

The Key-question Analysis on Reclamation and Utilization of Non-cycle Water Heat Energy and Its Recent Developments

Haiyang Bi¹, Duanmu Lin¹, Zhen Li¹, Yingxin Zhu²

¹School of Civil and Hydraulic Engineering, Dalian University of Technology, Dalian, China

²Department of Building Science, Tsinghua University, Beijing, China

Abstract: Taking the encountering problems of some cooling station in Guangzhou which utilizes the Pearl River water as cool source, the corresponding measures and rectifying effect for an instance, analyses the problems and obtains that the difficulties of reclamation and utilization of non-cycle water heat energy mainly result from two aspects: the selecting of designing parameters (such as fouling resistance, convection coefficient, resistance curve, and so on) and the strategy of anti-fouling and removal of fouling, then discuss the recent developments of the two aspects, lastly points out that reutilization of non-cycle water heat energy requires to research the problem which will be resolved further.

Keywords: non-cycle water heat energy; fouling resistance; convection coefficient; resistance curve

1. INTRODUCTION

In recently with the rapid development of modern science and technology and increasing crisis of energy and water resource, people pay more attention to the utilization of low temperature energy resource. River water is one of the recovered energy resources for its temperature varies little, the amount is steady. Utilizing river water as cool source may decrease amount of heat which is put into the air, ease the high temperature warm-hearted island appearance of town and have a great effect on the atmospheric pollution and the environmental protection. Omitting the cooling tower and saving the rule cooling water have the significant strategy sense on resolving the water resources crisis. Some cooling station in Guangzhou tries to utilize the Pearl River water which is filtered as cooling water of the air-condition refrigeration system directly, attempts to accumulate actual project experience and supply a fresh thinking of comprehensive utilization of river water.

2. THE ENCOUNTERING PROBLEMS AND CORRESPONDING MEASURES

Because water quality is worse than that previously forecasts and the condition doesn't benefit protection, cooling pump and condenser are filled with sundries and fouling, even blocked up, causing cooling water can not reach the design requirement in the air-condition season, the coefficient of heat transfer cuts down, and difference in temperature of condenser two sides broadens, causing the freezer warning to cease the engine, and need to wash inner in the short-term. From the point of view of operation,

the natural operation of system is affected seriously, operation expends a large quantity labour power and resource, for the installation constantly disassembles and washes, the unit life also decreases. The cool station takes the following measures to improve the situation: firstly, the aqueduct and taking-water part are cleaned; secondly, the filter net is replaced; thirdly, No.3 unit is equipped with an auto-clean device (C.Q.M), and so on. From the point of view of operation effect, the cleaning effect of C.Q.M is obvious, the measures delay the jam of heat exchanger and prolong cleaning period of heat exchanger, but the unit still requires cleaning once a moon. Fig.1 shows the operation situation of the No.1 unit. Fig.2 shows the operation situation of the No.3 unit.

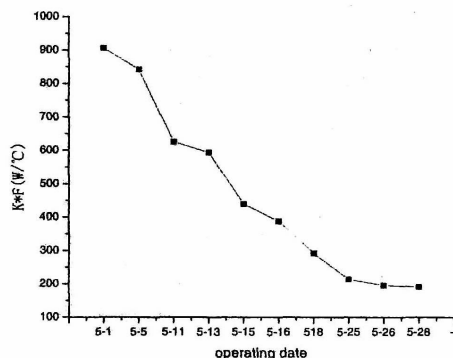


Figure1: Thermal performance over time of No.1 unit

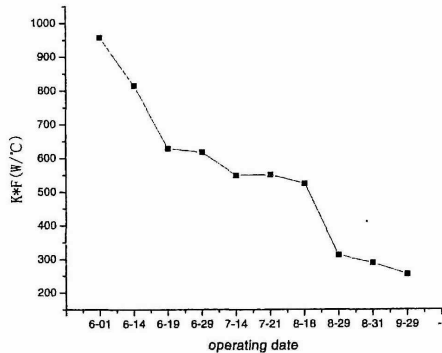


Figure2: Thermal performance over time of No.3 unit (equipped with C.Q.M)

K*F of No.1 unit on 2004.5.1 is 900W/°C and decreases to 200W/°C on 2004.5.8, the corresponding system difference in temperature increases from 1°C to 10°C, so the problem of thermal effectiveness is not resolved and the unit still requires cleaning.

