



# Application of film forming amines for preservation of water steam cycles with and without ACC

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- Over 30 years of expertise in development and application of Film Forming Amine water treatment strategies for:
  - Power plants (nuclear, coal, gas, biomass)
  - District heating networks
  - Cooling circuits
- Economical and ecological proceedings for cleaning, preservation and operation of water- and steam cycles
- State of the art Film Forming Amine Product ODACON®
  - Contains only Film Forming Amine, mainly Octadecylamine (ODA)
  - No emulsifiers or additional substances
  - Environmental friendly and biodegradable, no dangerous good in terms of transportation
  - Certified according to NSF G6 standard for direct food contact

# Agenda

- Basics for the use of Film Forming Amines
  - International Standards
  - Effects of Film Forming Amines
- Preservation Principles
  - Flexible Operation
  - Long Term Standstill
- Operational Experience
  - With Air Cooled Condenser
  - Without Air Cooled Condenser
- Conclusion

# Basic information

## Situation before 2016:

- "Film Forming Amines" are not fully describe as a defined chemical group
- Manufacturer Specific products that contain film-forming amines
- Blends of film-forming amines and for example, neutralizing amines, polycarboxylates, oxygen scavengers, emulsifiers, etc.
- Exact product compositions are often unknown or confidential
- Some products doesn't even contain amines
- Only less independent technical guidelines and investigations

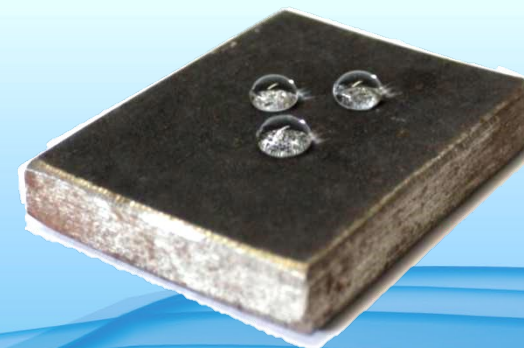
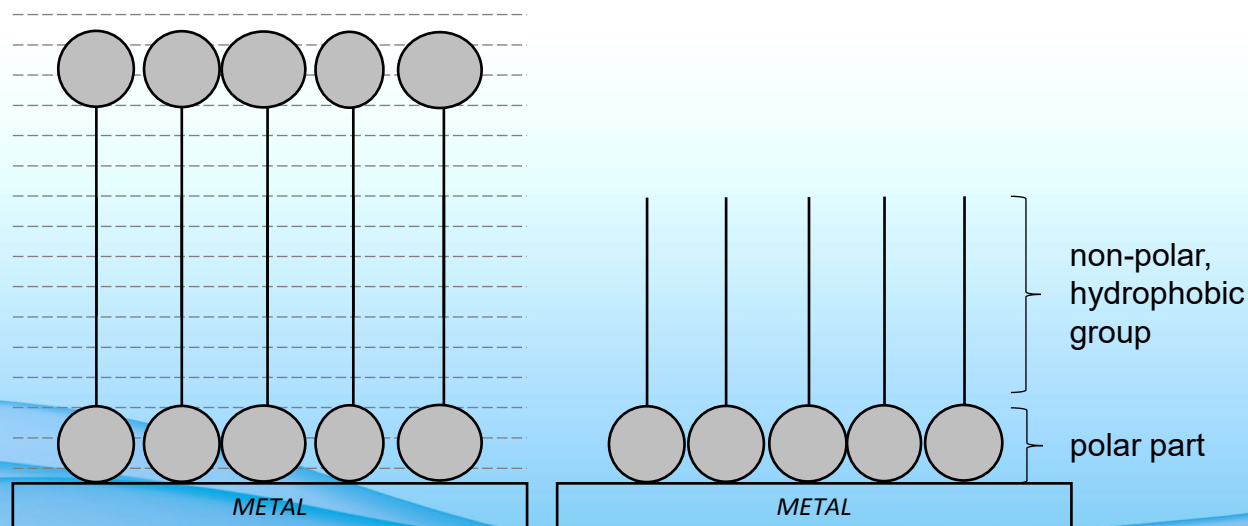
# International Standards – IAPWS Guidelines

