Report on the PowerPlant Chemistry Forum in Delhi, India

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ABSTRACT

This contribution is a report on the seventh PowerPlant Chemistry Forum (PPCF), held in Delhi, India, on November 22–23, 2018. The PPCF Delhi was organized by Waesseri GmbH, publisher of the PowerPlant Chemistry Journal, together with the International Association for the Properties of Water and Steam (IAPWS). Both SWAN Analytische Instrumente AG, Switzerland, and Forbes Marshall Pvt. Ltd., India, provided financial and organizational support by their sponsorship.

The agenda consisted of six sessions covering different aspects of water/steam cycle chemistry: cycle chemistry for fossil supercritical and subcritical units, chemistry in generator cooling water systems, cycle chemistry in nuclear plants, sampling and instrumentation as well as new technologies were the topics covered during the two days. Each session consisted of two to three presentations given by an expert in the field, followed by open floor discussions. A short summary of each presentation is given in this report.

For the first time in this series of events, a workshop on the activities of the IAPWS was included in the agenda. During this workshop the formation of a preliminary national committee of India was discussed and an initial group of interested experts formed as a result.

INTRODUCTION

In the past six years, Waesseri GmbH has organized more than 20 Power Cycle Instrumentation Seminars (PCISs) around the world with the mission of expanding the knowledge of cycle chemistry and the understanding of analytical instruments [1–5], with the most recent seminar held in Lima, Peru, in April 2018. This series will be continued in the future – more information on the upcoming events can be found on our webpage (www.ppchem.net).

Based on the feedback from the past seminars, Waesseri GmbH decided to start a new series of events – Power Plant Chemistry Forums (PPCFs) – with even more time for the participants to discuss and to share knowledge and experience with their colleagues from other power plants and with the international experts. The main focus of the forum also changed slightly as it does not concentrate on sampling and instrumentation only but instead includes a wide variety of power plant chemistry topics. The first PPCF was held in Johannesburg, South Africa, in March 2016 [6] and its success convinced the organizers to continue with this new format. A report on the PPCF held in Bangkok, Thailand, in 2017 has been published in this journal as well [7].

The seventh PowerPlant Chemistry Forum was held in Delhi, India, on November 22–23, 2018. The PPCF Delhi was organized by Waesseri GmbH, publisher of the PowerPlant Chemistry Journal, together with the International Association for the Properties of Water and Steam (IAPWS). Both SWAN Analytische Instrumente AG, Switzerland, and Forbes Marshall Pvt. Ltd., India, provided financial and organizational support by their sponsorship.

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This report will give a short overview of the PPCF in Delhi, India, and a short summary of each presentation.

DAY 1

The Status of Cycle Chemistry Worldwide for Fossil Supercritical and Subcritical Units
Barry Dooley, Structural Integrity Associates, UK

The first presentation was given by the chairman of the steering committee of the PPCF Delhi, Barry Dooley. He has been the Executive Secretary of the International Association for the Properties of Water and Steam (IAPWS) since 1989 and on the editorial board of the PowerPlant Chemistry Journal since 1999.

The presentation was divided in two parts: In the first part, achievable goals for optimum cycle chemistry were introduced, including the guiding principles and key operational aspects for once-through and drum units. In the second part the achievable goals were compared with the operational results from 210 cycle chemistry programs worldwide. Achievable goals for optimum cycle chemistry include:

- No boiler tube failures (BTFs) influenced by cycle chemistry
- No turbine chemical problems
- No flow-accelerated corrosion (FAC)
- Operational guidelines and action levels for all units and operating conditions
- Simple, reliable instrumentation and control (minimum level for each unit)
- Elimination of the need to chemical clean
- Optimized procedures for shutdown and layup
- Optimum managerial approach to cycle chemistry within a BTF reduction program
- Benchmarking for chemical cleaning, FAC and BTF

The guiding principles and key operational aspects then presented were based on the latest technical guidance documents of IAPWS [8–11], which provide advice and guidance for optimum cycle chemistry.

