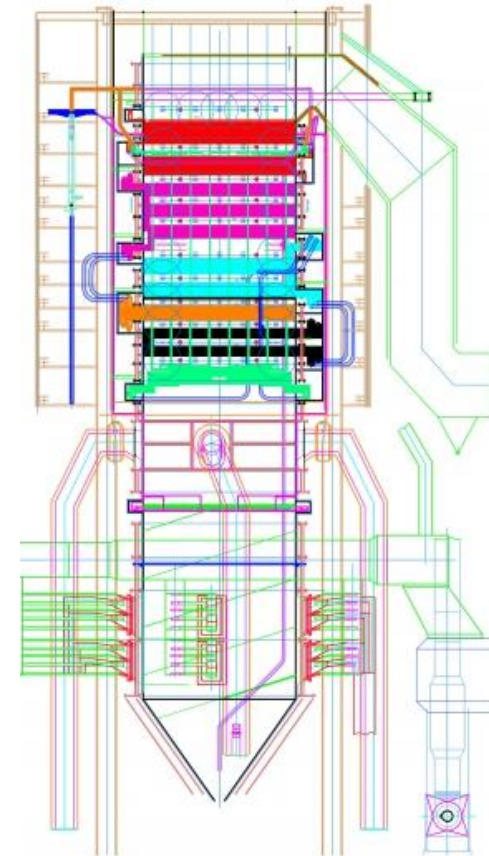
- Plausibility check of operating data with short report every two weeks
- Quarterly report
- Thermodynamic recalculation of operating data of boiler with **DimBo®**
- Evaluation of operating data of combustion system
- Check of relevant operating data regarding unusual deviations and evaluation of operational risks

➤ Recommendation for operation improvement



4 Additional Engineering Services

- Boiler balancing
- Water circulation calculation
- Pressure loss calculations
- Concept/basic/detail engineering
- Feasibility studies
- Fault analyses
- Cost optimization
- Calculation of transient processes with DynaBo



5 Customer Benefits

- **DimBo[®]** is a tool which covers various applications
- Calculation tools and methods based on long-term experience
- Independent of suppliers and technologies
- Realization of practical and individual solutions
- Technical advice and support based on experience in own engineering and supply

Thank you for your attention

