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60 Years of the First in the World Mobile Machine for Flash-Butt Welding of Rails in the Field Conditions

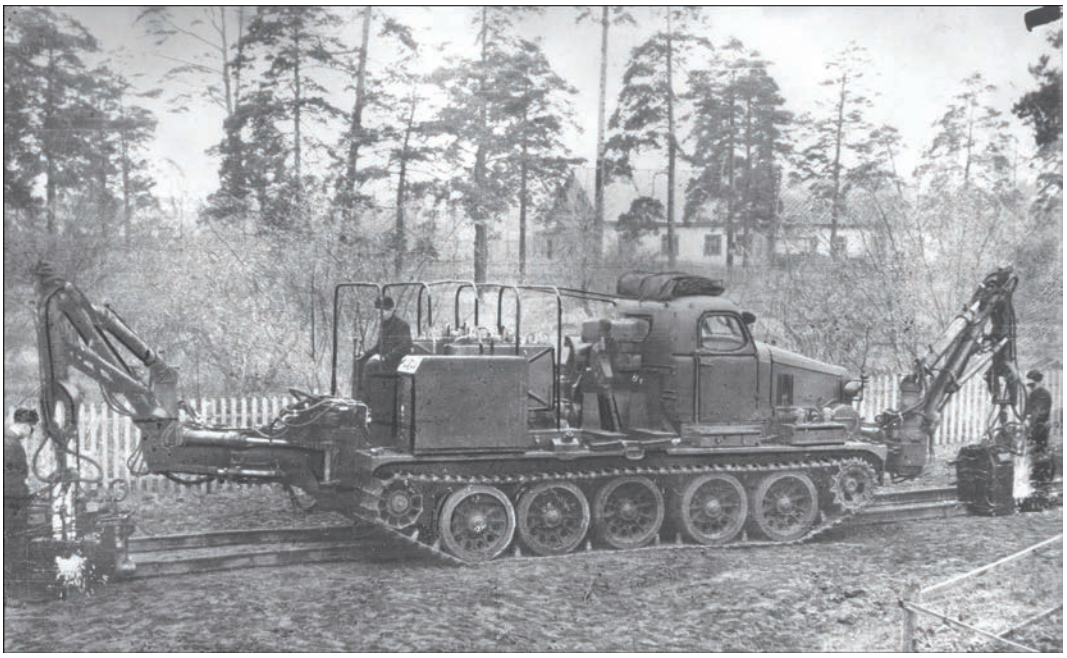
In the post-war years the tens of thousands of kilometers of railway tracks, damaged by war and quite unsuitable for any traffic on them, were available at the most part of the former USSR territory. The situation was redoubled also by the absence of production of new rails at that period. The way out of the situation was the only one: to start the restoration of railway tracks by using the remained undamaged rails to recommence the delivery of necessary cargoes along them. Moreover, even at this stage of reconstruction the task was to pass to the most progressive technology, namely to provide the continuous track (without double-sided cover plates), which will allow developing high speeds of traffic and being more reliable in maintenance.

The primary task was the searching for a reliable permanent joining of rail ends. Methods of welding, thermit and electric arc ones, known at those years, were characterized by a very low efficiency (1–2 butt joints per hour), and required to use a large amount of welding consumables and highly-qualified operators. At the same time the noted methods of welding did not provide the mechanical properties of joints, meeting high requirements to the continuous track joints (close to properties of the rail base metal).

Such requirements were satisfied by the flash-butt welding of rails, which was used at the factories abroad, equipped by stationary rail-welding machines. Using these machines the rail sections of 200–400 m length were welded in them and transported to the laying sites by special trains. Such machines consumed power of 400–500 kV·A, and their mass exceeded 200 tons. This circumstance allowed their application only in specialized rail welding shops, having the sufficient power supply (600–800 kV·A). The construction of similar enterprises at the USSR territory at that time was not possible.

In the middle of the 1950s the governmental task was put forward to the Electric Welding Institute: to design equipment for flash-butt welding of rails directly in operating track at its reconstruction and repair. Moreover, the welding process should be realized completely in the automatic mode and with account for minimized requirements to accuracy of cutting the rail ends as compared to the requirements under the factory shop conditions. The latter was specified by the fact that it is difficult to use the equipment for high-accuracy treatment of rail ends in the field conditions.

