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Authors: Susan Baines, Kumar sinha, Kathi Kirschenheiter—Bechtel Corporation

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Risk Mitigation by Managing Water Treatment System Interfaces in the Power Industry

SUSAN BAINES, KUMAR SINHA and KATHI KIRSCHENHEITER, Bechtel Power Corporation, Frederick, MD

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ABSTRACT: Managing power plant water treatment system interfaces for a LSTK Contract is critical to mitigate system performance and guarantee risks for the EPC Contractor and the Owner from development to commissioning. For system integration, it is important to have adequate guidelines and operating flexibility to determine the appropriate treatment steps for each system based on their requirements. Several case studies presented discuss the challenges in designing these systems and the strategies used to mitigate risk at their interfaces.

INTRODUCTION

In the present competitive power market, it is critical for an EPC contractor to manage water treatment system interfaces for a lump sum turn key (LSTK) contract in order to mitigate risks associated with system performance and effluent guarantees. Mitigation of risk begins at the conceptual design phase and continues through execution and commissioning. The agreement between the EPC contractor and the owner is binding and commonly referred to as the “scope book”. The scope book often explicitly defines the systems, but it is the interfaces between two suppliers where the EPC contractor assumes the major risks.

The typical major treatment systems for power plants are raw water pretreatment, boiler water makeup (i.e., demineralization), condensate polishing, cooling tower makeup, and wastewater treatment. Although not considered as a system in itself, one of the most challenging tasks is managing the interface between the boiler and the turbine with respect to boiler water quality and steam purity. Figure 1 provides an illustration of typical major water systems in a power plant. Figure 2 provides a list of common water quality control parameters at major system interfaces. Depending on the type of power plant and specific design requirements, there are often additional systems that may require makeup water treatment such as combustion turbine inlet air evaporative cooling systems for natural gas fired plants and ash conditioning systems for coal-fired plants.

All of these systems have different water quality requirements and potentially different suppliers. Therefore, for system integration, it is important to have adequate management guidelines based on experience and practical solutions to determine the appropriate treatment steps for each system with respect to operation and effluent guarantees.

The author's focus is specifically on the system interfaces and the challenges in designing these systems to minimize risk for both the EPC contractor and supplier and cause smooth transition from execution to startup and commissioning. A key to success is the management strategies used to smooth out the interfaces without incurring penalties and causing costly delays. The case studies presented illustrate these challenges and the proposed solutions.

TYPES OF RISKS

There are various effluent guarantee and equipment warranty risks a contractor has to consider when designing water treatment systems to meet the client's operational and control philosophy, system effluent guidelines, and regulatory requirements. The following are examples of risks associated with water treatment systems for the power plants.

1) Lack of adequate raw water quality data can affect overall system design and lead to inefficiencies in the system that need to be removed during startup and commissioning
2) Committing to a design too early in the development phase before performing raw water due diligence can lead to unnecessary scope changes
3) Conflicting requirements of system operating modes (i.e., online, offline, baseload, cycling), such as clarifier turndown capability, can result in oversized or undersized systems
4) Mismatching effluent guarantees at equipment or system interfaces can cause operational problems if not resolved during the design phase

RAW WATER PRETREATMENT

Raw water pretreatment system treats the plant makeup water source(s) to make it suitable for cooling tower makeup and prepares the water for the demineralization system. Raw water pretreatment system design depends on many variables. The major variables are the type of power plant such as solids fuel-fired power plants or combined cycle plants, makeup water source, the plant water systems' requirements (capacity as well as quality), and water withdrawal limitations from surface water sources, wells, or recycled water. With respect to managing the system interfaces, it is important to understand the design limitations of each system or sub-system. Having adequate raw water quality data with an understanding of the mean, maximum, and minimum concentration values, is extremely crucial to the success of the overall system design, integration, and management of system interfaces. Establishing optimum concentration values for design requires such statistical analysis of the water quality data. Analyzing how the proposed makeup water system design would respond to water that has higher and lower than design water quality characteristics, provides snapshots of the system constraints and their potential impact on water quality guarantees and equipment performance. (A great example of this is "seasonal solids" in surface water sources that may only see this high solids loading for a few days per year, but the plant must operate. The decision on whether or not to put in a clarifier has major impacts on the cooling

tower, demineralization system, evaporative coolers, Fire Water system, etc.)
Raw water pretreatment can include various treatment processes, such as clarification, chemical precipitation, media filtration, and stand alone membrane filtration. Polishing filters, which can vary from macro filtration to micro filtration and reverse osmosis, can follow these processes. Experience gained from contracts executed on these systems has shown that extra care needs to be taken when specifying the water quality at the equipment interfaces in the pretreatment area because it can have major ramifications on both the makeup treatment system as well as the on the effluent guarantees. If the pretreatment system feeds both the cooling towers and the makeup treatment system, this interface needs to be managed to ensure that the needs of both systems are met.

