Report on the PowerPlant Chemistry Forum in Johannesburg, South Africa

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ABSTRACT

This contribution is a report on the first PowerPlant Chemistry Forum, held in Johannesburg, South Africa, on March 24–26, 2016. The forum consisted of four sessions covering different aspects of water/steam cycle chemistry: life-cycle chemistry optimization, start-up chemistry and early operation experience, combined cycle power plant and utility plant chemistry, as well as plant failures and subsequent chemistry adjustments 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.

INTRODUCTION

In the past three years Waesseri GmbH has organized several Power Cycle Instrumentation Seminars around the world with the mission of expanding the knowledge of cycle chemistry and the understanding of analytical instruments [1–3]. Based on the feedback from the past seminars, Waesseri GmbH decided to start a new series of events – PowerPlant Chemistry Forums – 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 has shifted slightly as it does not concentrate on sampling and instrumentation only but instead includes a wide variety of power plant chemistry topics.

The first PowerPlant Chemistry Forum took place in Johannesburg, South Africa, on March 24–26, 2016. The forum consisted of four sessions covering different aspects of water/steam cycle chemistry: life-cycle chemistry optimization, start-up chemistry and early operation experience, combined cycle power plant (CCPP) and utility plant chemistry, as well as plant failures and subsequent chemistry adjustments The international and local experts invited to the forum presented case studies on each of the topics of the four sessions to build the foundation for the plenary discussions. After every presentation and at the end of each session enough time was scheduled for in-depth plenary discussions.

A short summary of each presentation will be given in the following sections of this report.

SESSION 1: LIFE-CYCLE CHEMISTRY OPTIMIZATION

The first session was opened by Michael Rziha, key principal expert at Siemens AG. Michael is the chairman of the International Association for the Properties of Water and Steam (IAPWS) Power Cycle Chemistry (PCC) Working Group, a member of several VGB workgroups, and a member of the PowerPlant Chemistry Journal's International Advisory Board.

His first presentation at this forum was about continuous chemistry optimization over the lifetime of a power station. With three case studies from the field he showed that without proper implementation and control of the cycle chemistry the power plant operators will face high economic costs due to efficiency losses and unplanned outages. The three case studies included stress corrosion cracking in relation to hydrogen embrittlement, heavy deposits on turbine blades, and heavy silica deposits – all three cases having the same route and outcome although they were in different plants. The economic costs for the operators can be avoided by remembering these simple rules:

- Changes in your plant may happen at any time.
- Changes in operational mode may change the chemistry.
- Trends and their analyses are essential.
- The denser the analytical data are, the better is your diagnosis.
- Limit values of guidelines are only recommendations to avoid the worst case.
- The optimum chemistry has to be worked out on an individual basis!

The next presentation was given by Randy Turner, technical director of SWAN Analytical Instruments, USA. Randy is the chairman of the American Society of Mechanical Engineers (ASME) Power Plant and Environmental Chemistry Committee, an advisory board member for the International Water Conference, a member of the IAPWS PCC Working Group, and he is on the American Water Works Association (AWWA) Online Monitoring Committee.

In his first presentation he showed how a coal-fired power plant changed its chemical regime from all-volatile treatment under reducing conditions (AVT(R)) to all-volatile treatment under oxidizing conditions (AVT(O)). Before giving a short introduction to the power plant and its unit data, an overview was given of what factors influence the selection of the right water/steam chemistry. The plant design, its metallurgy, the kind of cooling system, and the intended operational regime (base load, cycling, peaking) play a role in this selection.

The plant under discussion is a coal-fired unit with a controlled circulation drum boiler, copper condenser tubes, and copper alloy feedwater heaters. The originally implemented treatment system was AVT(R) with the appropriate monitoring equipment recommended by EPRI [4]. The following problems occurred:

- The chemistry for either metal (carbon steel and copper alloys) could not be optimized, which resulted in increased corrosion of both iron and copper and finally to more frequent boiler chemical cleanings.
- Steam drum liner cracks occurred, which resulted in increased mechanical carry-over and finally to turbine deposition.