In the second part, the result of an ongoing worldwide assessment was presented. The main message was that 50 % of all fossil plant damage can be related to continuing cycle chemistry problems with chemistry influenced tube failure (BTF) damage and failure mechanisms remaining the number one problem:

- FAC (leading safety issue)
- Under-deposit corrosion (hydrogen damage, acid phosphate corrosion and caustic gouging)
- Corrosion fatigue and stress corrosion cracking (transgranular and intergranular)
- Pitting

Corrosion product transport due to inadequate feedwater chemistry leads to deposition in waterwalls, which causes under-deposit corrosion and thermal fatigue. Steam turbine deposits are an ongoing problem with pitting, stress corrosion cracking and corrosion fatigue in the phase transition zone being the leading issues.

To approach the abovementioned problems (especially FAC), tools have been introduced which allow the plant operators to determine the key chemistry deficiencies, called repeat cycle chemistry situations (RCCS). A detailed article on FAC in steam generating plants was published in this journal earlier this year [12].

Challenges of Cycle Chemistry Management during Cyclic Operations – NTPC Strategies
Bikasendu Bhattacharya, retired General Manager of NTPC Limited, India

The second presentation was held by Bikas Bhattacharya, a member of the steering committee of the PPCF Delhi.

The basis of international climate policy changed significantly with the adoption of the Paris Agreement in December 2015. In line with the lead role taken by India, ambitious plans for maximizing power from renewable sources and for flexible operation of existing fossil-fuel-based power plants are becoming inevitable in NTPC. Flexible operation challenges the conventional wisdom and ability of a plant to maintain water chemistry, which can lead to increased corrosion and other associated chemistry-related problems. Flexible operation in this part of the world is mostly associated with extended low load operation, faster ramp rates and frequent cycling (startups and shutdowns).

Of late, some of the NTPC stations, which are experiencing such flexible operations frequently, have been facing increased failure problems in the steam generator and turbo generator system. Through root cause analysis it has been established that some of those failures are due to FAC, under-deposit corrosion, relative humidity pitting, corrosion fatigue and stress corrosion cracking. Issues of flexible operation associated with cycle chemistry problems are: air in-leakage, high dissolved oxygen (DO) in condensate, high condensate cation conductivity, pH fluctuation and corrosion-related issues leading to steam generator failures, turbine deposition, overloading of the condensate polishing units (CPUs), impeding the startup delays and ramping hold-ups too.

A detailed study has been carried out on a data base of those parameters, and strategies have been formulated to mitigate the impact to ensure the integrity of steam and turbo generator equipment. The brief action plan is based on upgrading of steam/water sampling and analysis systems (SWAS), modifying operating parameters and monitoring philosophy.

Seven Sins of Steam Sampling – Reloaded and Spiced-up

Manuel Sigrist, SWAN Systeme AG, Switzerland

The contribution looked back at the evolution of sampling system design in the past decade, illustrating typical pitfalls due to misinterpreted requirements and to design short-cuts. Where applicable, references to modern guidelines on water chemistry regimes and on appropriate system design were made. The presentation was based on an article which was published in this journal 8 years ago, but still the main "sins" continue to be repeated [13].

Steam/water sampling and analysis systems (SWAS) are a small subsystem within a typical water/steam cycle. This equipment is expected to detect contaminations of the cycle and to provide reliable control parameters to condition the water throughout the cycle. Performance and reliability of this subsystem play a key role in preventing damage and maintaining the integrity of all major components exposed to water or steam in the cycle.

In many world regions, the design practices of these systems are still based on historic operating practices. Such design practices, often combined with a lack of process understanding and a strong focus on system manufacturing cost, lead to systems with disappointing performance and high operations and maintenance costs.

Chemistry Management in Generator Cooling Water Systems

Robert Svoboda, Consultant, Switzerland

Robert Svoboda has been on the editorial board of the PowerPlant Chemistry Journal since 2004 and is a member of the steering committee of the PPCF Delhi. His presentation summarized a series of five articles to appear in this journal on corrosion and deposits in water-cooled generator windings [14–18].

