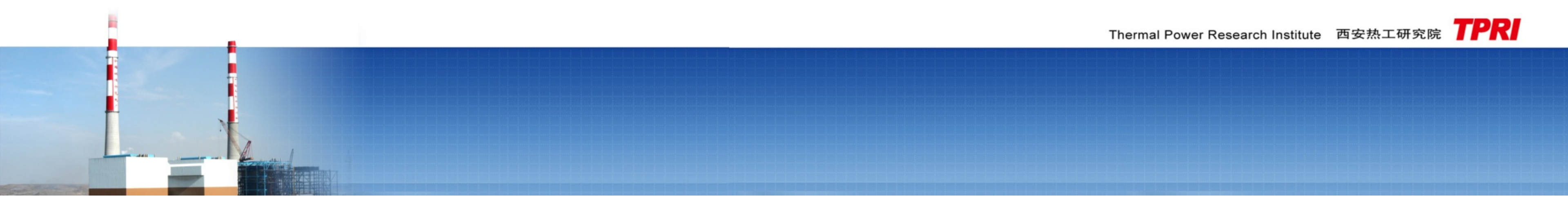

The ACC Users Group 6th Annual Meeting

Study on Long-term Reliable Operation of High Flowrate Mixed Bed Condensate Polisher in ACCs

Wenhua Tian; Peng Li; Junru Lei;Yong Guo;Xinhui Wang

Xi’an Thermal Power Research Institute Co. Ltd., P.R.China

Guohua Dingzhou Power Generation Co. Ltd., P. R. China

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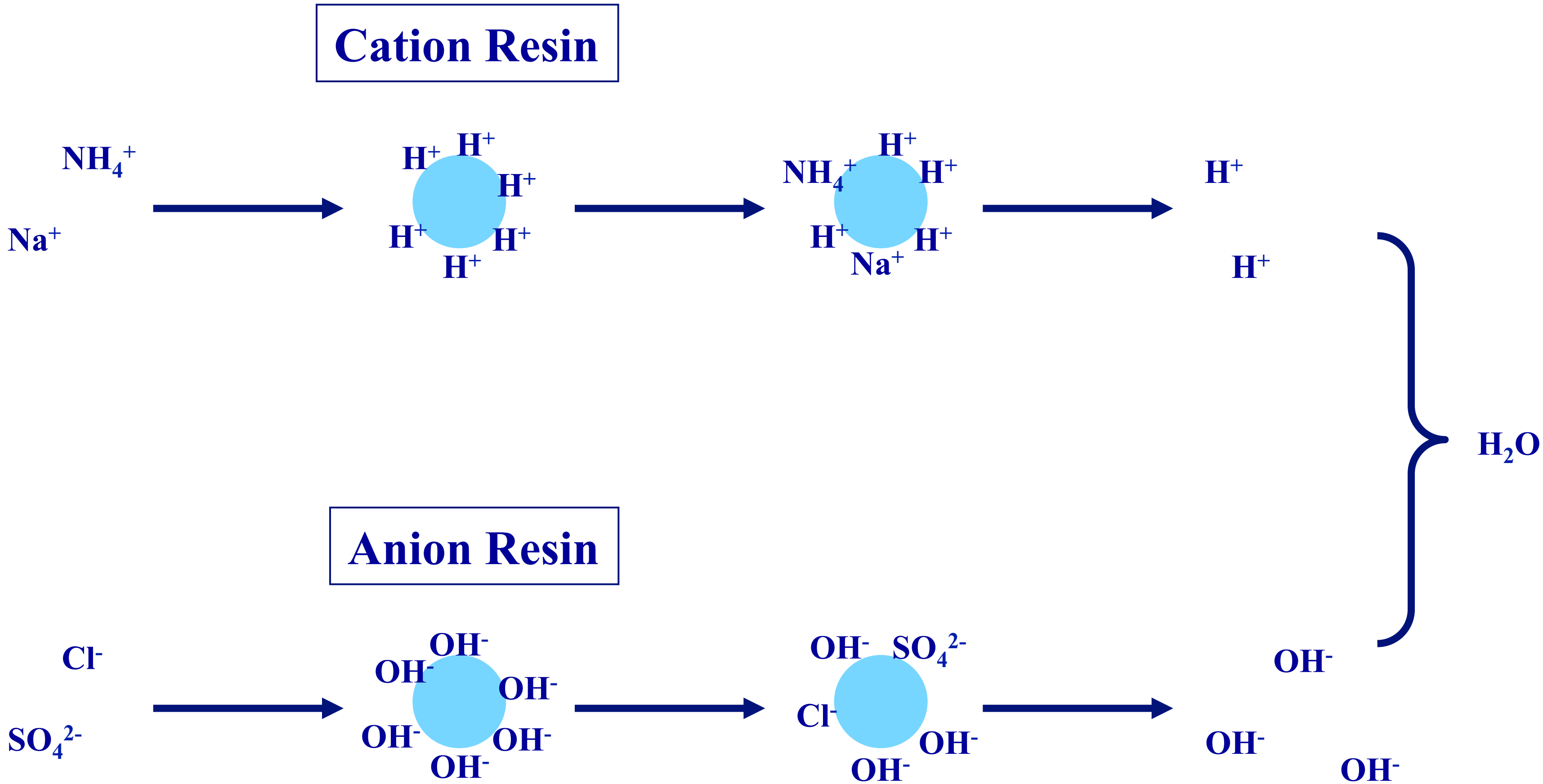
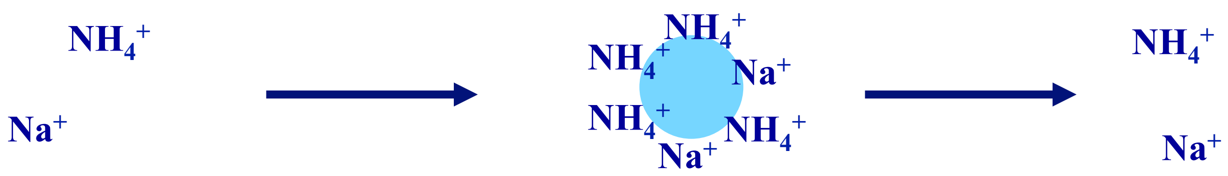
Contents