- IAPWS TGD 8-16 (2019) – Application of Film Forming Substances in Fossil, Combined Cycle, and Biomass Power Plants
  - Released in 2016 and reviewed in 2019
  - Standardized the terminology
    1. Film Forming Amines (FFA):
      - Octadecylamine (ODA) CAS-No.: 124-30-1
      - Oleylamine (OLA) CAS-no.: 112-90-3
      - Oleyl propylene diamine (OLDA) CAS-no.: 7173-62-8
    2. Film Forming Amine Products (FFAP):
      - Commercially available products with film-forming amines (FFAP)
    3. Film Forming Products (FFP)
      - commercially available products in which do not contain film forming amines (FFA)
  - Chapter 9.7 discusses systems with Air Cooled Condensors
- IAPWS TGD 11-19 (2019) – Application of Film Forming Substances in Industrial Steam Generators
  - Looks at industrial boilers also with a lower make-up water quality
  - Chapter 9.7 discusses systems with Air Cooled Condensors as well

# Effects of Film Forming Amines - Formation of stable protective layers

- Distribution coefficient similar to that of ammonia, so that there is a good distribution in the entire water - steam - cycle
- Formation of a bi-molecular or mono-molecular, diffusion-resistant and hydrophobic protective layer
- Strong and durable connection because of ion-bonding at the surface

→ long term preservation effect in standstill

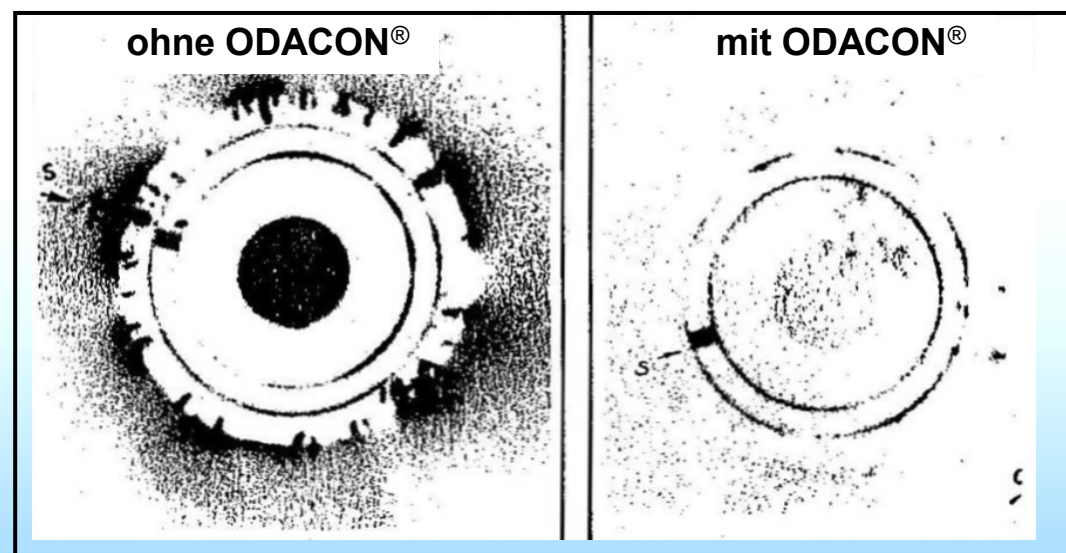




# Effects of Film Forming Amines - Removal of deposits and porous oxide layers

- FFAs have a mobilizing effect on oxides and corrosion active deposits like chlorides
- these deposits are gradually and carefully removed during adsorption even from crevices