After an assessment the plant operator decided to make some modifications in the metallurgy as well as the chemistry of the unit:

- to replace the drum liner,
- to replace copper alloy feedwater heaters with stainless steel feedwater heaters,
- to change the chemistry regime from AVT(R) to AVT(O).

The decreased mechanical carry-over due to the repaired drum liner resulted in reduced turbine deposition (copper, sodium, silica). Replacing the copper alloys in the feedwater heaters allowed the cycle chemistry regime to be changed to AVT(O), which reduced iron corrosion and therefore reduced chemical cleaning frequency.

SESSION 2: START-UP CHEMISTRY AND EARLY OPERATION EXPERIENCE

After the lunch break the forum continued with the second session, which was dedicated to commissioning and early operating experience. The first speaker was Ken J. Galt, chemistry specialist at ESKOM, South Africa. Ken presented experiences made during the commissioning and the first year of operation of Unit 6 of Medupi Power Station located near Lephalale in Limpopo province, South Africa. Unit 6 is the first of six 794 MW coal-fired units being constructed at Medupi Power Station, and commenced commercial operation in 2015. After completion of all six units, the station will have the largest direct air-cooled condenser (ACC) in the world. The ACC will consist of 64 fans (11 m diameter) per unit, grouped into 8 streets of 8 fan modules each, with a total footprint of 72 252 m^2.

Ken explained the different steps taken between the completion of Unit 6 in 2012 and the first synchronization in early 2015: from pre-operational chemical cleaning, with a detailed cleaning sequence and the considerations (e.g. steam generator materials) made during the planning, to steam blow-through and its purpose (discharge of loose particles, exfoliation of adhesive deposits) and ACC hot cleaning in Jan/Feb 2015. The condensate polishing plant design was explained in detail – its design is based on the

experiences gained at Matimba Power Station, a power plant that has been operated by Eskom in Limpopo province, South Africa, for more than 30 years. The performance of the condensate polishing plant (CPP) at Medupi Unit 6 has been good so far but there are still optimizations to be made. The long-term water/steam cycle chemistry is oxygenated treatment (OT) at elevated pH (9.8), but because of certain alloy materials in the superheaters, the early operation has been AVT(O) with feedwater oxygen levels below 20 $\mu g \cdot L^{-1}$. Generally, the cycle chemistry control over the first seven months of operation has been reasonably good.

The next presentation was held by Michael Rziha on the optimization of cycle chemistry during commissioning and the first year of operation. The main message was that there is no single "golden" standard and that guidelines cannot replace detailed knowledge of the individual plant – the optimum choice of the cycle chemistry is individual for each power plant. And even more important, cycle chemistry is an ongoing science – modifications may be necessary from time to time. With another case study Michael then explained in detail what parameters should be monitored and how to relate the collected data to other important information such as load transients or valve positions to analyze and understand how the cycle chemistry is changing and why. At the end of the presentation it was again made clear that optimum cycle chemistry will positively influence a plant's efficiency and lifetime expectations, and prevent unforeseen outages, all of these aspects together being a commercial justification for the work of the plant chemists.

The last presentation of the first day was given by Ken Galt and Philip du Toit, who is currently working for ESKOM, South Africa, as the senior chemical engineer at Medupi water treatment plant (WTP). The introduction was given by Ken, in which he recapitulated the decision making process for the water treatment plant to be installed at the newly built Medupi Power Station. Source water quality and effluent disposal regulations were the key indicators in this process, which led to the following water treatment process:

- Pretreatment:
  - Coagulation, flocculation, sedimentation
    - 2 × clarifiers (under construction)
  - Ultrafiltration (secondary in-line coagulation)
- Demineralized water production:
  - Double pass reverse osmosis
  - pH increase between passes for CO_2 removal (NaOH for adjustment)
  - Gas transfer membrane contactors for O_2 removal
  - Electrodeionization (demin polishing)

Philip du Toit continued the presentation by explaining in detail the experience made during the commissioning and first months of operation of the WTP. The WTP's final configuration was designed for the water quality of the water source the plant will be using in the future – during its commissioning phase, though, the water was taken from another, temporary source. The design data of the ultrafiltration, reverse osmosis, gas transfer membrane contractors, and continuous electrodeionization system as well as the operational control philosophy for each system were explained. An overall plant performance analysis and outlook on potential optimization followed at the end of this presentation.

