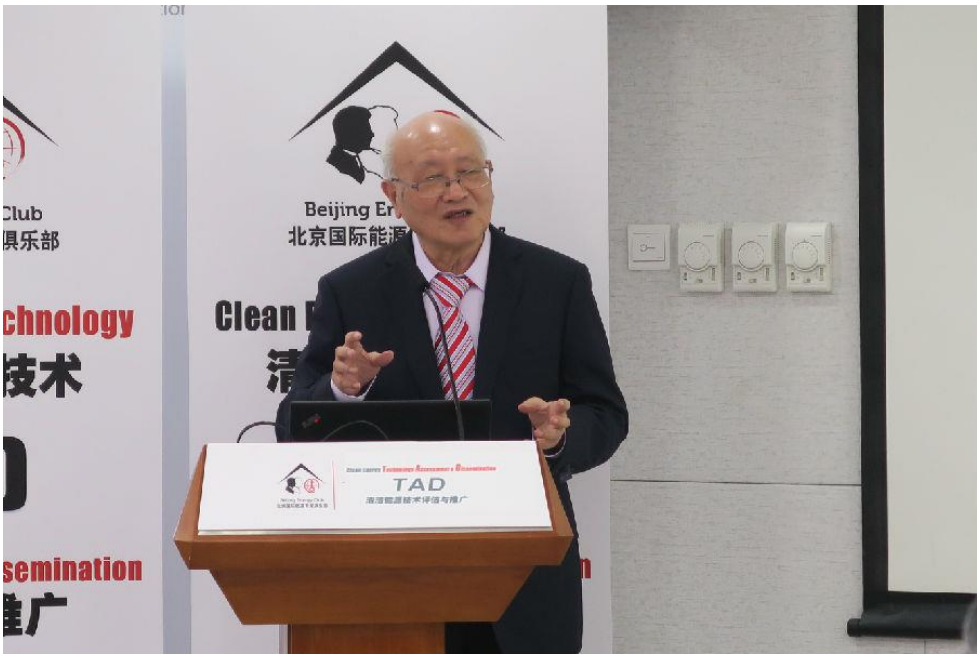
High-efficiency Energy Saving Technology of Hangzhou Pump

for Circulating Water Systems

Introduction Report



Beijing Energy Club
北京国际能源专家俱乐部

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The High-efficiency Energy Saving Technology of Hangzhou Pump for Circulating Water System - Introduction

Beijing Energy Club[1]

Energy conservation is a long-term strategy and a basic national policy for sustainable development in China. It means strengthening energy management, taking technically feasible, economically rational and environmentally and socially acceptable measures to reduce losses and wastes in every link of the chain from energy production through consumption, and utilizing energy more efficiently and more reasonably. Put another way, energy conservation needs to be realizable, generate proper input-output ratios, reduce pollution to the environment and meet required indicators for environmental protection by using existing technology. While effectively reducing energy losses and wastes, energy conservation should have zero adverse effect on improvement of normal levels of people's lives and businesses' operations.

There are a lot of circulating water systems (CWSs), including those for industrial cooling and those for central air conditioning cooling and refrigeration. CWSs are extensively configured in chemical industries (including petrochemical, coal-based chemical, salt-based chemical, agrochemical, and pharmaceutical industries), metallurgical industries, cogeneration industries, and civil public facilities (including airports, four- or five-star hotels, hospitals, large office buildings, and commercial complexes). The purpose of CWSs is to reduce heat generated in production processes (equipment) in operation through heat exchange. CWSs are an indispensable and important part of industrial economy and other economic sectors.

At present, issues are common in the field of CWSs in China. Firstly, there is a mismatch between actual operating conditions and design process. Due to the lack of a complete system for research on CWSs, there have occurred deviations between CWS construction and operation and the design, which in turn leads to actual operating conditions deviating from design conditions. Secondly, the operating efficiency of CWSs is quite low. CWS equipment is aged and operates at a poor efficiency. There are cases where fluid transport equipment does not match existing piping. In other cases, the power consumption of the entire unit is high because the head-tank CWS in the unit has not fully applied the siphon principle. Thirdly, operation management needs to be optimized. In most cases, CWSs are manually operated. As a production support, they meet the requirements of cooling equipment on temperature. But in terms of automation control, intelligent detection and feedback implementation, they are rather extensive, leaving certain room for improvement. The sampling survey, detection, and R&D on technical improvement by an energy conservation service involving 20 different types of chemical companies and 18 iron and steel companies reveal that the power saving ratios of CWSs range normally

[1] Disclaimer: This Report has been prepared on the basis of the information that the Secretariat of Beijing Energy Club (BEC) has at its hand, the materials supplied by Hangzhou Pump Energy Conservation Technology Co., Ltd. and the discussions from the Technology Assessment & Dissemination on Jul. 2nd, 2016. BEC shall not be held responsible for any risks, losses, damages, costs or expenditures, claims, and/or any other rights of claim that may arise from any investment or other business decisions made by any business organizations or individuals in accordance with the conclusional comments contained in this Report.

between 30% and 55% and the potential for energy conservation is huge. If a rough estimation is made at 20% of the energy conservation potential of CWSs in the industrial sector, then total savings on an annual basis would be more than 68 billion kWhs of electricity and over 23.8 million tons of standard coal, plus reduced emissions of more than 62 million tons of carbon dioxide.

On April 23rd, 2016, Beijing Energy Club launched the Clean Energy Technology Assessment and Dissemination (hereinafter referred to as TAD). As the second project in a series of assessment, TAD organized an assessment and dissemination by experts on Hangzhou Pump Energy Conservation Technology Co., Ltd.'s circulating water system high-efficiency energy conservation technology on July 2nd, 2016.