→ Protection against stress corrosion cracking



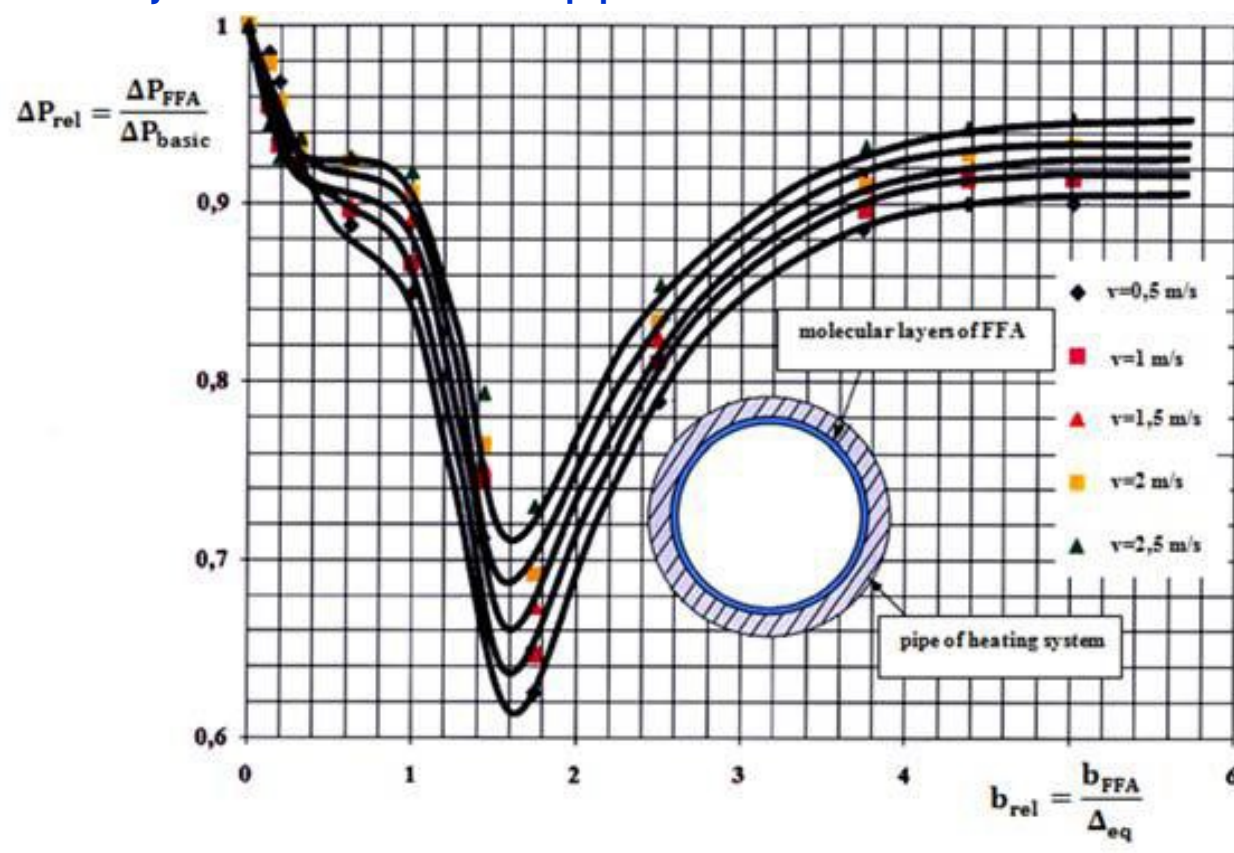
Autoradiography of stretched austenitic ring-shaped specimens  
(Blackness level = measure of chloride enrichment)

# Effects of Film Forming Amines -

## Removal of deposits and porous oxide layers

- reduction of the surfaces' relative roughness due to formation of mono- or bi-molecular amine layers
- significant improvements in terms of hydrodynamic characteristics

→ Reduction of the hydraulic resistance of pipelines



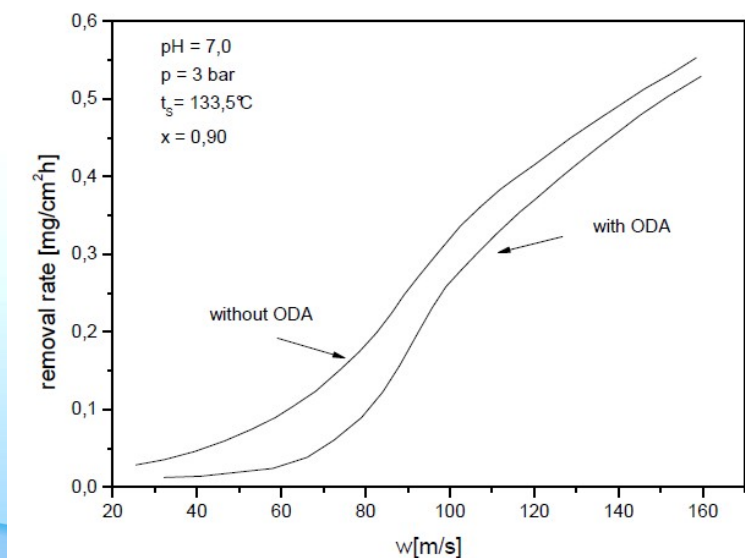
Extract from WIT Transactions on Engineering Sciences,  
Vol 91, 2015 "Prospects for the application of film-forming  
amines in power engineering"



