RAZVOJ NOVIH DODATNIH MATERIJALA ZA ZAVARIVANJE VISOKOTEMPERATURNO POSTOJANIH T/P 24 ČELIKA

DEVELOPMENT OF NEW WELDING CONSUMABLES FOR WELDING CREEP RESISTANT T/P 24 STEEL

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Ključne riječi: razvoj, dodatni materijali, bazične oplaštene elektrode, visokotemperaturno postojani čelici, testiranja postojnosti prema puzanju

Key words: development, welding consumables, basic electrodes without PWHT, welding, creep resistant steels, creep tests

Sažetak: U radu je prikazan razvoj novih bazičnih oplaštenih elektroda za zavarivanje visokotemperaturno postojanih CrMo čelika T/P24, u Elektrodi Jesenice. Kod određivanja sastava plašta elektrode proučavan je utjecaj različitih dodataka dezoksidanata i legirnih elemenata. Iz najboljih odabranih sastava su izrađeni testovi.
Dio mehaničkih testova izrađen je u IMT-u. Uspoređivani su rezultati u zavarenom i toplinsko obrađenom stanju. Najbolji materijal označen oznakom EVB P24 uspoređen je s podacima proizvođača osnovnog materijala.

Rad je dio projekata *Intelligent repair welding of power plant components*-SmartWeld – financiranog iz 5. programa EU.

Abstract : In this work the description and evaluation of development of new basic type electrodes at Elektrode Jesenice for welding creep resistant T/P24 steel is shown. In the development of the new flux composition the influence of different reducing agents and alloying elements were considered. From the best promising weld material different mechanical tests were done. We have also compared all weld metal characteristics in as welded and in PWHT condition. On the base of test results, the best welding electrode marked with EVB P24 was compared with creep data of base metal P24.

Development was a part of EU 5. Frame Growth project: *Intelligent repair welding of power plant components* with synonym SmartWeld.

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1. INTRODUCTION

Old power plants are big environmental polluters. In the future power plants will still remain one of the main energy sources. But requirements for environmental protection and operating economy in the future demand higher efficiency levels of steam power plants. This can be achieved with higher steam temperatures and pressures. Working conditions are now changing from level of 535 ˚C and 185 bar to higher temperatures and pressures like 630 ˚C and 300 bar. The materials in power plants have to assure safety operation till minimum 100 000 working hours. Because of these demands the producers must improve the materials that will be used in power plants. This is one of the reasons for development of new creep resistant steels.

15 years ago there was tendency to achieve higher creep resistance with alloying elements like vanadium (V), niobium (Nb) and nitrogen (N). On this basis new T/P91 steels were developed. Many power plants were built with this material. The development continues in the direction of higher creep resistant materials as P92, P911… These materials are used for constructing parts exposed to higher temperature, as for pre-heaters, evaporators, primary pipelines.
Parallel with development of higher alloyed creep resistant steels there was also demand to develop new steels for water walls and secondary pipelines. For many years T/P22 steel is used for this purposes. Then the T/P23 and T/P24 steels were developed from T/P22, alloying with Nb, boron (B) and titanium (Ti). Parallel with development of T/P24 creep resistant steel also welding consumables were developed for welding steel pipes together. After welding post weld heat treatment (PWHT) is needed to reduce internal stresses. But for water walls and repair purposes PWHT is difficult to perform.

In our work we will present some points in development of P24 welding electrodes that can also be welded without PWHT.
Company Mannesmann first produced P24 steel pipes in 1995 and P23 in 1997[2], and till now there is no standard for matching welding consumables.

2. WELDING CONSUMABLES DEVELOPMENT

Our market name of welding consumables for welding T/P24 and similar steel is EVB P24. To achieve good characteristics we wanted to fulfill the following conditions:

- Basic coating with low hydrogen content.
- Good welding characteristics.
- Good mechanical properties in as welded and PWHT condition.