Introduction

- **Rapid development of direct air-cooled supercritical in water-deficient areas of northern China**
- **High corrosion products content in Dingzhou power plant. (CPP system of the supercritical 660MW direct air-cooled units consists of 3×50% powdex and 3×50% spherical MB)**
- **To inhibit FAC, the feedwater treatment mode was changed to oxygenated treatment at elevated pH (9.6~9.8), resulting in obvious decline in operation cycle life of MB**
- **TPRI proposed solutions to extend the operating cycle:**
  - **Adjustment of resin ratio**
  - **Application of IRIC and optimization procedure**
  - **Correction of MB equipment defects**


Cation Resin
NH_4^+
Na^+
H^+ H^+ H^+ H^+ H^+ H^+
NH_4^+ H^+ H^+ H^+ H^+ Na^+
H^+
H^+
H_2O
Anion Resin
Cl^-
SO_4^{2-}
OH^- OH^- OH^- OH^- OH^- OH^-
OH^- SO_4^{2-} Cl^- OH^- OH^-
OH^-
OH^-
OH^-

Cation Resin Exhausted




Dingzhou Power Plant


CPP system

Analysis of MB Effluent quality

Table 1. Test results of effluent cation concentration, μg/L

NO.	Sampling Time	Na^+	NH_4^+	K^+, Mg^{2+}, Ca^{2+}
1	4 h	0.36	79.9	L [0.2]
2	3 h	0.42	98.3	
3	2 h	0.57	117.3	
4	1 h	0.59	134.0	
5	0 h	0.75	162.7	

Table 2. Test results of effluent anion concentration, μg/L

NO.	Sampling Time	CH_3COO^-	$HCOO^-$	Cl^-	F^-, NO_2^-, SO_4^{2-}, NO_3^-	PO_4^{3-}
1	4 h	L [0.1]	0.42	L [0.1]	L [0.2]	0.39
2	3 h	0.11	0.35			0.41
3	2 h	0.19	0.50	0.1		0.37
4	1 h	0.44	1.04	L [0.1]		L [0.3]
5	0 h	0.20	0.97	0.1		

"L" = below the limit of detection

Results

When ammonia breakthrough occurs and cation resin is exhausted, concentration of chloride and sodium ion are both less than 1 μg/L, meeting the expectations of DL/T 912-2005, "Quality criterion of water and steam for supercritical pressure units in fossil fuel power plant."

