Method and device for applying protective coatings to heat exchange tubes of system heaters

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Abstract. During exploitation of heat exchange equipment, the inner surface of tubes is exposed to the working environment negative effects, that leads to corrosion, abrasion and destruction. Currently, an urgent task is to develop a technology for recovery and protection of heat exchange tubes without complete replacement of the tube bundle, that will allow to reduce repair costs and improve the heaters’ efficiency. Existing devices for applying protective coatings have a number of flaws: bulkiness, low mobility, the need to use a 380 V network, the inability to use photopolymers. All these factors limit possibility to use these methods and devices. In order to eliminate such drawbacks, the present work developed a special device, allowing to protect and restore damaged surfaces of heat exchange tubes.

1. Introduction

During the long-term operation, the heating surface of heat exchange equipment may be destructed by corrosion of heat exchange tubes [1]. This phenomenon primarily occurs due to the high chemical activity of impurities contained in the transported medium. Also, untimely cleaning of heating surfaces can lead to increased corrosion destruction of tubes and appearance of cracks (figure 1). The hydraulic density of different heaters’ pipe systems becomes violated.

If defective pipes are found in the heater, they must be plugged on both sides. [2] The number of plugged tubes in the heat exchanger determines the degree of physical depreciation and, therefore, equipment's residual resource and service life. This technology leads to a decrease in the surface heat area, an increase in temperature pressures and a decrease in the turbine plant's efficiency with an increase in the specific fuel consumption.

The decision to replace the entire heater's tube bundle should be made in case of the heater's deterioration, violation of pipe system's density and reaching the standard number of plugged tubes [3]. However, due to design features of most heat exchange equipment, the procedure for replacing the tube bundles is extremely difficult and expensive. In addition, some power plant units have a limited residual life (9-14) years, that makes the installation of a new pipe system irrational.
Figure 1. Branched crack with ulcers and growths.

The development of a new technology that allows to restore damaged tubes without complete replacement of the tube bundle will significantly reduce repair costs [4].

2. The main solutions to the problem of heat exchange tubes corrosion

2.1. Methods and devices for protection of heat exchange surfaces from corrosion destruction

The repair of heat exchange tubes can be an alternative to replacement of pipe systems. Historically, the repair method was proposed first, that implies installation of pipe inserts (liners) at the pipes' full length and their subsequent decompression up to 100 MPa. In Russia, this method has been successfully used since 2010 at the energy and oil refining enterprises. [5] However, this method is not widely used due to the high cost and necessity to ensure tightness when the surface is severely damaged.

Also well-known technology of the All-Russian Research Institute for the Operation of Nuclear Power Plants (VNIIAES) of restoring the tubes' inner surface (in case of absence of penetrating damage) by applying galvanic metal coatings [6]. The polymer protective coatings can also be applied to the heat exchange tubes' inner surface using the spraying method [7] in order to slow down development of corrosion damage, but the effectiveness of such coatings for tubes with severe corrosion damage has not been confirmed on an industrial scale.

The authors of the work [8] proposed a method that allows to apply corrosion-resistant polymer coatings to damaged heat exchange tubes. This method implies applying a layer of a high-viscosity polymer compound with a thickness of about 60 microns to the heat exchange tube's inner surface by a single-pass putty method and using a moving rotating elastic screw. One of the method's advantages is possibility of filling non-through deep defects with a polymer coating, that enhances the tube surfaces protection.

Applying protective polymer coatings to the heaters' pipe system is about 30 % of the cost of its replacement [8]. However, it should be taken into account that such coatings' thermal conductivity increases the tube wall's thermal resistance of the heat exchange equipment. Therefore, the use of protective anticorrosive coatings should be excluded for newly introduced equipment.

The main flaws of the existing methods and ways for restoring the heating surfaces are the high cost of repairs and significant deterioration in heat transfer when applying polymer coatings to the heating surface. Thus, when developing a new method, it is necessary to take into account possibility of reducing costs of repair work and the absence of significant deterioration in heat transfer through restoration of the heat exchange tubes.

