T24: summary of the published tests so far

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Oxygen Content:

- all investigations show a higher susceptibility to cracking for higher oxygen content
- static tests only lead to cracking with elevated oxygen contents
- CERT Test only lead to cracking of oxygen content higher than 100-150 ppb
- cyclic tests lead to cracking also in degased water (no online control)

→ more work in this field needed

Heat treatment:

- A heat treatment in the range of 500 to 550°C (boiler heating temperature) leads to reduction of susceptibility
- microstructure becomes less susceptible at a temperature of 600°C
- TEM investigations showed increase in FeC precipitations at temperatures of 500°C

Chemical cleaning:

- not done in the projects after the first two projects
- influence not finally proven

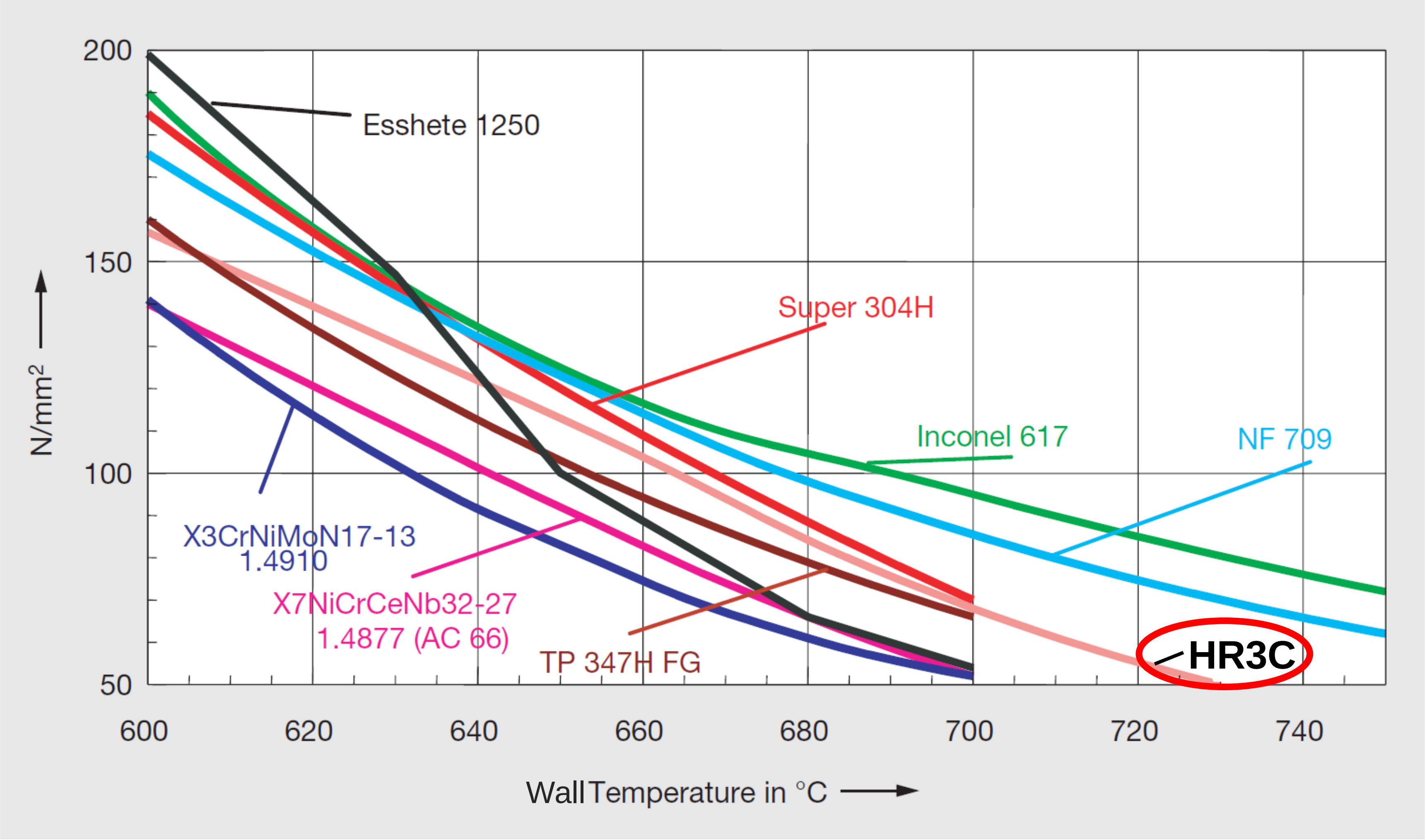
T24: potential actions in future projects

Before / during manufacture	Before / during assembly	Before / during commissioning
• T24-specific training and qualification of welders • Increased manufacturing supervision • Improved weld quality through consistent compliance with parameters • Heat treatment of the membrane tube wall – panels • Heat treatment of the transition piece	• T24-specific training and qualification of welders • Increased construction supervision • Increased welding supervision • Improved weld quality through consistent compliance with parameters • Under investigation: heat treatment of assembly seams	• Optimised pickling • Optimised chemical composition of feed water • Tailored start-up procedure • Heat treatment at 450 – 500 °C

The T24 material is suitable for use as pressure part material but places high demands on processing and needs subsequent measures during commissioning.