Analysis of approaches to improve operation cycle of hydrogen MB

- Calculation of operating cycle of hydrogen-form MB cation resin

$$H = Vc \cdot Ec / (Qc \cdot C_{NH_3})$$

H —operation cycle of MB, h

Vc—design volume of cation resin, m^3

Ec —working exchange capacity of cation resin, mol/m^3R

Qc—average influent flowrate of MB, m^3/h

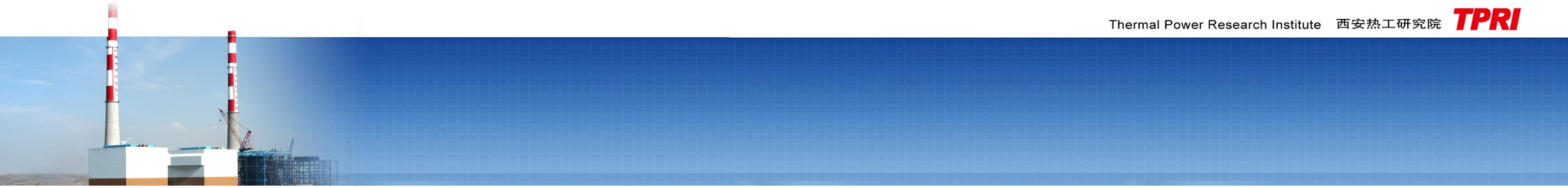
C_{NH_3}—average concentration of NH_3 in condensate, mmol/L.

Analysis of factors affecting MB operating cycle

- **External factor:**

Ammonia content (pH) in condensate

The operating cycle at pH of 9.4 is 2.2 times longer than at pH of 9.6, assuming consistent working exchange capacity of cation resin, resin volume, and MB capacity.



Internal factors

Design volume of cation resin

Resin working exchange capacity

Without changing MB vessel, the only way to increase cation resin volume is to increase its proportion in the vessel.

Accuracy of resin transport

Transported percentage of resin

Resin separation and mixing coefficient

Separation percentage of resin

Reliability of process control procedure

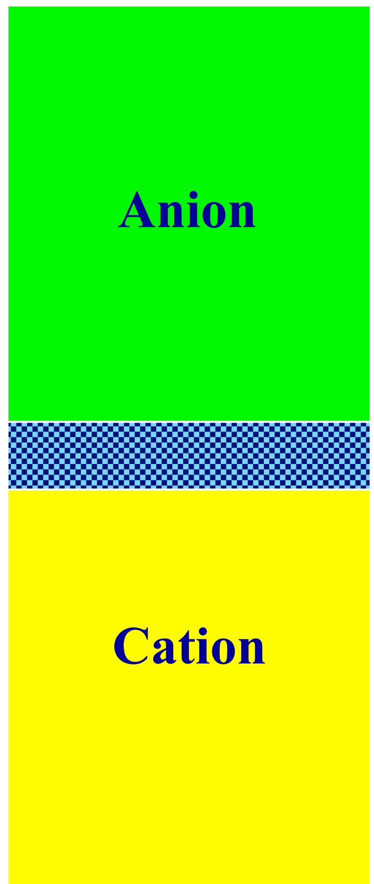
Integrity of water distribution design

Estimation of MB operation

- The pH in the Dingzhou Power Plant steam cycle must be be 9.6 in order to inhibit FAC and reduce the rate of deposition in the boiler.

The only way to extend the operating cycle of the MB is to increase the cation resin volume and improve its working exchange capacity, since at least 45% of the operating cycle life reduction is a result of the elevated pH required in the Dingzhou Power Plant.

MB Resin Regeneration: Separation



Actual resin volume in Dingzhou Power Plant

MB NO.	Actual Value, m^3	
	Cation Resin	Anion Resin
3-1	3.77	3.32
3-2	3.58	3.37
3-3	3.87	3.76
4-1	3.90	3.86
4-2	3.90	3.62
4-3	3.54	3.93

The design cation resin volume is 3.84m^3. Due to losses during regeneration, the volume of three batches of resin are significantly lower than the design value.

