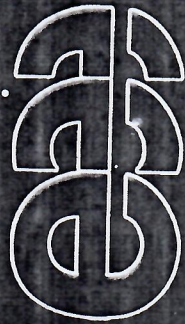


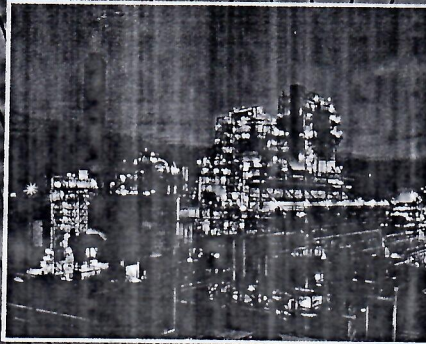
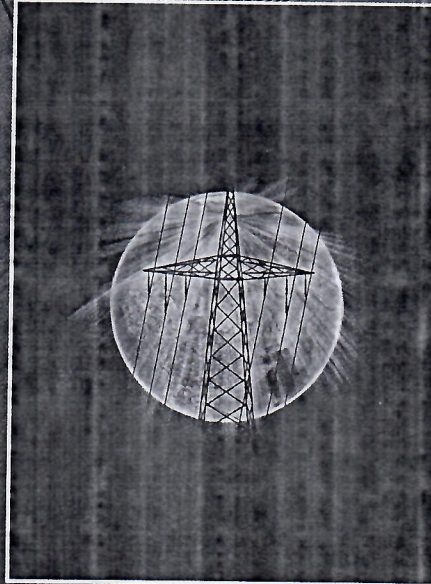
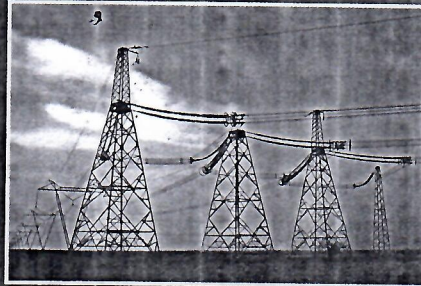
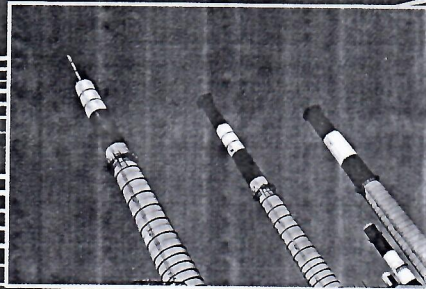
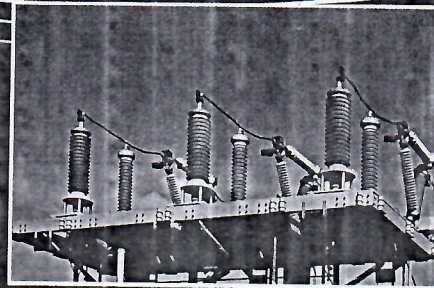
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**SAVEZ ENERGETIČARA**

Adresa: 11000 Beograd, Dečanska 5

Telefon: + 381 11 32 26 007

E-mail: [savezenergeticara@eunet.rs](mailto:savezenergeticara@eunet.rs)

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Glavni i odgovorni urednik  
Prof. dr Nenad Đajić

Adresa redakcije  
Savez energetičara  
11000 Beograd  
Dečanska 5  
tel. 011/322-6007

E-mail: savezenergeticara@EUnet.rs  
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# State Analysis of the Upper Ring of Guide Vane Apparatus at Hydro Power Plant Djerdap 1 Carried out on the Basis of Non Destructive Tests

## ABSTRACT

*Vertical Kaplan turbines, with nominal power of 176 MW, manufactured in Russia, have been installed in 6 hydroelectric generating units of hydro power plant "Djerdap 1". Turbines were designed for the lifetime of 40 years due to the required structural solution and the inability of performing periodic inspections and state analyses. Welded structure of the upper ring of guide vane apparatus is made by welding four segments made of St 3 steel together, in accordance with standard GOST 977/88. Ring segments were welded by using submerged arc welding (SAW).*