This Report covers performance properties, application fields and actual cases.

I. Company Profile

Hangzhou Pump Energy Conservation Technology Co., Ltd. (hereinafter referred to as Hangzhou Pump, www.hzpump.cn) is specialized in overall energy conservation technology research and development, design, production, energy performance contracting (EMC), and other services. It boasts a complete CWSs business chain of energy conservation and technical innovation. Hangzhou Pump started on the basis of the Fluid Transport Institute for Energy Conservation Design of Zhejiang Industrial Design & Research Institute. With stronger design and development capabilities, Fan Changhai, the founder of Hangzhou Pump, had obtained a series of patents, know-how and application results such as *A Correction method of online fluid system* , A *Boosting and Exhausting Device of Air Conditioning Water System*, *A Method and Device for Reducing the Lift of Circulating Pump in High Circulating Water System*, A *Method for Assembly and Working Condition Detection of Circulating Pump in Water Cooling System* successively. He also built a professional team with rich practical experiences.

In addition, Fan Changhai, chief designer of Hangzhou Pump, together with his technical team, had designed FCH high efficiency and energy conservation water pump (hereinafter referred to as FCH Pump) named after the initials of Fan Changhai and tailored in optimization according to the technical improvement of CWSs. FCH Pump has also become a nationally registered trademark proprietarily for Hangzhou Pump Energy Conservation Technology Co., Ltd.

So far, Hangzhou Pump has successfully implemented hundreds of CWS energy conservation and technical improvement projects and achieved conservation of up to 700 million kWh per annum for customers. With excellent ideas, leading technology, professional level, scientific attitude and rich experience, Hangzhou Pump has provided advanced, reasonable, safe and effective technical improvement solutions of fluid delivery system for customers. Hangzhou Pump adopts Energy Performance Contracting, General Project Contracting and other cooperation models according to the technical improvement requirements of different energy utilization companies. Thanks to the support of a large number of financial institutions, Hangzhou Pump is able to undertake large-scale energy conservation and technical improvement of CWSs for iron and steel, chemical, metallurgical and other industries. Thanks to its mature and reliable technical improvement, Hangzhou pump is able to provide incomparable efficient services for energy utilization enterprises for reducing the cost and enhancing the efficiency and upgrading the technology without affecting their normal safety and production. Hangzhou Pump has been included in the catalogue of

energy conservation and technical improvement companies, which was recommended by the National Development and Reform Commission and the Ministry of Finance of the People's Republic of China. It is the only professional energy conservation company with patent law protection engaged professionally in the study of fluid transport in China. In 2011, it was listed in the second batch of energy conservation service companies in China. In 2015, it was approved as a national high-tech enterprise in China.

A lot of companies have adopted Hangzhou Pump's patented technologies for energy conservation improvement, including Sinopec, PetroChina, CNOOC, China Aluminum, Sinochem, Shenhua, and iron and steel companies. PetroChina had successfully transformed Four-Cycle Expansion System of Daqing Refining and Chemical Company, while Sinopec had successfully transformed SSTPC, SECCO, Sinopec Yangtze Petrochemical, Sinopec Beijing Yanshan, and Sinopec Qilu Petrochemical. Hangzhou Pump had implemented technical service or improvement for energy conservation in Juhua Group, Zhuzhou Smelter Group, Yongcheng Coal Holdings Group, Haohua Yuhang Chemicals Co. Ltd. and other large companies. Its successful technical improvement systems for energy conservation in Jinan Iron and Steel Plant, Anyang Iron and Steel Plant, Juhua Group, Hangzhou Iron and Steel Plant, Laiwu Iron and Steel Plant, Rizhao Iron and Steel Factory, and Tang Shan Heavy Plate Co. Ltd. have been recognized generally by national, provincial and municipal departments and relevant companies and achieved good social and economic benefits.

II. Summary and Principle of High Efficiency Energy conservation Technology for CWSs

1. Summary

The high efficiency and energy conservation technology for CWSs aims to solve generally existing issues in current CWSs, such as closed valve operation, unreasonable pipeline layout, mismatching between pipeline characteristics and maximum efficiency point of circulating water, and other cooling processes. Through adjusting unreasonable operation modes, it can realize equipment, process and system energy conservation and achieve high efficiency and energy conservation in CWSs. Currently, it has applied for national invention patents in the field of high efficiency and energy conservation technology including A *Method for Correcting Online Fluid Conveyance System* (Patent No.: ZL20071066873.2) (now as the proprietary technology of Mr. Fan Changhai), *Assembly and working condition detection method for circulating pumps in water cooling system* (Patent No.: 201310062873.0), and Method and device for reducing circulating pump lift of high-level circulating water system (Patent No.: ZL201010204888.2).

"Optimal Cooling Process of Cooling CWSs", "Automatic Control Technology for CWSs" and "Water Treatment Technology for CWSs" are being researched and comprehensively utilized.

2. Principle

The core of high-efficiency and energy-conservation CWS technology lies in the correction of the online fluid system. This involves detecting and capturing the parameters of original design conditions for fluid conveyance system and establishing professional and hydraulic mathematical model based on the principle of optimal system working condition, discovering factors causing high energy consumption and

optimal operating condition point of system, designing and producing efficient fluid transmission equipment matching with the system, and replacing existing equipment, making the system always in the best operating condition and achieving the purpose of energy conservation and consumption reducing. (See Figure 1 for the principle).

