

## Film-Forming Amines

### Corrosion Protection and Preservation of the Water-Steam Cycle

Film-forming amines (FFA) complement to the existing water chemistry treatment in mitigating corrosion transport into steam generators (SGs). Moreover, they can form part of a feasible strategy for optimizing the layup procedures with respect to the subsequent outages.

#### Challenge

Most of the world's operating nuclear power plants are more than 25 years old and consequently subject to increasing outage durations, especially due to long-term refurbishments. For reason of plant-specific characteristics (material concept, water-steam cycle design), the scope for improving water chemistry is very limited. In particular, corrosion products, impurities and hardening substances (mainly silicate) carry a high risk of hard sludge formation.

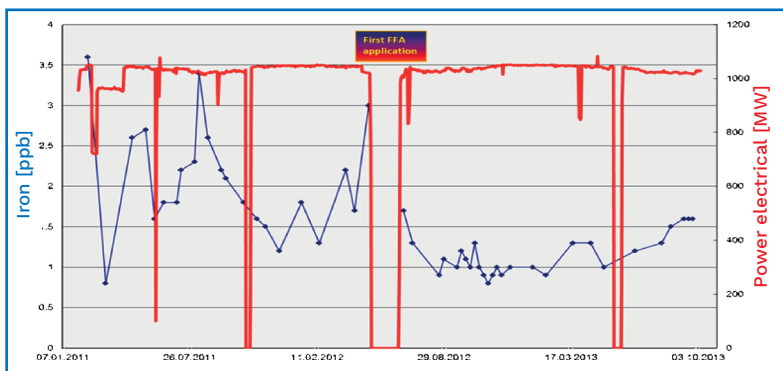
#### Solution

Our patented and field-proven application process of FFA effectively protects the entire water-steam cycle against corrosion.

FFA show a positive impact on hydrodynamic cavitation characteristics within two phase flow areas as well as on heat and mass transfer from and to the inner surfaces of the water-steam cycle.

FFA treatment is applied during full power operation as a complementary but time-limited measure to the existing secondary side water chemistry with the main objectives:

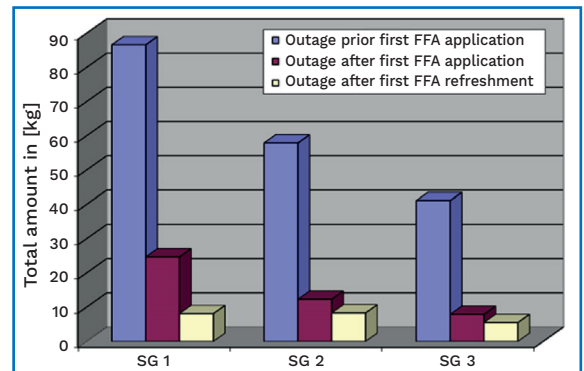
- To minimize corrosion product transport into the SGs during all operating modes
- To reduce wet/dry layup efforts during long-term outages.



Iron transport reduction into SGs

#### Customer benefits

- Layup effort is reduced and performance prior to outage optimizes outage schedule
- No environmental hazards of waste water after system layup
- Applicable at full power operation, controlled and time-limited injection of FFA into the water-steam cycle
- Mobilization and removal of impurities from secondary system
- Significant reduction of impurity ingress and smaller particle size
- Protective effect continues after restart
- Minimize consumption of harmful conditioning agent hydrazine during outages and subsequent cycles



Sludge from SGs during outage

**Your performance**  
is **our** everyday **commitment**

## Technical information

- Applicable at full power operation
- Complementary to adequate pH strategy without influencing plant operation and performance
- Compatible with plant materials and already existing protective oxide layers
- No environmental hazards of waste water after system layup
- Adherent non-wettable film lowers the corrosion rate
- Protective effect continues after restarting the unit
- Minimize consumption of the harmful conditioning agent hydrazine during outage periods and the subsequent fuel cycles
- Mobilization and removal of impurities from secondary system
- Significant reduction of iron ingress in feedwater during transient phase.
- Low iron concentrations ( $\leq 2\mu\text{g}/\text{kg}$ ) during normal power operation
- Successful operating experience in pressurized water reactors (PWRs) and pressurized heavy water reactors (PHWRs) in ten FFA applications worldwide



Visual inspection and water droplet test: condenser floor and protected oxide layer



Visual inspection and water droplet test at a PHWR: cut feedwater line (raw edge), moisture separator inside (welded area)

## References

### Almaraz Unit 1 and Unit 2 (PWR, Spain), since 2011

Focus on corrosion protection during outage, surface protection continuous after outage

- Inside surface cleaning of the entire water-steam cycle (removal of impurities and loosely bound corrosion products)
- Surface protection in wet steam areas

### Embalse (PHWR, Argentina), 2015

Focus on long-term layup

### Borssele (PWR, Netherlands), 2017

Focus on corrosion protection during outage, reduction of hydrazine

Contact: [chemistry-services@framatom.com](mailto:chemistry-services@framatom.com)  
[www.framatome.com](http://www.framatome.com)

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