# Effects of Film Forming Amines - Decrease of FAC

- Lowering the surface tension of water decreases the droplet diameter strongly
- Reduction of the maximum force on the surface during impact
- In combination with the formation of stable protective layers in steam and condensate system iron removal is decreased

→ FAC is reduced in single and two-phase flows



Removal rate caused by droplet impact erosion on C-steel as a function of the flow velocity

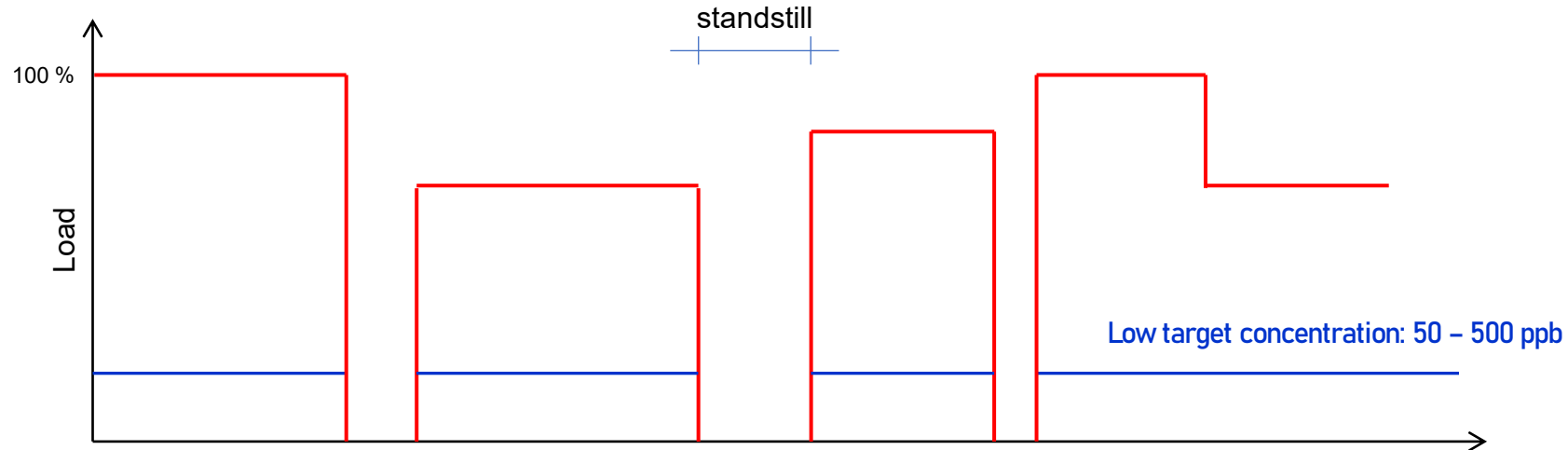


Stereo microscopic recording of samples plates in wet steam flow (magnification 1 : 12)

# Agenda

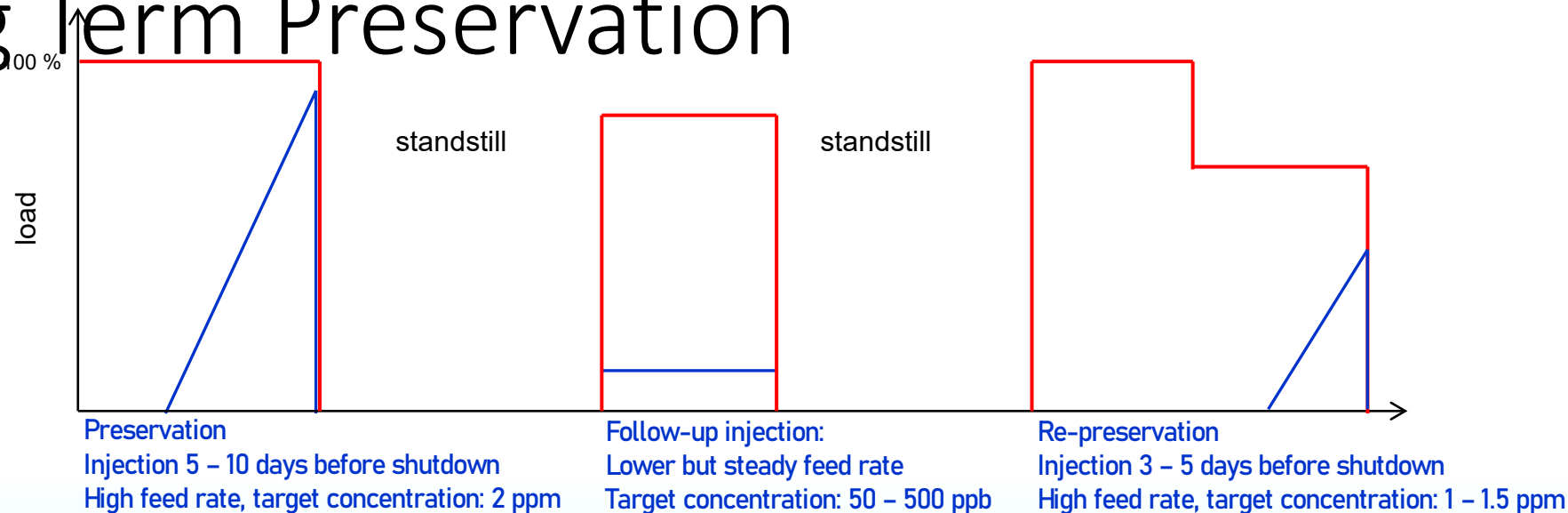
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# Preservation Principles - Flexible Operation