Advantages of austenitic boiler materials

mean creep ruture strength value 100.000 h

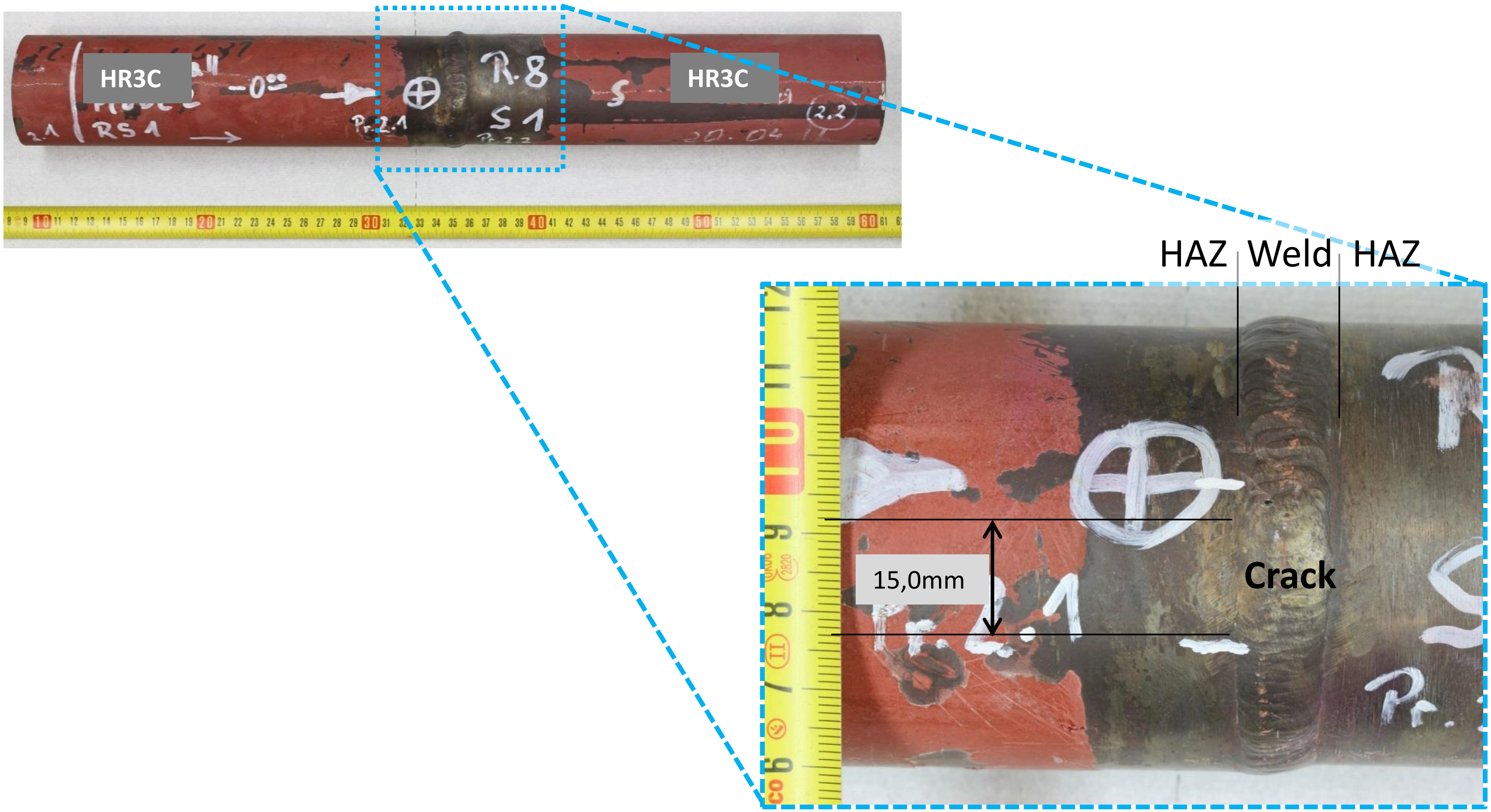


Source: BBPS

H3RC: important issues during superheater tube installation

- ✓ Preparation of microsections
- ✓ Assessment of microstructure to avoid hot cracks
- ✓ Weld seam for all at root
- ✓ Weld layer structure and seam with
- ✓ Small weld layers of the cap pass
- ✓ Welding parameters (Current, Energy input etc.)
- ✓ High welding quality of black and white connections (P92/HR3C) to avoid a repair that has a high effort
- ✓ In case of „boiler heating“ (use of T24) take HR3C samples to exclude cracked circumferential welds

H3RC: tube investigation on a crack in the heat affected zone (outside)