COOLING TOWER MAKEUP

Typically, if raw water is available, it can be used as cooling tower makeup without pretreatment. When it is necessary to increase the cycles of concentration to minimize system blowdown, treatment of cooling tower makeup water comes into consideration. The common methods are clarification, filtration, chemical precipitation to remove hardness and alkalinity, heavy metals, organics, and BOD. The large flows involved in cooling tower makeup treatment make it a critical interface that needs water quality management strategies. The strategies need to minimize performance risk imposed by the cooling tower supplier on the EPC contractor to operate the tower within a specified chemistry range while using the amount of water specified in the contract. Understanding cooling tower thermal performance in conjunction with chemistry limits will minimize water quality and quantity concerns.

BOILER WATER MAKEUP TREATMENT

The product from the raw water pretreatment system typically requires additional treatment for direct use as boiler makeup water. For a combined cycle plant, the steam turbine (ST) and heat recovery steam generator (HRSG) may specify special requirements based on preferred metallurgy, steam usage for air-cooling, or HRSG configuration (once-through or drum design).

Typical technologies required for boiler water treatment are listed in Table 1 below.

Table 1 – Boiler Water Treatment Technologies

Two pass RO followed by mixed bed ion exchange or EDI
Single pass RO followed by mixed bed ion exchange or EDI
Cation, anion and mixed bed ion exchange

MANAGING SYSTEM INTERFACES

In the authors’ view, the management strategies for water treatment system interfaces should be based on using a backward design approach (i.e., start with ST steam purity requirements to determine feedwater quality, then condensate, then boiler makeup, etc.) and implemented as discussed below.

BOILER/TURBINE – The strategy for managing this interface should be the following:

1) Establish startup steam chemistry limits with the turbine supplier during contract negotiations. The limits should be based on experience and should not be overly liberal or overly

stringent. An understanding of how steam purity limits are established will help in reaching such agreements between the EPC contractor and the boiler and turbine suppliers.

2) Provide these startup/normal operating chemistry limits to the boiler supplier and/or specify the drum steam/water moisture separators (as applicable) to minimize mechanical carryover.
3) Include grab sampling arrangement for saturated steam to monitor the steam/water separator in the boiler drum and the attemperator.
4) Provide practical cycle makeup water quality limits to the makeup water treatment demineralizer equipment supplier and if very stringent limits are being imposed, add equipment as necessary.
5) Create and implement a control plan with startup personnel on how startup chemistry will be managed so that steam purity stays within limits agreed to by the steam turbine supplier. It is also critical to include steps on how this will be demonstrated.

PRETREATMENT – The design of the pre-treatment system to prepare the water for the cycle makeup is critically important because issues originating in the pretreatment system can propagate through the water treatment plant.

CYCLE MAKEUP – For a two-pass RO/EDI system, request RO projections from the supplier for various operating conditions and their impact on EDI product water quality. For a two-pass RO/Mixed Bed system, request RO and MB projections for the various operating conditions while maintaining constant effluent quality from the mixed bed in each case.

INTERNAL FEEDWATER SYSTEMS – These systems include condensate polishers, chemical feeds, boiler/HRSG blowdown, and dearation to control the condensate and feedwater chemistry. These systems require design oversight to manage conditions or events that seldom occur during the life of the plant, such as condenser in-leakage. Here are a few strategies used to manage the interfaces of these systems.

1) Review the thermodynamic calculations performed by the dearator supplier.
2) Consider oxygen control of cycle makeup between the demineralized water storage tank and condenser hotwell by establishing reasonable supplier/sub-supplier chemistry limits.
3) Consider installation of permanent condensate polishers to mitigate startup schedule risk.
4) Utilize a simplified chemical feed regimen during startup of just ammonia and hydrazine. Alternate amines and oxygen scavengers, although they may have their uses over the life of the plant, will create carbon dioxide and elevate cation conductivity.

DURING COMMISSIONING – These activities include hydro testing, chemical cleaning, flushing the system components and rinsing to restore water quality.

Provide cleanup water quality criteria to construction. These should be based on practical limits but should be somewhat conservative since the demineralizer system is operating by this time and high quality demineralized water is being produced. If production capacity is an issue, permanent demineralizer plant equipment can be supplemented with temporary equipment.