- Cycling units with unplanned, unpredicted standstill and operation periods
- Steady and continuous FFA injection at low concentrations
- FFA injection at the suction side of feed water system
- Condensate polishing plant can be operated
- Water chemical operating values will be affected during implementation phase but will return to stable values

# Preservation Principles - Long Term Preservation



- Plants with seasonal shutdown or planned revision, scheduled shutdown date
- FFA injection directly in front of ACC or in condensate or feed water lines
- Condensate polishing plant should be bypassed
- Water chemical operating values will be affected during injection

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# Operational Experience – With Air Cooled Condenser

- Customer: Siemens Energy Austria GmbH
- Site Location: Ramat Gavriel, Israel
- Plant Characteristics: combined cycle power plant  
generation capacity: 70 WM
- Scope of Application: Preservation after commissioning  
due to delayed grid connection



Protect especially the ACC from corrosion until start of  
commercial operation

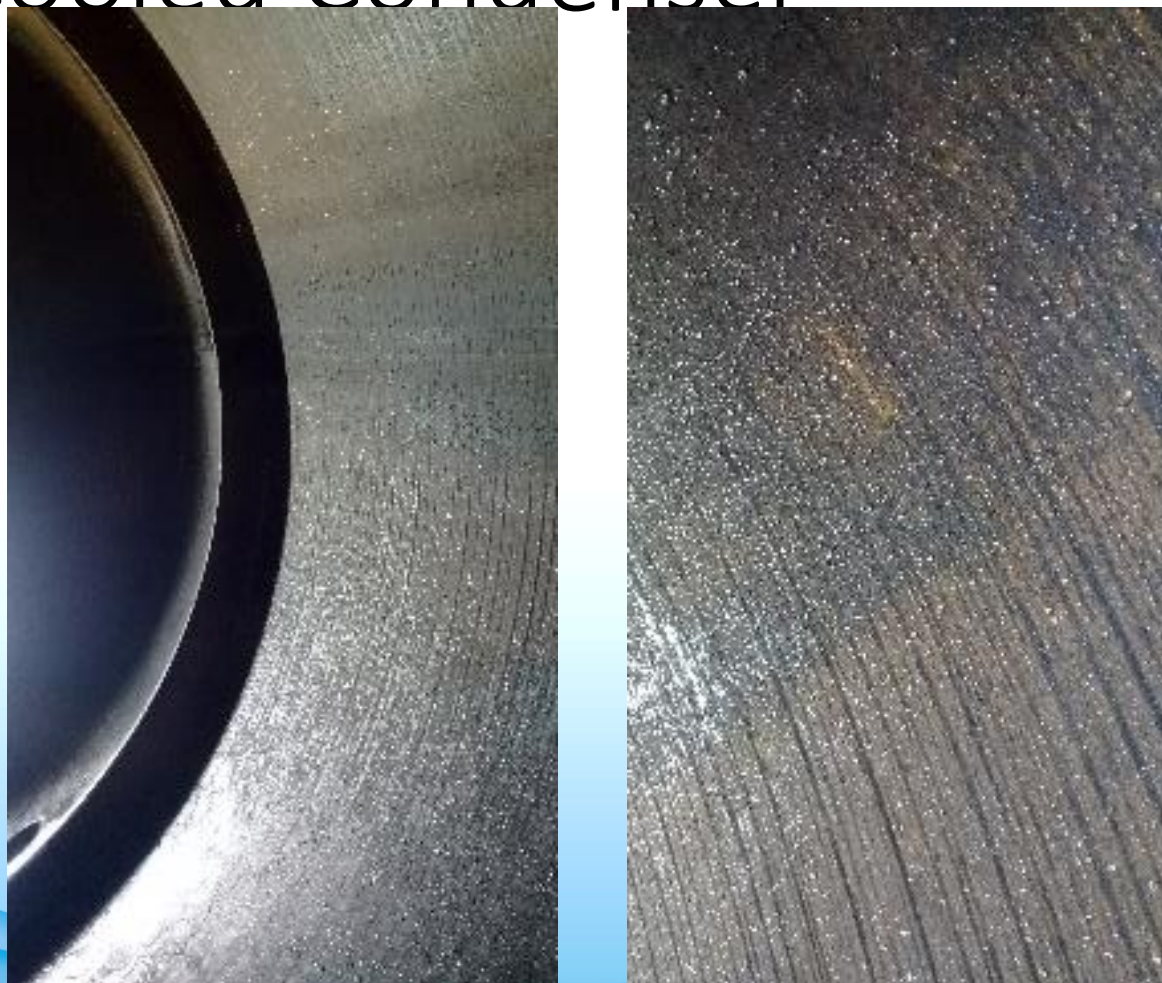
# Operational Experience – With Air Cooled Condenser