Water-cooled generators are equipped with hollow strands ("hollow conductors") made either of copper or of stainless steel. Chemistry-related problems with copper hollow strands include rare cases of corrosion and loss of electric insulation, and more frequently plugging of hollow conductors by deposition of copper oxides, thus impairing cooling water flow. Various water treatment regimens have been developed in order to mitigate this problem. Their aim is to control the formation, release, migration, and re-deposition of copper oxides.

Low-oxygen, high-oxygen and alkaline treatment have proven their benefits over the past 50 years, but no regimen is without problems. Adequate lay-up during shutdown is equally important as adhering to the water chemistry requirements. For the removal of such deposits, mechanical and chemical cleaning techniques have been established. In contrast, stainless steel hollow strands have only simple requirements on water chemistry, and there has been an absence of corrosion and chemistry-related failures in plant operation with their use.

IAPWS is currently preparing a Technical Guidance Document (TGD) on Chemistry Management in Generator Water Cooling during Operation and Shutdown – Robert Svoboda chaired the sub-task group developing the new TGD.

Oxide Growth and Exfoliation (OGE) in Steam Circuits

Barry Dooley, Structural Integrity Associates, UK

The topic of this presentation concerned the oxides which grow on the internal surfaces of superheater and reheater steam tubing and how they exfoliate from the surface. The oxides act as an insulating layer on the internal surface and with increasing oxide thickness the temperature of the tube increases. The oxide with time will exfoliate and the oxide particles can cause two serious problems, short term overheating failures of superheater tubes and solid particle erosion (SPE) in the first stages of the steam turbine. While these phenomena are important aspects of a number of plant damage mechanisms, they are not influenced by the cycle chemistry [19].

The presentation provided detailed information concerning the oxidation behavior in steam of alloys used as pressure parts in superheaters and reheaters of boilers and HRSGs. The development of the oxide morphologies on these alloys and the influence of those morphologies on the scale exfoliation behavior. The oxide growth behavior

was described for three tube materials: standard 1–9 % Cr ferritic steels, the ferritic-martensitic steel T23 and T91, and 300-series austenitic steels.

In summary, there is an established morphological picture for OGE on "normal" ferritic and austenitic alloys. There is a consistent picture for T91 and fine grain austenitics as well as for T23. There is NO effect of cycle chemistry on OGE and the use of oxygenated treatment does not lead to increased exfoliation of oxides and short-term overheating and boiler tube failures.

- The oxides on T11 and T22 can lead to SPE
- The oxides on austenitics can lead to short-term overheating
- The oxides on T91 can result in long-term overheating/creep or short-term overheating
- The oxides from T91 and T23 can lead to steam turbine deposits and maybe performance loss.

Modular Sampling System for SWAS Upgrades in Existing Plants
Aditya Sanjay Kanetkar, Forbes Marshall Pvt. Ltd., India

The SWAS is an important tool for enhancing the life of critical equipment like pressure parts, heat exchangers and the turbine. Generally, most newly built boilers and power plants are erected with these highly sophisticated SWAS systems. However, there are still a large number of plants and boiler users today that don't have online steam and water analysis systems and therefore need to upgrade their SWAS.

The biggest challenge in such existing plants is to accommodate the modern systems:
In existing plant layouts in compact space
Without major civil work/reconstruction in existing SWAS rooms

There are some important aspects to be considered when planning a SWAS upgrade:

- Compactness
- Safety in design
  - Pressure safety
  - Temperature safety
- Layout flexibility
- Aesthetics & ergonomics

Evaluation of High-Temperature Decontamination Process for Stainless Steel 304 LN Surface
V. S. Sathyaseelan, Bhabha Atomic Research Centre, India

Decontamination of stainless steel (SS) 304 LN surfaces is gaining importance as it will be the structural material of the main heat transport (MHT) system of the proposed Indian Advanced Heavy Water Reactors (AHWRs).