Actual working exchange capacity of cation resin

MB NO.	Cation resin volume, m^3	Operating cycle, h	Cycle water production, kiloton	Average ammonia concentration in condensate, mg/L	Working exchange capacity of cation resin, mol/m^3R
4-3	3.54	103	45	2.1	1496
4-3	3.90	108	52	2.1	1569
3-2	3.90	58	30	3.2	1448
3-2	3.90	53	28	3.2	1351
3-3	3.60	63	32	2.4	1255
3-3	3.87	93	43	2.0	1242
average					1393

The average working exchange capacity of the cation resin is 1393 mol/m^3R, lower than the specified capacity of 1750~2000 mol/m^3R.

Diagnosis

Inspection apparatus

Fig.1 ICS-1500 Ion Chromatograph

Fig.2 S3500 Laser Particle Sizer

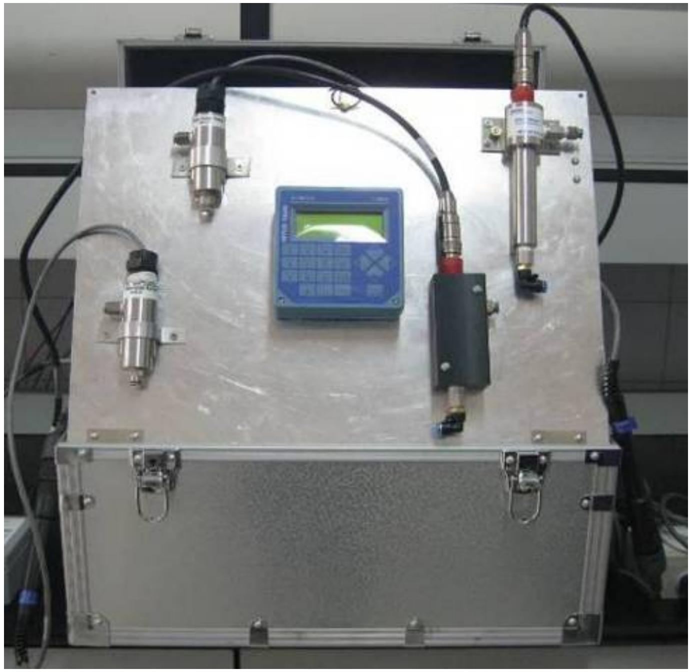


Fig.3 770MAX Multi-parameter controller

Fig.4 FLCS1012 Portable Ultrasonic flowmeter

Factors affecting MB operation

1. Accuracy of overall resin transport during regeneration

MB NO.	Actual Value, m^3		Deviation from Design, %	
	Cation Resin	Anion Resin	Cation Resin	Anion Resin
3-1	3.77	3.32	-1.8	-13.5
3-2	3.58	3.37	-6.8	-12.2
3-3	3.87	3.76	+0.8	-2.1
4-1	3.90	3.86	+1.6	+0.5
4-2	3.90	3.62	+1.6	-5.7
4-3	3.54	3.93	-7.8	+2.3

The deviation between actual and design is up to 13.5%, so operation cycle will be affected inevitably

2. Initial transported percentage of resin

The exhausted resin is thoroughly transported from the MB vessels, meeting the required standard of > 99.9%

3. Resin separation and mixing coefficient

With hydrogen form operation, the resin separation coefficient is 0.68 meeting the requirement of > 0, and the mixing coefficient is 2.12, meeting the requirement of < 3.0.

4. Separation percentage of resin

After the exhausted resin is separated, 0.08% of the cation resin is present in the anion resin, and 0.07% of the anion resin is present in the cation resin; these meet cross-contamination criteria of < 0.1%.