*During the rehabilitation of turbine A6 nondestructive and destructive tests were performed on parent material and welded joints in order to carry out the state analysis and estimation of level and causes of eventual degradation of the structure of the upper ring of guide vane apparatus at hydro power plant Djerdap 1.*

*This paper comprises results of magnetic particle tests and ultrasonic tests performed on welded joints. By ultrasonic testing it was determined that there is a lack of root penetration in welded joints, as well as lamellar tearing in parent material.*

*Analysis of the causes of parent metal degradation and occurrence of defects in welded joints of the upper ring of guide vane apparatus was carried out on the basis of results of experimental tests.*

**Keywords:** hydro turbine, the upper ring of guide vane apparatus, nondestructive testing, material degradation, welded joint

## 1. INTRODUCTION

Vertical Kaplan turbines, manufactured in Russia and with nominal power of 176 MW, were installed in 6 hydroelectric generating sets, *Figure 1* [1]. Strains in the structure of the upper ring of guide vane apparatus occur during manufacture and assembly (residual stresses) and during the process of performing functional tasks when in service (stationary and dynamic stresses). Due to the structural solution applied for the turbine and inability to perform periodic tests and state analyses, the upper ring of guide vane apparatus was designed for the service life of 40 years.

Researches conducted all over the world, which deal with integrity and reliability of turbine and hydro-

mechanical equipment in relation to material degradation, mostly refer to fatigue corrosion, cavitation and vibrations. There are no known articles that deal with welded joints and welded structures as wholes. Researches carried out on behalf of domestic hydro power plants are very modest in scope. A certain number of researches, which were used for the state analysis of the upper ring of guide vane apparatus, is listed in literature section [2-6].

## 2. RESULTS OF NON-DESTRUCTIVE TESTS

Upper ring of guide vane apparatus was manufactured by welding 4 segments made of steel St 3 together (factory tags of segments were 1-2, 2-3, 3-4 and