The development of the new technology and equipment for rail welding in the field conditions was carried out at the Electric Welding Institute integrally. Together with searching for welding technology, providing the required quality



Mobile complex K355 during tests at Kiev rail road tracks (1960)

Mobile rail welding complex on railway platform

of joints at a minimum power consumption, the control systems, providing its stable reproduction, independently of changing the service conditions, as well as equipment, having much less weight and dimensions, were developed. It was assumed to apply the equipment being designed as a tool, mounted on the rails being welded. It was found, that the significant decrease in welding process power, consumed in flash-butt welding of rails, can be achieved when using the power for welding with a continuous flashing for basic heating instead of used heating by resistance in stationary machines of the shops. Exciting by the continuous flashing at low specific powers became possible due to applying the controllers of flashing rate and high reduction (by 2–3 times) in resistance of welding circuit of the machines.

To produce the required heating in welding, a programmed reduction of voltage during flashing was suggested for the first time. Such technology, named as the continuous flashing with a programmed reduction in voltage, was used as a basis for the development of modes for welding of different rail types. For all the mentioned innovations, the International patents were obtained in the leading countries of the world. With their application, the first in the world mobile welding machine K355 was designed for continuous flash-butt welding of rails in the field conditions. It was characterized by a low weight (2.3 tons), allowed its application for mounting on rails using standard hoisting mechanisms. The welding machine power was 150 kW, it was enough to use the standard diesel-generating electric stations of 200 kV·A for its power supply. The first rail welding machines were mounted on all-terrain vehicles of a high trafficability, equipped with the hydraulic jacks and used in excavators. The electric supply of two welding machines, operating simultaneously, was realized from

generator, connected with a shaft of power take-off of all-terrain vehicle. Several tens of such mobile welding complexes were successfully used for restoration of railway tracks in hard-to-reach regions of the former USSR railroads.

During restoration of the railroads the main volume of welding works was connected with their reconstruction and laying of new sections of rails with sleepers. For these purposes, the mobile complexes were developed on the base of self-propelled railway platforms (PRSM) with a gantry hoisting devices. To increase the efficiency, the simultaneous welding of two butt welds by separate machines was provided.

In 1960, in accordance with documentation, worked out at the PWI, the Kakhovka plant of electric welding equipment (KPEWE) started production of the machine K355. By the middle of the 1960s about hundreds of such machines were in service in the USSR. Their design was continuously improved with account for needs of consumers. Since the middle of the 1970s the export of such machines to different countries of world started. They were bought by the USA, Great Britain, Austria, China and other countries. In total, from the data of KPEWE, 80 % of the world park of mobile welding machines is the machines, manufactured in Ukraine.

At the modern stage, the development of the new types of welding machines at PWI is continued. This is caused by the tendency of applying the high-strength rails of a new generation at the railway tracks.

In the recent decade the developments in the direction of updating the equipment for welding rails in the field conditions are continued. Here, the real tasks are taken into consideration for applying these machines in different regions of the world.

The application of the new technology of welding of high-strength rails, combined with their tension, required the creation of new generations of rail welding machines, characterized by much higher upsetting forces, equipped with built-in mechanisms for removal of weld reinforcement in a hot state. The above-given peculiarities of the new technology of welding of high-strength rails and systems of multifactorial control were used as a basis for the design of a new generation of mobile rail welding machines. Modern systems of computing technology, quick-response hydraulic drives and powerful systems of electron control of welding parameters are used in them. Such machines allow performing welding of long-length rail sections, combined with their tension.

The first machine K921 for welding rails by a pulsating flashing with tension was designed at the PWI in 2001 and manufactured by KPEWE in cooperation with the Norfolk Southern Company (USA). Its implementation and final testing of the technology of rail welding were carried out with the PWI participation on rail roads, which belong to this Company. For the first time in the world practice the flash-butt welding of rail sections of an infinite length, being up to several hundreds of kilometers without bolted joints, was performed. From the available data the total length of continuous tracks of infinite length, welded by the Company, exceeds 10 thou km.

In 2001–2005 the machines of K920 and K922 types of two modifications were designed. The parameters of these machines (forces of upsetting and clamping, machine dimensions) were optimized with account for applied technologies of repair and construction and available mobile rail welding complexes. In particular, it was possible to decrease greatly (by 1.5 times) the weight and dimensions of the machines as compared to the first experimental-industrial model K921.