5. Reliability of process control procedures

Some critical points are not controlled adequately, resulting in resin leakage during regeneration

6. Integrity of the water distribution equipment

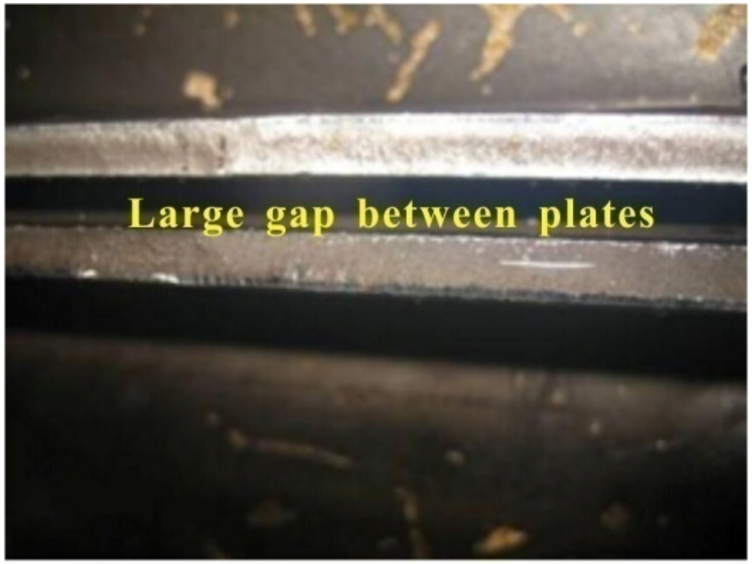


Fig. 5

Fig. 6

Evaluation results summary

NO.	Diagnostic Content	Standard Requirement	Actual Situation	Satisfied or Not
1	Accuracy of overall resin transport	Minimal deviation	Deviation-13.5%~0.5%	N
2	Adequacy of exhausted resin transport	> 99.9%	> 99.9%	S
3	Resin separation and mixing coefficient	Separation coefficient >0 Mixing coefficient <3	Separation coefficient 0.68 Mixing coefficient 2.12	S
4	Separation percentage of exhausted resin	Cation resin in anion < 0.1% Anion resin in cation < 0.1%	Cation resin in anion 0.08% Anion resin in cation 0.07%	S
5	Reliability of process control procedure	No resin leakage	Some critical points are not controlled adequately, resulting in resin leakage during regeneration	N
6	Integrity of water distribution device in MB	No gaps Strainers are double-speed	Maximum gap is 6mm Some of strainers are single-speed	N

The primary problems with MB operation

- Non-optimal resin ratio
- Inappropriate performance of photoelectric apparatus for interface inspection
- Resin losses during regeneration
- Defects in MB internal components

Optimization schemes

- **Adjust the filling volume and ratio of resin**

For Dingzhou Power Plant, the feedwater treatment mode is oxygenated treatment at pH of 9.6. In order to have increased cycle water production and operating life, the ratio of cation to anion resin should be increased from 1:1 to 3:2.

Apply IRIC and optimize the process control procedure

An instrument designed for image recognition and intelligent control of resin separation (IRIC), developed by TPRI, will be used for better control of resin transport for Dingzhou Power Plant.

