IAPWS Film Forming Substances (FFS) Conference, FFS2022
Highlights and Press Release

The fifth IAPWS FFS International Conference was held on the 22nd / 23rd and 29th / 30th March 2022 as a virtual event chaired by Barry Dooley of Structural Integrity Associates, UK and David Addison of Thermal Chemistry, New Zealand. FFS2022 was a unique conference on a narrow topic in cycle chemistry control of power plants and steam generating facilities. In 2022 the conference attracted a record number of 146 participants from over 30 countries which included 50 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 FFS2022 was organized by Mecca Concepts, Australia and Combined Cycle Journal, USA. Six sponsors supported FFS2022: Fineamin SA, Kurita Europe GmbH, Nalco Water, Reicon, Suez and Waltron LLC.

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 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, geothermal and industrial plant applications (biomass, dairy and naphtha crackers), and cooling water systems. Discussions took place among plant users, equipment and chemical suppliers, university researchers 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 international experts and researchers.

Key highlights from FFS2022 included:

- The participation of attendees from over 30 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, geothermal and industrial plants. Universally the presentations indicated reductions in the measurement of feedwater total iron and copper corrosion products.
- In the daily introductions for the conference it was indicated that there is now a wide range of FFS products and mixtures from at least 11 vendors globally. These can be described in four general categories: film forming products (FFP) which are non amine based, and film forming amine products (FFAP) which are pH or surfactant stabilized, homogenization / emulsions, or pH stabilized and blended with dispersants. This increasing range makes research, derivation of common guidance and solutions difficult, and more important that research is focused on the properties of absorbed films so that operators can change FFS products.
- Plant data from a unit transitioning to FFP (a non amine) from a previous blend of amine / non amine FFS was very encouraging because of economic reasons. Much further plant and laboratory studies are required to confirm the similarity of film properties and protection formed with the wide range of FFS currently on the market.
- 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 number of presentations provided key insights using Photoelectron Spectroscopy (XPS) to prove the presence of, but not the continuity of films with potential to move away from the standard hydrophobicity tests. This would be a great

future outcome for tube sampling and analysis if it can be proven to work in real operating environments.

- Film formation is still questionable in dry steam areas. It was emphasized that it is unlikely that an 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 of the reduction of single- and two-phase flow accelerated corrosion (FAC) using FFS containing ODA and OLDA under realistic plant feedwater conditions between 150 - 165°C at pH of 9.2. In previous years there had been no measurable improvement for two-phase FAC. While FAC scallops were observed in one set of recent experiments there remains no understanding of the effect of the FFS on the magnetite growth mechanism. Further experiments on the oxides were encouraged so that validations of arresting FAC in plants can be confirmed.
- The reduction of two-phase FAC in air-cooled condensers (ACC) by FFS application remains the only validated reduction by visual observation. This FAC investigative work needs to be extended to a wider range of FFA and initiated for FFP.
- It was pleasing to see that there were six presentations on application and research of FFS (mainly ODA) to nuclear plants. There has been FFS application (ODA) to nine set of nuclear plants in seven countries; detailed results were presented for one plant after 11 years of FFS application with positive results of feedwater iron levels of < 2 ppb and measured particle size reduction.
- Other active work for nuclear plants involved studies on the effect of FFS on degradation of gaskets and elastomers; preliminary results indicate that Viton is incompatible with neat FFA. Work is proceeding to develop a third IAPWS FFS Technical Guidance Document (TGD) for nuclear plants. Other research for the nuclear plants was discussed with special regard for corrosion and flow-accelerated corrosion in typical secondary water chemistry, and corrosion under layup conditions.
- There was special mention of the IAPWS Technical Guidance Documents (TGD) for Conventional Fossil, HRSG and Industrial plants in terms of the processes that should be adopted before application of an FFS to any plant (Sections 8 and 9 in the IAPWS TGDs are particularly important).
- Problems are still occurring in a few 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. These problems need further definition.
- For the first time at FFS conferences basic research was presented on film forming corrosion inhibitors (oleic-based imidazoline (OMID) and sodium lauryl lactylate (SLL)) in different corrosive environments (HCl, H_2SO_4) than found in power plants using XPS and EIS (Electrochemical Impedance Spectroscopy). It is hoped that the insights on how the filming molecules interact with metal surfaces (carbon steel) under severe chemical environments at lower temperatures can provide advancements in the studies of FFS on materials in power plant environments.
- The conference also included presentations of the effect of FFS on on-line instrumentation, decomposition / breakdown products of FFA, thermolysis and distribution of FFA, adsorption kinetics of film formation, and ion exchange resins.
- As a direct follow-on from the IAPWS previous FFS conferences there has 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 which result in the reduced levels of iron and copper corrosion product transfer that are reported in all FFS plant applications. This is one of the current major deficiencies in understanding FFS. 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 wide array of FFS available for plant application. The secrecy associated with some of the FFS products remains an impediment for the industry. The following represent an outline of these 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
    - 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
    - thermolysis and decomposition products for FFA and especially FFP under oxidizing and reducing potential conditions
    - uncertainty of adsorption onto oxide surfaces for all amine and non amine FFS and how films are affected by other amines
    - 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 at previous FFS conferences but research is needed for other FFA and FFP (any change in surface tension?).
    - Can FFS improve heat transfer?

Next year the sixth FFS conference (FFS2023) will be held in March in Florence, Italy.

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