



Failure analysis of a plate heat exchanger used in a blast chiller

A. Gagliardi^{a,b}, A. Lanzutti^a, M. Simonato^b, R. Furlanetto^b, M. Magnan^a,
F. Andreatta^{a,*}, L. Fedrizzi^a

^a University of Udine, Polytechnic Department of Engineering and Architecture, Via del Cotonificio 108, 33100 Udine, Italy

^b The Research Hub by Electrolux Professional, Viale Treviso 15, 33170 Pordenone, Italy



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ABSTRACT

A stainless steel plate heat exchanger (PHE) was received to investigate the cause of its perforation in service leading to mixing of the fluids (water and refrigerant) circulating in the system. The heat exchanger was employed in a blast chiller using seawater subjected to a reverse osmosis process followed by salinization and sanitizing treatments. This study includes the analysis of water samples in different points of the system, a metallurgical characterization of the material of the plates, a study of the composition of corrosion products and an evaluation of the electrochemical behaviour of the material in the water samples extracted from the system. The study revealed that the material of the plates was perforated by a corrosion process due to the high level of chlorides present in the water employed in the blast chiller. Moreover, the localized attack of the stainless steel plates is enhanced by the peculiar geometry of the heat exchanger that leads to crevice corrosion in the region of the joint between overlapping plates. The results obtained in this work indicate that the failure is associated to the water treatment process performed upstream of the heat exchanger.

1. Introduction

The plate heat exchangers (PHE) are fundamentally composed of overlapping plates. These plates are usually corrugated in order to induce a non-laminar flux in the system. The fluids passing through the PHE are separated by gaskets. In PHEs these fluids pass in the interspace between the plates in an alternated manner. PHEs are normally used in several fields including food processing, air conditioning and refrigeration systems, service heating and cogeneration, offshore gas and oil applications, marine applications, chemical processing, pulp and paper industry applications and solar energy applications [1]. The wide use of this type of heat exchangers is mainly due to a high heat exchange coefficient associated to the high heat exchange surface and the non-laminar flux of the fluids. Due to the high heat exchange coefficient, the PHEs are usually more compact and cheaper than other types of heat exchangers [1]. The failure of these types of heat exchangers is usually due to the following causes: fouling, corrosion and erosion [1–3], while in some cases fatigue can occur [4]. It is well known that austenitic stainless steels can be affected by localized corrosion in the form of pitting when in contact with tap water under favorable conditions [5]. These conditions include: high concentration of chlorides, high concentration of oxygen or other strong oxidants and high temperature [6–8]. Pitting attack is characterized by an acidification of the solution inside the pits [9]. This acidification increases the aggressiveness of the solution. The presence of an interstitial zone can lead to a crevice corrosion process in stainless steel. Also in this case, the electrolyte inside the crevice might become acid due to a local oxygen depletion inside the crevice [10]. For both types of corrosion, increasing the concentration of chlorides and the temperature leads to a higher susceptibility to localized corrosion of the austenitic stainless steels [11–14].

* Corresponding author at: University of Udine, Polytechnic Department of Engineering and Architecture, Via del Cotonificio 108, 33100 Udine, Italy.
E-mail address: francesco.andreatta@uniud.it (F. Andreatta).

