# NEW TECHNOLOGY OF ELECTRIC ARC BATH WELDING OF RAILS ON TRAM AND CRANE TRACKS

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New rail welding technology developed by the E.O. Paton Electric Welding Institute is described, and examples of its application at reconstruction and construction of tram and crane tracks are given. It is noted that after appropriate verification and authorization this method can be regarded as a serious alternative to the existing welding methods for performing operations in the railway track.

***Keywords:*** *electric arc welding, continuous-welded tracks, tram tracks, crane tracks, in-track rail welding, consumable nozzle, self-shielding flux-cored wire*

Continuously-welded track is the most advanced design of track structure, the main advantage of which is the possibility of practically complete elimination of rail butts that considerably reduces the dynamic forces and lowers train resistance (by 10 % on average). In addition, continuously-welded track extends the service life of track structure elements (from 1.3 to 2.2 times), reduces repair costs of track and rolling stock (up to 35 %), allows saving metal of web covers (5–7 t per 1 km), increases train velocity up to 160–200 km/h and more [1]. Despite the fact that the above advantages of continuously-welded track pertain to main-line railways, they are also realized to varying degrees at its application in all the kinds of railway transportation — on the tracks of industrial enterprises, metro, trams and cranes.

Rail welding is an integral part of trackworks, influencing the design and technico-operating parameters of track structure. Features of rail welding process are related to their material properties. Owing to high carbon content, rail steels are poorly weldable and are prone to hot and cold cracking. Their welding requires special welding consumables and specialized technologies. High requirements are also made of the accuracy of following the temperature modes of welding [2].

The weld should meet the same technical requirements as the rail proper. The latter is regarded as the load-carrying and guiding element of the track, which can stand static and dynamic loads, ensures a high smoothness of running, and is capable of resisting wear. In this connection the weld, similar to the rail proper, should meet safe operation requirements and create no hindrance to traffic. Welding process should ensure [3]:

- stable quality and satisfactory service properties of welded butt joints at minimum dependence on welder's qualification;
- maximum short total duration of welding process, particularly at track repair so as to fit within time widows allowed for these purposes;
- ability to apply portable welding equipment so that it could be easily transported and serviced;
- prevention of rail consumption or need to move them in the longitudinal direction;
- process adaptability to cross-sections of all types of used rails, as well as sufficient flexibility for application to rails with different degrees of wear;
- acceptable level of initial expenses for purchase of welding equipment and current expenses for performance of welding proper.

At present none of the applied processes of rail welding (flash-butt, gas-pressure, alumothermic, electric arc, bath welding) fully meets all of the above-listed requirements. In flash-butt welding providing the highest quality of welded joints and high efficiency (particularly in stationary conditions) cumbersome and expensive equipment is used, that makes its application in field conditions difficult and often not cost-effective or technically irrational, in particular, at performance of repair, when it is necessary to weld a relatively small number of butt joints. Application of this welding process is also complicated by the need to move welded rails and track opening. There are also certain difficulties in welding of frogs and switches with this process.

Gas-pressure welding was widely applied in 1930–1970s in the US railways mainly for joining rails in stationary conditions (in the shop and depot). However, increase of axial loads in 1980s lead to an essential increase of the number of butt joint failures, so that this welding process was ousted by flash-butt welding [4]. At present gas-pressure welding is rather widely applied in Japanese railways [5].

Alumothermic welding which has been applied for more than 100 years for joining various-purpose rails, features a high mobility and versatility, without, however, providing a sufficient stability or high quality of welded joints. At present the possibilities for improvement of this process in order to increase welded joint performance have been practically exhausted. Therefore, despite the numerous technological improvements and organizational measures taken by companies providing services on alumothermic welding, no breakthrough is to be anticipated in this area [6]. Moreover, this welding process did not develop in our country for decades, as a result of which quite expensive import consumables have to be purchased for its application.