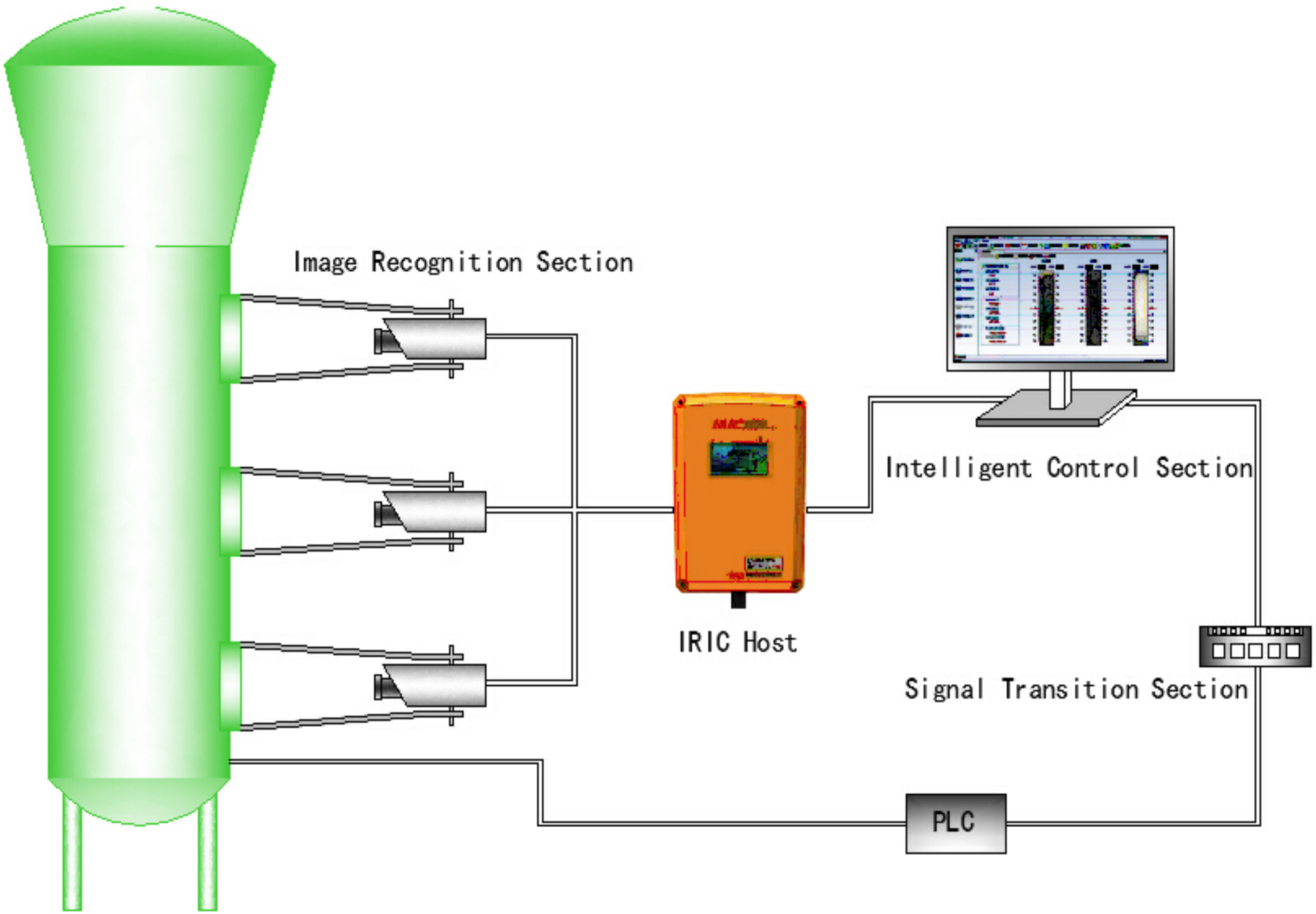


Fig. 7 IRIC system diagram in high-tower separation technique

The benefits of IRIC are as follow:

- The structure of the regenerating separation equipment does not need to be changed
- The cation / anion interface is imaged under high-speed conditions, and the interface image is dynamically updated
- The volume and cation:anion ratio of the MB resin is automatically measured, providing a more reliable separation process and control point
- Resin separation is accomplished automatically with electronic intelligence, without requiring manual intervention during the process
- Early warning of abnormal working conditions, including the resin volume and ratio, are provided

Fig. 8 Separation image recognition equipment

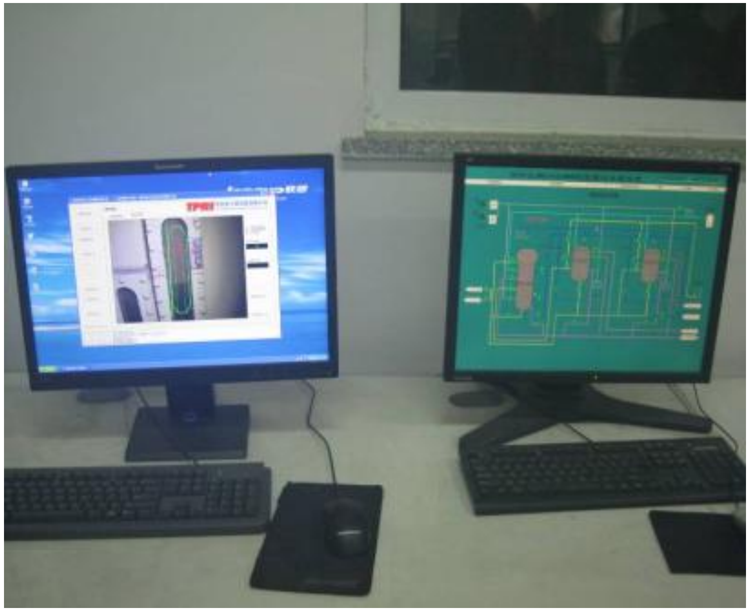


Fig. 9 Intelligent control monitoring

Eliminate internal defects in MB vessels

Fig. 10 Install angle steel at the gap between plates (Influent)

