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Evaluation of Surface Coatings on Heat Exchangers

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Compact heat exchangers are very popular due to their relatively low cost, effectiveness and compactness. In many industries plate heat exchangers are being used to replace shell and tube heat exchangers. In order to utilize heat exchangers in dirty applications, coatings can be applied to the heat transfer surfaces to enhance effectiveness and minimize fouling. Coating selection is extremely important since the wrong coating can decrease unit effectiveness, cause more fouling, or erode the surface.

An experimental investigation of coating effectiveness in compact plate heat exchangers is presented. New, cleaned and coated plate heat exchangers are considered in this study. Heat exchangers have been exposed to untreated lake water for various time periods. Transient effectiveness results compare the rate of fouling for coated and uncoated heat exchangers. Additional heat exchanger results compare end of test deposit weight gain. Transient observations of heat transfer surface appearance are also presented. All heat exchanger plates showed some deposit accumulation for the periods considered.

Results indicate that the thermal performance of the unit decreases with time, resulting in an undersized heat exchanger. Uncoated plates accumulate deposits up to 50% faster than coated plates and show a decrease in performance by approximately 20%. Surface coating and exposure time can affect fouling. Insight into improving the performance of these units and enhancing heat exchanger efficiency is discussed. Finally, a detailed examination of plate design, coatings, and heat exchanger operating conditions is currently being performed. Preliminary results indicate enhanced plate performance can be achieved by utilizing custom enhanced plates produced by Ridgidized Metals Corporation.

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1. Introduction

Fouling is complex, costly, and affects many different industries. Deposits create an insulating layer that restricts the flow of heat between the fluids, causing process efficiency to be reduced. Despite numerous investigations and years of studying the formation of deposits on heat transfer surfaces, this remains a major process problem. This study will examine transient fouling of heat exchangers that have been exposed to untreated lake water.

Deposit formation depends on the heat transfer surface, fluid dynamics and the environmental conditions. The flow, temperature and chemical composition of the fluid influence the composition of the deposit. The economic impact of fouling is enormous. Industries in the United States estimate the annual cost of wasted energy, due to fouling, is in excess of $250 million US dollars.

Muller-Steinhagen and Zhao [1997] investigated the development of stainless steel surfaces with low surface energy created by ion implantation. Zhao et al. [2008] further studied the advantages of ion-implanted stainless steel surfaces. Their experimental results showed that these implanted stainless steels, particularly SiF3+ implanted stainless steel performed much better than untreated stainless steel in reducing bacterial attachment. Rosmaninho et al. [2007] discussed modifying stainless steel process surfaces for use in the dairy industry. Kukulka et al. (2008)] investigated the effect of materials, surface coatings and finishes on fouling.

Plate style heat exchangers are being widely used throughout industry today. Their compact design, ability to transfer heat and low costs has made them easily adaptable for many systems. Large heat transfer coefficients are produced using Chevron/Herringbone patterns that increase surface area and induce turbulence in the flowing fluid. Water is typically used for cooling in many applications. The United States power industry pumps approximately 106 million gallons per minute for cooling purposes (as reported by Pugh and Hewitt [2004]). Some applications use once through water, while others utilize a closed loop system involving cooling towers and refrigerants. Closed loop systems may be less susceptible to fouling, but require costly equipment investments.

Little is known about the plate heat exchanger (PHE) fouling. This study will evaluate the tendency of plate heat exchangers to foul, and the effect of fouling on performance.

2. Experimental Details

Plate Frame Heat Exchangers (PHE) and Brazed Plate Heat Exchangers (BPHE) were evaluated in this study at the Great Lakes Research Center of the State University of New York College at Buffalo. The instrumented heat exchangers ran for the desired time period using once through, untreated surface water from Lake Erie. PHE's can easily be disassembled to allow an in-depth study of the internal fouling patterns that occur on individual plates. Each plate was inspected before and after testing. A summary of tests performed is given in Table 1.

Several heat exchangers were studied after coating their plates. Inspection, photos and careful weighing of each plate provided the means to evaluate the fouling patterns on the surfaces. All of the coatings exhibited no visual signs of delaminating or damage after exposure.

2.1 Heat Exchangers Studied

- Large PHE manufactured by API Heat Transfer (SN7-200-19) designed for a maximum pressure of 150 psig and temperatures from 32 ^{O}F to 230 ^{O}F.
- Small PHE manufactured by Swep International (M10NHx20) designed for a maximum pressure of 174 psig and temperatures from 32 ˚F to 230 ˚F.
- Brazed plate heat exchanger (manufactured by Advanced Industrial Components Inc.) consisting of 12 plates.