In 2010–2012, according to the license agreement with Holland Company (USA) the PWI designed machines K930 and K945, which have an enlarged travel of movable clamp of up to 450 m at upsetting force of 120 tons. This allows welding of long rail sections of large length in reconstruction of railway tracks. The mobile complexes for operation with such machines were designed, respectively. Ten such complexes are operating since 2014 at the rail roads of Great Britain. They use the machines K945, designed at the PWI and manufactured at KPEWE.

The modern mobile rail welding complexes, manufactured by KPEWE, represent self-propelled units, which are provided with a rail travel or a combined travel, allowing moving both on rails, and also on high-way and earthen roads.

A qualitatively new level of mobile rail welding equipment was achieved as a result of the cooperation of PWI with the Progress Rail Services Corporation Company (USA). In 2014–2018, in accordance with the license agreement, the machines K960 and K1045 were designed and manufactured, which made it possible to significantly expand the fields of FBW application.

The machine K960 (upsetting force of 200 tons) is the most powerful among the production line of mobile machines for welding rails with tension, created by PWI and in present it is successfully operated in the reconstruction and repair of railways in the USA.

A unique arrangement of the suspended single-rod rail welding machine K1045 provided the ability to perform works in hard-to-reach places (in the underground, in welding rail endings of crossing pieces), which is a significant competitive advantage as compared to the known rail welding complexes.

On the mobile complexes, except the rail welding machines, the diesel-generator units of 200–300 kW capacity, hydraulic jacks, auxiliary equipment for rail preparation for welding, system of nondestructive testing are mounted. Mobile complexes of similar type, where machines K920, K922, K930, K950 are applied, are used at the rail roads of Europe, by Holland Company in the USA, Network Rail Company in Great Britain, in China, Australia, Taiwan, Malaysia, India, Turkey, Saudi Arabia and Thailand.

Prof. S.I. Kuchuk-Yatsenko

*Calendar of March**

MARCH 1, 1936 Birthday of V.R. Ryabov (1936–2002) — representative of the Paton school, famous scientist and experimenter in the field of welding dissimilar materials. Principles and procedural approaches to studying the problem of weldability of metal composites were presented, and processes, promoting formation of high-strength joints, were investigated in his works. Results of studying the weldability of dissimilar and multilayer metals and aluminium composites became a significant contribution to development of their welding technologies, promoted wide introduction of the above-mentioned materials in structures of aviation and aerospace industry. He is author of more than 310 scientific works, including 20 monographs.

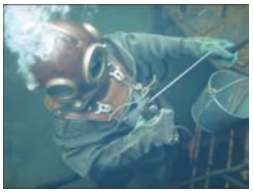
MARCH 2, 1927 Construction of Tuapse section of Grozny–Tuapse oil pipeline began. This was the first large Russian trunk oil pipeline from medium-diameter pipes. Construction was conducted from 1927 till 1928. Electric arc welding was applied for the first time in the world for joining pipes in the oil pipeline. This welding method turned out to be highly successful and found wide application further on.

MARCH 3, 1953 One of Castolin Electric Company patents was issued. This Company made a substantial contribution into development of welding technologies. The enterprise was established by Jean-Pierre Wasserman in 1906 in Lausanne, Switzerland. He discovered the method of brazing cast iron by braze alloys. In the following years, machines for spraying, coating, and welding and proprietary consumable materials have been developed. The company is present with its own subsidiaries in over 100 countries on all five continents and has a high international image.

MARCH 4, 1918 Birthday of N.G.Ostapenko (1918–1965) — representative of the Paton school. He was the first to apply carbon dioxide gas as shielding medium for carbon-electrode arc welding. N.G. Ostapenko also made a significant contribution into substantiation of wider application of flash-butt welding in the main oil pipelines due to use of special transformers and solving the problem of butt welding of casing pipes at their lowering into the well.

MARCH 5, 1870 Birthday of E.O. Paton (1870–1953) — outstanding scientist in the field of bridge building and electric welding, founder of the world-renowned Paton scientific-engineering school, Hero of Socialist Labour, winner of Stalin Award, founder of the Electric Welding Institute, which bears his name since 1953. His activity in bridge construction, structural mechanics, electric welding and electrometallurgy will forever remain in the history of world science and technology.