We have, before starting the development of EVB P24, compared different creep resistant steels, their PWHT after welding and existing welding consumables. We have made tests with our P22 welding consumables: EVB 2CrMo electrode and flux cored wire Filtub 18B FCW. Comparison of results in as-welded and in PWHT condition helped us to make the following steps in development of the EVB P24 electrode:

[2] J. Arndt et al.: The T23/T24 book: New grades for waterwalls and superheaters; 2nd ed. Vallourec&Mannesmann tubes, 2000

- Optimization of chemical composition for electrode coating.
- Welding with new electrodes.
- Performing mechanical tests at room temperature and at elevated temperatures.
- Micro and macro- structure evaluation.
- Performing creep tests with standard 1-D constant load equipment.
- Comparison of tensile strength of as-welded and PWHT T/P24 welds with T/P24 steel.

2.1. Optimization of chemical composition

First we have optimized the alloying of boron, niobium, vanadium and titanium in our EVB 2CrMo electrode to achieve similar composition to T/P24 steel. Silicon and carbon content were decreased to achieve higher impact strength in as-welded condition of the weld metal. Cromium (Cr), molybdenum (Mo), nickel (Ni) and manganese (Mn) contents were changed too. Materials with different chemical composition were mechanical tested at room temperature. Mechanical results have helped us to choose the best chemical composition at which, tensile tests at elevated temperatures, including creep tests were performed.

In Figure 1. the results of mechanical tests of as-welded EVB P24 weld performed at different temperatures are shown. From these results we can conclude, that material has higher tensile strength (Rm) in the case, when there is low content of nickel and high content of carbon. In the case of low content of carbon, the amount of nickel does not influence the strength.

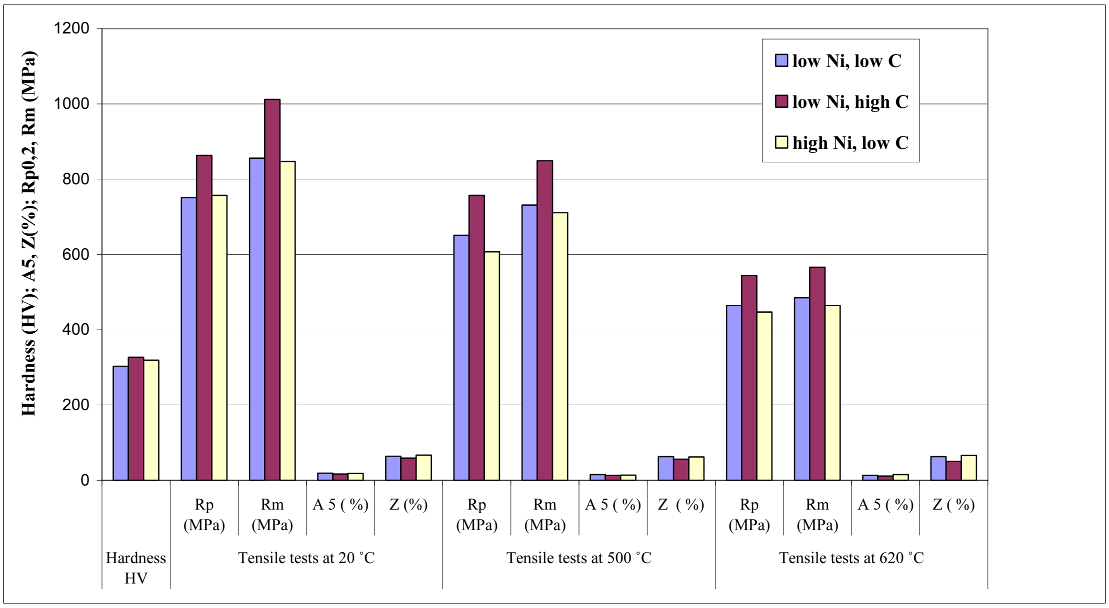

Figure 1. Results of mechanical tests of EVB P24 weld in as-welded condition with different amounts of alloying elements

Impact energy is also important mechanical data. For welding without PWHT the impact energy should be at least 40 J at room temperature. Results of Charpy-V impact energy for EVB P24 weld with different amounts of carbon and nickel are shown in Figure 2. The best impact results were obtained in the case of low carbon and low nickel content in the material.