The total resistance of CWSs in water yield QA is HA (design lift) according to the requirements of heat exchange capacity. The design efficiency ηA of water pump at Point A of design operating condition is the maximum, and the shaft power NA of water pump is the minimum. After the design water pump has been installed and commissioned, the working condition of actual operation is at Point B, and the operating parameters are flow QB, lift HB and shaft power NB. When the power of operating water pump shaft is much greater than the rated power of installed motor, water pump is vibrating severely with heavy noise and even burning the motor. At this moment, operators will increase the system resistance artificially, such as operating with valves closed and making the motor of water pump operate at Point C when the current is not more than the rated current so as to ensure continuous operation of the water pump. Based on the above analysis, issues are common in the field of CWSs, including outstanding issues such as high design lift but low actual lift, high flow, low efficiency, and high power consumption.

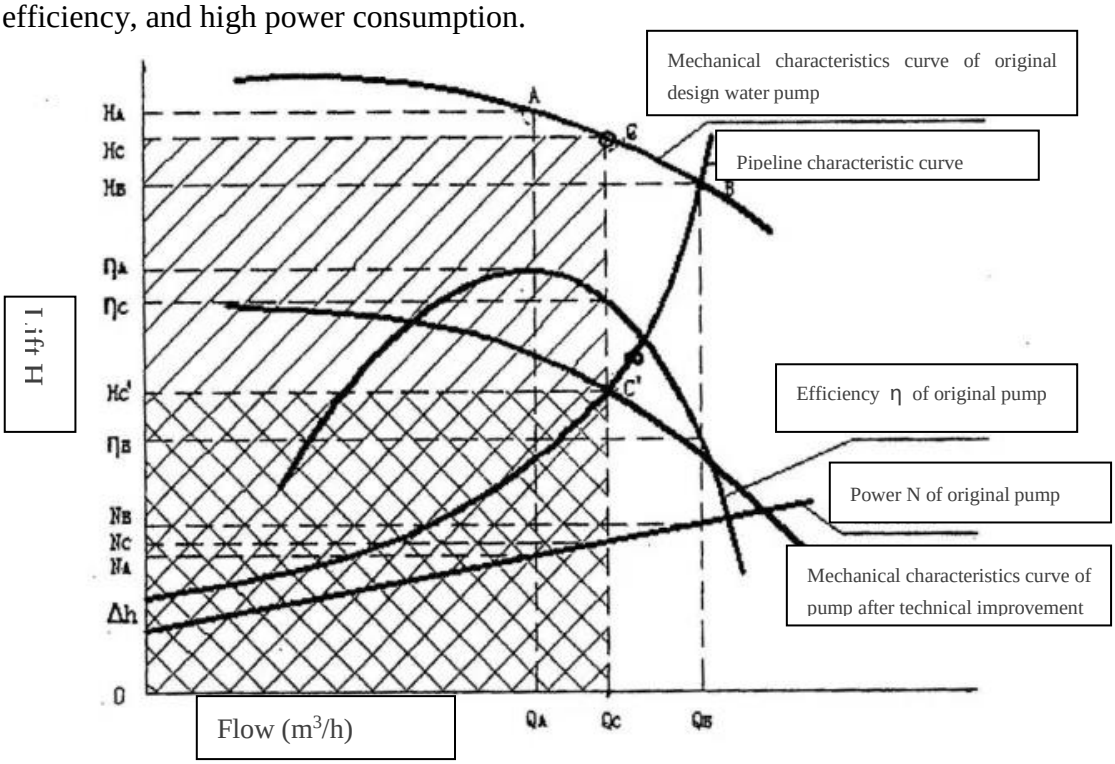


Figure 1 Mechanical Characteristics Curve and Pipeline Characteristics Curve for Water Pump

The relationship between water flow and water resistance in CWSs is determined by the dynamic equation of CWSs – Bernoulli Equation. The total resistance of water system (or the lift of water pump) is shown as follows:

$$H = \Delta h + \sum_{n-1}^{n} in + \frac{n^2}{2g} \qquad (1)$$

In which:

Velocity head (kinetic head) $\frac{n^2}{2g} = \frac{2^2}{2\times 9.8} \approx 0$ (2)

For the CWSs

Friction loss

$$\sum_{n=1}^{n} i_n = KQ^2 \qquad (3)$$

Substitute Formulas (2) and (3) into Formula (1)

$$H = \Delta h + KQ2 \qquad (4)$$

Formula (4) as above is an accurate and simplified kinetic equation for CWSs, which is used for engineering calculation. If expressed with a curve in Figure 1, this is a parabolic equation through Point B, i.e., the pipeline characteristics curve indicating that the water pump operating condition (Q, H) of the CWSs is certainly on the pipeline characteristics curve when the flow is equal to zero, the lift of water pump is equal to the geometric lift Δh, the flow is equal to QB, the lift of water pump is HB. That is the intersection between the mechanical water pump characteristics curve and the pipeline characteristics curve, and the flow at the intersection is the actually measured operation flow QC. The lift is Point C' of HC', i.e., the optimal operation condition point of water pump in technical improvement. According to the parameters (QC, HC') of the optimal operating condition point, any specially made water pump must be the optimal energy conservation pump matching with the CWSs in an efficient operation.

Because the shaft power of water pump is proportional to the product of flow and lift, the operating power of original water pump can be expressed with Areas 0, HC, C, QC, and 0. The operating power of pump in technical improvement can be expressed with Areas 0, HC', C', QC, and 0. The difference of Areas HC', HC, C, C', HC' between them is the saved energy consumption.

Each CWS has its inherent characteristic curve of pipeline, and therefore it is necessary to draw the characteristics curve of the CWSs, select the optimal operating condition point of technical improvement pump, and realize the effective energy conservation of CWSs by hydromechanics calculations according to measured flow Q, lift H and others parameters. A large number of cases have proved its accuracy.