Fig. 11 Replace strainers as needed (Effluent)

Implementation effects

Incremental improvement in cycle water production

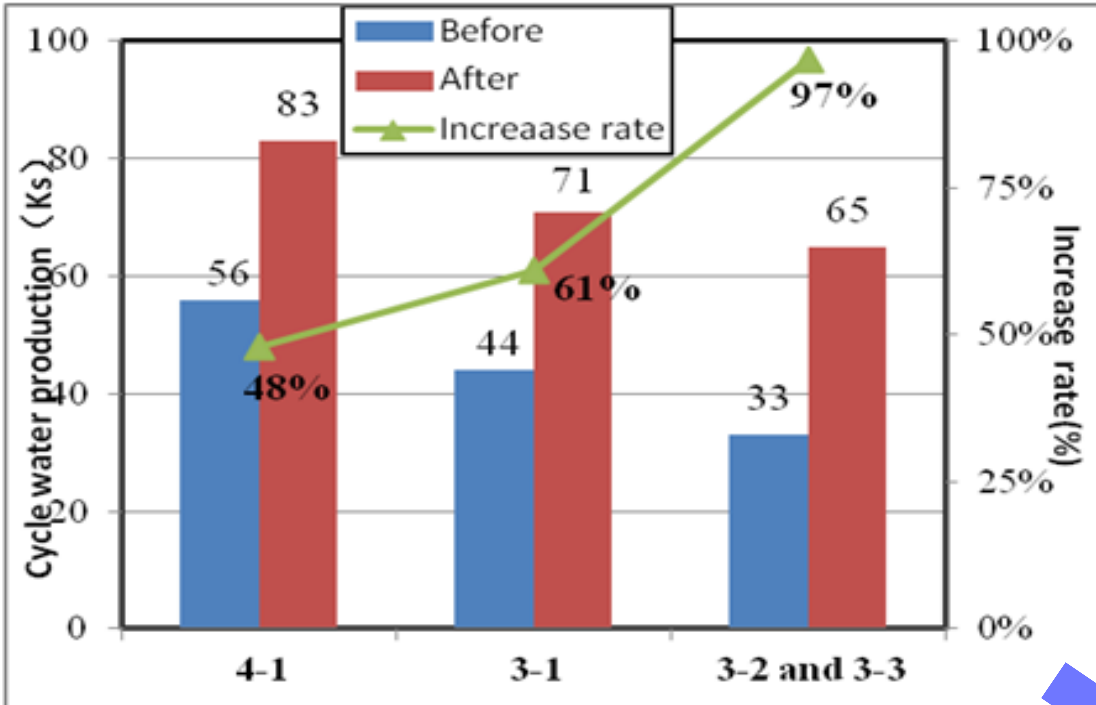


Fig. 12 Cycle water production comparison between before and after optimization

Cycle water production increased 69% on average after optimization

Improvement margin of cation resin working exchange capacity

Working exchange capacity of the cation resin is 1967 mol/ m^3R on average after optimization, increasing 41%, meeting the requirement of DL/T 333.1-2010

Standardized effluent quality

SiO_2 < 6 μg/L

Fe < 3 μg/L

Na^+ < 1 μg/L

Cl^- < 1 μg/L

Hydrogen conductivity (CACE) < 0.09 μS/cm

Economic benefit

Regeneration cycle

Service life of resin

Make-up water

Consumption of acid and base

Annual supplemental resin

Treatment cost of waste water

The annual direct benefit is about 1.68 million RMB (274,000 USD)