Source: VGB Material Laboratory

H3RC: intercrystalline cracking in HAZ

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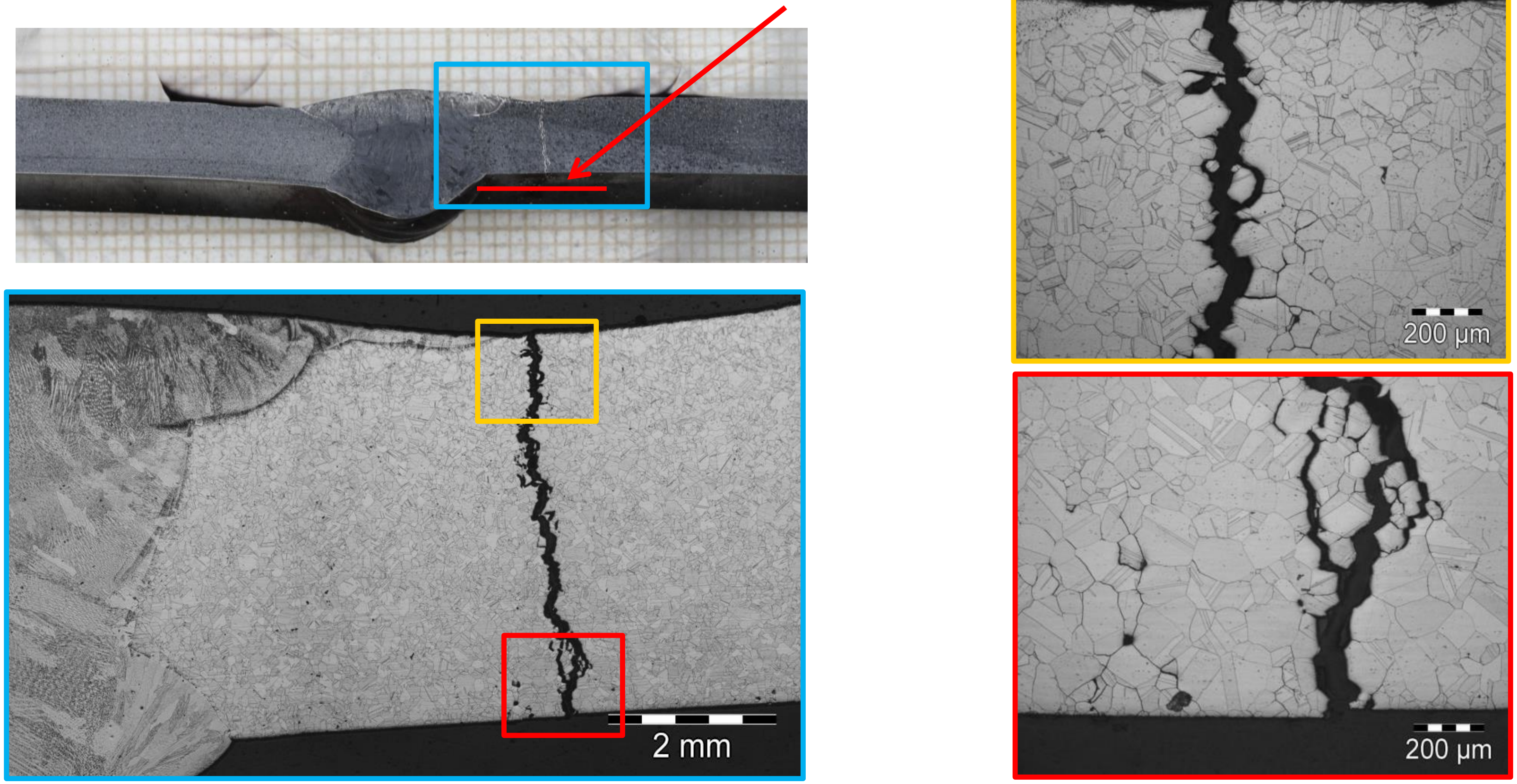


Source: VGB Material Laboratory

H3RC: conclusion

- The damage in the austenitc material (HR3C) is caused by an intercystalline corrosion.
- The material is sensitized by the welding process.
- Condensate formed during the boiler heating concentrates and promotes Intercystalline Corrosion.
- The relevant medium is **not chlorid**es (causes Stress Corrosison Cracking) **but sulfates** (causes Intercystalline Corrosion).
- An influence of chemical cleaning on the cracking could not be identified.