The second is the correction technology of high-level CWSs. High and low levels of cooling equipment in large and medium-sized petrochemical companies exist in the same CWSs. In order to ensure the flow and pressure of high-level cooling equipment, it is necessary to enhance the pressure of main pipe and the lift of circulating water pump. But for the excessive pressure of main pipe in the low-level cooling equipment, this will only cause significant waste of energy consumption. Aiming at the working condition, Hangzhou Pump had researched and invented "A Method and Device for Reducing the Lift of Circulating Pump in High-Level CWSs". A large and medium-sized petrochemical CWS with high-level heat exchanger is used to reduce the geometric lift caused by the residual pressure. The high-level circulating water correction technology can reduce the lift and energy consumption of circulating water pump, improve the operating efficiency of the system, and increase more than 20% of

energy conservation benefit while ensuring that both high and low levels of cooling equipment can operate normally.

The third is the optimization technology of cooling process for the CWSs. This is put forward on the basis of the above patent technology (i.e. fluid dynamics) and the research of heat exchange engineering. Because the true aim of the cooling CWSs is to realize the cooling effect of the process, or the heat exchange optimization of process equipment and cooling tower.

It is well known that the heat exchange capacity is determined by the water flow and the temperature difference between incoming and outgoing water flows.

That is heat exchange capacity = water flow × temperature difference.

The operation guideline of energy conservation cooling process is to adopt the heat exchange process with little water flow and large temperature difference as far as possible under the premise of keeping constant heat exchange capacity. This is because the energy consumption of circulating pump often is five times that of cooling tower fan.

The fourth is the automatic control technology for CWSs. Since the heat exchange capacity is not constant in the CWSs and the cooling effect varies with season, the circulating water pump and cooling tower capacity of CWSs are always designed according to the maximum circulating water capacity required by the maximum heat exchange capacity of the cooling equipment in the circumstance least favorable for cooling (high ambient temperature and humidity). From the thermodynamic analysis, the heat exchange capacity of cooling equipment is shown as follows:

$W = dT \times Q$

W – heat exchange capacity

dT – temperature difference between the inlet and outlet of cooling equipment

Q – circulating water flow through cooling equipment

In a season with low ambient temperature and humidity and good cooling effect of cooling tower, the inlet temperature of cooling equipment is low. Under the premise that the outlet temperature is constant, where the temperature difference increases, the circulating water flow could decrease in proportion to complete the same heat exchange capacity.

According to the characteristics of circulating water pump, the variation of circulating water flow has a cubic relationship with the power of circulating water pump. Put another way, the circulating water flow is decreased by 10%, the pump energy consumption by 27%, the flow by 20% and the pump energy consumption by 49%. Therefore, it is feasible to reduce the energy consumption of pump by adding a frequency converter at the front end of circulating water pump and adjusting the circulating water flow via the converter.

However, the flow regulation manually or only based on the measured temperature and pressure of main pipe in pump room cannot track or accurately track the actual heat exchange capacity of production equipment. Where the flow decreases substantially, the heat exchange effect and therefore the production will be affected. Where the flow decreases slightly, the energy conservation effect will be unobvious.

Therefore, it is necessary to design and configure a set of automatic control system which can detect pump outlet temperature, pressure, temperature of inlet and outlet of cooling equipment, flow and other key parameters and intensively control variable and constant frequency operations in circulating water pump and cooling tower fan. It can control the flow of circulating water pump and the air capacity of cooling tower fan to ensure that the CWSs are always in the optimal energy efficiency state by controlling the algorithm and adjusting the frequency according to the actual heat exchange capacity of cooling equipment and the actual cooling effect of cooling tower.

The fifth is to utilize the water treatment technology. Water treatment technology is to determine the pipe fouling and corrosion situation by detecting the water quality and other parameters of CWSs. According to the actual situation of water quality, it is to provide the medicament to eliminate the scale formation of circulating water pipe, and add the corrosion inhibitor and anti-scaling agent for a long period to prevent pipelines from scaling again and ensure the CWSs operating in a low resistance and high heat exchange efficiency for a long period on the premise of protecting pipelines from corrosion.

The comprehensive utilization of the above five technologies constitute the comprehensive system solution of high efficiency and energy conservation technology for CWSs. The technical improvement for energy conservation can be proposed on the basis of various unfavorable factors of energy consumption in energy consumption companies so as to reduce the overall operation energy consumption of CWSs.

III. Brief Introduction on Patent Technology of Hangzhou Pump

1. A Correction Method of Online Fluid System

National patent technology: *A Correction method of online fluid system*; Patent No.: ZL200710066873.2 (now as the proprietary technology of Mr. Fan Changhai).

The precise determination is conducted on operating conditions of CWSs, to input various parameters into the mathematics model of patent technology, calculate the pipeline characteristics curve of actual working condition, find out the optimal working condition point of system operation, re-design the efficient water pump matching with the pipeline characteristics curve, and ensure the required flow of the maximum system heat exchange. The technical improvement means of water pump replacement is used to achieve the goal of reducing energy consumption while eliminating water pump cavitation, vibration, closing valve, over-current, high motor temperature and other abnormal phenomenon in the operation of water system so as to optimize the system in nature.

2. Assembly and Working Condition Detection Method for Circulating Pumps in Water Cooling System

National invention patent: *Assembly and working condition detection method for circulating pumps in water cooling system*; Patent No.: 201310062873.0. According to the principle of optimal system working conditions, the professional hydraulic mathematical model is established through the detection and parameter acquisition of operating condition for CWSs, so as to find out the factors causing high energy consumption and the optimal operating condition point, design and produce the efficient fluid transmission equipment matching with the system and replace the

existing equipment of CWSs. In doing so, the system is always kept in the best operating condition, achieving the purpose of energy conservation and consumption reduction.