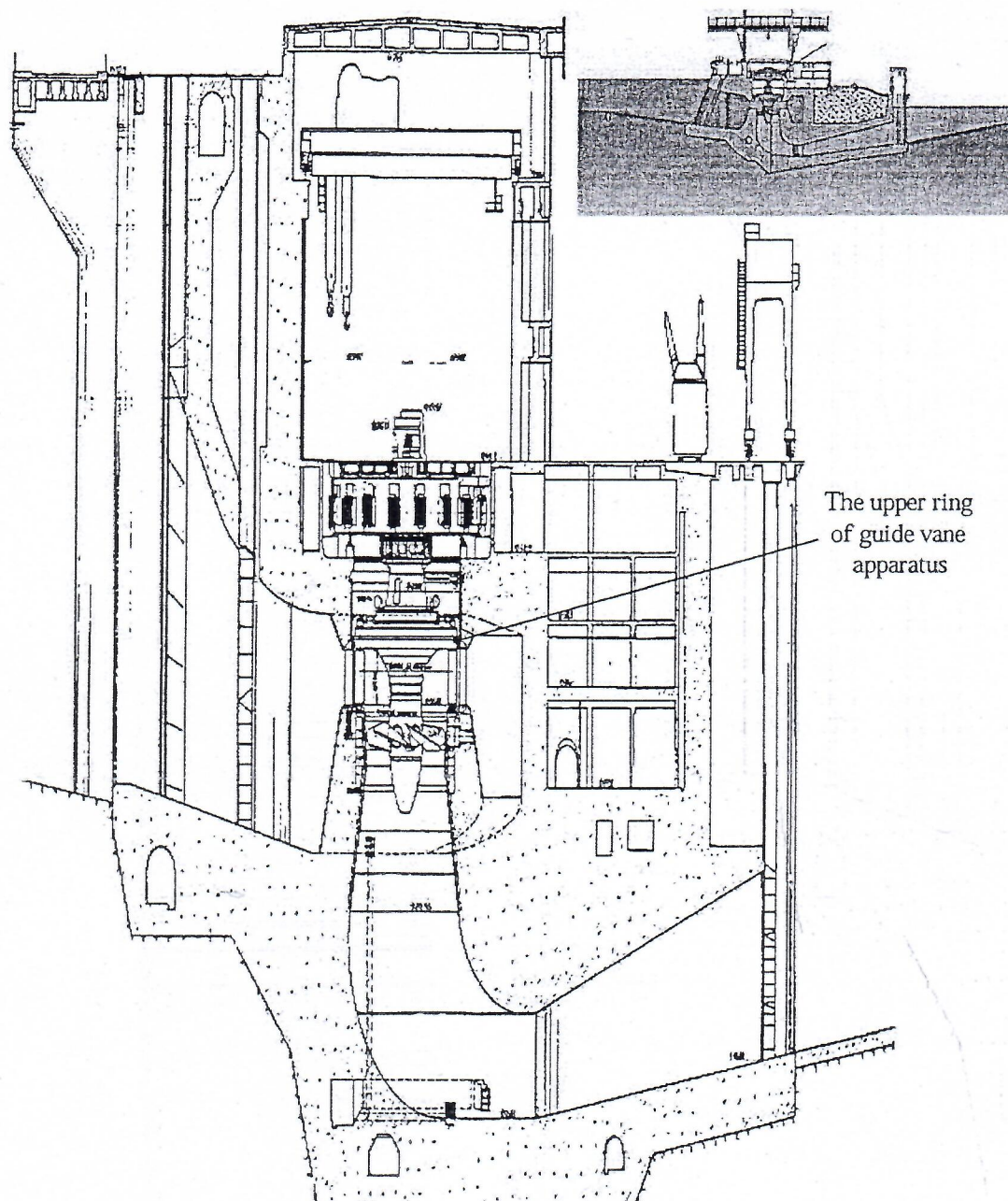


Figure 1. - Appearance of the vertical Kaplan turbine, nominal power 176 MW

4-1), in accordance with GOST 977/88. Welding of ring segments was carried out by flux-cored arc welding.

**2.1 Results of magnetic particle testing**

A large number of surface linear indications was detected during the magnetic particle testing performed at all 4 segments. Findings detected at segment 4-1 are presented in Figure 2.

**2.2 Results of ultrasonic testing**

Segment 4-1 of the upper ring of guide vane apparatus, at which lack of root penetration and lamellar tearing were detected, is presented in Figure 3. La-

mellar tearing caused pulling of the 40 mm thick sheet metal in the area of fusion of parent material and filler material. Representative echographs that were taken during the ultrasonic test carried out on segment 4-1 are presented in Figure 4.

**3. RESULTS AND DISCUSSION**

Non destructive tests were carried out in order to determine the condition of the structure of the upper ring of guide vane apparatus, causes of degradation of parent and filler material and occurrence of lamellar tearing in parent material.

Lamellar crack is a defect that occurs in a form of cascading cracks or lamellary distributed cracks in pa-

