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Fouling Investigation of Brazed Plate Heat Exchangers

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Fouling costs process industries billions of dollars annually. The economic and technical problems associated with fouling in process systems are known and well documented. A wide range of industrial processes involves the transfer of heat energy. In recent years the plate frame heat exchanger has emerged as a viable alternative to shell and tube exchangers for many applications. Such units are comprised of a series of plates, mounted in a frame and clamped together. It is well known that the performance of a heat exchanger is directly affected by the accumulation of unwanted deposits on heat transfer surfaces and results in a deficiency in the energy available. Additionally deposits can restrict fluid flow by narrowing the flow area and they also create a rough surface for the flowing fluid, resulting in increased pumping requirements. Total energy requirements increase because of loss of heat recovery and additional pumping requirements.

The control of the unwanted deposits in cooling water systems is often accomplished by the use of chemical additives that include; corrosion inhibitors, dispersants, detergents, threshold treatment to restrict crystal formation, crystal modifiers, biodispersants and biocides. Many governments and regulatory bodies have laid down stringent regulations for the control of water emissions creating additional operational costs. Therefore an economical design that allows for easy service would be the preferred alternative.

This study has focused on the effect of fouling on brazed plated heat exchangers. In this experiment, brazed plate heat exchangers were exposed to once through, cooling and process water. Upon examination of the heat exchanger, a large amount of fouling could be seen at some locations in the heat exchanger. Not only does the length of time affect the amount of fouling, but fluid temperature and velocity also has a strong influence. As each exchanger was removed from service, observations about the conditions of each exchanger were made. These observations included: visible film, color change, corrosion, deposit characteristics, etc. Additional tests were performed on previously operated heat exchangers that were chemically cleaned. In these cases a decrease in the rate of fouling can be seen after the exchanger has been cleaned.

1. INTRODUCTION

In recent years the plate frame heat exchanger has emerged as a viable alternative to shell and tube exchangers. Figure 1 illustrates a typical brazed plate heat exchanger constructed from stainless steel with copper brazing. This brazing process eliminates the need for gaskets or rolled joints and requires no pressure-retaining parts.

Figure 1 Brazed Plate Heat Exchanger Showing a Typical Flow Pattern

Fouling is complex, costly, and affects many different industries. Its development is more rapid in flowing systems where adequate nutrients are available. Fouling formation depends on the environmental conditions and properties of the process surface. The flow, temperature and chemical composition of the fluid influences the formation of the deposit. In systems with high shear forces, the deposits may grow only to a few micrometers, while in other systems, deposits can reach the thickness of several centimeters (Heitz et al. 1996). Stronger shear forces will not entirely prevent the deposits from forming, but will lead to thinner and firmer deposits. A low or stagnant flow allows growth to more easily attach to the surface.

Design approaches to overcome fouling include treatment, design and over design. Nesta and Bennett (2005) suggest over design using 20% excess area. Other design approaches suggest avoidance of fouling altogether. This is accomplished by optimization of design parameters and performed on a case by case basis.

2. EXPERIMENT

This ongoing heat exchanger fouling study took place at the Great Lakes Center for Environmental Research located at the confluence of Lake Erie and at the head of the Niagara River. It is unique facility that is part of the State University of New York System and is the only facility to operate an on-shore experimental laboratory on the Great Lakes. Once-through water from Lake Erie was used providing variable flow rates and temperatures. Nutrient level of the water varied with inlet conditions.

Several brazed plate heat exchangers were used in this study. The initial weights of the heat exchangers were documented. After the specified time period of running once-through lake water through the heat exchangers, the exchangers were taken off line. A large amount of fouling in the flow areas of the heat exchangers could be seen for some conditions. In several cases the heat exchangers were chemically cleaned after running and put back into service for another period of service. In either case, when the service times were complete, the exchangers were dried and weighed. They were then cut up in order to be analyzed and photographed. As each exchanger was removed from service and cut up, observations about the conditions of each exchanger were made. These observations included: visible film, color change, corrosion, deposit characteristics, etc

2. RESULTS

Figure 2 shows the locations in the exchanger that were evaluated. The areas examined provide a comprehensive representation of the fouling in a brazed heat exchanger. Table 1 provides fouling amounts and conditions considered. A decrease in the rate of fouling can be seen after the exchanger has been cleaned. Perhaps this is the result of the inhibitor being applied at the time of cleaning and the surface energy being changed. Figure 3 shows a comparison of fouling at various locations in an exchanger that has been in service for one year. It shows the characteristics of the fouling and how severe the fouling was after one year of operation.