MARCH 6, 1906 Birthday of David Roland Smith (1906–1965) — US artist, famous for his large abstract geometric sculptures from steel, representative of abstract impressionism, who created his works from metal. He gained his first experience of manufacturing metal products when he was still a student in 1925, working as a welder at Studebaker factory. Impressed by metal artwork of Pablo Picasso (1881–1973) and Julio Gonzalez (1876–1942), David Smith created his first sculpture using welding in 1933.



MARCH 7, 1942 K.K. Khrenov (1894–1984) was head of the laboratory of underwater welding and cutting at the Moscow Electromechanical Institute of Railway Engineers. The technology of underwater welding and cutting was studied and developed in detail, and appropriate personnel were trained over a short period. By the end of 1943 hundreds of underwater welders and cutters were performing work under the water. Underwater welding enabled conducting repair of underwater part of ships without placing them into the docks, sometimes directly in the open sea.

MARCH 8, 1924 Birthday of Antony Caro (1924–2013) — famous British sculptor. Beginning from 1960s, Caro's individual manner is characterized by abstract compositions, created using welding. In addition to steel beams and pipes, he uses in his work the forms resembling «found objects».

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MARCH 9, 1943 Testing of US Army tank of M6 modification began. The initial concept of the new heavy tank was defined already on May 22, 1940. In December 1941, the first sample of heavy 60 ton tank was manufactured in a locomotive plant in Baldwin. The tank hull was welded manually. In 1944 they switched to automatic submerged-arc welding. Welding of armored hulls of combat vehicles was performed both at alternating and at direct currents. Butt joints were assembled with edge preparation and 2 mm root face, then welded manually in several passes. Just 40 T1/M6 tanks of various modifications were manufactured all together, which were never used in combat.

MARCH 10, 1986 G.Z. Voloshkevich (1911–1986), a representative of the Paton school, died. He created the theoretical foundations of a number of new welding processes, directly participated in organizing a wide introduction of electroslag welding processes in production in heavy machine-building plants. In 1957 B.E. Paton and G.Z. Voloshkevich, together with the staff of Novokramatorsk Machine-Building Plant and Krasny Kotelshchik Plant (Taganrog) were awarded the Lenin Prize for development of the process of electroslag welding and production of large-sized critical items on its base. In 1958 this work received a Grand Prix at the Brussel's World Fair. A number of companies in industrialized countries bought licenses for application of this high-performance welding process.

MARCH 11, 1818 Birthday of Henry Saint-Claire Deville (1818–1851) — French chemist. In 1850 he developed a torch, in which hydrogen and oxygen were mixed in a special chamber, even before going out (a similar scheme is also used in modern welding torches). Introduction of a mixing chamber enabled regulation of the gas flame composition and temperature, by changing the ratio of combustible gas and oxidizer.

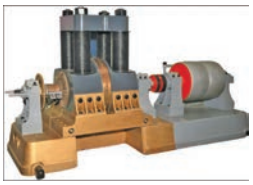
MARCH 12, 1683 Birthday of John Theophilus Desaguliers (1683–1744), British naturalist. He demonstrated the first outstanding example of cold pressure welding (without heating) at the Royal Society. Two lead spheres (the first of which weighed 1 pound, and the 2nd – two pounds), from which spherical segments were cut off, were pressed together by hand with simultaneous twisting. It turned out that as a result they were bonded. The spheres bonded to each other with such strength, that the supported by hand upper one pound sphere separated from the lower one only at more than 16 pound load. Examination of the contacting surfaces revealed that their bonding area did not exceed that of a circle of 1/10 inch diameter, although this surface could not be measured accurately, because of its irregular shape.

MARCH 13, 1903 Bouchayer, French scientist developed the design of «duplex-electrodes» (French Patent No.330200 of 13.03.1903) to make two spot welds at once. The upper and lower electrode assemblies had their own transformers. At parallel connection of the transformer windings just one spot can be made, and at serial connection — two spots at once. This invention essentially improved the productivity of spot welding process.