3. Method and Device for Reducing Circulating Pump Lift of High-Level Circulating Water System

National invention patent: Method and device for reducing circulating pump lift of high-level circulating water system; Patent No.: ZL201010204888.2. It particularly relates to a method and device for solving the issue of high pressure water return in high-level CWSs. The above high-level CWSs includes cooling tower, water tank, circulating pump, heat exchange equipment and connecting pipeline. The heat exchange equipment includes several heat exchangers at different water levels. Circulating water is conveyed by the water mains to heat exchangers and then collected back to the water patent tube through the auxiliary water return tube of heat exchanger and then to the cooling tower. It is characterized by the procedures that the said circulating water is conveyed into the cooling tower through the auxiliary water return tube of heat exchanger to facilitate pressure relief. With the method, the high pressure circulating pump in system can be changed into a low pressure circulating pump so as to reduce the lift of circulating pump and resolve the energy waste issue that people have been eager to solve but yet succeed.

4. A Boosting and Exhausting Device of Air Conditioning Water System

National invention patent: A *Boosting and Exhausting Device of Air Conditioning Water System*; Patent No.: ZL200520116220.7. Brief introduction: The newly practical model belongs to the technical field of air conditioning water system. Specifically, it is a boosting and exhausting device of water system relating to the central air conditioning.

In order to maintain a stable positive pressure of central air conditioning water system, an expansion tank is always provided at the top of building and connected directly with the water return cylinder of air conditioning water system through water pipe. In operation, especially at startup, it is easy to generate bubbles due to pressure fluctuations. When the top layer is in a low water pressure, bubbles cannot be discharged from water pipe so as to cause the air stagnating and form “gas jam”, seriously affecting the cooling effect of air conditioning. A *Boosting and Exhausting Device of Air Conditioning Water System* does not change any facility of air conditioning water system, and can eliminate “gas jam” to make it in a normal operation so as to solve the technical issue that need to be solved urgently in the air conditioning water system.

IV. Advanced Analysis on High Efficiency and Energy conservation Technology for CWSs

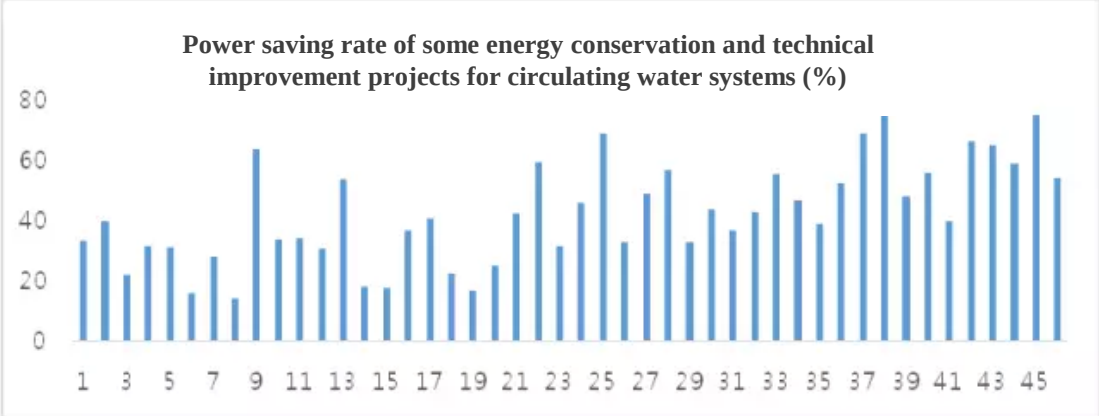
The advanced nature of high efficiency and energy conservation technology for Hangzhou Pump circulating water system is embodied in high efficiency, universality and economic feasibility.

(1) Efficiency: The technical improvement scheme for energy conservation can be proposed for energy consumption companies according to their various unfavorable energy-consumption factors. From the overall system optimization, the root cause of high energy consumption in the operation of CWSs is solved so as to reduce the overall operation energy consumption of CWSs. The high efficiency and energy

conservation technology for circulating water is a comprehensive multi-technology solution based on the fluid conveyance correction technology. The water treatment technology is used to reduce the resistance of circulating water pipe and improve the heat exchange efficiency of heat exchanger. The fluid conveyance correction technology is used to provide tailor-made equipment matching with the working conditions of CWSs, realizing the top efficiency of circulating water pump and the optical working conditions. The automatic control system of variable flow regulation is used to eliminate the residual error of circulating water flow due to climate. In doing so, it could eliminate negative energy consumption factors of CWSs from many aspects, and completely and thoroughly reduce the unreasonable energy consumption of CWSs.

(2) Universality: The high efficiency and energy conservation technology for circulating water applies not only in large chemical and metallurgical companies but also in hotels, airports, hospitals and other large commercial complexes. It has larger energy conservation range and power saving potential so it could change the phenomenon of single technology as a Band-Aid in energy conservation.

(3) Economic feasibility: Compared with the energy conservation benefits, the investment in technical improvement for energy conservation in CWSs is relatively small. The investment project of energy conservation and technical improvement in CWSs may recover costs in a short term. Energy consumption companies can greatly realize the cost reduction and efficiency increase. After recovering the cost, energy consumption companies can enjoy long-term energy conservation benefits and technical improvement results of intellectual property rights, or do not affect their normal production and safety. Therefore, it has a high value for market promotion.