- Preservation Plan: Injection of FFAP (ODACON®) in front of ACC  
Measurement of FFA concentration in condensate  
Control of preservation effect by visual inspection
- Results: Hydrophobic surfaces in condenser and feed water system  
No issues due to corrosion during start-up of the plant  
Feed water system:



# Operational Experience – With Air Cooled Condenser

Condensate Receiving Tank





# Operational Experience – Without Air Cooled Condenser

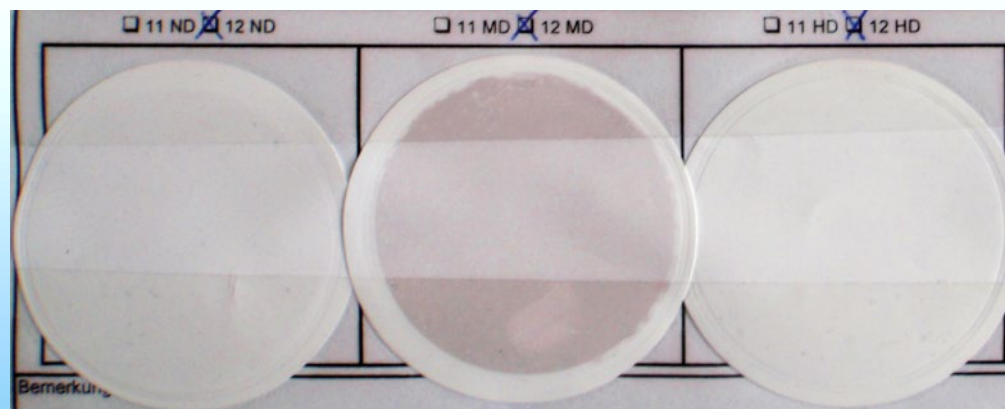
- Customer: Statkraft Markets, Germany
- Site Location: Hürth, Germany
- Plant Characteristics: combined cycle power plant  
generation capacity: 800 WM  
drum type HRSG,  $T = 555\text{ °C}$ ,  $p = 114\text{ bar}$   
no condensate polishing unit
- Scope of Application: flexible plant operation, less operation  
fast start-up required



# Operational Experience – Without Air Cooled Condenser

- Initial Situation: High iron levels during start-up, especially in IP section  
Clogging of filters

Parameters	Formula	Unit	LP	IP	HP
Iron <sub>Total</sub>	Fe	µg/l	< 20	< 80	< 20
Iron <sub>AAS</sub>	Fe <sup>2+</sup> / Fe <sup>3+</sup>	µg/l	3	29	3