No.3 unit is equipped with C.O.M in 2004 May and K*F of No.3 unit on 2004.6.1 is 900W/°C and decreased to 250W/°C on 2004.10.1. K*F reduces to 650W/°C on 2004.7.1; K*F goes down to 550W/°C on 2004.8.1; therefore the C.Q.M system has a good effect and meets the project problem basically. But K*F decreases to 300W/°C on 2004.9.1 and the unit still requires cleaning.

3. PROBLEM ANALYSIS

According to heat theory, overall heat-transfer coefficient (K) is calculated by equation:

$$K = f(\alpha_w, \alpha_{cf}, \lambda, R_f)$$

In which, K : overall heat-transfer coefficient;
 α_w : convective heat-transfer coefficient outside;
 λ : thermal resistance of tube; α_{cf} : convective heat-transfer coefficient inside; R_f : fouling resistance;

Because the refrigerant and material of heat exchanger are certain, α_{cf} and R_f are the main factors which affect K . As for Newton liquid, α_{cf} is affected by $Pr^{1/3}$. From actual project experience, liquid is not Newton liquid, actual α_{cf} is higher than designed α_{cf} which is calculated by natural equation, and viscosity has a great effect on α_{cf} , that is: it is not appropriate merely α_{cf} is calculated by natural equation and equation of α_{cf} need to be studied furthermore.

Fouling resistance of different criterion varies a lot, so selecting of R_f has a great effect in practice.

Experiment result of Literature ^[1]: R_f of the Pearl River water is 0.1~0.2 m²·K/kW; Literature ^[2] points to that R_f of mixing fouling is 0.8~2.33 m²·K/kW; but the mixing fouling thickness of condenser in some cooling station in Guangzhou is 1~2mm, and R_f is 0.429~2.5m²·K/kW which exceeds the criterion of HTRI/TEMA Joint Committee and the designing value, so unit performance decreases. R_f of heat exchanger in our country adopts the criterion of HTRI/TEMA Joint Committee because fouling resistance data of our country main water system and urban sewage is lack, but R_f of HTRI/TEMA has many shortcomings and limiting, such as data dependability is not perfect, time relatively is bad, etc. With the increasing of operating time, fouling also rises and aggrandizes R_f also, so thermal efficiency of unit drops. At the same time the incassation of fouling causes the circulating area decreases, then results in the increase of flow resistance; according to performance curve of pump and piping, we can see easily that pump flux drops, then reduces the thermal efficiency of unit.

4. THE RESEARCH SURVEY IN DOMESTIC AND ABROAD AND ANALYSIS

The primary characteristics of non-cycle water heat energy (such as river water, urban sewage, lake water, etc.) lie in two aspects: water quality is bad and water quantity is huge. When we utilize non-cycle water heat energy, conventional water treatment means and some anti-fouling measures in circulating water can't be put in practice because of water quantity, so generally non-cycle water directly goes into the heat exchanger after physics filtration. Based on these feature and purpose of reclamation and utilization, present study concentrates four aspects: research on fouling mechanism; research on prevent fouling of tube material; changing operation parameter for anti-fouling; research on wiping strategy of fouling.

4.1 Research on fouling mechanism

Fouling is a complex physics-chemical route and competitive process of momentum and energy and quality transmission, its theory relates to correlation knowledge of thermal conduction and chemistry kinetics and fluid mechanics and colloid chemistry and thermodynamics, etc. To accurately comprehend fouling mechanism is a significant mission. The earliest fouling model is proposed by Kern and Seaton ^[3]. In many years relevant fouling model pays attention to estimate of deposit rate and denude rate of special fouling ^[4-7].