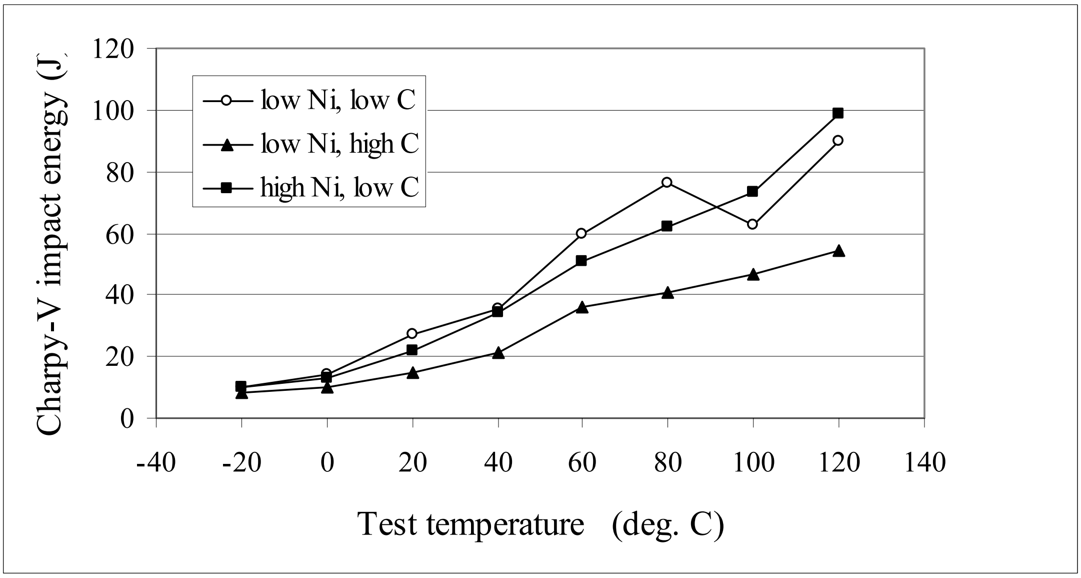

Figure 2. Influence of nickel and carbon content on Charpy-V impact energy of EVB P24 weld in as-welded condition

Hardenability of the material was checked with Jominy hardenability (quench) test. The material with low carbon and low nickel content achieved the lowest hardness.

According to mechanical test results we have chosen two different variations of chemical content for performing the creep tests, i.e. low nickel and low carbon content so as low nickel and high carbon content. Results of 1-D constant load creep tests are shown in Figure 3.