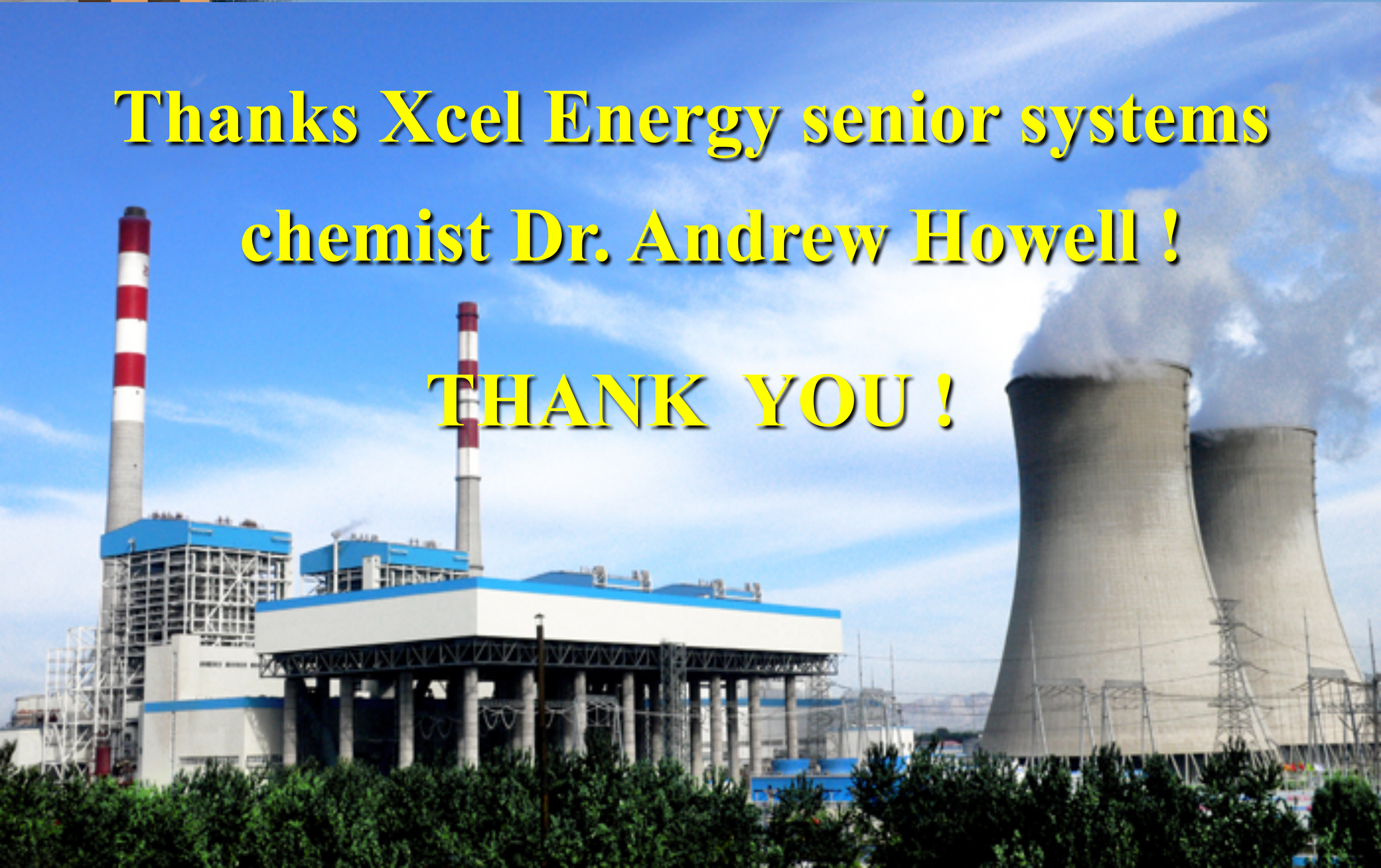
Conclusions

Implementation outcome

- **Cycle water production increased 69%**
- **Working exchange capacity of cation resin increased to 1967 mol/m^3R**
- **Concentration of chloride and sodium < 1 μg/L**
- **Total iron < 3 μg/L in effluent**
- **Resin leakage, inadequate resin separation and loss of resin during transport were resolved**

Benefit outcome

- **The resulted annual direct benefit is about 1.68 million RMB (274,000 USD)**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chemist Dr. Andrew Howell !
THANK YOU !

Correspondence Address

Wenhua Tian

- Address: Xi’an Thermal Power Research Institute Co., Ltd.
- Water & Wastewater Treatment Dept.
- No. 136, Xingqing Road, 710032, Xi’an, P.R.China
- Tel: (86-29) 82102246
- Fax: (86-29)82102439
- Mobil: 13991302260
- Email: Tianwenhua@tpri.com.cn