Title: CATHODIC PROTECTION OF HEAT EXCHANGER TUBES BY MEANS OF MOBILE SACRIFICIAL ANODES

Abstract: Cathodic protection of heat exchanger tubes by mobile sacrificial anodes is an anticorrosion treatment which is done by means of mobile sacrificial anodes (SA) which pass through the heat exchanger tubes carried by cooling water (H₂O). Mobile sacrificial anode, shown in Fig.3 has a form of a ball (1) made of an elastic, porous, polymeric material with the surface covered by metallic elements (A) in the form of points or particles (2) made of metallic material (M₂) having lower electrode potential than the metallic material (M₁) of the protected heat exchanger tube. Due to the presence of electrolyte i.e. water or sea water, a galvanic cell is formed between the metallic elements (A) and the metallic material of the heat exchanger tubes in which an electron donor is a metallic element (A) having lower electrode potential. The anticorrosion protection of heat exchanger tubes is achieved by transfer of electrons from the metallic elements (A) to the metallic material of the heat exchanger tubes.
CATHODIC PROTECTION OF HEAT EXCHANGER TUBES
BY MEANS OF MOBILE SACRIFICIAL ANODES

DESCRIPTION OF THE INVENTION

Technical Field

The subject of the invention is a method of cathodic protection of heat exchanger tubes by means of the mobile sacrificial anodes. According to the seventh edition of the IPC classification, the invention belongs to the following fields:

C23F13/00 – Prevention of metal corrosion by means of anodic or cathodic protection,

F28F19/00 – Prevention of deposit forming or corrosion in heat exchangers, e.g. by using filters.

Technical Problem and Background Art

The principal purpose of large heat exchangers or water condensers in power plants is the conversion of used steam into water. The main parts of the condensers are the front and the rear water boxes, which are connected by thousands of very long tubes. Cooling water, often seawater, enters the front water box, passes through the tubes and leaves the condenser through the rear water box. The steam streams around the heat exchanger tubes, cools down by cooling water running through the tubes, and turns into condensed water. Heat exchangers are usually protected against corrosion by the impressed direct current cathodic protection. The main problem is that the tubes interior is out of reach of the impressed current since it is an electrically screened area, making thus cathodic protection inefficient. Therefore, the heat exchanger tubes have to be made of expensive corrosion resistant material, e.g. CuZn20Al2F34. However, corrosion occasionally takes place even with these materials. It develops from the inner surface of the tubes causing eventually perforation and leakage. This requires shutdown of the plant and replacement of the perforated tubes.

In the professional and patent literature there is no evidence of a technical solution of the protection of heat exchanger tubes against corrosion by means of the mobile sacrificial anodes, which is the subject of this invention.
Essence of the Invention

The solution of protection against corrosion of heat exchanger tubes by this invention is based upon the use of the mobile sacrificial anodes. They are made of sponge rubber elements (preferably balls) like those used for cleaning the tubes, e.g. in Taprogge devices. The difference is that these balls incorporate metallic elements like pins, points or similar elements or particles made of metallic material less noble than the tube material. Such balls are placed into the cooling water which forces them to enter the tubes.

As the balls incorporating metallic elements pass through the tubes an electrochemical process takes place due to their contact. The metal in sponge balls acts as a sacrificial anode thus protecting the inner surface of the tubes that act as a cathode. The metallic elements in the sponge balls gradually wear out due to the corrosion process. Inefficient balls need to be replaced by the new ones.

The use of the proposed method of protection would eliminate the problem of corrosion in heat exchanger tubes. Also, the tubes could be made of cheaper materials.

Description of Figures

Fig. 1 – Elements of electrochemical process in an unprotected heat exchanger tube.

Fig. 2 – Elements of electrochemical process in a cathodic protected heat exchanger tube.

Fig. 3 – Cross section of a mobile sacrificial anode with metallic elements.

Fig. 4 – Heat exchanger with mobile sacrificial anodes in the tubes.

Description of Design and Application

Water containing oxygen, picked-up from air earlier, runs through the condenser tubes. The metal M1 of an unprotected condenser tube, Fig.1, corrodes due to the activity of the localized galvanic cells, the so-called corrosive micro-cells. Anodic process of metal corrosion by ionization and cathodic process of oxygen reduction take place simultaneously on the inner surface of the condenser tubes. Both processes cause corrosion of the tubes. Some points on the inner surface of the tubes act as localized anodes A and other act as localized cathodes K.

Anodic process is:

\[ M_1 \rightarrow M_1^{z_1+} + z_1 \cdot e^- \]
Cathodic process is:

\[ z_1 \cdot e^- + \frac{z_1}{4} \cdot O_2 + \frac{z_1}{2} \cdot H_2O \rightarrow z_1 \cdot OH^- . \]

The whole corrosion process is:

\[ M_1 + \frac{z_1}{4} \cdot O_2 + \frac{z_1}{2} \cdot H_2O \rightarrow M_1^{z_1^+} + z_1 \cdot OH^- , \]

where:

- \( z_1 \) – oxidation number of cation \( M_1^{z_1^+} \)
- \( e^- \) – electron.