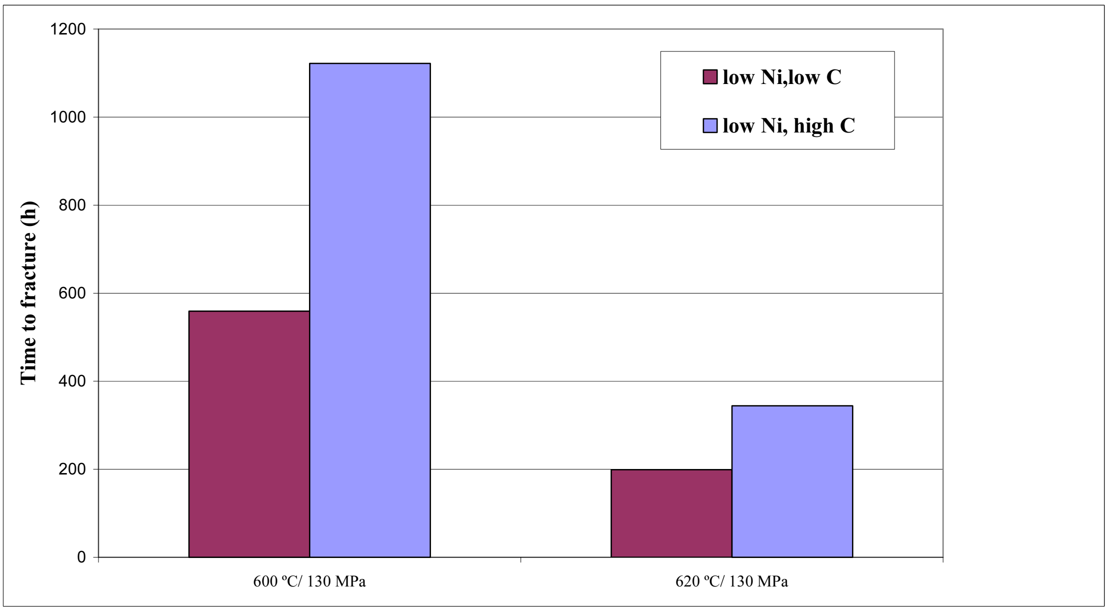

Figure 3. Results of 1-D constant load creep tests for as-welded EVB P24 weld

According to these results we have concluded, that in the case of creep resistance material with low nickel and low carbon is more promising than the others. So the next step in the development was to find similar material composition to steel T/P24, which ensures impact energy of 40 J at room temperature in as welded condition and good creep resistance. So in next step we have made comparison of the new composition of EVB P24 in as-welded and in PWHT condition.

2.2. Comparison of weld metal properties of EVB P24 in as-welded and in PWHT condition

New weldments were made with optimized chemical composition of low carbon and low nickel content in EVB P24 material. The welds were in as-welded and in PWHT condition. EVB P24 has bainitic-martensitic structure. Micro and macro-structure of EVB P24 in as-welded condition is shown in Figure 4. No significant difference between microstructure of as-welded and PWHT material was found.

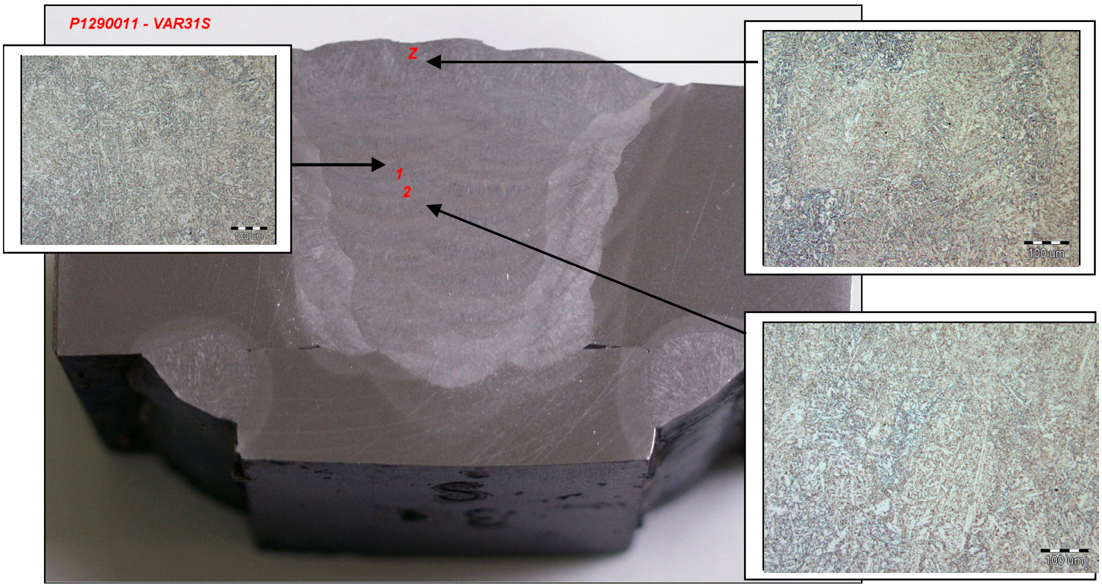

Figure 4. Microstructure of EVB P24 weld in as-welded condition

Impact toughness and tensile properties of the all-welded metal was then tested at room temperature and at elevated temperatures. In Figure 5. results of Charpy-V impact energy tests are shown for as-welded and for PWHT condition. The as-welded material showed Charpy-V impact energy of 40 J at room temperature. The impact energy of the weld material in PWHT condition is much higher: around 160 J.