V. Operating Process of High Efficiency and Energy Saving Technology for CWSs

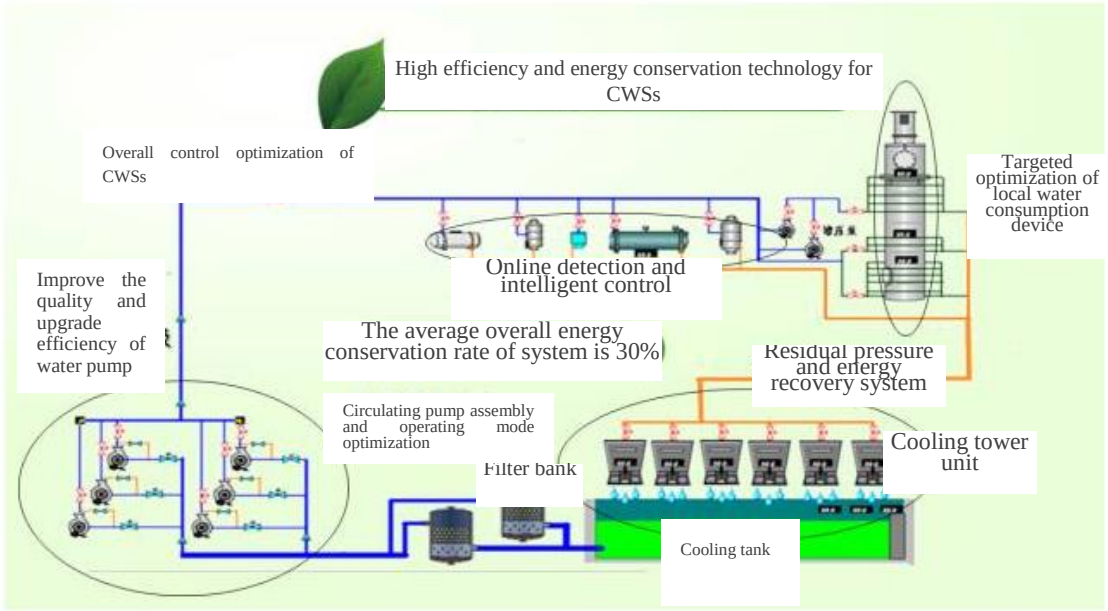
(1) Investigate working conditions: carry out systematic investigation on CWSs of key energy consumption companies to detect key point pressure, temperature difference of inlet and outlet, water flow and other data.

(2) Find issues: carry out comprehensive inspection on the system and quantitative analysis assessment on system performance, to provide theoretical and data basis for tapping the energy conservation capacity. Utilize patent results and software analysis, detect adverse factors existing in the CWSs, overcome drawbacks, optimize the system, and minimize its water resistance.

(3) Determine the scheme: adjust the system operating parameters, upgrade hardware equipment, and optimize the adjustment control strategy and mode so as to realize the optimal system operation. The technical improvement scheme is determined for energy consumption companies according to their technological conditions and operating indicators, including: ① establish a professional hydraulic and mathematical model according to the best operating principle, obtain the best system operating point, and design and produce the highly efficient fluid conveyance equipment matching with the system (general equipment design, manufacturing and acceptance shall meet the standard requirements of GB/T5657-1995, ISO9906-1999, and Q/FP2112-2006); ② determine the automatic control scheme according to the technological conditions of cooling equipment; ③ for coexisting of high and low level of cooling equipment in CWSs, a correction technology of high level circulating water is adopted as an energy conservation solution; ④ determine the water treatment scheme according to the water quality conditions; ⑤ adjust and set the operating mode of CWSs and the management specification.

(4) Project implementation: carry out equipment installation, process optimization and adjustment, operating commissioning, safety testing, power saving effect testing and others according to the overall technical improvement scheme of circulating water.

Component of Improvement and Energy Conservation Space in CWSs:



1. Efficient improvement of water pump in CWSs: adopt the latest CFD impeller technology, design the matched pump volute and pump body, completely replace the existing water pump, increase the optimal operating points and the high efficiency intervals, and correspondingly reduce the output power consumption of water pump.

2. Water supply pressure adjustment: take full use of atmospheric pressure and siphon principle, to reduce 7~8 m of water supply pressure for the closed CWSs. The technology can save 10%~25% of power consumption in the CWSs.

3. Adjustment of water supply flow: distribute the water supply reasonably according to the heat exchange capacity of heat exchanger and the process requirement, to save the unnecessary water capacity and reduce the output of water pump.

4. Optimization of valve and other fittings: replace the check valve at the outlet of the original water pump into a multifunctional and integrated valve system of water pump outlet to reduce the local friction loss of the pipeline, and optimize the unreasonable pipelines such as elbow to reduce the loss along the pipeline, lowering the operating lift of water pump and achieving energy conservation.

5. Improvement of turbine fan: for any system with higher installation position of heat exchanger and the higher water return pressure requirements of CWSs, improve the efficient turbine fan to replace the drive motor of original cooling tower fan. This technology can save the power consumption of cooling tower drive motor in the system.

6. Automatic control system: add a frequency conversion device on the water pump drive motor. Control the pump speed or startup/stop intelligently according to the water supply return flow, pressure, and temperature difference of circulating water so as to achieve the purpose of flow and pressure control. This technology is suitable for systems with large and frequent flow and pressure changes, which can greatly reduce the operating capacity of manual operating pump startup/stop and ON/OFF valve. It can increase the automation of CWSs as well as realizing energy conservation.

Professional Testing Tool for CWSs:

Data detection kit

Professional Research and Development Platform for CWSs:

Common test platform for hydraulic machinery

VI. Application Range and Energy Conservation Potential of High Efficiency and Energy conservation Technology for CWSs

1. Application Range:

There are a lot of circulating water systems (CWSs), including those for industrial cooling and those for central air conditioning cooling and refrigeration. CWSs are extensively configured in chemical industries (including petrochemical, coal-based chemical, salt-based chemical, agrochemical, and pharmaceutical industries), metallurgical industries, cogeneration industries, and civil public facilities (including airports, four- or five-star hotels, hospitals, large office buildings, and commercial complexes). The purpose of CWSs is to reduce heat generated in production processes (equipment) in operation through heat exchange. CWSs are an indispensable and important part of industrial economy and other economic sectors and a key field of energy conservation and emission reduction in China.