Decontamination of any SS surface is challenging as the corrosion product oxide formed on its surface is a mixture of chromites and chromium-substituted ferrites that cannot be easily dissolved. Hence, to develop an effective decontamination process for SS 304 LN surfaces, studies have been carried out with SS 304 LN specimens. In this context, oxide film was formed on SS 304 LN surfaces by exposing them to simulated AHWR coolant chemistry conditions. The film was characterised by scanning electron microscopy, x-ray photoelectron spectroscopy, laser Raman spectroscopy and chemical methods.

The oxide film formed was nickel and chromium substituted single-phase ferrite spinel. Dissolution of this oxide film was studied in low-temperature and high-temperature formulations. The normal low-temperature (85 °C) dilute chemical decontamination process consisting of nitrilotriacetic acid, ascorbic acid and citric acid (NAC) developed previously was found not to be effective in dissolving this oxide film. A multi-step multi-cycle process involving alternate oxidation and reduction processes was effective, but the process is time consuming, besides generating a large volume of radioactive waste due to multiple cycles. Hence, a high-temperature decontamination process based on nitrilotriacetic acid (NTA) at 160–180 °C was evaluated. The entire oxide film could be completely removed from the SS 304 LN surface within 10 hours at 180 °C in a single step. The estimated corrosion rate for SS 304 LN during the above process was only 0.035 μm per hour.

Non-Chemical Disinfection and Dechlorination to Protect RO & Demineralizer Treated Boiler Make-up Water
Michael Argaman, Atlantium Technologies, Israel

Chlorine and biocides have traditionally been used to mitigate biofouling and manage microbially induced corrosion, and are commonly injected into the feed lines of the water treatment process at power plants to reduce the microbial load. However, when the water treatment process consists of reverse osmosis (RO) trains, it is important to make sure the membranes are protected from oxidation by chlorine. Therefore, dechlorination is undertaken to remove free chlorine compounds from the feedwater in order for the RO trains and other chlorine-sensitive equipment to operate properly.

The advanced UV technology presented uses broad-spectrum ultraviolet (UV) lamps for the reduction of chlorine and for disinfection. Through photodecomposition by UV light, the system decomposes the free chlorine oxidant. Additionally, the technology provides disinfection to reduce the membrane biofouling potential.

The core of the discussed UV system is its water disinfection chamber made of high-quality quartz surrounded by an air block instead of the traditional stainless steel. This configuration uses fiber optic principles to trap the UV light photons and recycle their light energy. The photons repeatedly bounce through the quartz surface back into the chamber, effectively lengthening their paths and their opportunities to inactivate microbes or to destroy chlorine molecules.

After introducing the technology, two case studies from full-scale installations were presented. More details on the technology as well as one of the case studies were published in this journal in an earlier article [20].

IAPWS Workshop
B. Dooley, IAPWS Executive Secretary, and D. Addison, Head New Zealand IAPWS

The first day concluded with a session dedicated to IAPWS activities. For the first time in this series of events, a workshop on the activities of IAPWS was included in the agenda. Barry Dooley introduced IAPWS to the participants, showing its history, activities and importance for power plant chemistry worldwide.

Current members are Australia, Britain and Ireland, Canada, the Czech Republic, Germany, Japan, New Zealand, Russia, Scandinavia (Denmark, Finland, Norway, Sweden), and the United States, plus the associate members Argentina & Brazil, China, Egypt, France, Greece, Italy, and Switzerland.

David Addison then showed how the New Zealand National Committee of IAPWS was formed and how this experience could be transferred to form an Indian National Committee of IAPWS.

After these two presentations the formation of a preliminary national committee of India was discussed and an initial group of interested experts formed as a result.

DAY 2

Chemistry Optimization in Nuclear Power Plants
Joerg Fandrich, Framatome, Germany

The second day was opened by Joerg Fandrich, a member of the steering committee of the PPCF Delhi.

The objective of this presentation was to show by examples Framatome's service activities as well as most recent research and development projects related to the worldwide installed base fleet, and the importance of chemistry activities with respect to radiation source term control and corrosion product transport control.