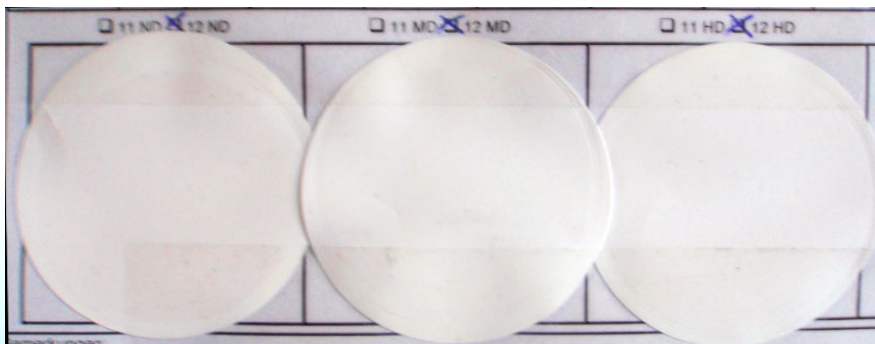
# Operational Experience – Without Air Cooled Condenser

- Preservation Plan: Preservation in several steps (short operation time with daily start / stop)  
Injection of FFAP (ODACON®) in the main condensate line after condensate pump
- Monitoring: On-line measurement of pH, acid conductivity (CC) and degassed conductivity DC  
Grab sampling for FFA analytic



# Operational Experience – Without Air Cooled Condenser

- Results:
  - Re-commissioning time was reduced about 50 %
  - Iron concentration during re-start in IP section reduced by 70 %
  - No additional nitrogen injection for short term protection and drying for long term protection necessary



# Operational Experience – Without Air Cooled Condenser

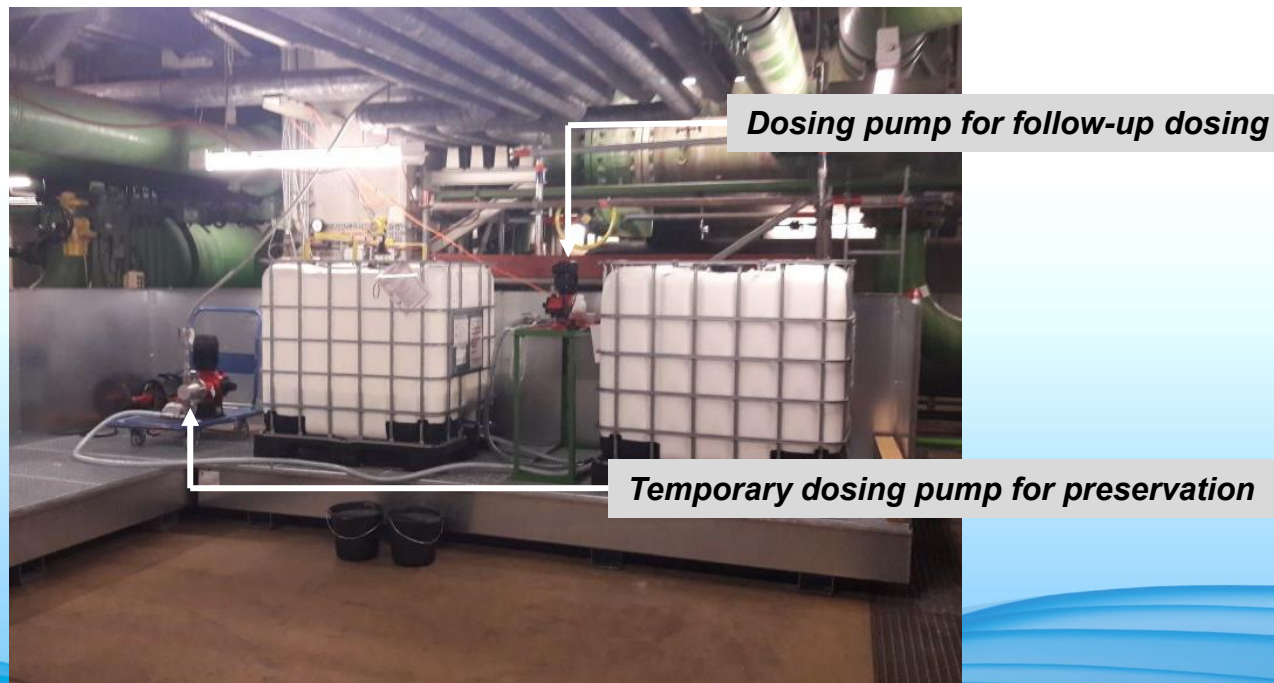
- Customer: STEAG Germany
- Site Location: Bexbach, Germany
- Plant Characteristics: coal fired power plant, 780 MW  
Steam capacity: 2,200 t/h  
Benson boiler,  $T = 535\text{ }^{\circ}\text{C}$ ,  $p = 195\text{ bar}$
- Scope of Application: Redispatch for network stabilization  
Fast start-up required