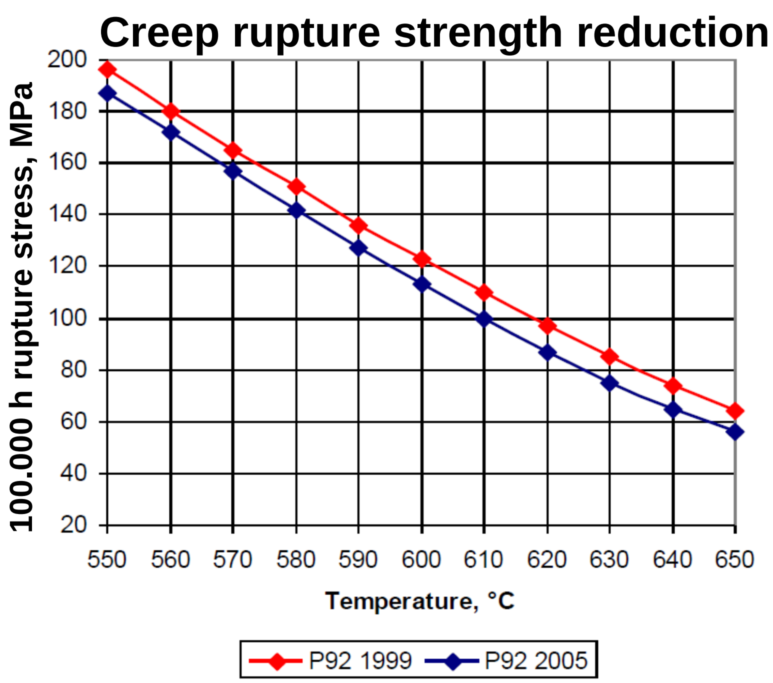
Reason

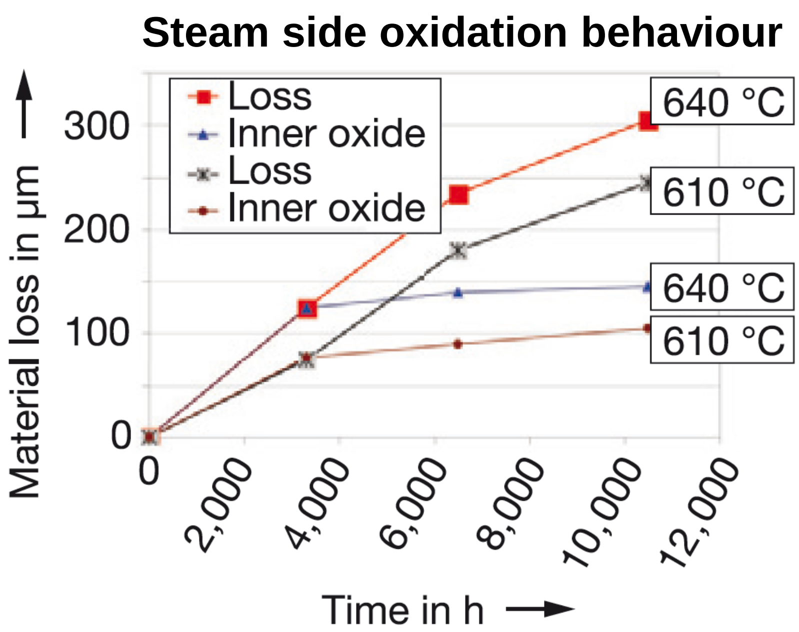
→ Up to now only sea-side/river side locations affected as sulfates preliminary exhausted by big container ships burning heavy crude oil.

Source: VGB Material Laboratory

Properties of P92

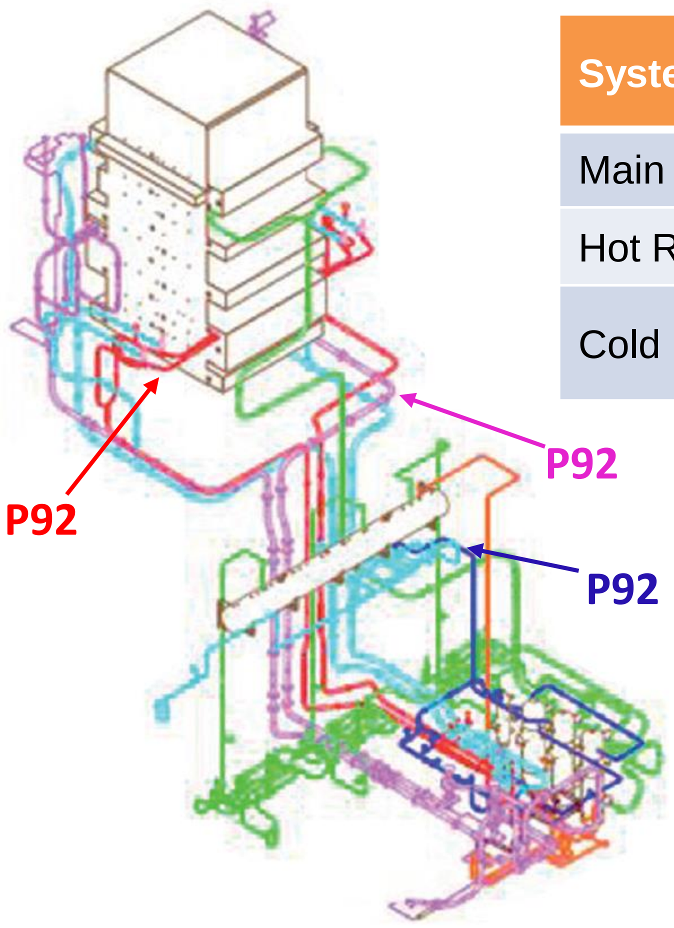
- Best performance of martensitic steels regarding creep strength
- Most preferred applications are Pipes and Valves in the range 580 to 620°C
- Creep rupture strength reduction of 8-10% in 2005 but still on high level
- Evaluation of weld strength factor is recommended
- 9% Cr-Steels applicable as superheater only at T < 550°C
  due to bad oxidation behaviour on steam side





Source: DONG, Alstom

Isometric drawing of GKM 9 piping, design and dimension of steam parts



System	Design Temp./Pressure	Diameter/ Wall Thickness	Material
Main Steam	605°C / 311 bar	320 x 101 mm	P92
Hot RH	625°C / 76 bar	470 x 43 mm	P92
Cold RH	415-590°C / 65-81 bar	674 x 32 mm	P92

P92 Y-Piece

P92 Headers

P92: important issues

Pipe manufacturing

- ✓ Control of material properties and heat treatment pre-sets
- ✓ Control of intrados and extrados temperatures at pipe elbows
- ✓ Control of applied bending moment to austenitic temperature ratio to avoid structural defects
- ✓ Proof of perfect heat treatment incl. sufficient thermocouples at components

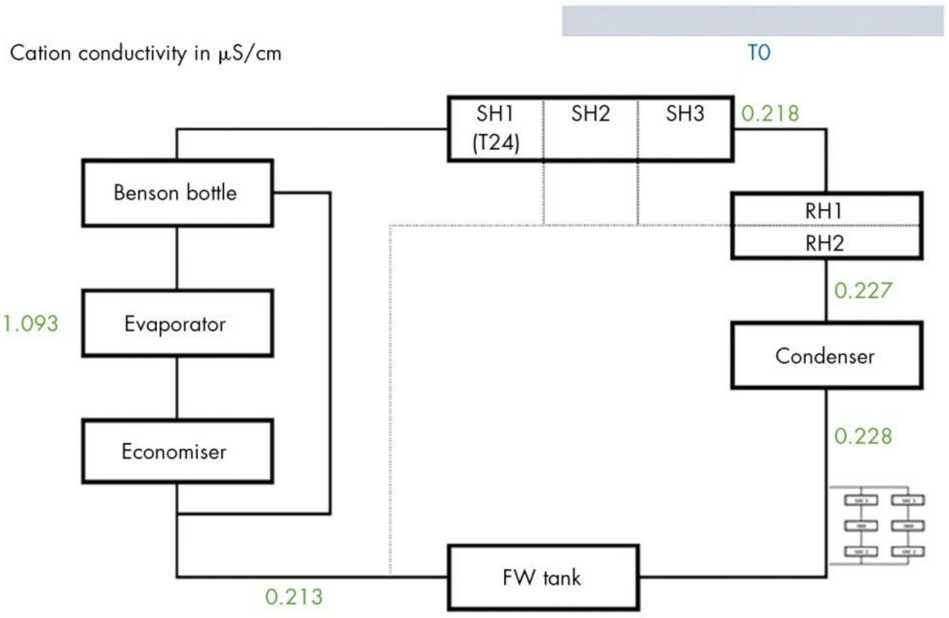
Welding (TIG, sometimes in combination with SMAW, TIG orbital narrow-gap)

