# SANACIJA PODNOG EKRANA KOTLA TOPLANE U VALJEVU

# Sanation of bottom panel of boiler in heating plant Valjevo

**Nikola Milovanović[1], Branislav Đorđević[1], Simon Sedmak[1], Uroš Tatić[1], Emina Džindo[1]**

[1] Inovacioni centar Mašinskog fakulteta, Univerzitet u Beogradu

***Ključne riječi:*** *sanacija, reparaturno zavarivanje, kotao, stanjenje cevi*

**Sažetak**

U ovom radu prikazana je metoda reparacije (zamene) donjeg podnog ekrana vrelovodnog kotla, snage 30 MW, proizvođača Remming, u toplani u Valjevu. Oštećenja koja su se javila na donjem podnom ekranu predstavljaju posledice uslova radnih uslova kojima je kotao izložen što je rezultiralo stanjenjem zidova cevi donjeg podnog ekrana. Prikazana je procedura postupka reparacije tj. zamene donjeg podnog ekrana. Reparaturno navarivanje je urađeno primenom MAG postupka u kombinaciji sa gasnim zavarivanjem. Pored toga prikazani su zahtevi tehnologije zavarivanja da bi jedna reparacija predmetne opreme bila uspešno izvedena.

**Abstract**

The technique for repairing (replacement) of a bottom panel of hot water boiler in Valjevo heating plant is presented in this paper. Hot water boiler was manufactured by Remming and has a power of 30 MW. Damage that occurred on boiler on the bottom panel were a consequence of exploitation conditions under which the boiler was working, which resulted in the thinning of pipe walls of the boiler bottom panel. Metal corrosion caused this thinning of pipe walls under the presence of sulfuric acid. The procedure used for repairing, i.e. the replacing of the bottom panel of the boiler is shown. Repair welding was performed using the MAG procedure, combined with gas welding. In addition, the requirements of the welding technology related to successful repairing of the equipment discussed in this paper is presented.

## 1. Introduction

Metal corrosion represents material destruction caused by the electro-chemical effects of external factors on its surface. Corrosion manifests in various forms of complex physical and chemical processes taking place at different locations within the element under working conditions [1-3]. Corrosion can be high-temperature or low-temperature, as well as local or surface. Low-temperature corrosion is the most commonly encountered type of corrosion. It can lead to considerable damage in steam boiler elements at low metal temperature and reduces their availability [4-6]. Thus, when designing such elements, measures should be taken in order to reduce or eliminate this effect with causes damage to the installation elements.

Public utility company heating plant in Valjevo started working in 2007. The heating plant contains two hot water boilers manufactured by Remming, with a power of 30 MW and 50 MW [7]. The plant uses a direct system, with temperatures of 130/75°C on the primary and 90/70°C on the secondary. The subject of this research involves the repairing of the bottom panel of the hot water boiler. Remming hot water boiler is shown in Figure 1.

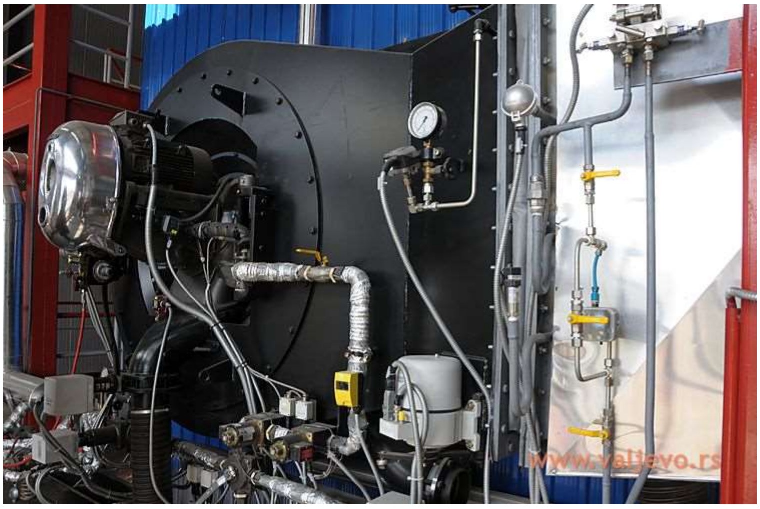


Fig. 1 The Remming hot water boiler

The purpose of the heating plant is to produce and distribute heat to end users. Oil fuel is used by the boilers for the combustion process. Technical characteristics of the hot water boiler are given in table 1. A total of two repairs were performed on the aforementioned boiler between 2007 and 2016.

