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# THE ASSESSMENT BOILER PLANT`S MATERIAL CONDITION ON STEAM LOCOMOTIVES IN LONG TERM EXPLOATATION AND RECOMMENDATIONS FOR RELIABLE AND SAFE OPERATION OF PLANT

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## ABSTRACT
*It is necessary to monitor the system of the material`s conduct and welded joints in service of power and processing plants in order to avoid damage and damage to equipment. Therefore, it is recommended to establish a system for monitoring of material conduct in long term service as a convenient method for continuously monitoring of the inevitable changes in material properties and damages. So, lets take timely measures for reliable, safe durable and economical plant operation.*
*Maintenance of steam locomotives is a complex process and their boilers are exposed to elevated temperatures and pressures leading to premature degradation of the material. This paper describes the testing stress states of boiler steam locomotives wich is a long term exploatation of brown coal mine in Banovići.*
**Keywords:** steam locomotive. boiler plate, welding, measuring stress state, elevated temperature, deformation and stress.

## 1. INTRODUCTION
Steam locomotive is at the peak of its development, in terms of economics it was weakest steam engine.Despite that, they were produced in diferent types and for diferent purposes. Since 1765**th** James Wat had invented and maded the first steam engine and since than its historical period it had conquered the whole world. When a steam locomotive was produced with a piston mechanism the all basic tehnical issues were solved, also the exploitation and maintenance was simple.In the exploatation of steam locomotive special attentions were to safetynes and proper work of steam boilers. Because it is a power plant which operate at elevated temperatures and pressures, There are clear rules that provide for supervision and monitoring of safety during operation in order to achieve maximum reliability and safety in order to prevent breakdowns.Assessment materials boiler is monitored at specific intervals on the basis of conducted examinations and tests. The requirements are mainly related to testing (measuring) stress condition of boiler plate. Test stress condition is by means of electrical resistance strain gauges at working and test pressure, the pre-testing of welds and wall thickness testing.

## 2. STRESS STATE TESTING OF BOILER PLANT
In accordance with the prescribed program of testings and applicable standards and norms, testing stress analysis was performed on the mantle of the boiler (drums 1, 2 and 3). Defining test (measurement) places – locating of critical sections and takeing the main stress directions (deformations) was performed prior to testings
Testings of stress conditions using the electrical resistance strain gauges is based on measuring the relative ohmic resistance as a function of changes in the relative length of the guide wire measuring

tape. Based on data of the relative ohmic resistance of the strain stress is determined at the measuring point.
By measuring the strain at critical points in the direction of principal stresses and knowing the properties of the materials from which the boiler mantle is maded using the equations of elasticity theory and automatic data processing, it is possible to calculate the stresses in the material at the measuring point. [4]

*Table 1 Tehnical datas of steam locomotive and boiler plant*

| T E H N I C A L  D A T A | | |
|---|---|---|
| Factory boiler number: | 3 9 6 | |
| Locomotive (series): | 8 3 - 1 5 9 | |
| Manufacturer: | Českomoravska-Kolber | |
| Factory building: | Đuro Đaković | Slavonski Brod |
| Year of construction: | 1 9 4 8 | |
| Maximum working pressure: | 1 2 , 0 | bar |
| Test pressure: | 1 6 , 0 | bar |
| The quality of the material of the boiler: | Prema: JUS C.B4.014 | |

**2.1. TESTING EQUIPMENT**
For testing of stress conditions, the following equipment is used:

- Spider 8, Measuring-amplifying system for measuring mechanical quantities, the universal type, in the case with 8 channels and with the possibility of conection with more devices to each other
- LY11-6 / 120, Electro-resistant measuring gauges;
- 1-DAK-1**,** Starter kit, supplies for the application of strain gauges;
- Catman Easy Version 1.1, Software for setings of devices transmisions of datas and visualization
- - Special cables for connection between the electrical resistance strain gauges and measuring-amplifier system for measuring mechanical quantities and other equipment. [4]