If the condenser tubes are cathodically protected, Fig. 2, the electrochemical process occurs due to the galvanic macro-cell. Metal \( M_1 \) of the condenser tube \( K \) is in contact with the metallic element \( A \) of sacrificial anode \( SA \), which is made of less noble metal \( M_2 \). One of the most suitable metals for metallic elements of sacrificial anodes is zinc. The anodic process of metal corrosion by ionization is localized to contact metal \( M_2 \) being stronger electron donor than metal \( M_1 \). The cathodic process of oxygen reduction takes place on the inner surface of the tubes, which means that the tubes are cathodically protected.

Anodic process is:

\[ M_2 \rightarrow M_1^{z_1^+} + z_2 \cdot e^- . \]

Cathodic process is:

\[ z_2 \cdot e^- + \frac{z_2}{4} \cdot O_2 + \frac{z_2}{2} \cdot H_2O \rightarrow z_2 \cdot OH^- , \]

where:

- \( z_2 \) – oxidation number of cation \( M_2^{z_2^+} \).

One of the possible designs of mobile sacrificial anode is shown in Fig. 3.

Mobile sacrificial anode is preferably a ball, 1, made of sponge rubber, e.g. polyurethane elastomer. Metallic elements, 2, can be pins or similar elements or particles molded together with sponge rubber bodies. They have to be less noble than the condenser tube material. Zinc is suitable for this purpose and also soft enough to be harmless to the tubes.
The use of the mobile sacrificial anodes in heat exchangers is presented in Fig. 4. Mobile sacrificial anode in the form of a ball with metallic points is shown in detail A and the one with metallic particles is shown in detail B of Fig. 4.

A number of mobile sacrificial anodes SA are placed into the cooling water $\text{H}_2\text{O}$, which enters the condenser tubes C from the front water box PVK. The sponge bodies (balls) are captured before the cooling water outlet and sent back to the cooling water inlet. While passing through the tubes, the metallic elements of the mobile sacrificial anodes maintain contact with the tube walls. Since the presence of electrolyte (water or sea water) is inevitable, the galvanic cell is formed in which the electron donor is less noble metal i.e. metallic elements incorporated in sponge rubber bodies (balls). Thus, they protect the tubes from corrosion gradually losing weight themselves. The periodic replacement of mobile sacrificial anodes is needed when they become inefficient as their metallic elements wear out by the corrosion process.
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CLAIMS

1. Cathodic protection of heat exchanger tubes by mobile sacrificial anodes, characterized by that the anticorrosion protection of heat exchanger tubes is performed by means of a number of mobile sacrificial anodes (SA) which pass through the heat exchanger tubes carried by the cooling water (H₂O).

2. Cathodic protection of heat exchanger tubes by mobile sacrificial anodes according to the claim 1, characterized by that a mobile sacrificial anode (SA) consists of elastic, porous, polymeric, spherical material (1) and metallic elements (A) in the form of points or particles (2) made of metallic material (M₂) having lower electrode potential and hardness than the metallic material (M₁) of which the heat exchanger tube is made.

3. Cathodic protection of heat exchanger tubes by mobile sacrificial anodes according to the claims 1 and 2, characterized by that the metallic elements (A) of mobile sacrificial anode (SA) are made of zinc or other metallic material.

4. Manufacturing procedure of mobile sacrificial anodes according to the claims 1 and 2, characterized by that the metallic elements (A) are incorporated in a mobile sacrificial anode (SA) during its manufacture procedure.
\[ \text{H}_2\text{O} + \text{O}_2 \]

Fig. 1

\[ \text{H}_2\text{O} + \text{O}_2 \]

Fig. 2

Fig. 3
A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C23F13/10 C23F13/14 C23F13/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C23F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>DATABASE WPI&lt;br&gt;Section Ch, Week 197328&lt;br&gt;Derwent Publications Ltd., London, GB;&lt;br&gt;Class M14, AN 1973–39825U&lt;br&gt;XPD02294001 &quot;Electro–chemical corrosion inhibition of steam condenser – using spherical anodes&quot;&lt;br&gt;&amp; JP 48 022570 B (AGENCY OF IND SCI &amp; TECHNOLOGY) 6 July 1973 (1973-07-06)&lt;br&gt;abstract</td>
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Name and mailing address of the ISA

European Patent Office, P.B. 5816 Patentlaan 2 NL - 2280 HV Rijswijk<br>Tel. (+31–70) 340–2040, Tx. 31 651 epc nl, Fax. (+31–70) 340–3016

Authorized officer: Desbois, V
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