Table 1 Technical characteristics of the hot water boiler

| | |
|---|---|
| Maximum allowed working pressure | 16.0 bar |
| Test pressure | 33.00 bar |
| Boiler volume | 14.100 l |
| Maximum allowed working temperature | 130 °C |
| Boiler power | 30 000 kW |
| Boiler heating surface | 656 m$^2$ |

## 2. Backround of the problem and examinations

During the preparation for a new heating season and after visual inspection of the boiler, it was noticed that the pipes in the bottom panel were damaged, and that it should be further examined for the purpose of determining of the extent of damage (figure 2 left). Due to exploitation conditions, which included frequent starting and stopping of the analyzed boiler work (the boiler is not working during the night), material loss occurs in internal membrane wall surfaces. Due to moisture separation on membrane walls, water bonds with the residual sulfur-trioxide, which results in the forming of sulfuric acid – $H_2SO_4$, which causes low temperature corrosion. As the bottom panel is slightly sloped, sulfuric acid accumulated in it. It aggressively affects the metal, resulting in parent material damage.

Fig. 2 Left) Damage of bottom panel at the connection between the membrane and pipe; Right) pipe wall thinning

In order to make the proper decision about the need for repairing and the adequate technique for it, i.e. the need to replace the bottom panel, ultrasound measuring the pipe wall thickness was performed. Pipe wall thinning was confirmed by a report wherein it can be seen that the wall thickness was reduced by 30%. Measured thickness ranged from 3.0 to 4.4 mm, compared to the design thickness of 4.5 mm. After the results were obtained, it was decided to repair the part of the bottom panel, including pipes 6 to 29, when viewed from the left lateral side. The repairing involved the replacement of pipes in the bottom panel. During the repairing, non-destructive tests were carried out by the Welding Institute, whereas the complete repair process was monitored by the appointed body. After the first dismounting of the pipes it was observed that the biggest thinning and damage occurred in the zone around the connection between the pipe and the membrane (Figure 2 right).

Repeated measuring of pipes tickness of boiler bottom panel was performed by the Welding Institute for three cross-sections [8]. Shown in figure 3 is the bottom panel of the boiler, including the cross-sections that were measured. The first cross-section is located at a distance of 300 mm from the original cutting line, the second one is located 1000 mm from the cross-section I-I and the third measured cross-section is located at a distance of 300 mm from the collector.