But in the practice fouling is mostly mixing fouling, frequently there is a concurrence of several mechanism. Zubair and Sheikh ^[8] research the fouling

problem from a new point of view, they analyze thermal resistance rule with changing of time, sum up four styles: linearity, exponent law, falling rate and asymptotic rate, introduce probabilistic approach, and establish fouling probabilistic model. According to risk level and the time to reach a critical fouling thermal resistance Xu Zhi-ming^[9] deduces four fouling models accounting for initial fouling thermal resistance.

4.2 Research on prevent fouling of tube material

In the long haul people think tube material of the low face capacity may ease adhering of fouling. Adamson^[10], Baier^[11], Kjaer^[12] report that PTFE (Polytetrafluoroethylene) may prevent building of fouling, and is easy to cleaning. Müller-Steinhagen^[13-14] invents a kind of surface of preventing fouling using DLC (diamond like carbon). Many research studies indicate fouling of copper surface is better than that of other surface because copper ion has poisonous effect to the microbe. The writer also experiments fouling of copper tube and PTEE tube, and concludes PTEE tube is easy to adhere fouling.

4.3 Research on wiping strategy of fouling

Operating parameter is the significant element of fouling formation. Adopting self-clean twisted tape^[15], circulating fluidized bed technique, and spring tube bundles heat exchanger^[16] on the one hand has online cleaning function and prevent fouling formation, on the other hand, turbulent strengthening also intensifies thermal effect. Self-clean twisted tape can continuously sweep the inside tube, guard against fouling deposit and has thermal reinforcement, its thermal performance can increase 50% or so. Spring tube bundles heat exchanger also has the dual effect of preventing fouling formation and enhancing thermal effect.

4.4 Research on wiping strategy of fouling

Water quality of non-cycle water is bad, and heat exchanger surface is easy to adhere to fouling, the thermal effectiveness of heat exchanger decreases to a minimum acceptable level, cleaning of the equipment becomes necessary to restore the performance. At present there are two kind of cleaning: mechanical cleaning and chemical cleaning, C.Q.M system of No.3 unit in some cool station in Guangzhou belongs to the former; chemical washing is easy to lead to circumstance pollution which departs the first purpose of reclamation and utilization of non-cycle water heat energy, so in practice people prefer to physical cleaning. There are auto-cleaning brush device (Japanese patent 61-86599) and sponge globe washing system (Israel patent), etc.

Fouling is a complex physics-chemical route and competitive process of momentum and energy and quality transmission, so at present it is difficult to build a general model for all kinds of fouling, especially mixing fouling; because of bad water quality of non-cycle water heat exchanger surface is easy to adhere to fouling, research on prevent fouling of tube material has a little effect in practice, that is in actual project fouling is necessary; urgent work is how to dispel

fouling while not affect operation in actual project, C.Q.M system and auto-cleaning brush device belong to the fashion, however C.Q.M system still doesn't resolve the fouling problem from actual operation effect because of sponge globe randomness, thermal effectiveness of unit obviously decreases and unit needs to clean after two months, furthermore, C.Q.M system is expensive and increase first investment. The auto-cleaning brush device (Japanese patent) can auto-clean fouling, but there is not correlative report, such as cleaning time, which is thermal resistance of unit which is equipped with auto-cleaning brush device, etc; although self-clean twisted tape and spring tube bundles heat exchanger have dual effect of prevent fouling and enhancement of thermal effectiveness, flow parameter has a great impact on it, in practice it is difficult to grasp its effect.

5. CONCLUSION

The primary characteristics of non-cycle water heat energy (such as river water, urban sewage, lake water, etc.) lie in two aspects: water quality is bad and water quantity is huge. Heat exchanger surface is easy to adhere to fouling; when the thermal effectiveness of heat exchanger decreases to a minimum acceptable level, cleaning of the equipment becomes necessary to restore the performance.