On startup it is important to establish pH control early during cycle startup and do not overfeed pH chemical. Overfeeding any chemical during startup is undesirable because the only options available to deal with this issue are steam venting and boiler blowdown that are extremely time-consuming. Sometimes the fastest way back from a boiler chemistry issue is to stop and drain some or all of the water out of the boiler and refill before starting again. This can sometimes be faster than struggling along with poor quality boiler water.

SYSTEM INTEGRATION GUIDELINES

The overall system integration should be based on the following guidelines.

1) For the water/steam system, obtain water/steam purity requirements from each major equipment supplier.
2) Estimate the steam purity by using theoretical calculations and compare with the actual requirements of the boiler and turbine suppliers
3) Based on the steam purity requirements and material selection, determine the best suited cycle chemistry regimen either by well recognized calculations or via data collected on previous projects
4) Be specific about the water quality criteria at each interface particularly when the interface is at an equipment supply break between two suppliers. Package equipment in a practical manner to avoid one supplier from relying too heavily on another supplier's equipment to function perfectly. Allowing reasonable margins at these scope breaks can pay dividends.
5) Avoid equipment that must operate at peek performance to meet stringent water quality standards. If the middle of the range is acceptable, then obtain agreement between all parties or add equipment.
6) Understand the supplier's "black-box" to avoid unreasonable expectations and having to make modifications to the supplier's system in the field.
7) When multiple project acquisitions are considered, the contractor should be sensitive to individual project water quality and equipment requirements as well as the capabilities of the equipment suppliers.

CASE STUDIES

The following five case studies illustrate some of the challenges discussed earlier to mitigate system performance guarantee risks by managing water treatment system interfaces. The case studies have been selected from actual projects that have been executed in the past five years.

CASE STUDY A – A combined cycle project has river water as the plant makeup water source. The river water is first treated by clarification. The majority of the clarified water (97%) is used for cooling tower makeup while the remaining is further treated by filtration for use as makeup to the demineralizer system and service water users.

One of the challenges faced with specifying and evaluating the systems during the Bid/ Evaluate/ Award phase for this project was that because of project specific constraints (site footprint) not every vendor supplied all of the process equipment that was specified. A different vendor was selected to provide the pretreatment system and another to supply the demineralizer system. Consider Vendor A to be the pretreatment equipment supplier and Vendor B to be the demineralizer equipment supplier. When the demineralizer system initially failed to meet the product water quality in the specification, Vendor B was quick to point that Vendor A's equipment failed to meet their inlet feedwater quality requirements. The problem turned out to be organic carryover from the pretreatment system that manifested itself in plugging up the ultra-filter in the demineralizer train. The ultrafilters were down stream of multi-media pressure filters that were in the demineralizer vendor's scope, and the pre-treatment supplier contended that they should have protected the UF even with clarifier upsets. The system interface requirements were managed by providing an envelope for each vendor that was tied down to some other specified parameters such as total organic carbon (TOC), oil and grease, and total suspended solids (TSS). These specified parameters were then tied down to the performance criteria and system flow requirements. This case study shows that even well defined, common water quality parameters can continue to cause difficulties during startup and commissioning unless the over-lapping water quality criteria are adequately understood during specification development.

CASE STUDY B – This example is also from a combined cycle project, but using well water as the plant makeup water source. Again, the majority of the well water is used for cooling tower makeup while the remaining is further treated by filtration for use as feedwater to the demineralized water system.

The issue with this project was that the supplier for the demineralized water system subcontracted a portion of the final treatment equipment (EDI) to another vendor. So even though the EPC contractor had one main water treatment vendor to interface with, which minimized risk between the raw water pretreatment and demineralizer systems, the lack of complete technical understanding of the scoped equipment between the supplier and sub-supplier led to operating difficulties with the EDI and some costly proposed fixes. The water quality coming out of the upstream two-pass reverse osmosis system met the specified water quality for the process but would not produce EDI effluent of the proper quality. There was also a non-regenerable mixed bed demineralizer vessel installed downstream of the EDI, so that the effluent from the entire system met the quality specification and this problem did not impact the startup schedule for the contractor. However, the underperformance of the EDI caused an un-necessary load on the non-regenerable mixed bed DM and an unacceptable operating cost to the owner. The issue was eventually solved when CO_2 leakage past the RO and the EDI was discovered to be the source of the elevated conductivity. Adjusting the caustic feed ahead of the RO solved the issue with EDI under performance. Both the EPC contractor and the equipment supplier must work closely in analyzing and specifying equipment. This case study illustrates the need for teamwork and a complete system wide technical understanding between the main supplier and its sub-supplier. Elimination of the system interface (pretreatment/demineralization) did not eliminate the water quality performance issue and the inherent technology constraints.