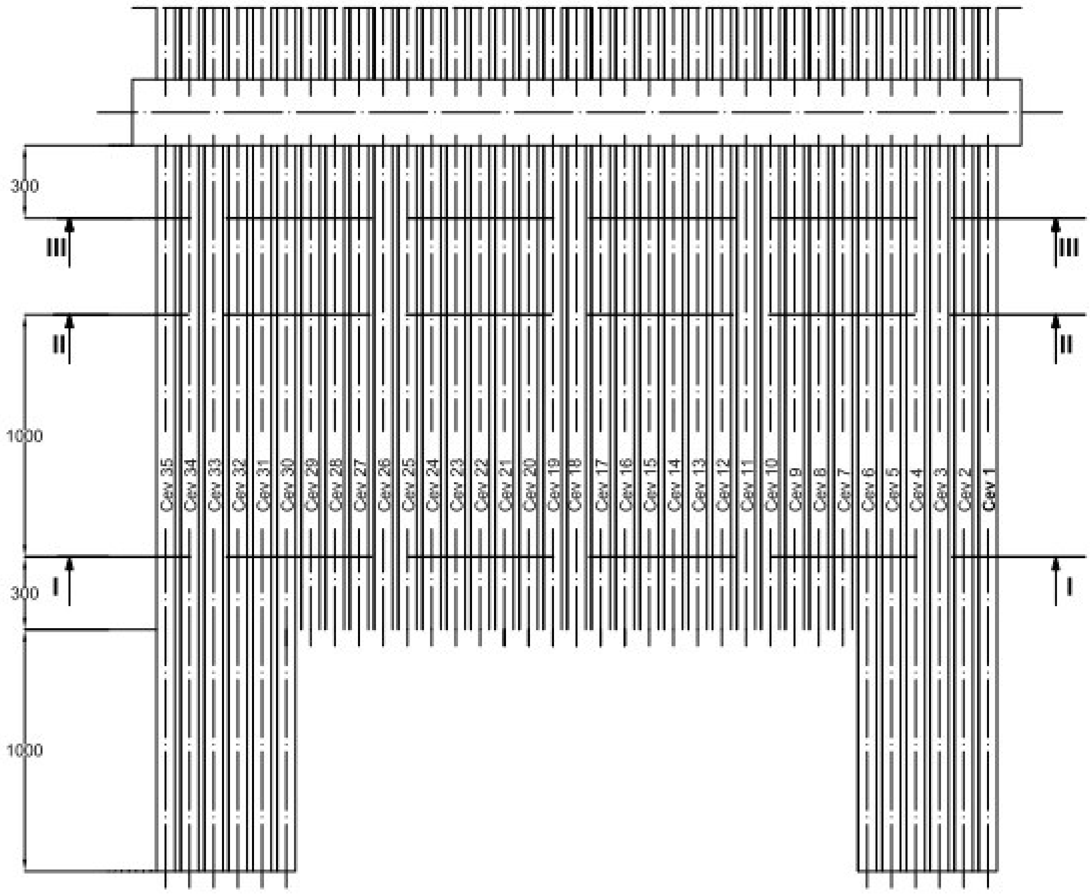


Fig. 3 Bottom panel test zones

After measuring, it was determined that the pipe wall thickness in the zone of the connection between the membrane sheets and pipes, ranged from 1.3 to 3.2 mm. It was decided to extend the repairs to all 35 pipes of the bottom panel along the length of 3500 mm from the boiler front wall.

## 3. Parent material used for hot bottom panel of the boiler

Lower floor grid was made of membrane walls which are formed by seamless pipes with dimensions of Ø76.1 x 4.5 mm and membrane strips with a width of 23.9 mm, thickness of 6 mm and a distance of 100 mm between them. Seamless pipes were made from material P235 GH TC1. This steel belongs to a group of steels which are used for working at elevated pressure and temperature levels, in steam generators, boilers and distributors. It is used for working at temperatures up to 450 °C. Its chemical composition is given in table 2, whereas its mechanical properties are shown in table 3.

Table 2 Chemical composition of steel P235 GH TC1 [9]

| Element | C | Si | Mn | Cr | Mo | P | S |
|---|---|---|---|---|---|---|---|
| Percentage (%) | max 0.16 | max 0.35 | 0.6-1.2 | max 0.3 | max 0.08 | max 0.025 | max 0.015 |

Table 3 Mechanical properties of steel P235 GH TC1 [9]

| Mechanical property | $R_e$ (N/mm$^2$) | $R_m$ (N/mm$^2$) | $A_s$ % |
|---|---|---|---|
| Value | 235 | 360 - 480 | 24 -25 |

Membrane strips were made of structural steel S235JRG2. S235JRG2 steel plate is the carbon and low alloy steel, and belongs to the group of structural steels. As the structural steel, S235JRG2 steel is mainly used in riveted, bolted, or welded construction of bridges and buildings. Its chemical composition is given in table 4, whereas the mechanical properties are given in table 5.