At present coated-electrode arc bath welding is mainly widely accepted for joining tram and crane rails. This process, however, does not ensure a reliable quality of welded joints, as it essentially depends on welder's qualifications and is greatly inferior to other welding processes as to efficiency. In order to improve the efficiency, a process of semi-automatic arc bath welding of rail butts was developed, which was applied by Berlin Transportation Company in repair of metro rail tracks [7]. A special elongated current-carrying nozzle and self-shielded flux-cored wire were used. As a result, welding efficiency increased by 30 %, compared to manual coated -electrode arc welding. Arc bath welding was applied with success, in particular, at construction of high-speed Yamagata-Shinkansen line in Japan [8], where improvement of technology and welding consumables, as well as application of special heat treatment enabled a significant improvement of welded joint quality. Nonetheless, welding efficiency remained on a low level (time of welding a butt joint was 75 min) [9]. Nippon Steel developed a new process, intended to replace alumothermic welding and manual arc bath welding of rails in the future [9, 10]. It is based on a combination of gas-shielded welding by a rotating consumable electrode (welding of the rail foot) and electroslag welding (welding of rail web and head). The entire process is performed in the automatic mode using a computer-controlled unit.

This technology ensures much higher mechanical properties of welded joints than alumothermic welding does. However, the time of welding a butt joint is equal to about 100 min, although there is a possibility of shortening it to 50–60 min in the future that will just bring this process closer to alumothermic welding in efficiency.

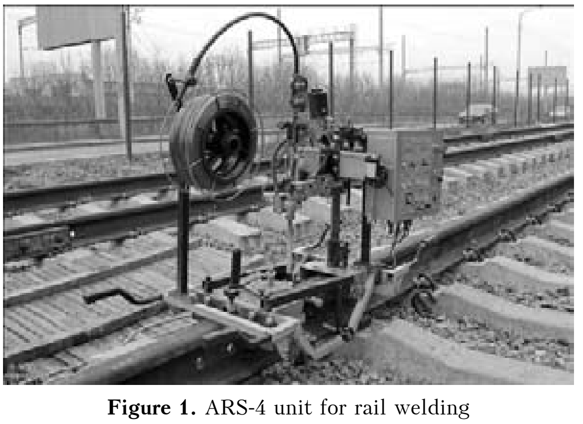

**Figure 1.** ARS-4 unit for rail welding

Several attempts were also made to develop the process of electroslag welding of rails [11–14]. However, despite the quite serious study of the subject, no satisfactory results have been achieved so far [15].

The E.O. Paton Electric Welding Institute of the NAS of Ukraine developed a new technology of rail welding, which was called automatic arc welding by bath method using consumable nozzle, or in short consumable-nozzle arc welding. It features application of self-shielded flux-cored wire, fed through a longitudinal channel in a special flat consumable nozzle, that allows welding to be performed in the gap of 12–16 mm, and in some cases — of up to 22 mm in the butt.

The proposed welding method, being a further development of arc bath welding, allows increasing the efficiency of operations 2–3 times owing to process mechanization, and at the same time significantly improving the quality indices of welded joints, while preserving the high mobility and versatility of the equipment.

It is designed, first of all, for welding the tracks of industrial enterprises, tram (also high-speed operation) and crane tracks, and in the long-term after appropriate verification and obtaining permission also for performance of on-line repair operations in main-line railways. Specialized equipment — ARS-4 unit was developed (Figure 1).

**Specification of ARS-4 unit**

| | |
|---|---|
| Rated DC supply line voltage, V | 24 |
| Power consumed by the source, kV·A | not more than 15 (3 × 380 V) |
| Rated welding current, A, at 100 % duty cycle | 350 |
| Diameter of applied flux-cored wire, mm | 2.4 |
| Ranges of adjustment of electrode wire feed rate, m/h | 50–300 |
| Electrode movement speed, m/h | 4–12 |
| Transverse travel of electrode, mm | 180 |
| Electrode oscillation frequency, Hz | 0.5–2.0 |
| Amplitude of electrode end oscillations, mm | 0–20 |
| Overall dimensions, L × W × H, mm | 1320 × 520 × 850 |
| Unit weight without wire or shoes, kg, | not more than 40 |

It features portability and owing to replaceable forming fixtures it is easily readjusted for welding rails of various typesizes. FORSAZh-500 inverter of Ryazan State Instrument-Making Plant (RF) is used as the welding source. Power can be supplied both from three-phase mains of 380 V voltage, and from self-sufficient electric generator of 25–30 kV·A power, with power consumed in welding being equal up to 15 kV·A. Average machine time of welding a butt joint of R65 type rails is equal to about 20 min that allows a combined team of five people (two welding operators and three trackmen) achieving the efficiency of up to 16 butts per shift.