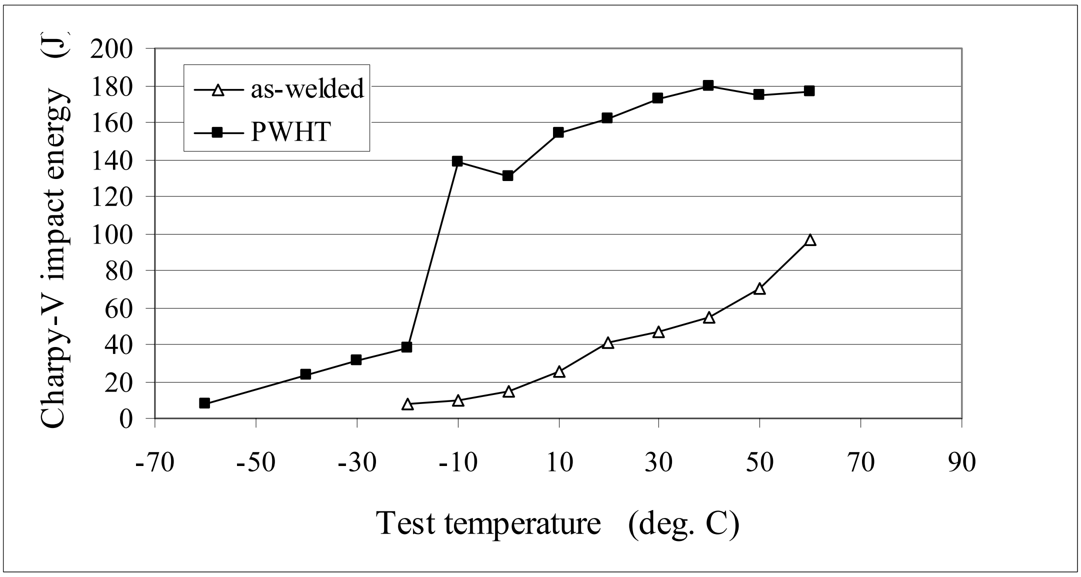

Figure 5. Charpy-V impact energy of EVB P24 weld in as-welded and in PWHT condition

In Figure 6. the tensile test results are shown. Hardness in as-welded material is higher than it is in the case of PWHT, but it still does not exceed 350 HV, which is the upper limit for P24 steel. As-welded material has better results of tensile tests at all test temperatures than PWHT weld.