2.2. Description of developed materials

Nowadays, polymer compositions are among the most promising protective and restorative materials [9]. However, they alone cannot be used for protecting the water heaters' heating surfaces due to the heat medium's high temperature and their low thermal conductivity. A polymer epoxy compound of
amine curing was formed taking into account these flaws for corrosion protection of heat exchange tubes' inner surface, including sealing of corrosion ulcers, cavities and holes in the tubes [10] (figure 2).

Special fillers were used in order to increase the developed coating's heat resistance and thermal conductivity. Metal powders or their oxides or metal alloys are used as target fillers in dispersed form [11].

The composition of the developed protective coating "blocker" was called "BLOCKOR-MKK115" and is aimed to block the intergranular corrosion of stainless tubes of heat exchange equipment for operation at a temperature of +115 °C, as well as to restore this equipment's heating surfaces after destruction.

![Figure 2. Heater's tube of system water with coating "BLOCKOR-MKK115".](image)

We prepared an experimental stand in the testing laboratory in order to confirm declared properties of the coating [12]. The study found that the thermal conductivity coefficient of the coating was 0.91 W/mK [13]. Therefore, the proposed coating with a thickness of 30 to 100 microns will not create significant thermal resistance, so it can be used to protect heating surfaces of heat exchange tubes.

3. Developed device for applying anticorrosive coating
The source [14] describes the method of applying protective coatings in detail. However, it has a number of disadvantages and limited opportunities for use of anticorrosive coatings.

- The device has a bulkiness, that does not allow to restore and protect heat exchange tubes in cramped conditions that are typical for the turbine department;
- The application device's equipment has low mobility and requires significant time to set up and start the restoration process;
- Three-phase 380 V network is required for the device drive operation, that limits possibility of using device and requires special electrical safety measures for specialists and personnel;
- The device does not allow to use polymeric light-curing materials that may be part of the protective materials, that limits the considered method and heat exchange tubes protection device's functionality.

An original device for protection and restoration of heat exchange tubes has been developed as part of R&D in order to eliminate the above shortcomings.

The proposed device consists of several independent units:

- Unit of high-speed rotation of a flexible cable with the speed of 200-300 rpm;
- Unit of translational movement of the painting device along the tube's entire length with the speed of 1-10 m/min;
- Attachment for light curing.

Unit of high-speed rotation of a flexible cable (figure 3) includes a standard asynchronous motor with voltage of 220 V with a device capturing the flexible cable.
Figure 3. Unit of flexible cable with high-speed rotation:
1 – electronic unit; 2 – housing; 3 – gear motor IRW050.

Unit of translational movement of the painting device (figure 4) is made as a hand-held pistol-type device with a supply voltage of 36-42 V, that allows to work in cramped conditions and closed volumes with electrical safety.
Figure 4. Unit of the painting device's translational movement:
1 – mounting unit; 2 – clamping device; 3 – pulley; 4 – limit switch unit; 6 – guide pipe;
7, 8 – housing board; 9 – rack; 10 – gasket; 11 – lining; 12 – replaceable shell; 13 – housing; 15, 16, 17 – screws.

Activating lamps can be applied for light-curing compositions containing photopolymers – devices for photopolymerization [15], giving high-intensity blue light with a wavelength of 400-500 nm. Thus, in contrast to the existing device for restoration and protection of heat exchange equipment, the developed device is:
- More functional (allows the use of photopolymer compositions);
- Mobile and compact, that makes protection operations in cramped conditions and closed volumes possible;
- More electrical safe.

Conclusion As the result, a device for applying polymeric material, including photopolymers, that have a number of advantages over existing analogues to protective coating, sealing corrosion ulcers, caverns and penetration defects in heat exchange tubes was developed and proposed.

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