Welding is performed with a consumable nozzle, making reciprocal motions of varying amplitude (Fi-

**Figure 2.** Schematics of nozzle displacement in arc welding of rails by bath method with a consumable nozzle

**Figure 3.** Welding crane tracks

gure 2) that ensures complete penetration of the edges being welded across the entire rail section. Foot welding is performed on a ceramic backing by multipass welding. After that a special lever mechanism is used to perform pressing down of copper shoes without interrupting the process, providing formation of weld side surfaces in welding of the rail web and head.

In most of the cases preheating before welding is not performed, butt preheating up to 250–300 °C is required only at the temperature below +5 °C, and welding can be performed at ambient air temperature down to –5 °C.

Consumable-nozzle arc welding was earlier introduced in mounting of crane tracks of bulker terminal of Tuapse Commercial Sea Port (RF) (2009–2010) and Iliichevsk Sea Fishing Port (Ukraine) (2011) (Figure 3). In these facilities welding of butt joints of crane rails KR100 and KR120 was performed (Figure 4).

During 2009–2011 this method was also used to weld more than 900 butt joints of R65, T62 rails (Figure 5 *a*, *b*) and low-profile webless rails LK-1 (Figure 5, *c*) at reconstruction of high-speed tram line in Kiev and tram tracks in Lvov.

Developed special welding consumables and welding technology ensure rather high values of mechanical properties of welded joints. Hardness of metal of R65 rail welded joints is equal to *HB* 260–320; weld metal ultimate strength is 800–900 MPa. Breaking load at rail testing for static bending is 1500–1650 kN at bending of 16–22 mm.