2. Assessment on Energy Conservation Potential:

The industrial power consumption in 2012 was 3.6 trillion kWh in China. The power consumption of CWSs accounted for about 11% of total power consumption of industrial companies. The annual power consumption of industrial circulating water in China was 396 billion kWh, of which more than 80% of CWSs have above 15% energy conservation potential. The systems with above 25% energy conservation rate accounted for 50% and can save 70 billion kWh annually.

At the same time, the annual industrial investment is increased at certain proportion, in which, that of new CWSs is increased by about 5%. Through the technical improvement for energy conservation of new CWSs, the annual energy conservation of more than 3.5 billion kWh can be achieved additionally.

Analysis on Potential of Key Industries:

(1) Petrochemical Industry

In petrochemical industry (including Sinopec, PetroChina, CNOOC and other large chemical companies), the annual power consumption of CWSs is more than 160

billion kWh. Due to outdated equipment model of water pump, poor matching between water pump and pipelines, poor regulation ability of the system, lower efficiency of water system, CWSs suffers large energy consumption waste. According to the statistics, only the CWSs of Sinopec has more than 90% potential for energy conservation with the average energy conservation rate up to more than 25% and the annual energy conservation capacity more than 4.3 billion kWh. By the analogy, the annual energy conservation space of the three state-owned petrochemical corporations is closed to 10 billion kWh. The annual power saving scale of various chemical companies in China is more than 45 billion kWh.

(2) Iron and Steel Metallurgical Industry

After comprehensive technical improvement for energy conservation is conducted for the CWSs of iron and steel companies with annual output of 2 million tons of crude steel, the annual power saving capacity will be about 30 million kWh, and the average power saving capacity per ton steel about 15 kWh.

The annual production capacity of iron and steel industry in China is more than 700 million tons. After the technical improvement for energy conservation has been implemented in CWSs, the power saving consumption will be more than 10.5 billion kWh.

(3) Central Air Conditioning of Civil Public Facilities

For 300+ 3A Grade hospitals, 4,000+ four-star and above hotels, many large airports and other urban complexes in China, the annual power consumption capacity of central air conditioning CWSs is more than 9 billion kWh. From 100+ central air conditioning systems for which the technical improvement for energy conservation has been completed, the average power saving rate is about 50%. Therefore, the annual power saving potential of CWSs of central air conditioning is up to more than 4 billion kWh in China.

VII. Comparison between Hangzhou Pump's High Efficiency and Energy Saving Technology and Other Energy Conservation Technologies

(1) Single Frequency Conversion and Energy Conservation Technology: When the system water flow is surplus or the production needs to adjust (or control) the water flow, the frequency conversion adjustment can save energy and control the process. But the simple frequency conversion technology without the support of intelligent control system may affect the normal equipment cooling and production due to improper flow regulation. Therefore it should be used with caution. Meanwhile, Due to the high cost of the frequency conversion adjustment device of high pressure circulating water pump, the application of frequency conversion technology in the energy conservation field of high pressure motor can also be affected.

(2) Hydraulic Turbine Technology: The basic principle of hydraulic turbine technology is to replace fan motor on the cooling tower by hydraulic turbine. Propelled by excess pressure of the circulating water at the inlet of cooling tower, the hydraulic turbine rotates and completes the cooling function of cooling tower. The application condition of hydraulic turbine is sufficient excess pressure of circulating water at the inlet of cooling tower. But the lift of circulating water pump will be negatively affected. Therefore, it is only a local specific energy conservation mode of CWSs. It is counterproductive if the technology is not applied properly.

(3) Impeller Cutting Technology: The technology aims at valve closing operation for CWSs. When the valve is opened completely, the flow is excess and overloaded, therefore related system needs improvement on energy conservation. The principle for system energy conservation is to reduce the flow and lift of circulating water pump through impeller cutting to ensure that after the technical improvement the flow of CWSs upon the complete opening of valve is consistent with that of the original system and the energy consumption can be reduced according to the impeller cutting degree. The technology can effectively eliminate the closing operation of valve and the energy consumption consumed by the circulating pump to overcome the valve resistance. But there is a certain range of impeller cutting, and if beyond the range, the operating efficiency of circulating water pump will be reduced. Therefore, the range of impeller cutting technology and energy application is very limited.

Comprehensive Comparison on Energy Conservation Technologies of CWSs:

Item	Hangzhou Pump's High Efficiency and Energy conservation Technology	Frequency Conversion Technology	Hydraulic Turbine Technology	Impeller Cutting Technology
Technical principle	Comprehensive solution for equipment, process and system energy conservation with comprehensive fluid correction technology	Flow and lift of stepless adjustment pump through frequency conversion	Replace the fan of cooling tower by hydraulic turbine, the latter is driven by excess pressure of cooling tower	Reduce the flow and lift of pump through the mode of impeller cutting
Method of implementation	Select the best solution according to site process characteristics	Increase a frequency conversion cabinet	Replace the fan of cooling tower by hydraulic turbine	Remove pump impeller to carry out impeller cutting
Stop the system	No	No	Sometimes yes	No
Service conditions	Applicable to most CWSs	System with flow changing	System with excess pressure	System with closed valve operation
Power saving effect	≥30%	20%	6%	8%

VIII. Application Cases of High Efficiency and Energy conservation Technology for CWSs

1. Technical improvement Project for CWSs of Shanghai Sinopec Mitsui Chemical Co., Ltd.

Shanghai Sinopec Mitsui Chemical Co., Ltd. is a joint venture established by Sinopec and Mitsui Chemicals respectively with 50% investment in April, 2006. The production devices with annual production of 120,000 tons of bisphenol in Phase I was completed and put into production in December 2008. Sinopec is one of top 500 companies in the world. It has the largest production capacity of phenol acetone in China and can provide reliable raw material guarantee for the production of bisphenol A. Mitsui Chemicals is one of the largest bisphenol A producers in Asia and one of the most important producers worldwide. It has the first-class bisphenol A production technology in the world.

