DOW FILMTEC™ Membranes BW30-365FR, BW30-400 and DOW™ Ultrafiltration SFP2660

Cooling Tower Blowdown Reuse in Gaojing Power Plant

Site Information

Location:
Beijing, China

Capacity:
Second Phase, 150m^3/h;
Third Phase, 160m^3/h

Time in Operation:
Second Phase – 2004
Third Phase - 2006

Waste Water Source:
Cooling Tower Blowdown, Power Plant

UF/RO Module Installed:

- DOW™ Ultrafiltration SFP2660
- DOW FILMTEC™ BW30-365FR
- DOW FILMTEC™ BW30-400

Challenges:
High scaling Potential for RO Skids

Figure 1: Snapshot of Gaojing Powerplant

Project Background

Constructed in the 1960s by Datang Corporation, and located in Mengtougou, the Gaojing Power Plant is one of the earliest power plants in Beijing. For the past 40 years, the Gaojing Power Plant has supplied 6 X 100 MW/hr of heat and electricity to its local communities and industries. In 2003, with increasing environmental requirements from the government, the plant, using membrane technology, started to reuse the blowdown from their cooling towers as the feed to its eight boilers. OMEX Environmental, a wholly owned subsidiary of The Dow Chemical Company, supplied three phases of wastewater reuse system, with productivity of 60m^3/h, 150m^3/h and 160m^3/h, respectively. In the second phase, an integrated solution of ‘ultrafiltration (UF), reverse osmosis (RO), and electrodeionization (EDI)’ was applied; while in the third phase, dual membrane process with UF and RO was adopted after clarifications.

Typical Compositions of the Cooling Tower Blowdown

Item	Average
pH	8.65~8.86
Suspended Solid (SS) (mg/l)	8.8 ~25.4
Conductivity (µs/cm)	1620~2790
COD_{Mn} (mg/l)	5.18~12.14
Total Hardness (mmol/L)	10.25~16.1
Cl^- (mg/l)	182~336
M-Alkalinity (mmol/L)	4.86~7.2
P- Alkalinity (mmol/L)	0.39~0.64
SO_4^{2-} (mg/l)	186.33~407.88
SiO_2 (mg/l)	11.8~33.4

Table 1: Average water quality of the blowdown in 2008

Table 1 shows the average water quality of the blowdown during 2008. Starting from May 2007, the source of cooling tower makeup has been changed from surface water to secondary effluent from the Gaobeidian Municipal Wastewater Treatment Plant. It can be seen from Table 1 that the waste stream contained high hardness, alkalinity, SO42- and silicon dioxide at times, which are typical characteristics of cooling tower blowdown. In addition to this, the concentrations of different contaminants varied substantially with seasons and cooling tower makeup quality. These high scaling potential and unstable properties could cause problems in the subsequent waste water reuse systems.

Process Flow and Key Treatment Units

An illustration of the process flow in the second phase reuse system is shown in Figure 2. The blowdown water was first pumped into a multi-media filter to remove suspended solids and reduce the turbidity from over 20 NTU to around 4-8 NTU. Then the UF unit further decreased the turbidity to less than 0.4 NTU and protected the subsequent RO unit from colloids, suspended solids, bacteria and large molecular weight organics. Reducing agents, anti-scalant and acid were then dosed before the first pass RO system, in which most of the dissolved solids and SiO_2 were removed. The permeate water from the first pass RO was then degasified, and the pH was increased to 9.5 by NaOH dosing before entering the second pass RO. In the end, EDI was installed for final demineralization to meet the requirement of boiler make up.

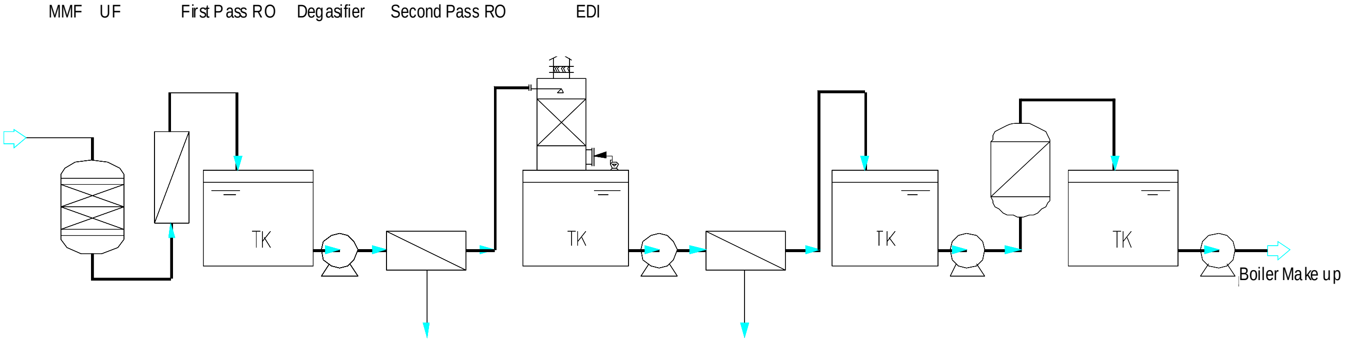

Figure 2: Process Flow of the second phase reuse system

The key treatment units in the second phase reuse system are listed in Table 2 and shown in Figure 3.