Initially, the exchanger surface consisted of a shiny smooth metallic finish. For short run cases, surface deposits gradually develop and were spotty and not consistent. Several areas on the exchanger contained large amounts of deposits that were easily flaked from the surface, whereas in most areas the material appeared to adhere to the surface and was not easy to remove.

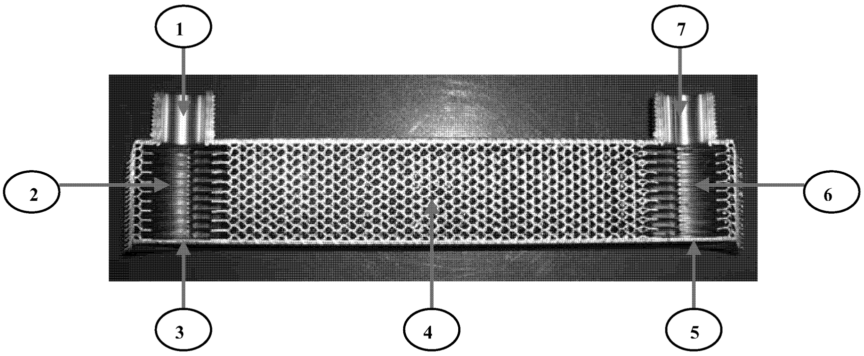
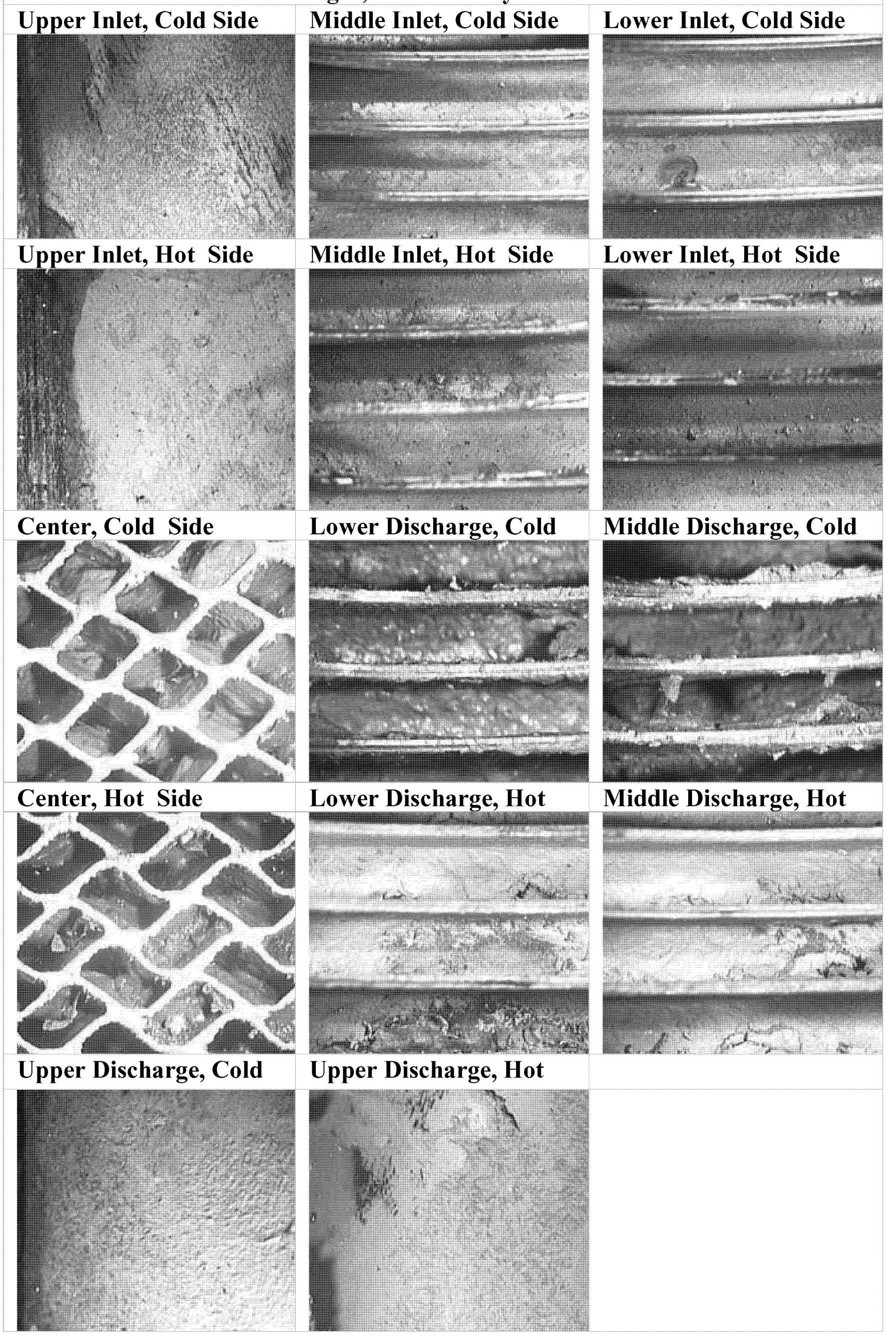