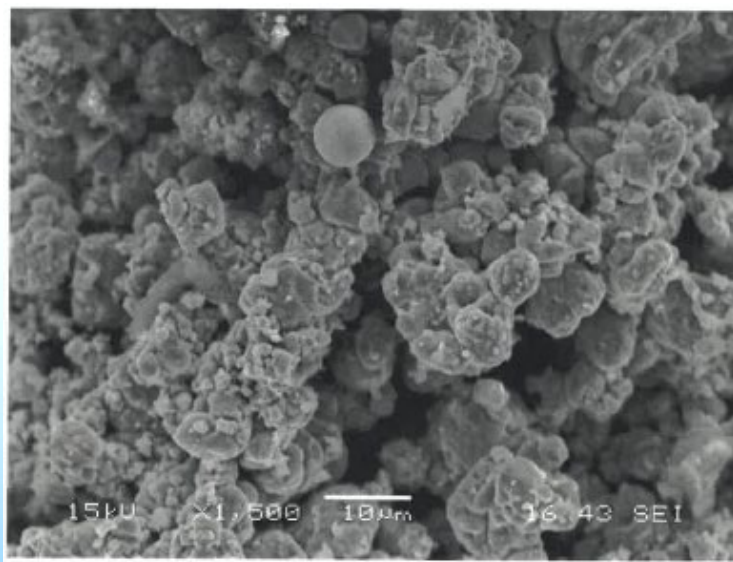
# Operational Experience – Without Air Cooled Condenser

- Preservation Plan: Plant operation for 3 days only possible  
FFAP injection in the main condensate line after CPP and after condensate pumps  
Bypassing the CPP during start of injection
- Injection Skid:

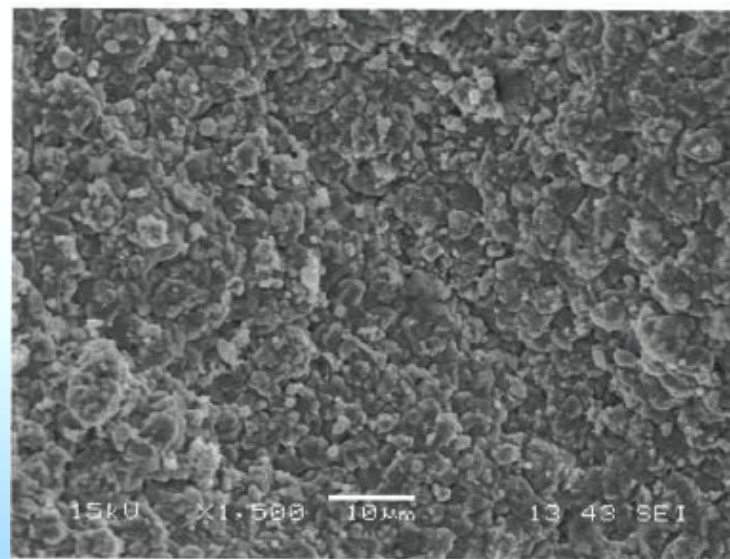


# Operational Experience – Without Air Cooled Condenser

- Results:
  - Iron concentration after start-up is the same as during continuous operation (< 5 ppb)
  - No drying for long term protection necessary
  - FFA treated surface is smoother and without porous oxide layers



Surface of non-treated sample pipe  
Magnification 1500x



Surface of ODACON-treated sample pipe  
Magnification 1500x



# Conclusion

Film forming amines (FFA) offers a variety of advantages and benefits compared to other technologies for long term preservation or flexible operation of the water steam cycle in power plants with air cooled condensers in reference to costs, usability, efficiency and environmental sustainability.

The start-up process after standstill is improved regarding the time to reach the parameters for turbine operation and the consumption of water and fuel.

Using FFA during operation can bring additional benefits besides the standstill corrosion protection, like reduced FAC, reduced SCC and increased heat transfer.

# Thank you. Any Questions?

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