Due to the lift of water pump inconsistent with the actual loss of pipeline resistance, and heat exchange positions are in a high level, the backwater valve of the CWSs in the first stage must be turned down, and the water pump has to operate in the high efficiency zone so as not to make water pump operate with an excess flow capacity and power. When valve is turned down, the resistance loss at valve is increased. All the excess lift of water pump is lost invalidly here. In actual operation, both inlet and outlet valves of pump have to be turned down to 50%. Therefore, the energy consumption is very huge.

The summary on the technical improvement for CWSs in Phase Ⅰ is shown as follows:

1. After the energy conservation improvement, equipment is operating stably. Vibration noises meet the requirements and are safe and reliable, and functional indicators have also met the technical requirements of equipment.

2. Large pumps have been replaced by small ones. After the energy conservation improvement, the outlet pressure of circulating water pump is reduced from 0.54 MPa to 0.33 MPa and the efficiency of circulating water pump is increased from 74% to 91%.

	Water pump parameters before technical improvement	Water pump parameters after technical improvement
Serial No.	1#2#3#	1#2#3#
Pump model and specification	SM602-640	KPS50-500
Direction of rotation	Clockwise	Clockwise
Pump power (kW)	800	800
Voltage (V)	6000	6000
Flow (m^3/h)	3840	2200-3300
Lift (m)	50	30-40
Speed (r/min)	980	980

Pump manufacturer	Sulzer (Dalian) Pump and Compressor Co., Ltd.	
Motor model	YKK500-6W	YKK500-6W
Motor (kW)	800	800

3. After the energy conservation improvement, they can meet the requirements of water demand and production process.

4. The comprehensive energy conservation rate has reached 54% surprisingly to attain the power saving rate as agreed in the contract.

The power saving effect of each pump is shown as follows.

System name			Power after technical improvement (kW/h)	Power saving capacity per hour (kW)	Power saving rate	Acceptance time
	Pump No.	Power (kW/h)				
Cooling CWSs	A	718.54	318.62	399.92	55.66%	Dec. 12, 2013
	B	718.54	342.18	376.36	52.38%	Dec. 12, 2013
Comprehensive		1437.08	660.79	776.29	54.02%	Dec. 12, 2013
Total	The annual power saving capacity after technical improvement in Phase I was 6.67 million kWh, and the annual power saving cost was 4.81 million yuan.					

2. Technical improvement Project for CWSs of Puyang Longyu Chemical Co., Ltd.

Puyang Longyu Chemical Co., Ltd. (Puyang Longyu) is a modern large-scale chemical company established according to the agreement *On Reorganizing Puyang Methanol Plant and Investing the Construction of Puyang Methanol Project* signed by Puyang People's Government and Yongcheng Coal Power Holdings Group. Founded on February 1, 2007, Puyang Longyu is located at Huanghe West Road, Puyang, Henan Province with a registered capital of 100 million yuan, and is a wholly owned subsidiary of Yongcheng Coal and Electricity Holding (Group) Co., Ltd.

Puyang Longyu cooperated with Hangzhou Pump in a contract energy management mode in 2014 to carry out energy conservation improvement of gasification circulating water and rectification circulating water. Hangzhou Pump patented technology was adopted in the project to carry out technical improvement for "gasification circulating water pump and methanol rectification circulating water

pump" of Puyang Longyu. By using the analytical investigation on detection data of water pump operating condition, combing with the fluid mechanics characteristics of system pipeline and rectifying unfavorable factors existing in the system, five FCH efficient pumps were customized according to the optimal operating parameters to replace three gasification circulating pumps and two methanol distillation circulating water pumps that operated in adverse conditions and low operation efficiency. The original one standby gasification circulating water pump and one standby methanol distillation circulating water pump were still kept to be standby to reduce the "invalid energy consumption", improve the efficiency of transmission, and realize the system energy conservation.

Puyang Longyu invited the third party audit institution (Jiangsu Energy Conservation Center) to carry out on-site verification on the energy conservation effect of technical improvement project for CWSs, and put forward a verification report. The main conclusions of on-site verification are shown as follows:

1). The improvement project had been started from April, 2014 and completed and accepted and put into operation on August 26, 2014. Before the project improvement, the main equipment had been operating stably for more than 2 years.

2). In the project, Hangzhou Pump patented technology had been adopted to rectify adverse factors existing in gasification CWSs and methanol distillation CWSs of Puyang Longyu, optimize the pipeline system, and replace three water pumps of gasification CWSs and two water pumps of methanol distillation CWSs. The original one standby gasification circulating water pump and one standby methanol distillation circulating water pump were kept still for standby.

3). The comprehensive power saving rate of five water pumps is 31.36% and achieve the requirements of above 20% in the contract. After having been implemented with energy conservation improvement, the system was operating stably, and technical and economic indicators have met the requirements.

4). The project is an energy efficiency sharing contract energy management project. The sharing period agreed in the contract is 35,000 hours of equipment operating time, and the energy conservation benefit sharing mode has been stipulated in the contract.

5). Before the project technical improvement, kilowatt hour meters were installed respectively for seven water pumps. Puyang Longyu provided energy consumption statements. Measuring instruments are complete and meet the requirements.

6). The energy conservation improvement of the project is within the support range of financial incentive fund. The audited energy conservation of the project is 2,521 tce.

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