Figure 2 Brazed Plate Heat Exchanger Observation Locations	
1	Upper Inlet
2	Middle Inlet
3	Lower Inlet
4	Center
5	Lower Discharge
6	Middle Discharge
7	Upper Discharge

Table 2 Fouling Weight (lbs) accumulated after running once through lake water through a brazed heat exchanger for various conditions

	Run Time (days)	Time After Cleaning (days)	Fouling weight (lbs)	Inlet Temp. Hot Side (deg F)	Inlet Temp. Cold Side (deg F)	Flow (ft/sec)
1	45	0	0.337	100	40	2
2	45	0	0.120	80	40	3.75
3	45	0	0.140	100	40	3.75
4	45	45	0.132	100	40	2
5	45	45	0.032	80	40	3.75
6	45	45	0.083	100	40	3.75
7	365	0	0.809	100	40	2
8	365	0	0.416	100	40	3.75

Figure 3 Comparison of Fouling at Various Locations of a Brazed Heat Exchanger, after 365 days for Test 8.



The 90 day observations (after a cleaning at the midpoint) showed fewer deposits than the 45 day observations, and once again showed both flaky and well developed deposits. The difference in the consistency of the deposits was the result of the shear forces present. Fewer deposits, in the case of the 90 day study, could be the result of the inhibitor that was applied in the cleaning process. In both cases, the low velocity runs produced the most fouling. Table 3 describes the surface appearance of a low flow situation, described in Test 7. Hays et al. (2005) discuss fouling tendency in smooth and rough surface tubes and provide similar results for a shorter time period.

Table 3 Surface Appearance Observations of a Brazed Plate Heat Exchanger for Test 7.

	Low Flow, Cold Side	Low Flow, Hot Side
Upper Inlet	Light deposit of film with medium thick patches of film scattered across inlet. No metal visible.	Light and inconsistent deposit of film. Around 40 percent metal still visible.
Middle Inlet	Light deposit of film, consistent, no metal visible.	Mostly medium deposit of film with thick deposits near the upper rand hand corner.
Lower Inlet	Light deposit of film, consistent, no metal visible, some very small clumps.	Medium deposits of film, inconsistent, lighter than deposits in middle inlet.
Center	Very thick deposits of sediments, blocking around 40 percent of flow area.	Very thick deposits of sediments, blocking around 40-50 percent of flow area.
Lower Discharge	Light to medium consistent deposits of film.	Extremely thick deposits of sediment blocking nearly 60 percent of area. Heavier on edges. Mostly brown-orange sediment with some medium-sized green clumps.
Middle Discharge	Light to medium consistent deposits of film. One heavy, almost flaking spot in lower left corner.	Thick deposits of brown-orange sediment, heavier on left hand side. Small green clumps mostly on right hand side.
Upper Discharge	Thin deposit of film with inconsistency on right hand side. Orange substance in lower left corner. Some metal visible.	Thin, inconsistent deposits of film, heavier on sides. Some metal visible.

Larger amounts of fouling deposits were always observed on the hot side of the exchanger. These results would be expected, however the amount of fouling that the low velocity and higher temperature cases yielded were not expected. Not only does immersion time affect the amount of fouling, but surface conditions, fluid temperature and velocity also have strong effects, agreeing with Nesta and Bennett (2005) view that fouling correlates with velocity, temperature and composition. After the exchanger had been cleaned chemically the deposits did not grow as fast as they did in a factory delivered heat exchanger. Future fouling studies will focus on the effect of surface coatings.

3. REFERENCES

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