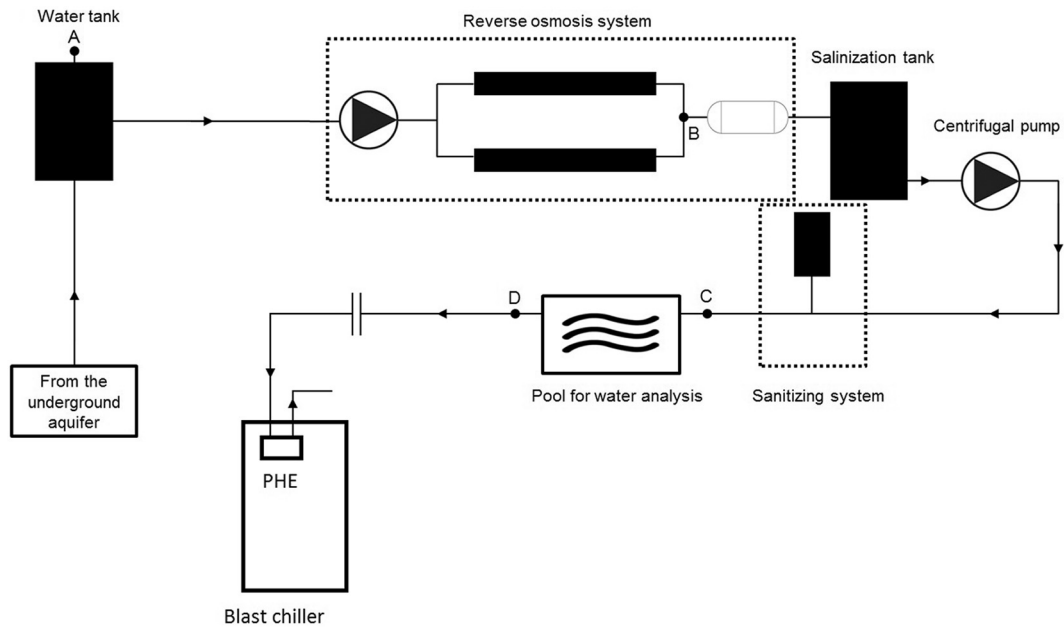


Fig. 1. Scheme of the water treatment plant employing an heat exchanger in the blast chiller. Points where water samples were collected in the plant for composition analysis are indicated in the scheme: A (water tank), B (outlet of the reverse osmosis system), C (outlet of the sanitizing system) and D (inlet of the blast chiller).

The case under study concerns a failure analysis of a PHE used as a condenser in a blast chiller. In order to determine the causes of the failure, this study consists in the following steps: visual inspection, to determine the point of failure and to identify the type of damage; SEM-EDXS investigation to determine the morphology of attack; water analysis to evaluate the aggressiveness of the solution in contact with the sample; electrochemical tests in order to evaluate the electrochemical behavior of the plates in the water samples extracted at different points of the system under investigation.

2. Anamnesis

The stainless steel PHE of the blast chiller considered in this work operated for nine months after installation at a client site. After this period, the blast chiller lost its ability to reduce the temperature of the fluid, and mixing of fluids circulating in the heat exchanger was reported. The fluids passing in the heat exchanger are seawater subjected to a reverse osmosis process followed by salinization and sanitizing treatments and the cooling fluid R404A. A scheme of the water treatment plant and the location of the blast chiller with PHE in the system are schematically shown in Fig. 1. The seawater used in the installation is pumped from an underground aquifer and stored in the tank A. Due to its high salinity, the water is treated according to the scheme visible in Fig. 1 in order to make it potable. The first step of the treatment consists in a reverse osmosis process. Subsequently, the water is re-salinized in a dedicated tank and sanitized with Chlorostabil 299-B (a solution of sodium hypochlorite) with an automatic system continuously adding the sanitizing agent to the water. Successively, the water passes through a pool where it is periodically analyzed and other sanitizing agents could be further added.

3. Materials and methods

3.1. Visual inspection of the damaged component

Fig. 2 shows a section of the AISI 304 stainless steel PHE near the entrance of the fluids (water and R404A refrigerant). The perforation occurred in the portion of the heat exchanger located near the entrance of the fluids. The plate where the perforation was observed (and the position of the leak) is indicated in Fig. 2A. The water passes through the channels on the left side, while the refrigerant fluid flows through the channels on the right side. As it can be seen in Fig. 2A, the inlets of the fluids are uniformly covered by abundant deposits. The same type of deposits are observed on the AISI 304 plates of the heat exchanger. Fig. 2B shows that the deposits are yellowish on the surfaces in contact with water, while they are black on those in contact with the refrigerant. In particular, it can be seen that the plates of the heat exchanger are uniformly covered by the deposits (Fig. 2B).

The plate exhibiting perforation (indicated in Fig. 2A) was extracted from the heat exchanger for characterization. Fig. 3A shows the region of the plate where perforation occurred while the point of perforation is visible in Fig. 3B. As it can be seen in Fig. 3B, the perforation occurred near the joint between two overlapping plates that was obtained by brazing with copper. This damage was most likely associated to the mixing of the fluids.

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