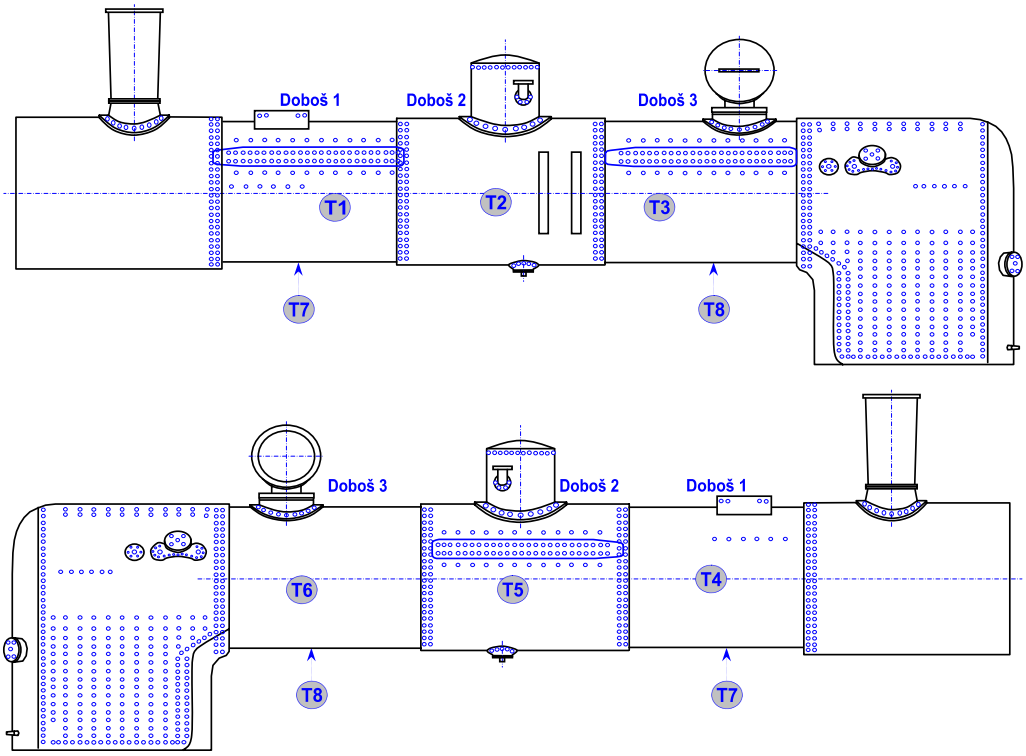
*Table 2 Measuring an amplifying system for measuring mechanical quantities*

| | |
|---|---|
| Manufacturer: | HOTTINGER BALDWIN MESSTECHNIK<br>HBM Mess - und Systemtechnik GmbH |
| Type: | Spider 8 (universal type) |
| Number of channels: | 8 (eight) |
| Other informations:<br>  | - 4,8 KHz;<br>- possibility of conection with more devices each other;<br>- for setings, transmision of datas and visualization it using the software "Catman Easy" |

### 3. SELECTION OF TEST POINTS AND TESTINGS

Selection of measurement points was based on the results of examinations and testing of the boiler shell in accordance with the prescribed program of testing and applicable standards and norms. Test points are located on the mantle of the boiler (drums 1.2 and 3) or in areas where the examinations and tests (visual control and ultrasonic wall thickness measurement of shell boilers) perceived weakening of the boiler shell structure due to exploitation.

Measuring gauges are placed on the directions of principal stresses.




**T1** - drum 1 - transversal left side of the boiler shell;
**T2** - drum 2 - transversal left side of the boiler shell;
**T3** - drum 3 - transversal left side of the boiler shell;
**T4** - drum 1 - transversal right side of the boiler shell;
**T5** - drum 2 - transversal right side of the boiler shell;
**T6** - drum 3 - transversal right side of the boiler shell;
**T7** - drum 1 - transversal bottom side of the boiler shell;
**T8** - drum 3 - longitudinal bottom side of the boiler shell

