IAPWS Film Forming Substances (FFS) Conference, FFS2023 Highlights and Press Release

The sixth IAPWS FFS International Conference was held on the 21st–23rd March 2023 in Prato, Italy chaired by Barry Dooley of Structural Integrity Associates, UK and David Addison of Thermal Chemistry, New Zealand. The FFS conferences are unique on a narrow topic in cycle chemistry control of power plants and steam generating facilities. In 2023 the conference attracted 70 participants from 28 countries which included 20 plant operators/users and representatives from 11 FFS chemical suppliers.

The FFS conferences are developed and supported by the International Association for the Properties of Water and Steam (IAPWS), and FFS2023 was arranged in Prato by Mecca Concepts, Australia and Combined Cycle Journal, USA. The sponsors of FFS2023 were Kurita Europe GmbH, Nalco Water an Ecolab Company and Termanox Water Treatment Solutions.

The major activities at FFS2023 were multiple presentations and discussion sessions outlining the current knowns and unknowns in relation to FFS and their properties in relation to their application as corrosion inhibitors in fossil, industrial, nuclear and other water/steam plants. Key research needs were documented by the conference attendees, which included the majority of global FFS suppliers, multiple users, research groups, and independent industry experts. This is part of the development of an IAPWS Certified Research Need (ICRN) which will be completed and approved at the IAPWS 2023 meeting (September 2023 in Turin, Italy). This ICRN is intended to help drive additional research into the critical, currently unknown fundamentals of FFS which will help to lower the application risks in plants, reduce the failures and improve the performance of FFS applications.

Key highlights from FFS2023 included:

- The participation of attendees from 28 countries illustrated the strong and increasing interest around the world in understanding and applying FFS.
- International updates were presented on recent experiences from fossil, combined cycle/HRSG, nuclear and industrial plants. Universally the presentations indicated reductions in the measurement of feedwater total iron corrosion products. Some examples showed increase of CACE (Conductivity after Cation Exchange). Mobilization of impurities (e.g., sulfate) was also noted in some examples.
- In the introduction of the conference it was indicated that there is now a wide range of FFS products and mixtures from at least 12 vendors globally. This increasing range makes research, derivation of common guidance and solutions difficult, and most important that research is focused on the properties of adsorbed films.
- One of the leading questions among users worldwide is whether FFS applications can be changed from a FFP to a FFA because of economic reasons, or vice versa.
- As at previous FFS conferences there was general visual observations of hydrophobic films in the water-touched areas (mainly feedwater and condensate) of plants. But there is growing consensus that the presence of a hydrophobic film might not be related to the reduction of corrosion and the transport of corrosion products.
- Film formation is still questionable in dry steam areas. It was emphasized that it is unlikely that a FFS film will be able to form and exist in steam temperatures at 600°C + and whether FFS can change the growth of oxides in steam. There was also continuing discussion on the lack of understanding on the effect of FFS on the oxides which grow in steam circuits, and on the chromia oxides which form in the phase transition zone (PTZ) of the steam turbine.
- Laboratory experiments provided positive results on monitoring FFA adsorption, corrosion and corrosion kinetics using EIS (Electrochemical Impedance Spectroscopy).
- The reduction of two-phase FAC in air-cooled condensers (ACC) by FFS application remains the only validated reduction by visual observation. FAC investigative work needs to be extended to a wider range of FFA and FFP with the production of direct evidence, not just general reduction of iron transport.

- Applications and research of FFS (mainly ODA) to nuclear plants were presented for one Candu unit in Romania and a PWR in The Netherlands. On-going research was presented on corrosion and layup testing with FFA and FFP.
- Two presentations were included on the application of new FFS in food environments. These highlighted blowdown reduction and a reduction of water consumption.
- One presentation focused on FFS in auxiliary closed cooling water systems.
- The steam turbine was a focus of work presented this year on cleaning of deposits, increasing efficiency and possible elimination of PTZ (phase transition zone) problems.
- Problems are still occurring in plants worldwide following application of an FFS where there were no pre-application chemistry reviews of corrosion product transport and deposition levels in boiler waterwalls and HRSG HP evaporators. Some examples of problems were presented: increased levels of internal deposits, boiler / HRSG tube failures especially under-deposit corrosion, and formation of "gunk" (gel like deposits) on heat transfer and drum surfaces and in steam turbines.
- It was emphasized that there has still not been any work presented to understand the mechanism of the interaction of an FFS with surface oxides representative of those in the condensate and feedwater of plants, and how an FFS film might change the growth mechanism and/or morphology of the oxides resulting in reduced levels of iron and copper corrosion product transport. This is recognized as the current major deficiency in understanding how FFS work in providing protection. As at previous FFS conferences future work was encouraged on the interaction of FFS films with existing oxide/deposit surfaces of Fe_3O_4, Fe_2O_3, FeOOH, CuO and CuO_2 in condensate/feedwater and boiler/evaporator water environments.
- Overall and in the conference conclusion it was clear that the understanding of FFS application has improved worldwide since 2014 but that there is still a large amount of fundamental work needed to understand the mechanisms of the now wide array of FFS available for plant application. Up to now most research work has been addressed to ODA followed by OLDA, and the secrecy associated with some of the FFP products remains an impediment for the industry. The following represents an outline of the research requirements which will be published in an IAPWS Certified Research Need (ICRN):
  - effect of FFS on growth mechanisms of Fe, Cu and Cr oxides in water and steam. Better understanding will help to explain the effects of surface roughness and overdosing of FFS
  - relation between surface coverage and degree of corrosion protection
  - effect of FFS on boiler and HRSG tube failures (under-deposit corrosion and corrosion fatigue) and stress corrosion cracking
  - film formation, kinetics, structure, equilibrium and stability (film thickness and porosity on water- and steam-touched oxide surfaces) for all FFS especially FFP
  - thermolysis and decomposition products for FFA and especially FFP under oxidizing and reducing potential conditions especially FFP
  - uncertainty of adsorption onto oxide surfaces for all amine and non-amine FFS and how films are affected by other additions to the FFS. Characteristics of film layers and correlation with surface protection
  - whether protection of superheated steam surfaces can be achieved for all amine and non-amine FFS
  - Increased steam turbine performance for amine-based FFS (ODA) was illustrated but research is needed to determine if FFS other than ODA reduce the surface tension
  - can FFS improve steam turbine efficiency and whether FFS in general can clean deposits from PTZ surfaces
  - can FFS improve heat transfer in feedwater, boilers/HRSGs and condensers
  - impact on membranes (EDI and RO)
  - impact on ion exchange resins
  - compatibility of FFS with other chemical additives (e.g. chemical cleaning agents, dispersants)
  - relationship with any reduction of emissions.

Next year the seventh FFS conference (FFS2024) will be held in March again in Prato, Italy.

Please contact Barry Dooley(bdooley@structint.com or bdooley@IAPWS.org) for further information on FFS and the IAPWS FFS Conferences.