Table 4 Chemical composition of steel S235 JRG2 [10]

| Element | C | Si | Mn | Cr | Mo | P | S |
|---|---|---|---|---|---|---|---|
| Percentage (%) | max 0.2 | 0.55 | max 1.4 | max 0.3 | max 0.08 | max 0.045 | max 0.045 |

Table 5 Mechanical properties of steel S235 JRG2 [10]

| Mechanical property | $R_e$ (N/mm$^2$) | $R_m$ (N/mm$^2$) | $A_s$ % |
|---|---|---|---|
| Value | 215 | 340 | 24 |

## 4. Repair procedure and technology

Bottom panel of the boiler was exposed to variable thermal load due to frequent starts and stops during its exploitation in the heating season. After the damage analysis was performed, a repair and welding plan was developed. Repair plan initiates with the determining of reason for repairing, and the following activities are conducted for this purpose:

- Selection of the welding procedure,
- Calculation of the preheating temperature (if necessary)
- Selection of the additional material
- Determining of the number of passes (layers)
- Determining of technological surfacing parameters
- Determining whether there is a need for additional heat treatment

### 4.1 Selection of the welding procedure

Repairs were performed on all 35 pipes of the panel. The bottom panel was cut along the length of 3500 mm from the front panel. After cutting and dismounting of the pipes, they were replaced with new seamless pipes with dimensions of Ø76,1x5 mm, made of material P235 GH TC1, and membrane strips with a width of 23.9 mm, thickness of 6 mm, made from S235 JRG2 steel. The material used for seamless pipes is 0.5 mm thicker than the one used for the original bottom panel pipes. Two procedures were selected for the needs of this repair process:

- MAG procedure of arc welding
- Gas-flame welding (with acetylene + oxygen)

### 4.2 Selection of the additional material

The selection of additional materials is performed in accordance with the percent content of carbon and other alloying elements, as well as in accordance with cleaning mechanisms. Taking into account the selected repair procedures, the quality of the parent material used for the bottom panel, new materials which are built into the panel, the geometry after preparation, as well as the conditions in which the equipment in question is working, the following additional materials have been adopted, according to the selected procedure:

1. For the purpose of connecting seamless pipes of the bottom panel with the new pipes, the gas-flame procedure was selected, using the VP 42 Ø2.0 mm wire as additional material. This wire is coated with copper for gas-flame welding of non-alloyed steels, pipe steels and boiler sheets.

2. For the purpose of connecting pipes with membrane strips, the arc welding procedure was selected, whereas the additional material was the VAC 60 wire. This wire was coated in copper for gas welding. It is suitable for welding of non-alloyed steels with tensile strength below 530 N/mm2, such as boiler sheets, fine-grain steels, pipe steels.
Iznos jačine struje uklopa ovisi o trenutku uključenja i o remanentnom magnetizmu u jezgri.

Commercial designations, electrode manufacturers, chemical composition and mechanical properties of the pure weld metal with electrodes than can be acquired in the market are given in table 6.

Table 6 Mechanical properties of the additional materials [11]

| No. | Commercial designation | Manufacturer | Chemical composition % | | | | | Mechanical properties | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | C | Mn | Si | Cr | Ni | $R_e$ (MPa) | $R_m$ (MPa) | Hardness (HB) |
| 1. | VP 42 | Jesenice | <0.15 | 1.1 | <0.25 | - | 0.50 | 310 | 410-560 | 110-130 |
| 2. | VAC 60 | Jesenice | 0.08 | 1.50 | 0.90 | - | - | 420 | 500-640 | - |

### 4.3 Repairing of the bottom panel of the boiler

After the additional material has been selected, the repair was performed on the bottom panel of the steam boiler. In the following section, the activity flow of the repair process is presented.

Appropriate WPS lists were created for the purpose of repairing of the bottom panel, including WPS lists for the connection between new and old pipes as well as between pipes and membrane strips. Cutting along the line of all damaged pipes of the bottom panel was performed (35 pipes with a length of 3500 mm). After the cutting, the ends of seamless pipes were prepared for welding according to the technology prescribed by the WPS lists. Edges of the pipes ends were filleted and these ends were cleaned and degreased as seen in Figure 4.