After a final plenary discussion, the first day's official program ended and the participants were invited to join the dinner in the nearby steakhouse within the Montecasino complex.

SESSION 3: CCPP AND UTILITY PLANT CHEMISTRY

The second day started with a presentation by David Addison, the principal of Thermal Chemistry Ltd, New Zealand. David is the chairman of the New Zealand branch of the IAPWS and a member of the IAPWS PCC Working Group.

David first presentation of the day focused on the challenges faced in combined cycle plants. Three case studies helped to illustrate the potential costs of instrumentation failures and substandard sampling and analysis systems. In a lot of smaller utilities and industrial plants not enough attention is paid to the sampling system monitoring equipment, which leads to unnecessary failures and outages of the plant. Four lessons could be drawn from the three case studies presented:

1. If you aren't monitoring a process correctly, then you can't control a process correctly.

2. Effective sampling, analysis, and data storage and processing systems are essential – the best performing plants worldwide have these.
3. Daily grab sampling on its own is ineffective for providing control.
4. Troubleshooting a cycle chemistry process is extremely difficult without good data – there is a potential for major cost implications due to the occurrence of steam turbine and boiler tube failures.

The second presentation of this session was held by Alwin Verstraeten, chemical and environmental engineer at Sloecentrale B.V., Netherlands. Alwin presented the latest developments in the optimization process of the cycle chemistry of the Sloecentrale combined cycle plant.

An article on earlier steps of this optimization process was presented last year in this journal [5]. As the reliability and availability of the two single-shaft units are key for Sloecentrale, the company made an assessment of the flow-accelerated corrosion (FAC) risk. The result of this assessment has been a step-by-step optimization of the chemistry in the plant. Chemistry has been optimized with regard to ammonia injection to increase the pH in the cycle. When looking at the iron measurements, the conclusion can be drawn that the feedwater is under control ($> 90\ \%$, $< 2\ \mu g \cdot L^{-1}$).

However, the drums are not within the target limit of $> 90\ \%$, $< 5\ \mu g \cdot L^{-1}$. In order to improve the protection of the boiler, the power station has started a trial with two different set-ups for the two boilers:

– On Unit 10, Anodamine™ is being tested – the product has a surface active chemistry.
– In parallel, on Unit 20 a higher pH dosing is being tested.

The tests started on March 24, 2016, and will be continued until the power station has enough information to conclude which set-up will be used in the future.

After a short coffee break the session continued with another presentation held by David Addison. His second presentation dealt with steam turbine stress corrosion cracking in a once-through supercritical power plant. During a shutdown of the plant, deposits were noted on the low-pressure turbine. Further inspection revealed pitting and cracking on the blade roots and a subsequent metallurgical analysis confirmed stress corrosion.

A root cause analysis (RCA) process was initiated to determine what had occurred at the plant with the focus on preventing a repeat failure situation and preventing problems in the other unit. The RCA involved metallurgical analysis and a detailed review of the plant, its chemistry,

and possible contamination pathways. The main findings were the following:

– A lack of steam sodium analysis prevented early confirmation of steam purity issues.
– The condensate polisher plant was a powdered resin system, which was operating with a leak that was allowing resin to escape the vessel, enter the boiler, and then thermally decompose and contaminate the steam. The plant had no resin trap or filter installed at the outlet and no turbidity or particle detection either. Therefore, the loss of resin in the polisher was only detected by the decreasing volume in the vessel with no link as to where it was going.
– The feedwater ammonia dosing was reported as having operated fully automatically for only a short period before the RCA. Throughout all the previous years, the operation had required manual control during plant start-up.
– There were no steam turbine lay-up and storage practices in place.
– Once deposits had formed on the steam turbine, the reaction of oxygen and moisture during off-line periods initiated pits on the turbine surfaces.
– Cracks then propagated from these pits when the turbine was in service.