CASE STUDY C – This example is from another combined cycle project, but using gray water (secondary or tertiary treated sewage effluent) as the plant makeup water source. In the development of the gray water makeup quality, it is the EPC contractor's responsibility to define water quality parameters and their values as a basis for water treatment design. This defined quality is normally based on data received from the client/owner and reasonable assumptions on values for which key parameters are missing. These assumed values can lead to overly conservative designs by forcing the contractor to design for unrealistic peak conditions and add unnecessary cost. In this example, the EPC contractor specified a maximum concentration of oil and grease in the gray water of 10 ppm, which was an assumed conservative value based on the fact that discharged tertiary-treated sewage is limited to this concentration. To meet this assumed value for oil and grease, a precoat filter was then incorporated into the design ahead of the RO to meet the scope book contractual limits. The contractor's specification required the vendor to produce less than 1 ppm of oil in the precoat filter effluent. By performing a more thorough sampling and characterization of the makeup water quality as the project proceeded, it was determined that a precoat filter would not have been required in the first place for this tertiary treated sewage. This was discovered too late in the project schedule to change. In optimizing system design and establishing water quality limits, the owner's participation and understanding of technical issues related to water treatment are extremely helpful. Decisions based on limited information must be by definition conservative. When later information is available, these designs can appear overly conservative.

CASE STUDY D – This example is from the same projects as described in case study A and C. In both cases the plant makeup water was filtered for use as makeup to the combustion turbine inlet air evaporative coolers.

The average makeup rate to the evaporative coolers was based on an assumed four cycles of concentration. The manufacturer provided typical guidelines for determining cycles of concentration based on the makeup water quality. As the project progressed the evaporative cooler supplier changed their guidelines to ones that were more stringent. Although this information was supplied to the project, a thorough analysis was not performed to confirm that four cycles of concentration was adequate. During the commissioning phase of the project, the makeup water quality to the evaporative coolers was questioned and the new guidelines surfaced. Both projects had to retrofit a filter in the evaporative cooler makeup line for iron removal and one project had to retrofit an additional filter for oil and grease removal. Earlier discussions with the evaporative cooler equipment suppliers and establishing water quality limits for evaporative cooling could have prevented the schedule impact and the cost of additional equipment. The lesson learned here is to ensure that the water quality requirements are discussed with every user prior to writing equipment specifications and to keep track of these issues as the project progresses in case the supplier changes their specification.

CASE STUDY E – This example is from a two-unit solid fuel project with circulating fluidized bed type boilers, cooling towers and a zero liquid discharge (ZLD) configuration. The plant makeup water source is well water for cooling tower makeup. To meet the ZLD requirement, the design included an evaporator to treat the cooling tower blowdown. The distillate from the evaporator was originally designed to be further polished by an EDI system prior to use as cycle makeup. This configuration (Evaporator-EDI) was a first of a kind for the contractor. The selected water treatment equipment supplier sub-contracted the EDI to a sub-supplier. During commissioning activities, it was discovered that the EDI was not performing and was plugging prematurely with fine suspended solids. The resulting analysis suggested that the silt density index (SDI) of the evaporator distillate exceeded the EDI feedwater requirements. The EPC contractor would normally expect the main equipment supplier to discuss internal interface water quality requirements with their sub-supplies. Because this was a first of a kind technology configuration, a more detailed review of the specification by all parties may have alleviated some of the problems encountered in the field. In order to meet the demineralized water quality required for cycle makeup, a leased, portable mixed bed demineralizer system was utilized instead of the EDI.

CASE STUDY F - This example is from a combined cycle plant with an Air Cooled Condenser (ACC). The plant is designed for two-shifting service with daily startups. The plant is designed for rapid startup and load changes to respond to fluctuating load demand. In order to control chemistry during startups to meet the requirements of both the steam turbine vendor and the HRSG supplier, a POWDEX condensate polisher was added to the cycle. Some reasoned that this was too conservative of an equipment choice, since the unit has an ACC. In an ACC there is little chance of in leakage since the cooling medium is air. However, previous experience with Air Cooled Condensers has shown that the large internal surface area in the ACC takes a very long period of time to clean up. The internal surfaces are prone to contamination during construction, which can persist for a long period of time after initial commissioning. Also, with frequent startups the ACC internal surfaces can shed contaminates on each startup as surfaces are exposed to air each time vacuum is broken. During the commissioning, the POWDEX polisher controlled the cation conductivity of the HRSG feedwater and the steam well within supplier limits. Schedule holds for chemistry clean up were minimized, which allowed the project to reach completion within the allotted time. The saving in startup schedule balanced the capital cost of the equipment. What was viewed as a possibly overly conservative equipment choice allowed the interface between the ACC supplier, HRSG vendor and Steam Turbine supplier to be effectively managed to reduce schedule pressure at the end of the project.