MARCH 14, 1692 Birthday of Pieter van Musschenbroek (1692–1761), Dutch physicist. Musschenbroek's most well-known achievements include development of the Leyden jar — the first capacitor, invented by Musschenbroek and his student, Cunaeus in 1746 in Leyden. Irrespective of Musschenbroek and a little earlier, the capacitor principle was discovered by Ewald von Kleist, Pomeranian Catholic Dean, on October 11, 1745. The capacitor is widely used in modern welding engineering, for instance in capacitor-type welding.

MARCH 15, 1906 Rolls-Royce Company was registered. At that time businessmen treated welding with distrust. However, if welded joints could not be avoided, it was allowed to make them by gas welding under the mandatory condition that the weld was located in non-critical part areas. They tried not to apply welding for heavy-duty parts. Still, with the advance of technology, entrepreneurs began applying welding more and more often. And now the full range of welding technologies is used in manufacture of new Rolls-Royce models.

MARCH 16, 1942 First trial launch of Fau-2 rocket. Fau-2 was exactly the first ever artificial object, making a suborbital space flight. Later on, it gave an impetus to creation and development of rocket science. Specimens of Fau-2 rocket were manufactured by the Germans at the end of the war, under the conditions of deficit of strategic raw materials. Therefore, a large number of inexpensive substitutes were used in production. For the same reason the rockets were mostly made of steel. Such an important component as the tail part of the rocket was made from a steel sheet by spot welding. The machine for spot welding of rocket body sections, in which welding was performed in several points simultaneously, was interesting from the engineering viewpoint.



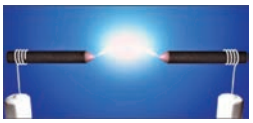
MARCH 17, 1890 N.G. Slavyanov (1854–1897) — Russian engineer, inventor of electric arc welding, filed a petition for issuance of privileges of Russia for the invented by him «method of electric casting of metals». The first generator ensuring «direct» power supply for this welding process was made by N.G. Slavyanov in 1888. The machine for welding using this generator, worked at the Perm factories up to 1895. It was used to perform more than 1500 practical welding operations.

MARCH 18, 1917 Birthday of V.E. Paton — Honoured Inventor of the Ukrainian SSR, talented engineer, brilliant designer. In 1948, he developed an all-purpose automatic welding machine-tractor TS-17, which had no analogs in domestic and foreign technology. He made a significant contribution to development of specialized machines for welding and spraying in space, for conducting astrophysical experiments. V.E. Paton is the winner of three state awards, and author of 90 inventions.

MARCH 19, 1894 P.N. Yablochkov (1847–1894) died. He was Russian electrical engineer, military engineer, inventor and entrepreneur. He is famous for development of the arc lamp (which went down in history under the name of «Jablochkov candle») and other inventions in the field of electrical engineering. In 1875 during one of the numerous experiments, P. Jablochkov came up with an idea of a more perfect design of the arc lamp (without the interelectrode space regulator) — future «Yablochkov candle». He often cooperated with N.N. Benardos, founder of carbon electrode arc welding, giving him the opportunity to do work in the enterprises and develop electric welding.

MARCH 20, 1831 Chevalier Paul ship was commissioned: the first French vessel of 2750 t displacement with an all-welded hull. By the advice of Alfred Kruppe (1907–1967), electrodes with a chromium-molybdenum steel core and coating developed by A. Stromenger, English chemist, began to be applied for welding armour plates in the ship construction. Arc welding was widely used in France also at construction of cruisers of Duplex class and battleships of Dunkerk class.

MARCH 21, 1800 In 1800 Alesandro Volta, Italian scientist (1745–1827), informed the Royal Society in London about development of an energy source, better known as «Voltaic pile». Alesandro Volta lowered two plates (zinc and copper) into a jar with acid and connected them by wire. After that, the zinc plate began to dissolve, and gas bubbles began to appear on the copper plate. Volta suggested and proved that electric current flows through the wire. This is how the Voltaic cell — the first galvanic cell was invented. But at the dawn of electrical engineering this is exactly the device which became the first source for the electric arc.



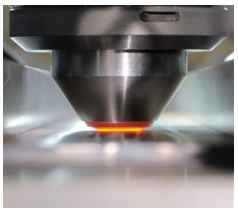
MARCH 22, 1892 August de Meritens, French electrical engineer, was born in 1834. He published French Patent No.123766 (improved magneto-electric generator). Experiments with magneto-generators became his most famous work. A. Meritens also produced the first torch for carbon electrode arc welding and patented in 1881. It was successfully used for welding in manufacture of acid cells. August de Meritens also invented a special device for welding operations — enclosed hoods and hazardous fume extraction pipe. These were the first means of welder's protection.