- ✓ Control of preheat treatment and intermediate layer temperature
- ✓ Control of joint preparation
- ✓ Control of welding parameters (Current, Energy input etc.)
- ✓ Control of root and support layer welds
- ✓ Control of post weld heat treatment
- ✓ Qualification of welders must fulfil WPS and WPQR
- ✓ Repeated heat treatments have no influence on material properties in case of restoration (e.g. header)

Seawater ingress during commissioning

Serious incident during commissioning at a weekend night in a full flow condensate polishing plant (2 trains, 50 %)

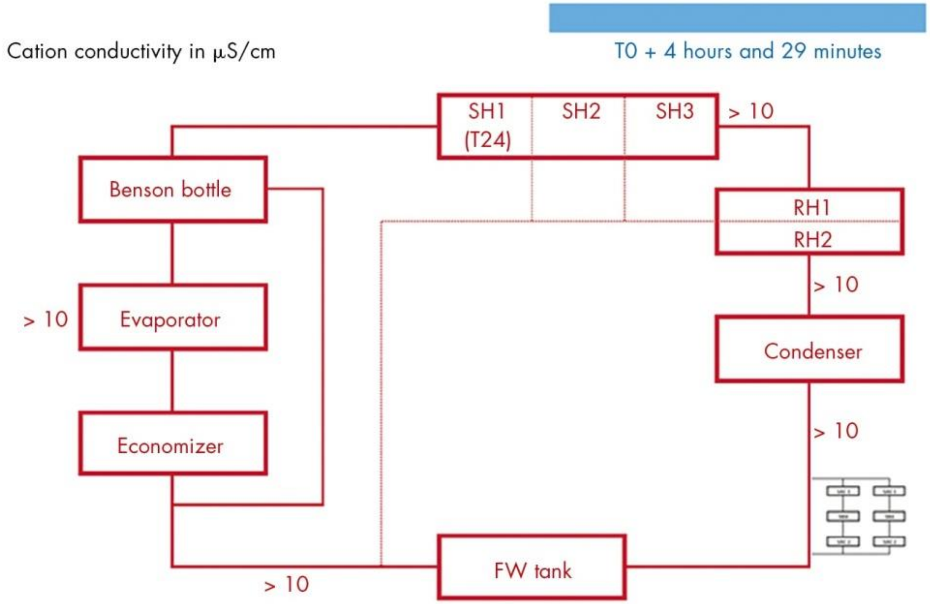
- Sea-cooled plant was operated in sub-critical conditions (110 bar, 440°C), turbine bypass, CPP w/ all volatile treatment
- Perforated condenser tubes (as a result of a fallen square plate) were the root cause
- Plant was operated 10 hours under seawater ingress conditions
- After 14 days the plant was started again
- The integrity of the boiler is under investigation as the incident happened few weeks after thermal passivation