The majority of worldwide operating nuclear power plants are older than 30 years and are faced with or entering a plant life-time extension program. Furthermore, nuclear operators worldwide have challenging requirements on their agenda: long-term refurbishment programs, power uprate programs, flexible load operation demands and more strict requirements regarding environmental safety and usage of hazardous substances.

Due to plant-specific design characteristics (design and material concept), chemistry-related improvements are very limited. Nevertheless, chemistry improvements can contribute significantly to supporting the plant operator in limiting the efforts and respective costs.

Within this challenging context, chemistry control efforts become more and more important. Performing chemistry-related modifications in most cases is a cost beneficial alternative compared to design and component modifications.

Long-term operation and modernization programs in nuclear power plants result in expensive refurbishment activities to maintain the structural integrity and optimum performance of the main safety-related components. Chemistry-related activities as mid- and long-term measures can support these system-related activities by

- Optimizing startup and shutdown control
- Creating optimum pH(T) conditions in all systems to minimize general corrosion
- Complementing the standard chemistry control program by new technologies (i.e. film forming substances [21]).

Tata Power CGPL Experience with Cycle Chemistry of Supercritical Plants: On the Path to World Class Performance
Amitava Datta, CGPL Mundra Tata Power, India

The next presentation was held by Amitava Datta, a member of the steering committee of the PPCF Delhi.

Coastal Gujarat Power Ltd (CGPL), Mundra, a 100 % subsidiary of Tata Power, got the opportunity to have the new 830 MW supercritical technology, where the Mundra team also started a new concept in India for boiler water treatment, i.e. oxygenated treatment (OT), at the earliest possible time. OT chemistry started with its first unit within a period of four operating months. As the confidence grew slowly, the last, i.e. the 5th, unit was changed to OT within one operating month.

CGPL Mundra has faced a lot of unknowns and challenges in implementing OT. As a greenfield project there were some problems starting OT in the first unit, but with growing knowledge and confidence gradually all units were converted to OT over less and less time. As the Mundra station is conceptualized on competitive tariff bidding, the fixed cost was kept very low and for this the installed equipment standby was also kept very low. The challenges therefore also exist in operating areas: for instance, the whole demineralized water production system is designed on 1 % make-up and for all five units there is only one condensate polishing unit (CPU) regeneration unit.

The presentation explained the observations during the start of OT treatment in all units and it also showed the different experiences during the 5 years of the OT program in all 5 units.

Mundra has a state of the art laboratory for low-level iron testing. Ultimately, CGPL has achieved less than 1 $\mu g \cdot L^{-1}$ iron in the feedwater cycle. In connection with particle iron, Mundra implemented an online turbidity analyzer in the condensate cycle. An excellent correlation between particle iron and turbidity has been established and the correlation is being followed during startup to reduce the time for analysis. The presentation also explained how to have confidence in dissolved oxygen monitoring and accordingly oxygen dosing to maintain oxygen levels.

Key Aspects of Successful Cycle Chemistry Programs – Minimising the Risks of Deposition and Corrosion Related Problems in Fossil and Industrial Steam Plants via the Use of IAPWS Technical Guidance Documents
David Addison, Thermal Chemistry Limited, New Zealand

The next presentation was given by David Addison, a member of the steering committee of the PPCF Delhi, a member of the IAPWS Power Plant Chemistry (PCC) group and chairperson of the New Zealand Association for the Properties of Water and Steam (NZAPWS).

There are common cycle chemistry issues experienced globally:

- Incorrect cycle chemistry program for the plant design
- Lack of suitable sampling and analysis systems
- Ongoing operation with suboptimal steam purity and quality
- No layup and storage protection in place when offline (boiler and turbine)
- No manuals/documentation/training of staff

Three case studies helped to illustrate these observations: case study A discussed a once-through supercritical plant, case study B a once-through subcritical plant and case study C a combined cycle power plant. For each case study, first an introduction to the plant and plant history (cycle chemistry status and issues before the improvement) was given before showing how the cycle chemistry improvement project was outlined with the support of IAPWS Technical Guidance Documents (TGDs).