MARCH 23, 1942 Birthday of Abbott Lawrence Pattison (1916–1999) — US abstract painter. His sculpture «Kneeling Women» won the Medal of the Arts in 1942. The master used autogenous welding in his work. He was one of the most famous artists working in this field.

MARCH, 24, 1988 M.G. Belfor (1920–1988), a representative of Paton school, died. He made a significant contribution to establishing the fundamentals for design of welding equipment. His developments of automatic machines for electroslag and arc welding, which were classical examples of modern welding equipment, received international recognition. Alongside introduction of design developments of mechanization and automation means, he promoted advanced welding methods and equipment, gave a lot of his energy to education of young designers and researchers. He is author of 8 monographs and 62 foreign patents.

MARCH 25, 1958 RL-201 (Avro CF-105 Arrow) made its first flight. It was a delta-winged interceptor aircraft, developed by Avro Aircraft Limited (Canada) in 1953–1959. The aircraft design was in many ways advanced for its time. Inert-gas tungsten electrode welding in equipment supplied by Lincoln Electric Company was used for joining the aircraft components. The aircraft inner structure was a spatial frame from butt-welded tubes. The weapon bays were also made from stainless steel tubes, welded frames and beams.

MARCH 26, 1953 One of Sarazin's patents for welding electrode is issued. R. Sarazin and O. Moneiron, French inventers, developed a method of applying a thick layer of coating on metal rods, which included compounds of alkali and alkali-earth metals (fluorspar, marble, chalk and soda). They have low ionization potential. Therefore, the arc was more readily excited and maintained at application of such electrodes. It is known that N.N. Benardos also applied carbon electrodes with a «wick», i.e. electrodes, the core of which was filled by sodium and potassium salts.



MARCH 27, 1968 The British Welding Institute (TWI) was formed through merging of a number of organizations. TWI works across all the industry sectors and in all aspects of production. The institution also offers training and examination services on NDT, welding and inspection all over the world. Employing over 900 staff, TWI cooperates with welding organizations from 80 countries of the world. The history of the organization starts in 1923. Later on, in 1946, the British Welding Research Association (BWRA) was established. One of the outstanding achievements of the Institute was invention of friction stir welding.

MARCH 28, 1945 Polish Institute of Welding was established in Gliwice. It is the largest and most important research center in Poland, which performs work on investigation, development and introduction of welding technologies. The number of staff is 170 people. An important direction of the Institute activity is education and training of specialists in the field of welding and nondestructive testing. The Institute publishes its own welding scientific and technical journal «Biuletyn Instytutu Spawalnictwa».

MARCH 29, 1853 Birthday of Elihu Thompson (1893–1937) — one of the founders of electricity industry in the USA, outstanding engineer, inventor and pioneer, whose discoveries in the field of alternating current led to invention of alternating current motor by him. This is exactly the scientist, who is believed to be the «father of resistance welding», who managed to introduce it into industry. Elihu Thompson had his own vision of the future of electricity. In the course of his career, which lasted five decades, he received 696 US patents for inventions of arc lamps and generators, which were the base for development of welding equipment.

MARCH 30, 1929 Irving Langmuir (1881–1957) called the ionized gas in gas-discharge lamp «plasma». The matter, which became the fourth state of substance, was discovered exactly when studying the electric discharge in a tube with rarefied air. He was awarded the Nobel Prize in Chemistry (1932) for studies in the field of surface chemistry. In 1962 the industrial technology of plasma cutting was realized by K.K. Khrenov and E.M. Esibyan, PWI scientists. Today this technology surpasses all the other cutting methods in popularity.

MARCH 31, 1948 Academician E.O. Paton initiated establishment of «Avtomaticheskaya Svarka», scientific-technical and production journal (called «Trudy po Avtomaticheskoj Svarke pod Flusom» collection during the first two years). By the breadth and depth of coverage of published materials the journal filings over the 70 years of its existence are often called the welding encyclopedia. It helped in the formation of already several generations of welders.