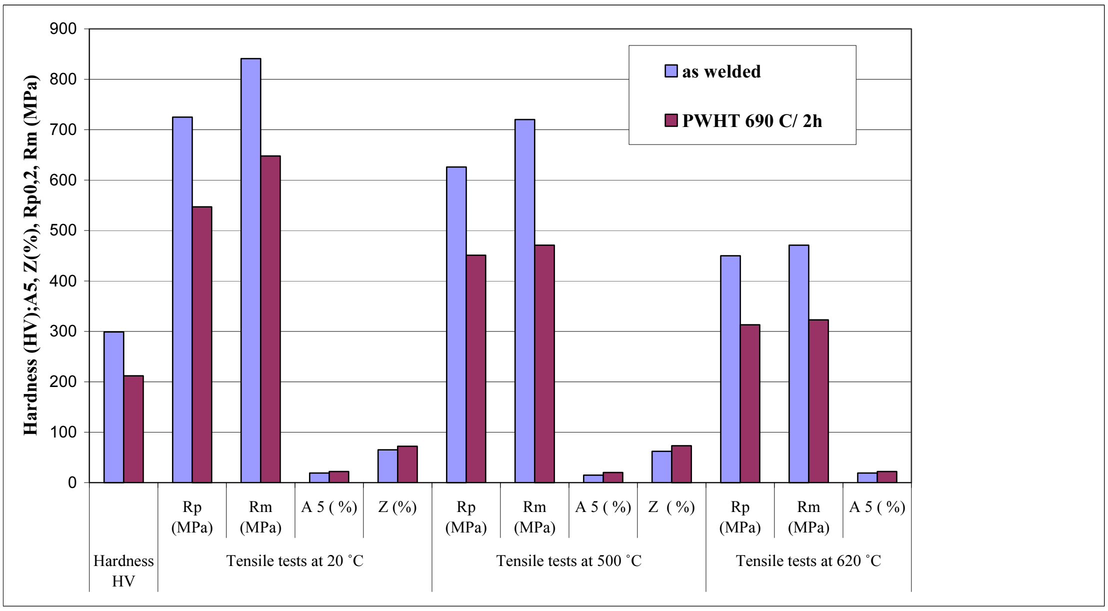

Figure 6. Comparison of hardness and tensile test results between as-welded and PWHT EVB P24 weld. Tests were performed at 20 °C, 500 °C and 620 °C

Important information for the constructors is tensile strength. In Figure 7. the comparison of tensile strength between EVB P24 weld in as-welded and in PWHT condition, and Mannesmann T24 steel in PWHT condition at different temperatures is given.

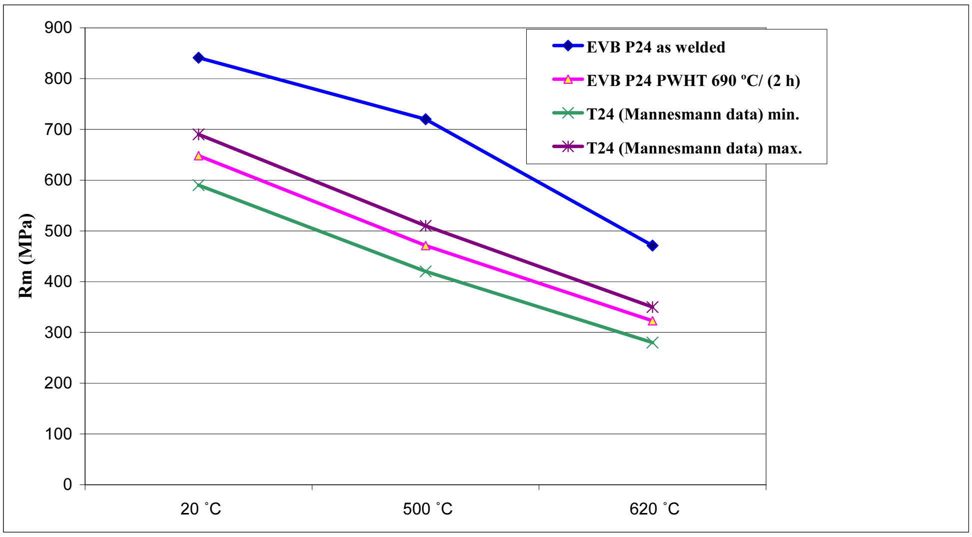

Figure 7. Comparison of tensile strength of EVB P24 weld in as-welded and in PWHT condition, and of T24 steel in PWHT condition at different temperatures

From Figure 7. we can see, that tensile strength of PWHT all-welded EVB P24 material is between min. and max. limits of the PWHT T24 steel. As-welded all-welded material has higher tensile strength at all tested temperatures. Our new welding material EVB P24 has very similar tensile strength to the Mannesmann T24 base material tensile strength.

Material EVB P24 was then creep tested too, i.e.: in as-welded and in PWHT condition. The results of creep tests are shown in Figure 8. and they are expressed in the form of Larson-Miller parameter (LMP):

$LMP = (T + 273)(C + \log t_r)\, 10^{-3}$
T (°C) - temperature
t_r (h) - time to fracture
C = 20 - constant

In all cases we can see, that at short term creep tests (t_r < 1000 hours) as-welded material has better creep resistance than the same material in PWHT condition. According to LMP projection, creep properties of as-welded and PWHT welds would be very similar at lower stresses. But of course, for verification of good short term creep test results, long term creep tests are running now.