2.2 Coatings Utilized

- Teflon based coating used for temperatures ranging from -100˚F to 500˚F and pressures to 4000 psi.
- PPG E-Coating (Electro Coating) – used for temperatures to 400˚F.
- Epoxy based coating specifically designed to reduce the effects of fouling, good for temperatures to 275˚F and pressures to 1750 psi.
- Heresite is a coating that is conventionally used on heat transfer equipment. This is a phenolic thermosetting coating that can resist temperatures to 400˚F.

Table 1 PHE Types and Conditions

Type	Uncoated	Uncoated Cleaned and Rerun	Teflon Based Coating	Electro - Coating	Epoxy Based Coating	Heresite Coating
Large PHE	X	X	X			
Small PHE	X	X		X	X	
Brazed PHE	X					X

2.3 Sample Processing and Data Collection

Each PHE was equipped with four pressure transducers and four thermocouples, located at fluid entrances and exits to the PHE. Data was collected with a Lab view data acquisition system. The process fluids came from an unregulated, unfiltered natural source. Tests ran for 45 days at a constant flow rate (1 GPM), constant hot side temperature of 100 deg F and a variable (natural source) cold side temperature that averaged 46 deg F.

At the end of the test period the heat exchanger was shut off, drained and completely air dried. After drying, the heat exchangers and the individual plates were weighed; observations of the surface appearance of each plate recorded; and finally, photographs of the plate surfaces were taken to capture the characteristics of the deposits on each surface.

3. Results And Conclusions

Typical heat transfer results for a large uncoated PHE are shown in Figure 1. Over the length of the study, heat transfer was reduced by almost 15%. In the first quarter (270 hours), the energy removal is constant, while the second quarter shows a decline of approximately 33.5 BTU/HR. The third quarter shows a period of stabilization with a decline in energy removed of 3.8254 BTU/HR. Finally, the last quarter shows deposit growth and a decline in energy removal of 22.241 BTU/HR.

Once all of the plates were properly photographed, each individual plate from the heat exchanger was weighed. The original and fouled weights were compared, Delta Weights calculated and presented in Figure 2. A visualization study was performed in figure 3 to inspect fouling patterns internal to the heat exchanger. More fouling took place in the upper plates, specifically plates 7 – 13. The individual plate visual inspection showed that the bottom plate (plate number 2) had a distribution of deposits across the entire plate with a concentration in the corner of the inlet section. One also sees the onset of corrosion on the upper plate (see Figure 3) in the corner adjacent to the inlet. Material buildup near the discharge section was evenly distributed and deposits were easily removed during plate cleaning. These results were for the large, uncoated PHE, results differed for other PHE cases.

The data that was collected from the uncoated plate heat exchangers showed major performance deterioration over the 45 day testing period due to the fouling deposits that had accumulated. Performance of uncoated PHE's is reduced by 56.5%, while the performances of coated heat exchangers were reduced by 47%. Performance of small uncoated PHE's exposed to lake water is decrease by 77%, while small E-Coated PHE's show a reduction of only 58%.

Performance of a PHE after cleaning typically showed improvement. Large, uncoated PHE's increased performance by 1%; Small, uncoated PHE performed 11% better; and small, E-Coated PHE's showed 8% better performance. An increase in performance was typical in all performance evaluations of cleaned PHE's.

Visual fouling patterns were not consistent in either deposit pattern or accumulation amount. Typically plates accumulated deposits in the corners adjacent to the inlet and discharge. Corrosion was eliminated in all cases using coatings. Enhanced plate designs, utilizing Rigidized Metals specialized heat transfer surfaces, are currently being evaluated. Preliminary results show excellent performance for uncoated plates; while newly designed, Rigidized Metals Corporation coated PHE's shows little performance degradation.

