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# Corrosion failure analysis of galvanized steel pipes in a closed water cooling system

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ABSTRACT

The present study is focused on the corrosion failure analysis of a water cooling system serving a polyethylene terephtalate (PET) preform molding plant.

Piping mainly located both after the water pretreatment and in the injection molding machines was affected by an extensive corrosion phenomenon and several leakages of coolant occurred, involving the risk of loss of functionality of the whole plant.

The main problem detected in closed cooling circuits was a marked modification of the water chemistry and a great amount of metal ions leading to recurring fouling of the inner surfaces of molds and cooling channels.

Analysis of water flowing in the closed cooling circuit operating at 6 °C revealed a very high amount of metals in the flowing water and in the sediment (zinc and iron). Moreover the water pH was slightly acidic. Data were compared with water from supply well.

Preliminary electrochemical characterization was carried out on galvanized steel pipe, in order to evaluate the aggressiveness of water both from the cooling circuits and from the supply wells.

The results of laboratory analysis together with the scrutiny of the available technical documentation showed that the damage of the plant was the consequence of an inadequate plant management, mainly for what concerns materials selection and water chemical treatment.

## 1. Introduction

Water cooling systems are an essential part of many industrial processes. They require proper chemical treatment and preventive maintenance in order to ensure continuous plant productivity. The functionality and the service life of the cooling system equipment are provided by selecting suitable materials of construction and supply water of required quality [1,2]. Typical building materials for cooling systems include carbon steel, stainless steel, galvanized steel, copper and copper alloys. The addition of a corrosion inhibitor, sometimes coupled with a biocide, can help to prevent scale formation and corrosion in industrial water cooling systems. Chromate, nitrite and molybdate compounds are the most reliable inorganic corrosion inhibitors [3–6]. Recently, organic/inorganic mixtures have been also developed as corrosion inhibitors [7,8]. Closed cooling systems often require also the addition of antifreeze.

Galvanized steel pipes are often used for water cooling systems both in industrial plants and in domestic buildings [9,10]. The extensive use depends on their good performance against corrosion, their mechanical workability and the resistance to biofouling [11,12]. The zinc layer protects steel against corrosion by two effects: a barrier effect and a galvanic protection because Zn acts as a sacrificial anode. However, galvanized steel pipes can be affected by localized and generalized corrosion that sometimes lead to the

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corrosion failure of water cooling systems before their expected service life [13–16]. The composition of the water heavily affects corrosion phenomena in water distribution pipes. For example, soft waters are referred as aggressive, because they tend to prevent the formation of films of calcium carbonate [17]. Corrosion can also be enhanced either by high levels of chloride and sulphate, low pH or high temperature [18,19]. The rate of corrosion decreases considerably when protective films originate on the surface of the metal. Monitoring and prevention of corrosion phenomena is of outstanding importance in order to avoid main damages like pipe break-down and water leakages, decrease in the cooling efficiency, collapse of the system, shut-down of the whole plant for maintenance services [20].

The present paper reports on the corrosion failure analysis of galvanized steel piping in a water cooling system serving a PET (polyethylene terephtalate) preform molding plant.

PET preforms are the basis of very common plastic bottles typically used for drinking waters, fruit juices, soft drinks, oils and milk. PET preforms are usually produced by injection molding. The starting material are PET pellets, melted at 270 °C and injected under high pressure into a mold to make the preform. In each inner mold part there is a water cooling circuit. The temperature of cooling water is generally in the range 6–20 °C. Proper functioning of the cooling circuit is critical for ensuring stability of the end-product. If PET is exposed to temperatures above 270 °C, the polymer may thermally degrade and produce acetaldehyde. Acetaldehyde can migrate into bottled drinks and give the product an acidic taste [21–23]. Therefore the proper control of the process is essential to obtain products in compliance to customer requirements.

The aim of the present study was to determine the reasons of unexpected corrosion failures detected at different locations of the whole piping cooling system.

The plant under investigation is located in the center of Italy and has 20 lines of production (injection molding machines) that operate 24 h/day. Six closed cooling systems, operating at 6 °C and 20 °C, serve the injection molding machines. A schematic of the plant site is reported in Fig. 1. The plant site includes two different wells: i) Well 1, serving the cogeneration plant to recover part of the energy required for the process; ii) Well 2, providing make-up water to the closed cooling circuit in order to compensate potential leakages.

Water is pumped by submerged pumps from both wells. The internal walls of the wells (30 cm diameter) are made of carbon steel. After pretreatment, water from Well 1 is conveyed to water pretreatment and cogeneration system by galvanized steel pipes. Water pretreatment is constituted by sand filter and softener. On the other hand, water from Well 2 is conveyed by polypropylene pipes to a drum, then to sand filter and softener and finally to the chiller. Within the water pretreatment, the interconnections are mainly constituted by galvanized steel, but copper, carbon steel and stainless steel are still present. From the chiller to the inlets of production lines, water flows through pipes made of AISI 304. Then the water enters the closed cooling circuits of the PET preform molds

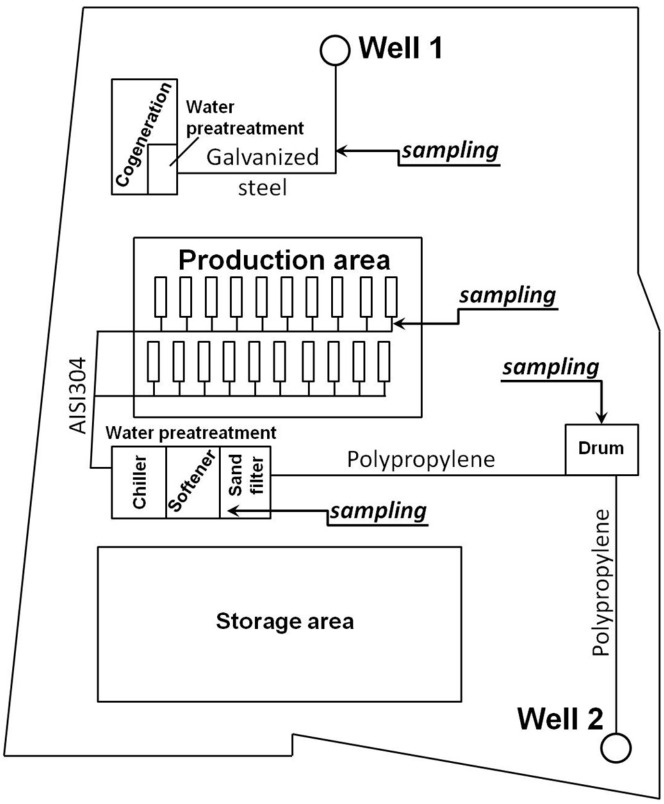


**Fig. 1.** Schematic of the plant site. Arrows indicate the original location of analyzed metal samples.