Three key lessons could be drawn for the discussed case studies:

- Compliance with IAPWS Technical Guidance Documents significantly decreases the probability of a plant having major cycle chemistry problems and related failures.
- Effective cycle chemistry monitoring is critical – you cannot control what you cannot measure.
- The majority of cycle chemistry problems are totally avoidable.

Some Challenges in Development of Cooling Water Treatment Program for Power Plants
Ashwini K Sinha, Corrosion and Water Management Consultants, India

During the process of heat transfer, cooling water can cause fouling, scale deposition, biofouling and/or corrosion in the system, affecting the life, performance, reliability and efficiency of all the cycle chemistry components. As the condensers are under vacuum, any condenser tube leakage will result in contamination of cycle chemistry and subsequently in damage to critical components like boiler tubes, superheater tubes, turbines etc. in order to control such problems, suitable treatment of cooling waters is necessary.

In most places the water quality variations are very high, even within one single year, due to varying constituents of the water. Due to high demands on the water required for the cooling applications, the once-through mode of cooling water has now been banned by Indian authorities. Only recirculating water is to be used at power plants in the country. Further, considering the high make-up water requirements, nowadays emphasis is being put on the recycling of waters and power plants are being asked to use treated sewage water as make-up to cooling towers.

All these things create serious challenges for developing suitable chemical treatment programs at the power plants as unlike boiler water chemistry, which has been standardized based on boiler type, pressure and temperature, cooling water treatment programs have to be site specific with provisions for modifying the program based on the water quality available and the operating mode of the power plant.

The presentation discussed these points through three different case studies. The first case discussed the use of treated sewage water as make-up to a cooling tower, the second case dealt with the recycling of seawater reverse osmosis (SWRO) reject water as make-up to cooling towers and the third case discussed adverse effects of fly ash silos presence near cooling towers.

Best Practices in Cycle Chemistry Optimization & Corrosion Management across Adani Power Limited
Santanu Bhattacharya, Adani Power Limited, India

The next presentation was given by Santanu Bhattacharya, a member of the steering committee of the PPCF Delhi.

Adani Power Limited (APL) has become the biggest private power producer in India with a total installed capacity of 10 440 MW. The thermal power plants are situated over the length and breadth of the country.

APL has four thermal power stations in four different states in India.

Adani Power Mundra Limited (APMuL) is situated in the coastal town of Mundra, Gujarat, and has 4 620 MW (4 x 330 MW + 5 x 660 MW) installed capacity. The plant uses seawater to fulfill all types of water demand in the plant and other nearby facilities. The condenser is seawater-cooled as well. A wide variety of issues emerged in the course of commissioning and operation. All issues were dealt with great technical acumen, and best practices were established in every sphere of cycle chemistry and corrosion management. The presentation depicted the journey of APMuL to becoming a benchmark in this area.

Adani Power Maharashtra Limited (APML) has five supercritical units (660 MW). The APML units had experienced severe exfoliation issues in the boiler, and the units were stabilized after taking all required measures. The lesson learnt from the severe boiler exfoliation incident were shared in the presentation.

Adani Power Rajasthan Limited (APRL) has two 660 MW supercritical units which operated with the original equipment manufacturer recommended chemistry regime. The transformation journey to the latest chemistry regime was portrayed in the presentation.

Udupi Power Corporation Limited (UPCL) is a take-over plant with two 600 MW subcritical units. The severe structural corrosion issues due to the coastal environment were a great challenge after take-over. The journey of transformation from a severely corrosion-ridden, shabby plant to a picturesque plant in a greener background was shown.

APL has implemented many best practices to eliminate off-load corrosion by preservation of the boiler, TG, heaters etc. during long shutdown periods. The presentation focused on such issues with vivid examples supported by theoretical reasons.

Conductivity, from Bleeding Edge to Leading Edge
Manuel Sigrist, SWAN Systeme AG, Switzerland

Conductivity measurements are the most commonly used online measurements for water/steam cycle chemistry monitoring. This is due to the simple measuring principle, and the sensitivity to all types of ionic contamination.