The key lessons learned from this case study are that once-through supercritical units have almost zero tolerance for cycle chemistry problems – almost any steam contamination event results in deposits forming on the steam turbine.

SESSION 4: PLANT FAILURES AND SUBSEQUENT CHEMISTRY ADJUSTMENTS

The last session of the forum was intended to present case studies of power stations that have learned lessons from plant failures and improved their cycle chemistry to prevent future damage.

David Addison started the session with a case study from a conventional fossil plant, giving first an introduction to the plant and plant history (cycle chemistry status and issues before the improvement) and then showing in detail how the cycle chemistry improvement project was outlined and implemented.

The power station mainly faced the following challenges:

- Multiple major condenser tube leaks had occurred with total contamination of the steam path and turbine. Short-term overheating failures occurred in the superheater and reheater.
- There had been no chemical cleaning of the boiler since commissioning – high feedwater iron transport rates and suspected FAC failures.
- There was carry-over occurring (mechanical) due to drum level control issues.
- The majority of the steam and water sampling systems were out of service, with a heavy manual sampling and analysis workload placed on the chemists, which consumed almost all their available time.
- Feedwater dosing (ammonia and reducing agent) were all manually controlled (auto-controllers had failed ~10 years earlier).

The recommendations for improvement were based on guidelines issued by IAPWS [4] and included the full replacement and upgrade of the sampling system and monitoring equipment, a switch from AVT(R) to AVT(O) for the feedwater with low-level phosphate treatment in the drums, the repair of auto-dosing controllers, an overhaul, repair, and upgrade of the WTP to improve performance, a full boiler and turbine chemical cleaning, and last but not least, cycle chemistry training and mentoring for the chemical staff.

Within 2 years the site has managed a major cycle chemistry turnaround – from extremely poor to near world class. This turnaround required solid commitment from the corporate level, management, engineers, and chemists.

The last presentation of the forum was given by Randy Turner, who presented a final case study in which he showed how a coal-fired unit optimized its cycle chemistry to mitigate FAC. First he gave a quick overview of the factors influencing FAC and the different locations where FAC may occur in the water/steam cycle. Then he showed the unit's technical data and the chemistry regime employed before the improvements were made.

The main problems were caused by the copper condenser tubes and copper alloy feedwater heater. The plant could not optimize the AVT(R) chemistry for either metal (carbon steel and copper alloys) used in the water/steam cycle. Furthermore, the unit experienced elevated levels of dissolved oxygen (DO) in the condensate during periods of high make-up water production. As a result, the unit experienced FAC in the feedwater system and the steam attemperation system.

To solve these problems, the following recommendations were made:

- Maintain feedwater pH at 9.25–9.35.
- Maintain hydrazine at the lower end of the range 5–10 $\mu g \cdot L^{-1}$.
- Maintain redox potential at the upper end of the range –75 to –100 mV.
- Address issues causing elevated DO.
- Use T11 or T22 steel when making repairs to areas experiencing FAC.
- Change feedwater heaters to ferritic or stainless steel as the opportunity arises allowing a chemistry change to AVT(O).

As a result of the abovementioned changes the unit experienced significant improvements in the water/steam cycle, i.e. FAC was reduced, copper corrosion did not increase, and the scale growth rate was reduced.

CONCLUSION

The forum in Johannesburg attracted over 70 station chemists, managers, technicians, and engineers. The feedback from the audience was very positive. The plenary discussions were very fruitful, and the break times were also used intensively to share and discuss experiences from the attendees' own plants with the local and international colleagues.

In order to serve as many people within the industry from all around the world as possible, new events are already being planned and prepared. Future Forum dates, venues, and other details will be published in this journal as soon as they are available.

REFERENCES

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