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Analysis of the factors involved in failure of a brass sleeve mounted on an electro-valve

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ABSTRACT

Several electro-valves have failed because of the fracture occurred on the internal sleeve made in a typical free cutting leaded brass CW614 N (UNS 36000). The morphology of the observed fracture surface clearly indicates that the failure phenomenon has been ruled by a stress corrosion cracking mechanism. On the other hand, all the electro-valves operate in an environment featured by potable water that does not justify an alchaline concentration able to induce the SCC phenomenon. The analysis of the observed surface and the comparison of the stress that can induce SCC clearly point out that the failure has been induced by the application of excessive torque on the threaded sleeves to grant their fixing. The performed investigation allows us to indicate the correct procedure in order to avoid the failure of the sleeves and also the change of the applied alloy or an excessive increase of the resistant thickness of such a component.

1. Introduction

Some typical electro-valves are constituted by a core where a sleeve is located within the inducing coil. This sleeve assures the correct sliding of an internal mobile stopper activated by an electromagnetic field (Fig. 1).

The electro-valves equipped with a brass sleeve are generally used for the application in the distribution network of the drinking potable water. On the other hand, some failure cases have taken place in this environment and they are caused by the fracture of the inner sleeve (Fig. 2). The sleeve is forced within the hole through the bolt applied on the upper threaded extreme.

The size, shape and surface features of the sleeve can be observed in Fig. 3.

The brass alloys are frequently affected by a stress corrosion cracking (SCC) process, especially promoted by alchaline environment usually featured by the presence of ammonia (NH_3). On the other hand, the wide geographic diffusion of the observed failure events make it difficult to think that water can be strongly affected by ammonia concentration in such a high concentration to induce SCC phenomena. Actually, the European and Italian rules about the pollution of potable water does not permit a NH_4^+ concentration besides 0.5 mg/dm^3 (Table 1) [1].

2. Experimental observations

The experimental observations have been performed on several failed samples. Several failed samples have been observed in the same condition of extraction from the electro-valve while another group has been completely fractured to allow the

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Fig. 1. An example of a whole electro-valve with the threaded brass sleeve.

Fig. 2. Example of a fractured sleeve mounted on an electro-valve.

examination of the fractured surface and permit the comparison among the surface of the intentionally induced fracture and the one occurred during the working period (Fig. 4).

The samples have been observed through a SEM–EBS–EDS equipment in order to analyze the morphology of the fractured surfaces and identify the possible presence and the nature of the residuals present on the analyzed surfaces (Fig. 5).

The surfaces of the fracture formed during the working period show an intergranular morphology abundantly covered by several corrosion residuals (Fig. 6) (Table 2). The layers of corrosion residuals examined on the outer surface of the sleeves (Figs. 7–9) show a heterogeneous composition characterized by the frequent presence of copper, lead and zinc with the sporadic presence of chlorine, potassium and silicon probably derived from the chemical compounds present in the potable water (Table 3). In some parts of the corrosion layers some acicular phases have been pointed out (Fig. 9), that are featured by a significant presence of lead (Table 4), especially if compared with other corrosion layers. Although the possible presence of NH_3 cannot be recognized because this chemical species completely evaporates, its significant concentration can be excluded by the absence of any residual scale featured by blue and azure hue that should be present as a consequence of the exposure to an environment strongly enriched by NH_3 that is responsible for such a type of localized patination.

The fracture development observed on the surface of the sleeve confirms a brittle behaviour of the material during the crack formation corroborated by the presence of several secondary branches (Figs. 10–12). The analysis of the corrosion residuals observed within the crack clearly confirms a dezincification phenomenon. The thickness of such a revealed layer of residuals (trapped between the crack surface) is approximately about 5 μm (Table 5), such a phase can perform a load on the notch tip that has to be summed to other external applied loads.

On the contrary, the fracture intentionally induced on the non-cracked portion shows a characteristic ductile aspect (Fig. 13).

3. Discussion

The examination of the fracture morphologies clearly indicates the development of a brittle fracture promoted by a stress corrosion cracking process. On the other hand, the corrosion residuals are the typical ones formed on the brass in contact with potable water and organic matter as clearly indicated by several authors [2–5] who revealed presence of dezincification