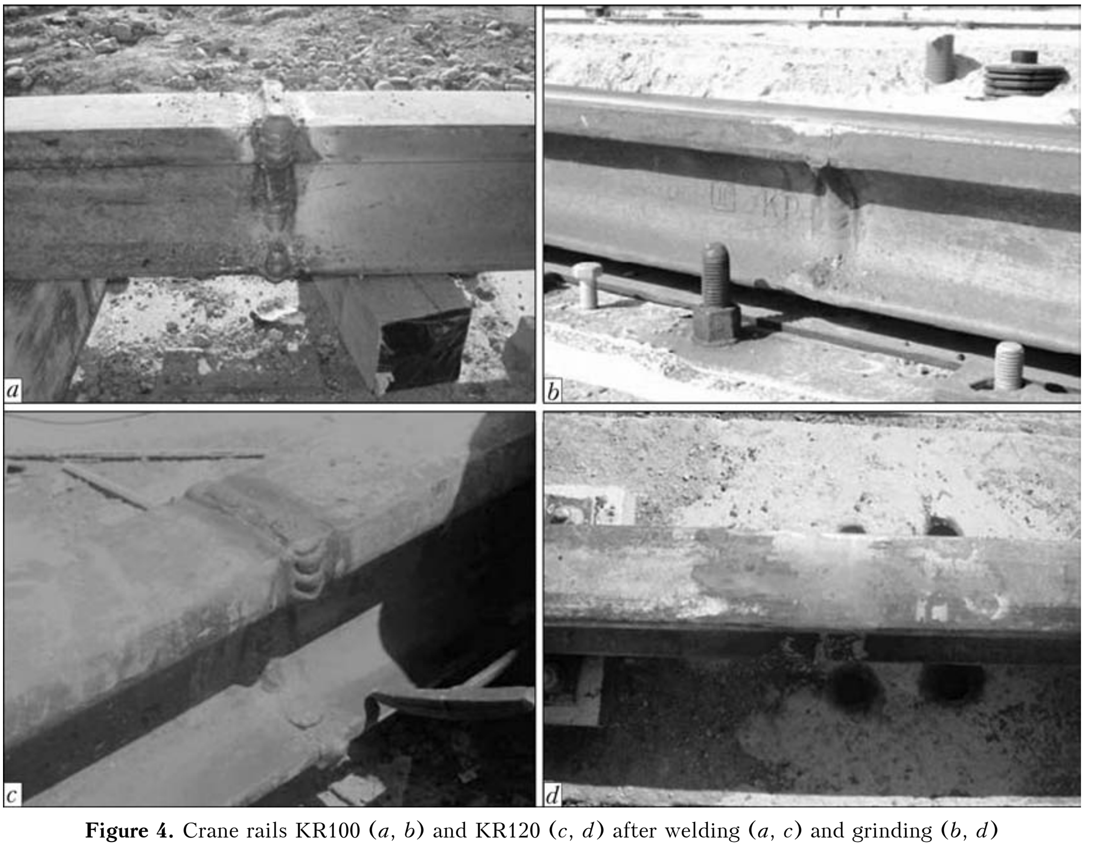


**Figure 4.** Crane rails KR100 (*a*, *b*) and KR120 (*c*, *d*) after welding (*a*, *c*) and grinding (*b*, *d*)

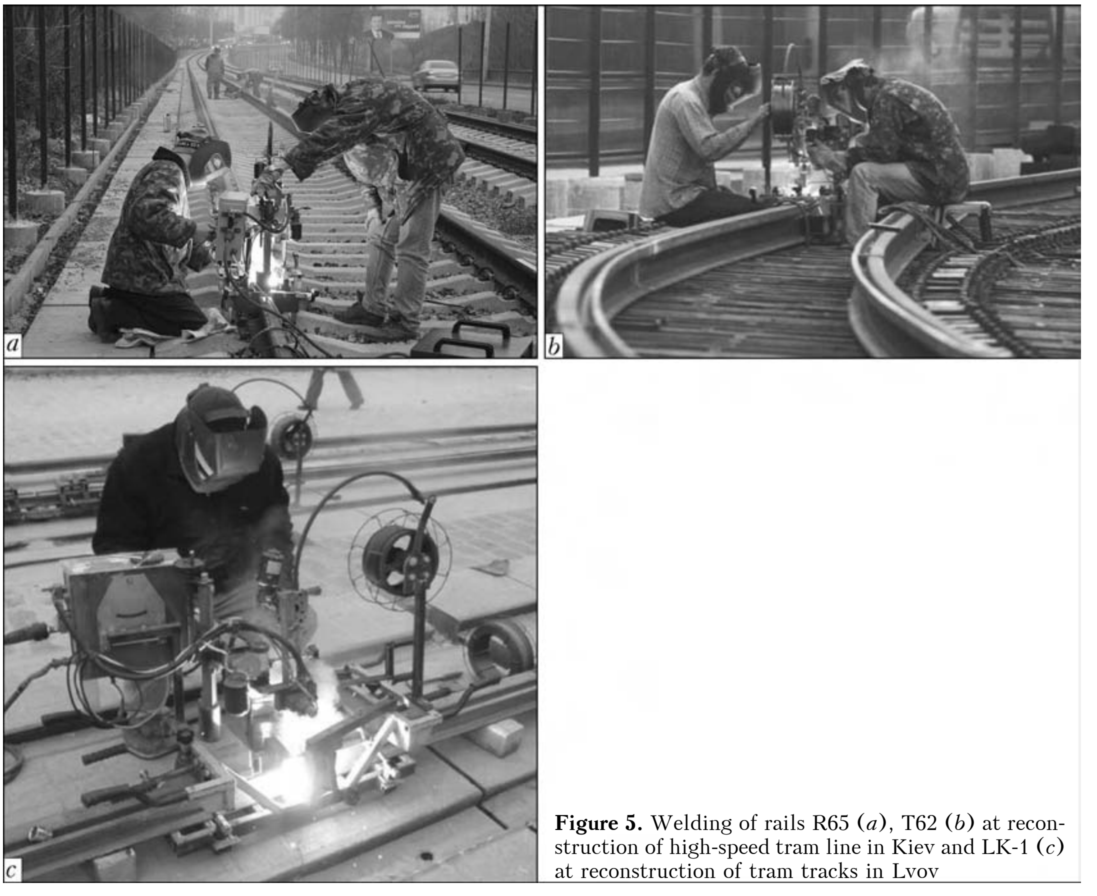

**Figure 5.** Welding of rails R65 (*a*), T62 (*b*) at reconstruction of high-speed tram line in Kiev and LK-1 (*c*) at reconstruction of tram tracks in Lvov

This welding process offers the following advantages:

- higher and more stable quality of welded joints compared to manual arc bath welding and alumothermic welding;
- high efficiency — up to 16 butt joints per shift;
- no shielding gas or flux required;
- no preheating (at +5 °C and higher temperature) or heat treatment of the butt required;
- low power consumption (consumed power of up to 15 kV·A);
- easy readjustment of equipment for welding rails of various typesizes;
- high mobility that is particularly important at performance of repair operations.

Thus, the new process of electric arc welding by bath method with a consumable nozzle, developed at PWI, owing to its advantages, can be regarded as an alternative to the existing processes of welding during performance of operations in the track.


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