Source: Laborelec

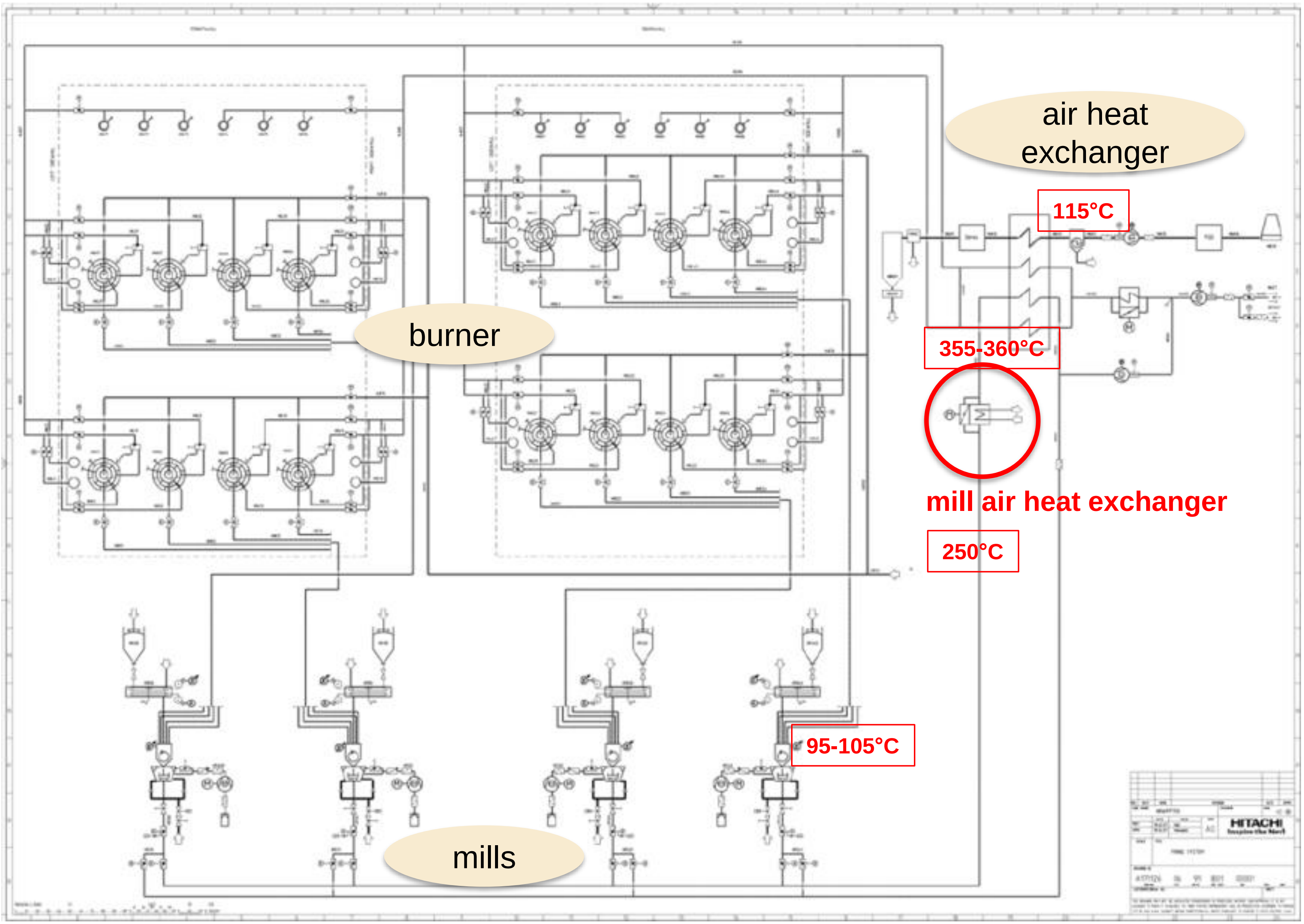
Seawater ingress during commissioning

- Installling a pH-analyzer to directly detect the pH-value
  - pH-value was calculated on the basis of the cation conductivity which resulted in wrong values, prevented an early understanding of the situation
- Online chemistry analyzers must be fully commissioned
  - Sodium analyzer not yet commissioned
  - Conductivity alarms not yet programmed
- CPP fully functioning
- Minimum chemistry knowledge of the operating team required

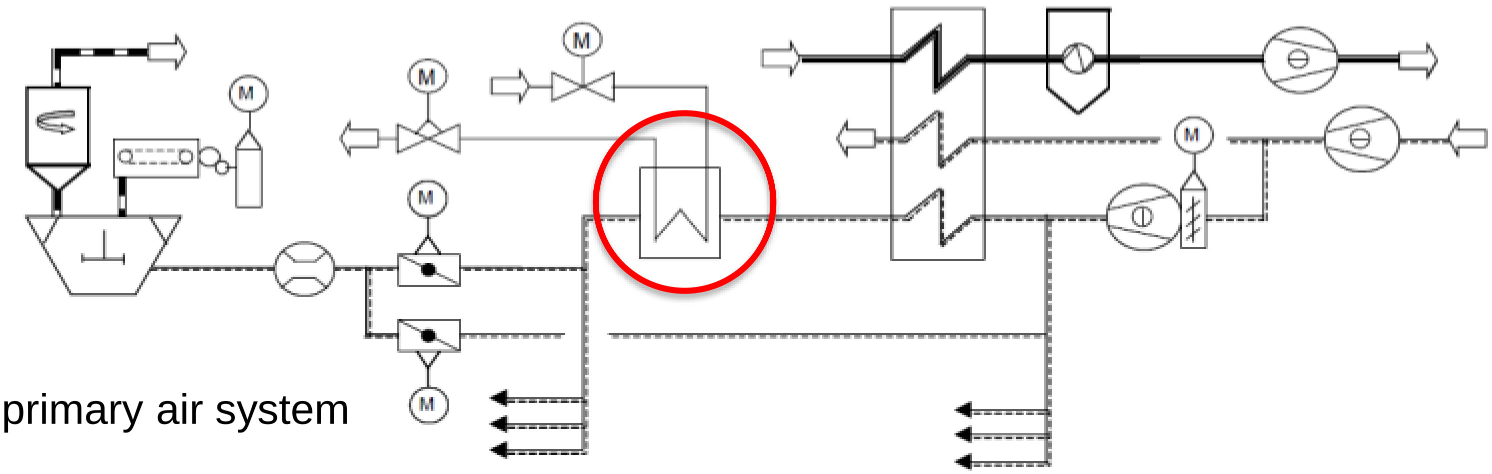


Source: Laborelec

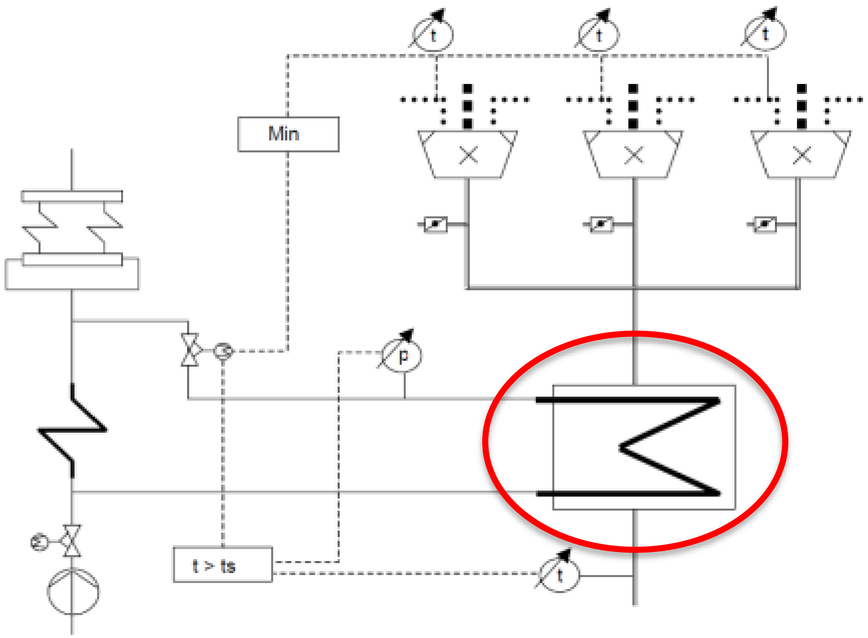
First operating experiences: heat recovery concepts



