IAPWS Film Forming Substances (FFS) Conference, FFS2024 Highlights and Press Release

The seventh IAPWS FFS International Conference was held on the 26th – 28th March 2024 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 2024 the conference attracted 50 participants from 16 countries from all over the world which included 10 plant operators / users and representatives from 12 FFS chemical suppliers.

The FFS conferences are developed and supported by the International Association for the Properties of Water and Steam (IAPWS), and FFS2024 was arranged in Prato by Mecca Concepts, Australia and Combined Cycle Journal, USA. The sponsors of FFS2024 were Swan Analytical Instruments, ECOLAB, Kurita and Anodamine.

The major activities at FFS 2024 were multiple presentations and discussion sessions outlining the current status in relation to FFS and their properties in relation to the 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. The seven year suite of conferences has been a key part in the development of the IAPWS Technical Guidance Documents and have helped to advance proper use of FFS as part of the aims of the IAPWS Certified Research Need (ICRN) which will be completed and approved at the IAPWS 2024 meeting (June 2024 in Boulder, Colorado, USA). 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 failures, improve the performance of FFS applications and eventually allow FFS to be changed at plant sites.

Film Forming Substances consist of two main categories of chemicals using the internationally accepted nomenclature: amine based (FFA, Film Forming Amine, and FFAP, Film Forming Amine Product) and non-amine based (FFP, Film Forming Products) which are of proprietary compositions. The conference provided a forum for the presentation of new information and technology related to FFS, new research results, case studies of fossil, combined cycle / HRSG, nuclear and industrial plant applications (biomass, dairy, farming, electrode boilers), cooling and auxiliary water systems. Discussions took place among plant users, equipment and chemical suppliers and industry consultants. The conference provided an opportunity for plant operators / users to raise questions relating to all aspects of FFS with the industry's inernational experts and researchers.

Key highlights from FFS2024 included:

- The participation of attendees from 16 countries illustrated the continuing strong 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. Interesting applications for supercritical units raised questions on additions of FFP when using oxygenated treatment. Universally the presentations indicated reductions in the measurement of feedwater total iron corrosion products. Some examples showed increases of CACE (Conductivity after Cation Exchange).
- 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 importantly that research should be focused on the properties of adsorbed films.
- One of the leading questions among users worldwide remains 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. A survey of the conference participants indicated that the presence of hydrophobic films does not uniquely relate to the reduction of corrosion and the transport of corrosion products but appears to be an artefact of application. Also surface tension of an FFA (OLDA) is reduced at low levels and related to the contact angle of wettability in this range.
- A deeper understanding among the attendees was apparent around what are the metrics for success for a FFS program in plants is evolving and developing and moving beyond just using the presence of hydrophobicity as a single assessment point.
- Laboratory experiments provided positive results on monitoring OLDA adsorption on to oxide surfaces, corrosion and corrosion kinetics using EIS (Electrochemical Impedance Spectroscopy). The work on the interaction of the FFA with oxide surfaces rather than metal surfaces was strongly encouraged especially for the other FFS.
- Additional successful application of FFS for industrial boiler pre-service cleaning and preparation, and for waste incineration boilers were discussed for the first time at the FFS conferences further expanding the applicability of these products in water/steam cycles. Cooling system applications were also highlighted as well as an update for the use of FFS in electrode boilers.
- Changes in heat transfer rates and improved efficiency results were discussed as areas needing further development.
- On the nuclear plant side results were presented on the effect of FFA and FFP on the compatibility of elastomers and gaskets. The effect of FFA (ODA) on steam generator sludge with relatively high levels of alumina were investigated. Laboratory investigation using a recirculating loop into the impact of FFA on corrosion rates found no change in surface oxide morphology.
- The couple of presentations on the available analytical methods for FFS were much appreciated; it was emphasized that the exact composition of FFAP should be known to provide a more accurate analysis.
- Problems are still occurring in plants worldwide following application of FFA and FFP 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.
- Overall, and as conference conclusions, it was clear that the understanding of FFS application has improved worldwide since the first FFS conference in 2017 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. Previously most research work has been addressed to ODA followed by OLDA. However, 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. This is recognized as the current major deficiency in understanding how FFS work in providing protection. Future work is needed 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.
  - 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.
- thermal hydrolysis 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 amine and non-amine FFS.
- increased steam turbine performance for amine-based FFS (ODA) was illustrated but research is needed to determine if other FFS reduce the surface tension.
- impact on membranes (EDI and RO).
- impact on ion exchange resins.
- compatibility of FFS with other chemical additives (e.g. chemical cleaning agents, dispersants).

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