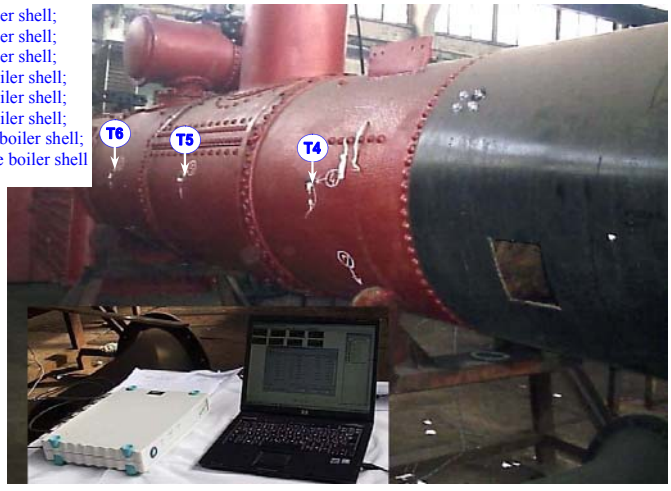



*Figure 1. Scheme of measurement*

## 4. TEST RESULTS

Testing was performed according to plan, during the test, the sizes which are in functional relation with deformations and stresses are folowed

Calculation of stress was conducted by obascu: (E - modulus of elasticity, ε - elongation).

He results of measurements of strain and stress conditions in the measuring points T1 T8 ÷ are given in Table 3.

*Table 3. Values of test pressures and the measured voltage (20 °C)*

| Strian | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 |
|---|---|---|---|---|---|---|---|---|
| | $\sigma_{i1}$ | $\sigma_{i2}$ | $\sigma_{i3}$ | $\sigma_{i4}$ | $\sigma_{i5}$ | $\sigma_{i6}$ | $\sigma_{i7}$ | $\sigma_{i8}$ |
| [MPa] | [MPa] | [MPa] | [MPa] | [MPa] | [MPa] | [MPa] | [MPa] | [MPa] |
| 0,00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0,40 | 24 | 26 | 31 | 22 | 21 | 18 | 26 | 28 |
| 0,80 | 51 | 59 | 64 | 49 | 46 | 41 | 55 | 56 |
| 1,20 | 79 | 93 | 96 | 77 | 72 | 66 | 85 | 82 |
| 1,60 | 106 | 119 | **125** | 104 | 99 | 91 | 113 | 106 |
| 1,20 | 79 | 92 | 95 | 77 | 72 | 65 | 84 | 78 |
| 0,80 | 54 | 57 | 62 | 51 | 47 | 42 | 56 | 52 |
| 0,40 | 28 | 27 | 29 | 26 | 23 | 20 | 27 | 24 |
| 0,00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

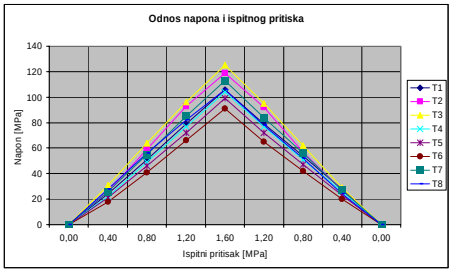



*Figure 2. Relation diagram of the test pressures and the obtained stresses*

## 5. ANALYSIS OF TEST RESULTS

Analyzing the results of the measured strains given in the tabular overview, based on the theory of elasticity and the assumption that the stresses and strains are in the limits of elasticity and using Huk law that applies to stretching linearly proportional to stress where

$\sigma = E \times \varepsilon$ [N/mm2], the work presure(P = 1.20 MPa) and test presure(P = 1.60 MPa) at specific measuring points of the boiler shell are obtained the maximum stress states that are shown in Table The measuring points are located on the left side of the boiler shell (T3 and T2) and on the bottom of the boiler shell (T7 and T8). Comparing the results of stress state during loading and unloading of the boiler, it can be concluded that they are approximately equal, which means that the tested structure behaved elastically.

Taking into consideration the elasticity of the material from which the sheath of boiler is maded and the maximum measured stress state, it can be concluded that the maximum stress conditions are in tolerant limits.

1,20 MPa, $\sigma_{imax.} = 96$ MPa $< \sigma_e = 245$ MPa i 1,60 Mpa, $\sigma_{imax.} = 125$ MPa $< \sigma_e = 245$ MPa.

## 6. CONCLUSION

The success of the extension of useful life of power plants are basically reduced to the problem of timely observe the damage and determining the dynamics of their growth.

Dinamic growth of the damage can be successfully monitored only with the organized sistem of monitoring of material behavior in plant operation. On the basis of such a system as a real boiler plant, it can be explored and determined the legalityes of the growth very impressive and clear damages and assess the achieving time of tolerant and critical sizes.

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