To allow reliable and repeatable measurements, it is essential to understand what factors will affect and potentially bias the measurements. Instruments, sensors and sample preparation devices (cation exchanger, degasser etc.) must be able to cope with these disturbances.

Practical examples of good practice and bad practice installations were used to illustrate the importance of temperature compensation, proper sensor design, cation exchanger set-up, degassing principles etc.

For designers and operators, guidance for the assessment of any online conductivity measurement set-up was provided.

Chemistry Improvements at Pickering Nuclear Power Generating Station, Canada
Anil Garg, Ontario Power Generation Inc., Canada

Pickering Station is located on the north shore of Lake Ontario. It has 6x514 MWe operating units. All units have been in service for ~ 40 years. Many chemistry improvements were discussed in this paper for various systems, which have resulted in getting the chemistry performance indicators on target.

The presentation covered various chemistry improvement initiatives such as:

- Rigorous receiving and inspection process for the use of various chemicals, materials and ion exchanger (IX) resins at the station following a chemistry colour coding procedure and the maintaining of a common process chemistry quality assurance database.
- Successful application of operating experience in modifying the IX column configuration in various systems such as heat transport, moderator, and stator cooling water systems for better chemistry control.
- Water treatment plant upgrades have been completed successfully, which has resulted in achieving an improved resistivity of demineralized water. This in turn helped to get boiler ion concentrations to WANO limiting values.
- In the heat transport system (HTS), a mass flow controller (MFC) was installed for dosing-controlled hydrogen and to achieve the desired dissolved deuterium concentration. Also, adjustments were made to pH values in the HTS to resolve the black deposit (iron oxides) issue on the fuel bundles. Also, HTS bleed filter pore size reduction from 0.45 micron to 0.05 micron is in progress for crud removal and dose reduction.
- In the moderator system, portable cart has been successfully procured and used for the moderator cover gas (MCG) chemistry control during unit startup when online gas chromatograph goes out of order.
- Stator cooling water chemistry is improved due to increased IX resin volumes and the use of palladium based de-oxy resin. Modifications are in progress for the de-oxygenation of the make-up water and also changing neutral to alkaline pH using alkalizer for the corrosion control.
- Portable dissolved oxygen analyser is procured to measure feedwater dissolved oxygen going to the steam generators, fulfilling the requirement of EPRI.
- End shield cooling cover gas chemistry is improved by the addition of hydrazine which scavenges oxidizing species and in turn reduces radiolytic production of hydrogen.
- Irradiated fuel bay (IFB) chemistry is improved by the shock treatment of hydrogen peroxide.
- Dealloying of Monel-400 U4 steam generators 11/12 preheater tubes at P19 is controlled by changing morpholine concentration and other chemistry controls.
- Various improvements were achieved with respect to the corrosion product transport (CPT) reduction program, such as condenser hot well cleaning during unit startup, analyzing feedwater samples using the x-ray fluorescence instrument for fast results, and corrective actions.

Also, continuous improvement to the chemistry program is going on to the best of industry standards by applying internal and external operational experience, benchmarking, self-assessment and technical exchange with various international organizations such as the Candu Owners Group (COG), Institute of Nuclear Power Operators (INPO), World Association of Nuclear Operators (WANO), and Electrical Power Research Institute (EPRI).

With all these modifications and improvements to the chemistry program, the WANO chemistry performance indicator (CPI) has improved to 1.02 (2018) from 1.10 (2009).

This is the result of timely and effective communication of chemistry concerns to the organization (Senior Leadership Team), providing details and consequences to the nuclear assets.

Case Study: Root Cause Detection of Contamination Source in Water/Steam Cycle Chemistry Using Online Chloride and Sulfate Analysis
Akash Trivedi, METTLER TOLEDO Thornton, Inc., USA

Power plants are constantly focused on water/steam cycle chemistry in their drive to combat corrosion and damage to plant assets. A variety of parameters are measured to monitor and control contaminants in the power plant water, with industry guidelines specifying acceptable limits for such measurements. As a result, analysis of plant upsets can be effectively conducted by evaluating these parameters and finding the root cause of the upset.