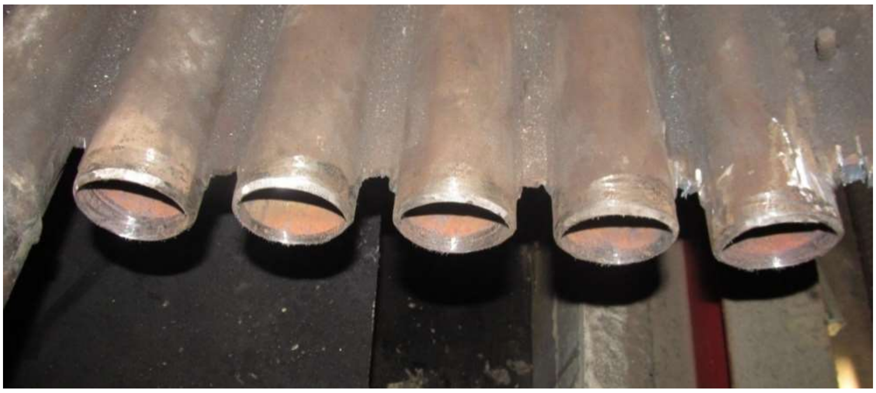

Fig. 4 Prepared bottom panel pipes – cleaned and degreased pipes

The ends of new seamless pipes, which are built into the boiler combustion chamber, were also prepared, in accordance with the technology specified by the contractor. Pipes were connected using the gas-flame welding procedure. Shown in Figure 5 is the appearance of the connected pipes.

Fig. 5 Connecting of old and new pipes of the bottom panel

### 4.4 Welded joint control

After the new and old pipes have been connected, welded joint inspection was performed via radiographic technique. It was performed by the Welding Institute. Since the welding was successful (there were no defects in the welded joints), welding of membrane stripes and the pipes was performed next. It was performed according to the welding technology prescribed by the contractor “Topling-grejanje” [12]. Membrane strips were connected to the pipes using a MAG procedure. The welded joint can be seen in Figure 6.

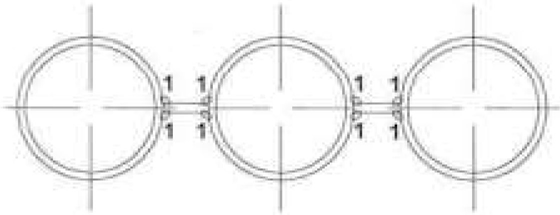

Fig. 6 Welding of membrane strips to the pipes

After the completion of the repair process and all activities and controls related to it, the boiler was tested as a whole, using water pressure. The pressure magnitude of 20.8 bar was determined in accordance with the technical documentation. During the testing, water was used as the test medium. A control manometer with the measuring range of 0 – 25 bar was used as well, with accuracy rating of 0.6. During the test and immediately after it was complete, there were no signs of moistening, dew and leaking in the parent material and welded joints in bottom panel walls of the steam boiler. There were also no signs of strain in the tested equipment. Water pressure testing was successfully performed and it was concluded that the steam boiler in question, manufactured by Remming, was ready for exploitation.

## 5. Discussion and conlusions

For the purpose of determining the extent of damage, an independent body was hired to perform non-destructive tests on the equipment in question. After detecting and defining of the damage extent, repairs were undertaken. In order to perform high quality repairs, an appointed body was hired to monitor the repair process.

In order to perform high quality repairs, it is necessary to perform the control process in multiple stages:

- Defining of the extent of damage and the cutting line
- Review and approval of the technical documentation for the repairing process by the appointed body
- Control during the dismounting of damaged pipes and preparations for welding of new ones
- Radiography control following the welding of old pipes to the new ones
- And the final strength testing using cold water pressure, after the repair was completed.

Assuming that all requirements provided by the welding technology, i.e. the WPS list, are met, high quality repairing can be expected. It is necessary to conduct inter-stage control along the above points, which should be accompanied by non-destructive testing in order to avoid the occurrence of defects in the welded joints, which could lead to downtimes during later exploitation. In addition to the above, it is necessary to hire an appointed body for pressure equipment in order to monitor such repairs and approve the necessary welding technologies.

In the example presented in this paper, the repair procedure, i.e. the replacement of the bottom panel was proven to be a good solution, taking into account that the repair in question was performed during August 2016 and that during the heating season 2016/2017 there were no downtimes and issues related to the exploitation of this equipment.

Since the problem was removed, but its cause was not, further considerations should take into account the introduction of procedures involving more frequent NDT control of all critical locations of the boiler in question, since this was the third intervention on this boiler since it started working. One of these solution can include the reconstruction of the equipment for the purpose of avoiding poor technical solutions.

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