First operating experiences: Mill air heat exchanger and firing system

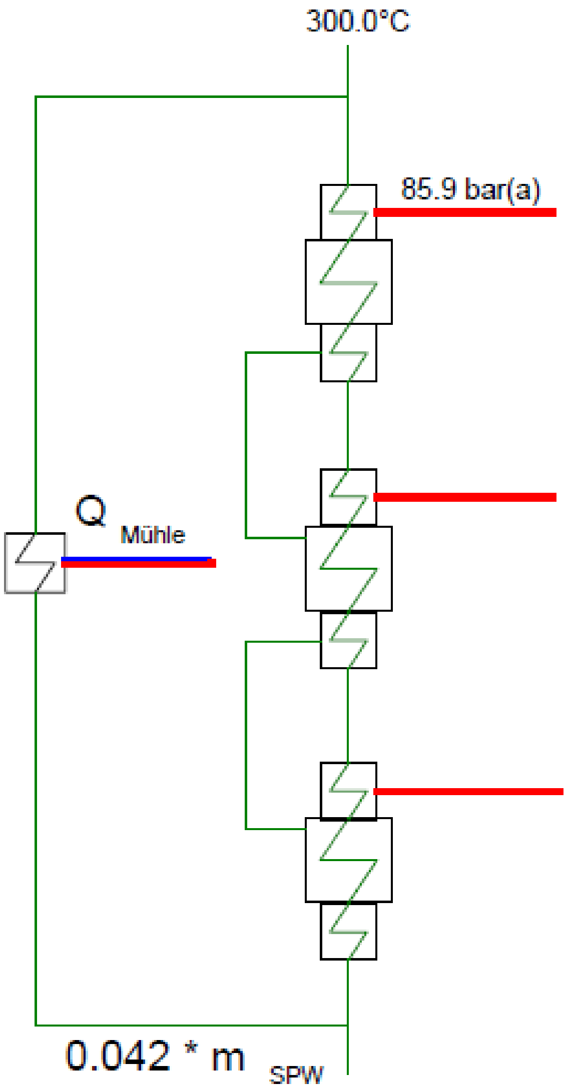


Integration in primary air system



Integration in feedwater preheating system

First operating experiences: mill air heat exchanger thermodynamics



Design data 100 %, reference coal:

- load air preheater 100 %
- Q Heat exchanger 3,5 MW th
- feedwater bypass flow 4,2 %
- reduced live steam flow - 0,75 %
- net efficiency increase 0,1 %-p

References:

- (D) Walsum 10, Datteln 4, Wilhelmshafen (NL) Maasvlaakte
- only realized in Hitachi boilers (patent Steinmueller-Babcock-HPE)

Experiences:

- quite limited so far (Walsum COD 2014)
- no major flaws
- issues in quality of heat exchangers and control optimization (complex interconnection of water-steam and firing-air systems)

First operating experiences: reheat temperature control

Main goals

- Increase unit efficiency of base load plants by avoiding or limiting reheat (RH) spray attemperation in full load operation
- Extend boiler operation time

Different technical options

1. **Triflux Heat exchanger (see next slide)**
   - experiences in GKM7 (SCHC 80‘s), Niederaußem K (SC LIG 2005)
   - unit efficiency increase 0,2 – 0,3 %-p
2. **Biflux Heat exchanger**
   - concept similar to Triflux but with external steam-steam heat exchanger
   - some experiences only in very old plants from the 60‘s/70‘s
3. **Design for variable reheat temperature**
   - Temperature drop approx. 2,5-3 K/min. with load change rate of 5%/min.
   - Temperature drop from 620 °C (100% load) to 585 °C (40% load)
   - unit efficiency increase 0,2 – 0,3 %-p