The presentation provided a case study on using online chloride and sulfate measurement to conduct root cause analysis for plant upsets, using an analyzer based on microfluidic capillary electrophoresis (MCE) technology. A report on this technology has been published in this journal [22].

Ameren's Sioux Power Plant in St Louis, MO (USA) experienced a cycle chemistry excursion detected by various parameters measuring outside of acceptable limits. Using data from online chloride and sulfate measurement, the plant was able to rule out chloride and sulfate contamination as the cause of the excursion. The plant could focus on troubleshooting conditions that could cause organic contamination and was able to bring the water/steam cycle chemistry back under control quickly.

Optimum Cycle Chemistry for Fossil and Combined Cycle Plants with Air-Cooled Condensers (ACC)
B. Dooley, Structural Integrity Associates, UK

ACCs come in many sizes and forms, but the FAC and corrosion damage is the same worldwide with all chemistries and plant types. This is based on assessment and inspections done worldwide in Australia, Canada, Chile, China, Cote d'Ivoire, Dubai, India, Ireland, Israel, Mexico, Quatar, Abu Dhabi, South Africa, UK and US.

Corrosion and FAC in ACCs and the consequences:

- High concentrations of iron around the cycle
  - Boiler/HRSG deposits (expensive chemical cleaning)
  - Boiler/HRSG tube failures (overheating and thermal fatigue)
  - Steam turbine deposits (including aluminum)
- Need for iron removal processes:
  - Condensate polishing and/or filters
- Limitations around the cycle:
  - Condensate polishing (may have to change mode)

Overall an ACC "controls" the unit cycle chemistry; international guidelines are now available for ACCs and two-phase flow [9].

The ACC Corrosion Index to compare and categorize corrosion and track improvements was introduced next: DHACI (Dooley, Howell, Air-cooled Condenser, Corrosion Index [23]). The index separately describes the lower and upper sections of the ACC, according to the following:

DHACI for Lower Ducts

A. Ducting shows no general signs of two-phase damage

B. Minor white areas on generally grey ducting. Maybe some tiger striping with darker grey/black areas of two-phase damage

C. Serious white bare metal areas in the hot box and at numerous changes of direction (e.g. at intersections of exhaust ducting to vertical riser). White areas are obvious regions of lost metal.

DHACI for Tube Inlets

1. Tube entries in relatively good shape (maybe some dark deposited areas)
2. Various black/grey deposits on tube entries as well as flash rust areas, but no white bare metal areas
3. Few white bare metal areas on a number of tube entries. Some black areas of deposit
4. Serious white bare metal areas on/at numerous tube entries. Lots of black areas of deposition adjacent to white areas

5. Most serious. Holes in the tubing or welding. Obvious corrosion on many tube entries.

Some aspects relate to FAC (adjacent black and white areas in severe turbulent areas, increasing local pH reduces damage), but some aspects don't. Increasing condensate pH to 9.8 will gradually "arrest" the FAC damage at the tube entries and iron levels will reduce to IAPWS suggested levels. This is documented by reducing the DHACI. Film forming substances also work, but sufficiently detailed documentation of before and after application is not yet available.

Damage on cross members is not "arrested" as quickly by increasing pH. This could be explained by liquid droplet impingement caused by the larger droplets leaving the phase transition zone of the low-pressure steam turbine.

CONCLUSION

The PPCF in Delhi attracted over 75 station chemists, instrument technicians, designers, and C&I-engineers from India and neighboring countries. Linked to participation was a free e-paper subscription to the PowerPlant Chemistry Journal for the next year.

For the first time in this series of events, a workshop on the activities of the International Association for the Properties of Water and Steam was included in the agenda. This fruitful cooperation will be repeated in future events.

The feedback from the audience was very positive and this reaffirmed the organizers' decision to repeat this kind of event on a regular basis. New events are already being planned and we will publish detailed programs in the upcoming issues of this journal.

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