Facility	Capacity m3/h	Capacity Per Train m^3/h	No. of Trains
Multi-media Filter	270	270	1
Disk Filter	235	117.5	2
UF	235	117.5	2
First Pass RO	186	93	2
Second Pass RO	167	83.5	2
EDI	150	75	2

Table 2: System information on unit operations of the second phase

Figure 3: Pictures of the key treatment units

System Performance

The performance of the reuse systems in the year 2008 are described in this section.

Figure 4 plots the silt density index (SDI) of the UF permeate compared to time for both phases of the reuse system. For the third phase system, a constant SDI value less than three (usually around 2.5) indicated a good and stable UF operation performance. In the second phase, however, the SDI value varied from three to four, probably due to higher turbidity of the UF influent of the second phase. After approximately five years of operation, the UF membrane is still able to produce quality water that meets the required RO feed water quality.

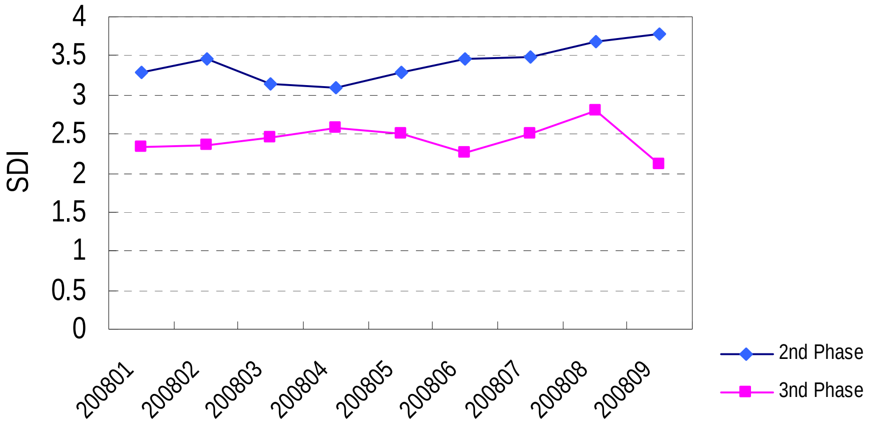

Figure 4: SDI of UF permeate (Second and third phase)

The salt rejection rate of the first pass RO was stable at between 97 percent and 98 percent, while that of the second pass varied from 71 percent to 93 percent, as shown in Figure 5. This is due to the fact that the conductivity of the second pass RO was as low as 40-80us/cm. The conductivity is in many cases the most important quality parameter of the product water. Since carbon dioxide is not rejected by the membrane, it is present in the product water, where it reacts to form carbonic acid and causes the conductivity to increase. The passage of carbon dioxide can be prevented by adjustment of the feed water pH to RO to a value of about 8.2. At this pH, most carbon dioxide is converted into hydrogen carbonate, which is rejected well by the membrane. The problem could also be solved by the installation of degasifier, as was the case in the Gaojing Power Plant.

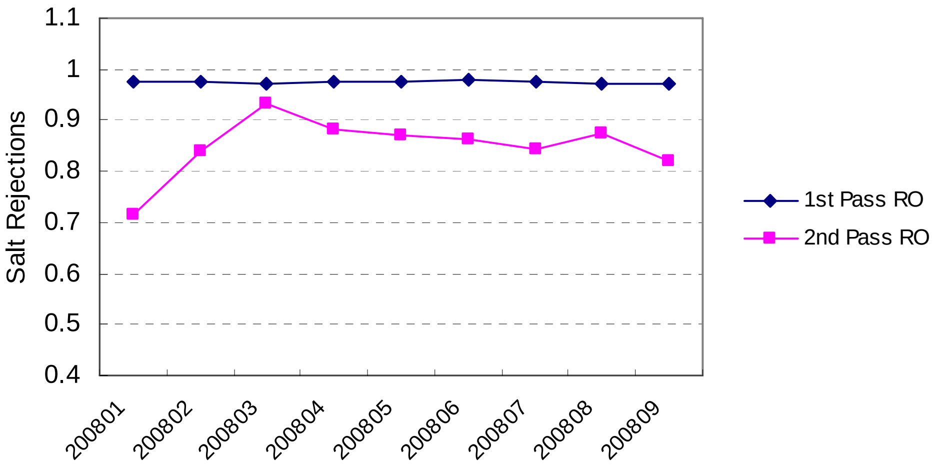

Figure 5 Salt Rejections of the RO units (Second phase)

The recoveries of the two-pass RO systems were 75 percent and 90 percent, respectively. For the second phase system with EDI after the RO system, the effluent resistance increased to above 14 MΩ-cm.