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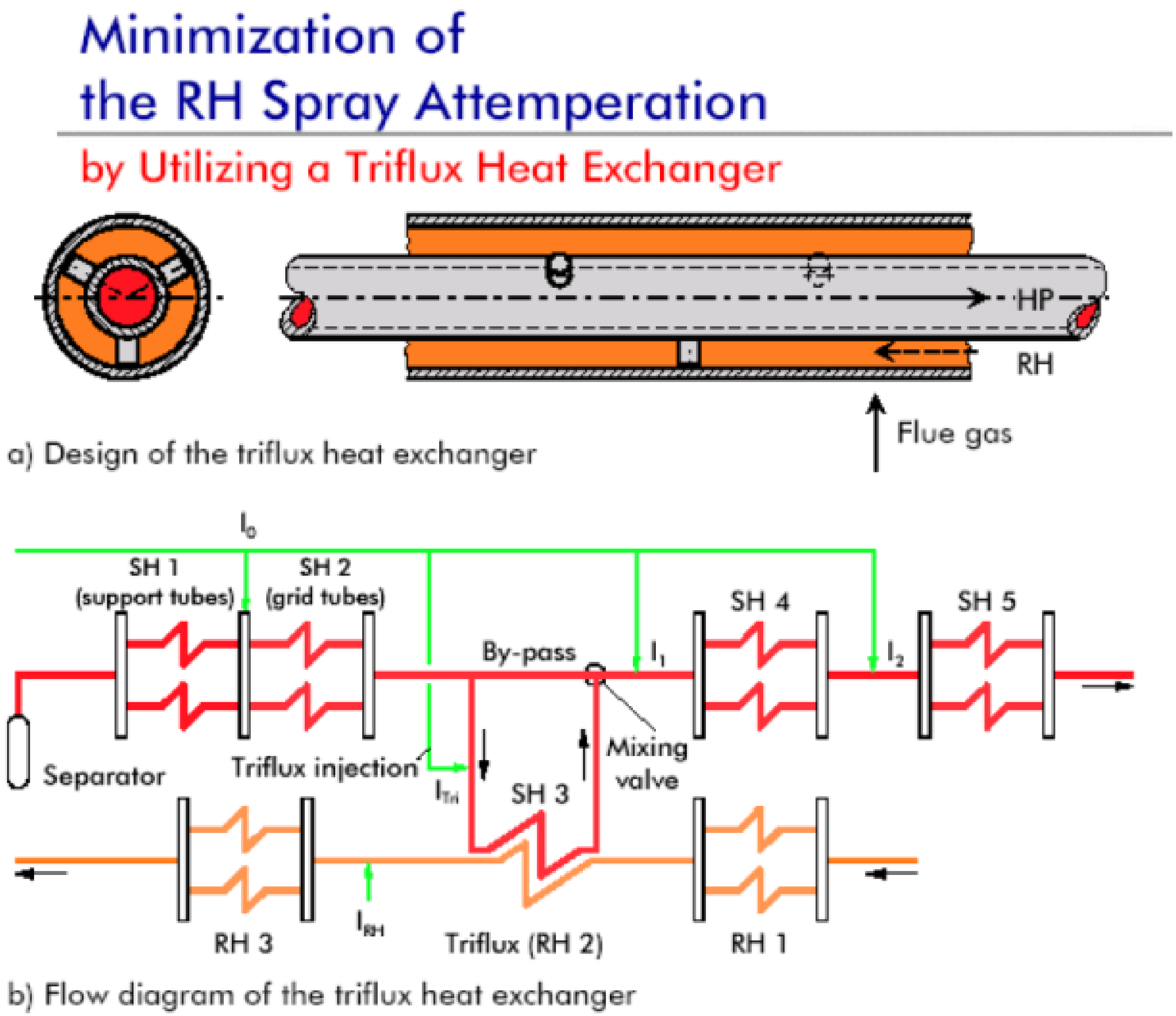


Source: RWE/Alstom

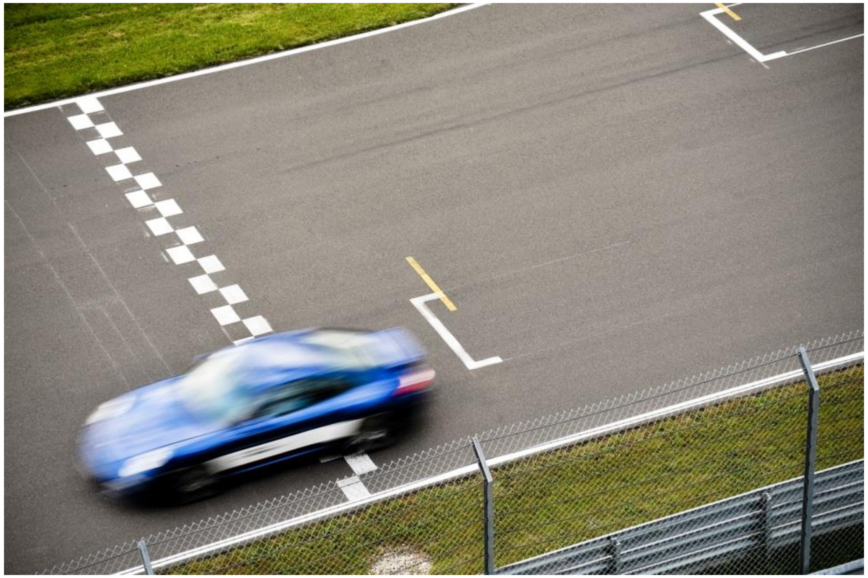
First operating experiences: reheat temperature control

Major issues	Triflux	Variable RH temp.
Spray attemperators have to be installed anyhow in the reheat system for fast control of outlet temperature and in case of string imbalances , start-up		
Additional equipment (capex)		
Additional stress to high temperature components (e.g. RH headers, U-SC IP turbine)		

Very few Triflux systems are in operation (nevertheless with good operational experiences) and so far no variable RH temperature concepts have been realized.

Summary

- → Active role of the owner/operator during project execution
- → Comprehensive design and planning
- → Overcome challenges of new materials.
- → Sound and realistic scheduling
- → Quality Assurance and Control is very important



- → Good process knowledge and thinking in systems are pre-requisite for smooth commissioning. A functioning I&C system is indispensable.
- → Most of the plants are just entering commercial operation. Heat recovery concepts have been applied.

The new built projects have been faced with many challenges. The proof of economic operation is outstanding and in times of less operating hours even more difficult.

german cooperation
DEUTSCHE ZUSAMMENARBEIT

धन्यवाद

Thank you

for your interest!

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