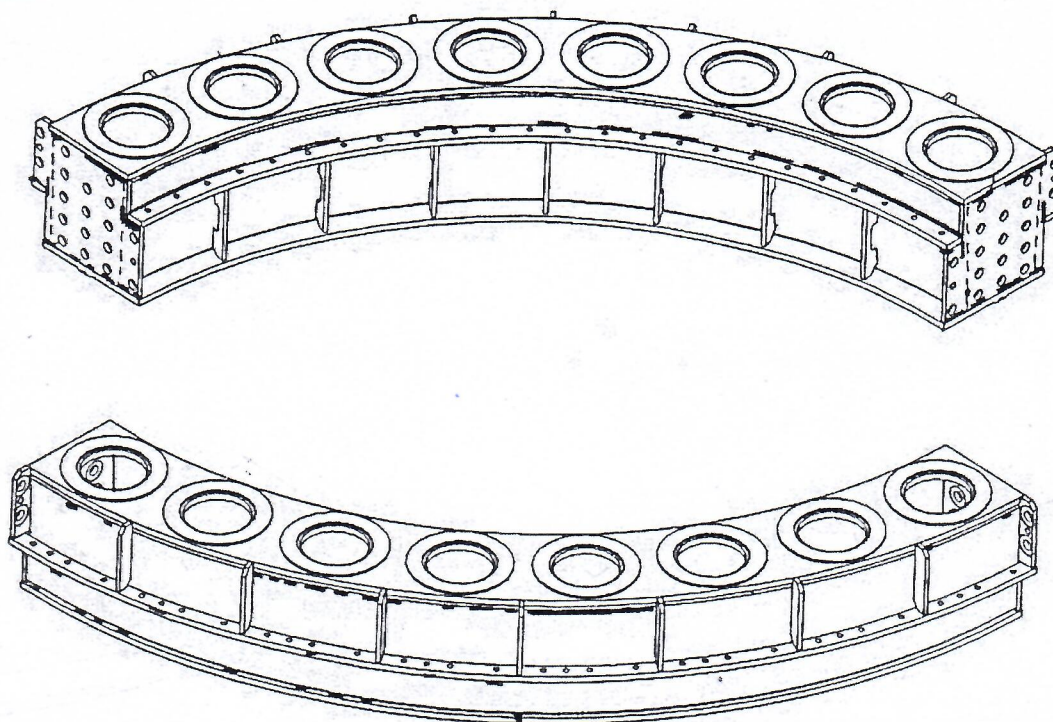


Figure 2. - Appearance of results of the magnetic particle test performed at segment 4-1