SUMMARY

There are risks that EPC contractors have to take when designing water treatment systems for power plants. The most common risks discussed in the paper are at system interface points. To adequately manage these risks, the paper provides system integration guidelines along with several case studies to illustrate lessons learned related to these issues. The risks are manageable and the interfaces can be well defined with the proper understanding of individual system components.

Following some specific guidelines and having timely discussions with major equipment suppliers can avoid water quality issues that pose additional risk and impact schedule, scope, and budget. The main prime movers that control these interfaces are steam turbine suppliers, combustion turbine suppliers that need demineralized water, boiler suppliers, and the water treatment system suppliers. The EPC contractor must mitigate risks by applying water quality constraints that are reasonable, practical, and achievable without costly modifications.

Figure 1 – Typical Major Water and Treatment Systems in a Power Plant

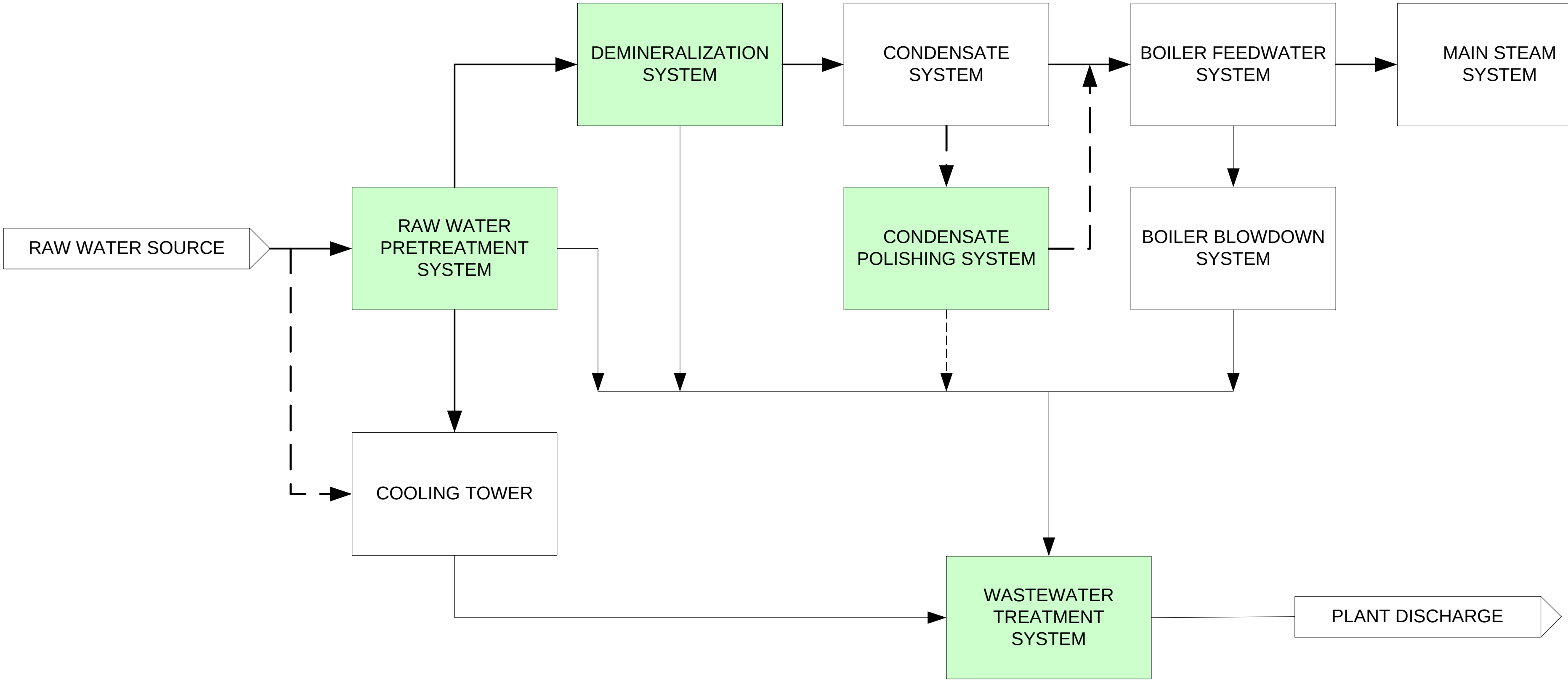

Figure 2 – Typical Water Quality Control Parameters at Major Interfaces