System Performance, continued

UF could only remove a very small portion of the organics, with effluent COD_{Mn} around four to eight mg/L into the RO systems. The first pass RO unit was able to reduce COD level to below two mg/L, with rejection rate around 70 to 80 percent; however in the second pass, the RO unit almost could not further remove any organics, as shown in Figure 6. It indicated that the organics passed the first pass RO probably had small molecular weight less than the molecular weight cut-off (MWCO) of the RO element.

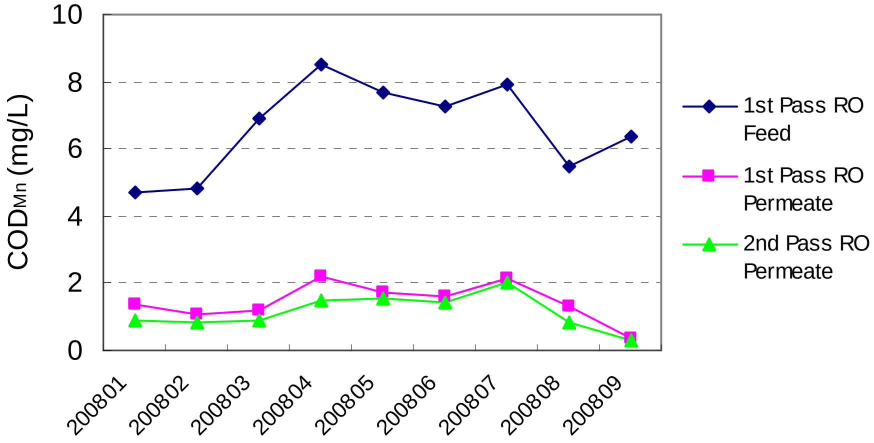

Figure 6: COD Removal Rate in RO system (Second phase)

NaOH was dosed in the first pass RO effluent to increase pH of the second pass RO influent. It also helped to increase silica rejection of the second pass RO, as shown in Figure 7. The silica level could be controlled below 10 parts per billion (ppb) in RO permeate. Then, EDI further reduced silica to less than three ppb.

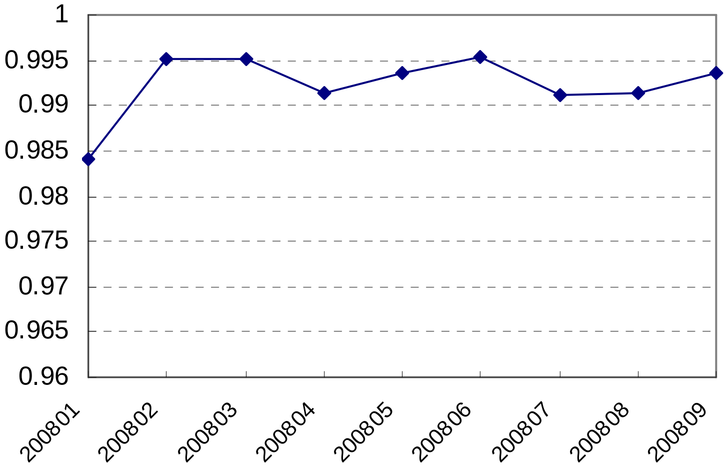

Figure 7: Silica Rejections in second pass RO

Chemical Dosing and Cleaning Process

- Oxidant dosed in UF influent and backwash water to prevent biological growth
- Reduce agent dosed in RO feed to protect RO from oxidation, dosage controlled by online ORP monitor
- Anti-scalant dosed in RO feed to avoid $CaCO_3$ $CaSO_4$ scaling
- pH adjustment between first and second pass RO
- UF unit was back washed every 30 minutes with air scrub every five hours. Clean in place (CIP) was performed every three months. RO unit was cleaned at pH 12 first and then at pH 2 in 30° C. The CIP frequency was once per month.

Conclusion

Water recycling systems for cooling tower blowdown have become more and more common in fossil fuel power plants because of the large volume (about 60 percent of all wastewater comes from power plants). The main technical challenge is that this water stream is very unstable with high hardness, HCO_3^- concentration, silicon content, SO_4^{2-} and sometimes COD. High salt content and unstable pH properties make cooling tower blowdown water a difficult type of wastewater to reuse. Dow's experience in membrane technology offers innovative solutions to guide application development in this area. As in the case of Gaojing Power Plant, dual membrane technology together with proper pretreatment and chemical dosing helped to realize more than 70 percent reuse of the cooling tower blowdown.

Notice: The use of this product in and of itself does not necessarily guarantee the removal of cysts and pathogens from water. Effective cyst and pathogen reduction is dependent on the complete system design and on the operation and maintenance of the system.