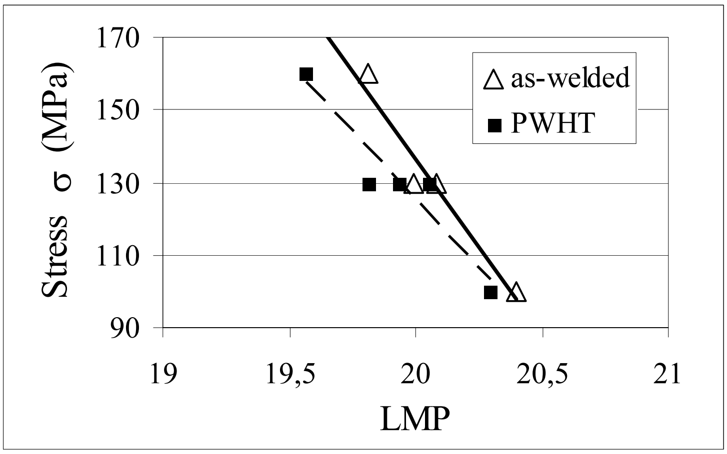

Figure 8. Creep data of EVB P24 weld in as-welded condition and in PWHT condition

2.3. Other activities with new developed EVB P 24 electrode

T/P24 steel pipes were welded with new developed EVB P24 electrode[3]. In this welds new welding technologies were tested, so that lower residual stresses were achieved. Weldments were then tested on creep, hardness and residual stresses[4,5]. Residual stresses in weldments were measured with neutron diffraction test at Welding Institute of Bratislava[6,7].
Beside welding electrodes EVB P24, flux cored wires (FCW) Filtub P24B with similar composition were developed too.

New developed electrodes EVB P24 found application in welding of pipeline connections for water-wall in steam power-plant, as shown in Figure 9.

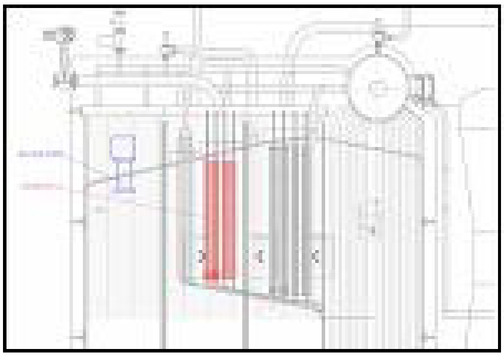

Figure 9. Water-wall, where EVB P24 electrodes were used for welding pipeline connections

[3] J. Pecha, O. Peleš: Final report, Slovak Energy Systems, SmartWeld, 2004
[4,5] S. T. Mandziej: Final report, Advanced Materials Analyses, Bratislava, SmartWeld, 2004; University of Limerick final report for SmartWeld, University of Limerick, 2004
[6,7] Final report, Welding Research institute, Bratislava, SmartWeld, 2004; Final report, Institute of Material Science of Slovak Academy of Sciences, Košice, SmartWeld, 2004

3. CONCLUSIONS

In the present work some steps in development of new welding consumable for welding T/P24 and similar steels are shown. The optimized composition with low carbon and low nickel content was found the best, due to the highest Charpy-V impact energies, lowest hardness at Jominy tests and acceptable tensile and creep strengths. The comparison between as-welded and PWHT condition of EVB P24 weldment shows the acceptable hardness, tensile strength and Charpy-V impact energies in both cases. Weldments with this new developed welding electrode were made too, they were tested and due to good results implanted in the water-wall production.

4. ACKNOWLEDGEMENTS

The financial support of this work, project Research Program 0206-503, was provided by the Ministry of Education, Science and Sport of the Republic of Slovenia, and partially from the EU 5FP project, SmartWeld, contract number G1RD-2001-00490, and is gratefully acknowledged.

5. REFERENCES

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