The main difficulties of reclamation and utilization of non-cycle water heat energy mainly result from two aspects: the selecting of designing parameters (such as fouling resistance, convection coefficient, resistance curve, and so on) and the strategy of anti-fouling and removal of fouling. At present there is short of mixing fouling theory model and correlation experimental data, especially actual fouling data of our country main water system and urban sewage. As a result urgent work presently is to develop online auto-clean device which can be put into practice, build fouling model which can direct actual project, such as cleaning period, the value of fouling resistance, resistance curve, etc.

REFERENCES

- [1] Liu Jin-ping, Liu Xue-feng, Kong Qing-jun. Experimental Study on Fouling Resistance of Cooling Water in Condenser of Chiller, Fluid Machinery, 2004, 32(3).
- [2] Yang Shan-rang, Xu Zhi-ming, Sun Ling-fang. Fouling and Strategy of Exchange Equipment, Science publishing company, Beijing 2004.4.
- [3] Kern, D. Q., and Seaton, R. E., A theoretical analysis of thermal surface fouling, Br. Chem. Eng., 4, 258-262(1959).
- [4] Epstein, N., Fundamentals of heat transfer surface fouling: With special emphasis on laminar flow, in Low Reynolds Number Flow Heat Exchangers(S. Kakac, R.K. Shah, and A. E. Bergles, eds.) Hemisphere, Washington, D.C., 1982, pp951-964.
- [5] O'Callaghan, M., Fouling of heat transfer equipment: Summary review, in Heat Exchangers: Thermal-Hydraulic Fundamentals and Design (S. Kakac, A. E. Bergles, and F.

- Mayinger, eds.), Hemisphere, Washington, D.C., 1981, pp1037-1047.
- [6] Kern, D. Q., and Seaton, R. E., A theoretical analysis of thermal surface fouling, *Br. Chem. Eng.*, 4, 258-262(1959).
 - [7] Epstein, N., Fouling in heat exchangers, in *Proceedings of the Sixth International Heat Transfer Conference*, Toronto, Canada, August, Vol. 4, Hemisphere, Washington, D.C., 1978, pp279-284.
 - [8] Zubair S M, Sheikh A K, Shaik M N. a Probabilistic Approach to the Maintenance of Heat-Transfer Equipment Subject to Fouling. *Energy*, 1992, 17(8):769-776.
 - [9] Xu Zhi-ming, Guo Shu-Qing, Yang Shan-rang. Analytical Fouling Model Based on Probabilistic Approach, *Journal of Engineering Thermophysics*, 2003.3, 24(2).
 - [10] Rankin B H, Adamson W L. Scale Formation as Related to Evaporator Surface Conditions. *Desalination*, 1973, 13:63-87.
 - [11] Baier R E. Substrata Influences on the Adhesion of Micro-organisms and Their Resultant New Surface Properties. In: Bitton G, Marshall K S, eds. *Adsorption of Micro-organisms to Surface*. New York: Wiley-Interscience Publishers, 1980. 59-104.
 - [12] Kjaer E B. Bioactive Materials for Antifouling Coatings. *Progress in Organic Coatings*, 1992, 20: 339-352.
 - [13] Müller-Steinhagen H, Zhao Q. Anti-Fouling by Metal Surface Modification. UK Patent. GB96/02681, 1999.
 - [14] Müller-Steinhagen H, Zhao Q. Investigation of Low Fouling Surface Alloys Made by Ion Implantation Technology. *Chemical Engineering Science*, 1997, 52: 3321-3332.
 - [15] Yu Xiu-min, Wu Jin-xiang, Yu Tian-lan. The rotating and vibrating spiral of cleaning and preventing fouling automatically, *CHEMICAL CLEANING*, 1996.9, 12(3).
 - [16] Cheng Lin, Tian Mao-cheng, Zhang Guan-min, Qiu Yan. Theoretical Analysis of Complex Heat Transfer Enhancement by Flow-induced Vibration. *Journal of Engineering Thermophysics*, 2002.5, 23(3).