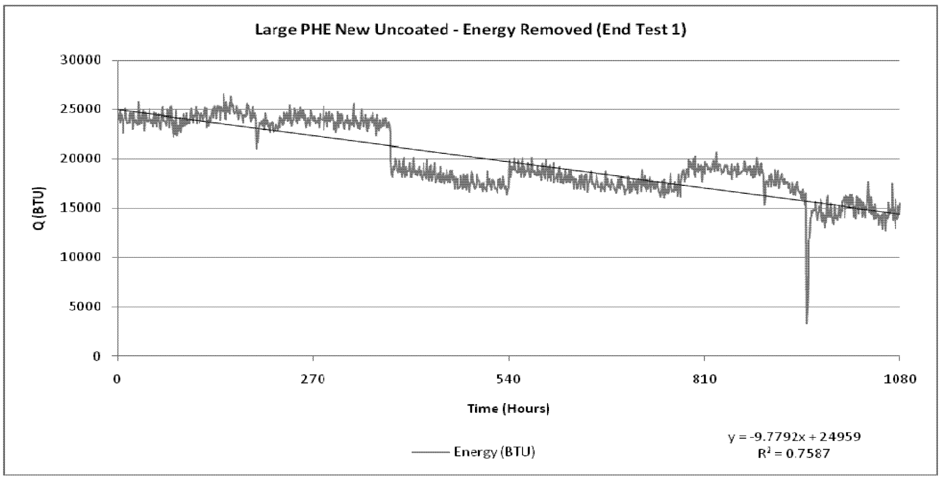


Figure 1 Transient Energy Removal of a Large, Uncoated PHE Running Once Through Lake Water

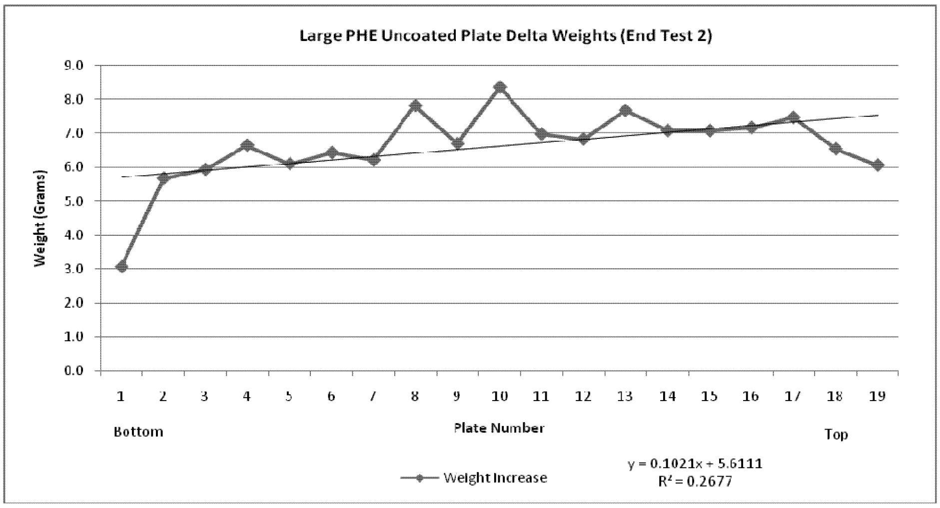
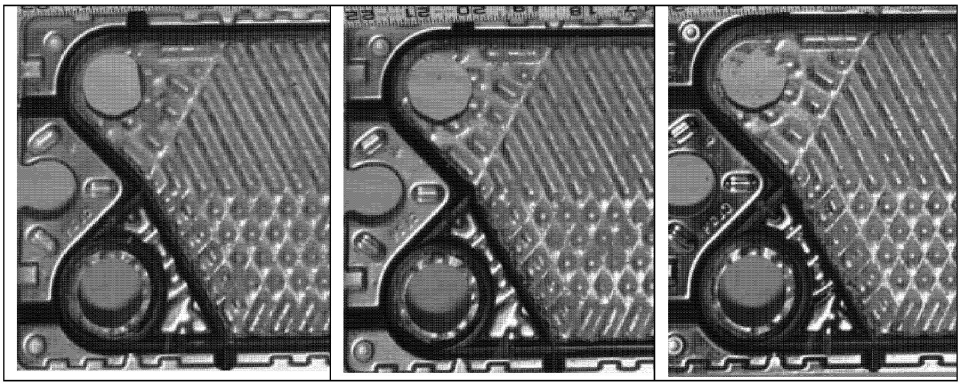


Figure 2 Change in Weight, after 45 days, of Individual Plates in a Large, Uncoated PHE Running Once Through Lake Water



a.)Top b.) Middle c.) Bottom

Figure 3 Photographs of Individual Plates from the Left Section of a Large Uncoated, PHE after 45 days of Running Once Through Lake Water (a) Plate 18 (b) Plate 10 (c) Plate 2

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