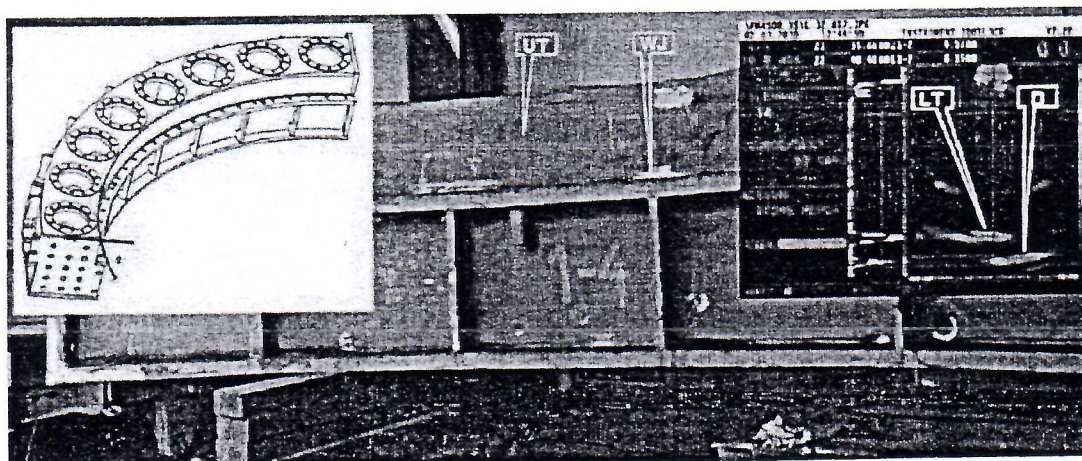
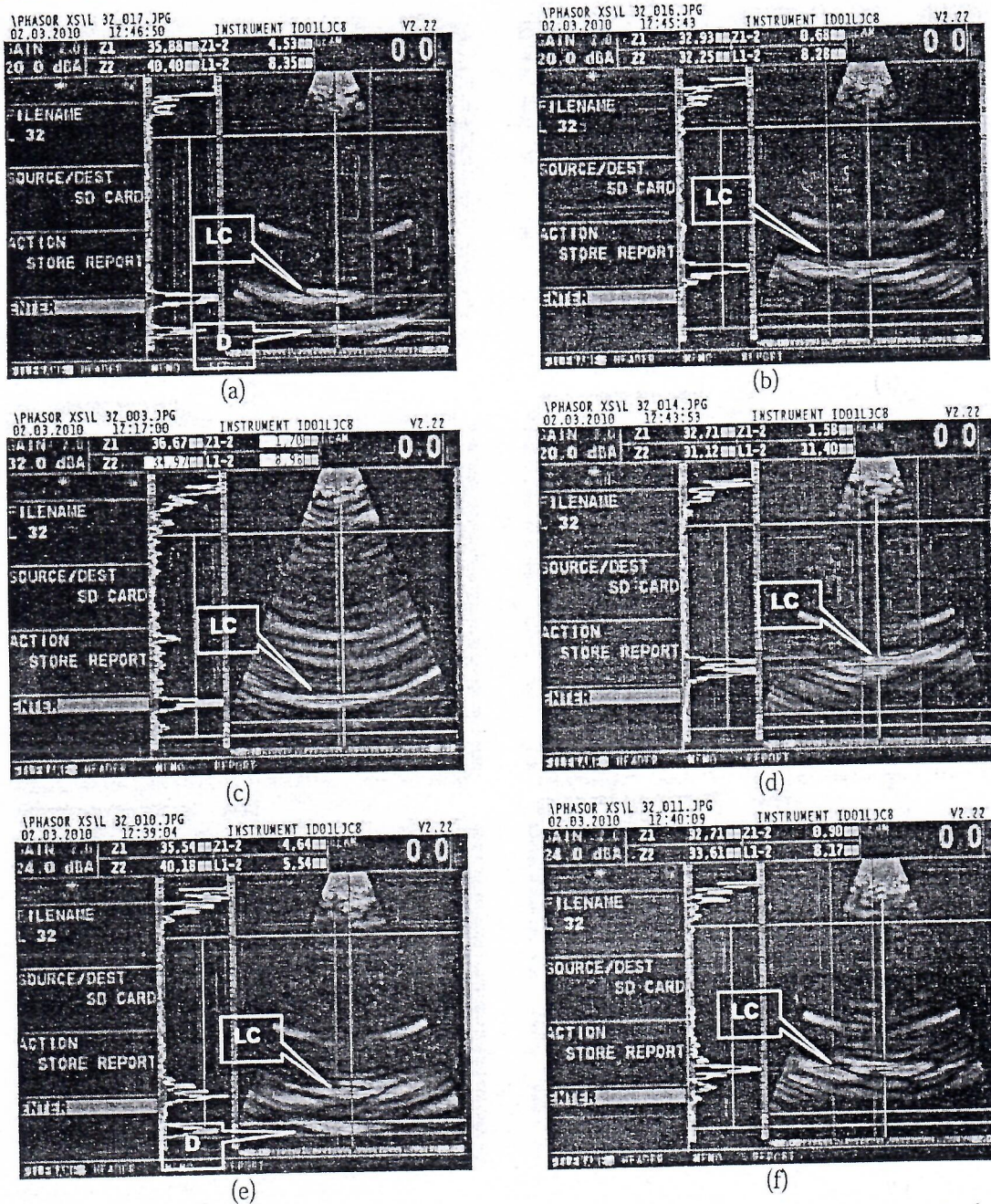


Figure 3. - Appearance of segment 4-1 of the upper ring of guide vane apparatus



*D – indication that refers to the lack of root penetration; LC – indication that refers to lamellar tearing in the root area of the welded joint; Z1 and Z2 – depth of indication measured from the surface; Z-Z2 – distance between indications, depthwise; L1-L2 – distance between indications, projection-wise.*

**Figure 4. - Appearance of representative echographs**

rent material. Causes of occurrence of lamellar cracks are as follows:

- extent, type and form of impurities that occur during steel manufacture,
- residual stresses that occur due to welding and stresses in the direction of sheet metal thickness due to assembly,
- hard structures that occur due to application of inadequate welding technology and proneness to cold cracking.

Surface linear indications in welded joints, detected through magnetic particle testing, are fatigue

cracks that occur due to variable loads at the upper ring of guide vane apparatus during service, while lack of root penetration is a direct consequence of the application of inadequate welding technology.

#### 4. CONCLUSION

Research results show that this is a rare situation in which there are 2 equally significant causes of degradation of parent material and weld metal. In this case these are degradation caused by a mistake in steel



manufacturing technology and degradation caused by a mistake in technology of manufacture of the welded structure.

### ACKNOWLEDGEMENT

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