что лишь десятилетиями позже появилось и за границей.

Возрождение идей изобретателя в России началось через 30 лет после его смерти. Предложенные им методы позволили создать современные высокопроизводительные способы промышленной автоматической дуговой электросварки.

Сварка как процесс изготовления неразъемных соединений нашла массовое применение при изготовлении металлургического, химического, энергетического и транспортного оборудования, магистральных трубопроводов, в транспортном машиностроении, строительных, железнодорожных и прочих конструкциях. Без нее невозможно производство судов, автомобилей, тракторов, самолетов, подвижного состава железнодорожного транспорта, турбин, котлов, мостов.

Перспективы сварки безграничны. В нынешнее время дуговая электросварка плавящимся металлическим электродом – один из основных технологических процессов во многих отраслях промышленности, им выполняется около 95% сварочных работ при производстве изделий из металла.

Ученый в области металлургии и сварки академик Б. Е. Патон писал: «Будучи по специальности металлургом Н. Г. Славянов разработал основы металлургических процессов, которые происходили при сварке. Он внес в методы электросварки много усовершенствований и по праву считается основоположником современной металлургии сварки».

Деталь, важная в эпоху глобальных сетей: в Перми в доме, построенном по проекту изобретателя, находится мемориальный дом-музей Н. Г. Славянова. **По-видимому, нет никаких препятствий посетить его любому из нас.**

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SAVED BELL-RINGING

(Dedicated to 160th anniversary of birth of Nickolay Gavrilovich Slavyanov)

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ABSTRACT

There will be few people who would like to question Nickolay Slavyanov's priority in invention of electric arc welding by consumable cathode (also known as arc welding with consumable metal electrodes, or shielded metal arc welding). The merits of 38 years old Russian engineer were recognized with formulae «For realized technological revolution» that followed his decoration with medal and diploma of 1892–1893 Chicago World's Fair: Columbian. And the inventions of Nickolay Slavyanov were fruitful not only for locomotives and steamships. The overwhelming majority of welding operations have been made till now with his method. In May, 2014 there will be celebration of 160th Anniversary of birth of this great talent.

ENGLISH SUMMARY.

Future inventor Nicholay Gavrilovich Slavyanov was born in a large family (8 boys and 3 girls) of the captain of the tsarist army on 5 May (April 23, old style), 1854 in village Nikolsky of Zadonskiy county in Voronezh province (now Zadonskiy district of Lipetsk region). He spent his childhood at the family estate of his father, where he received his primary education at home.

In 1862, the boy was sent to Mikhailovsky Cadet Corps, located in Voronezh. He was not going to be a military man, so in the penultimate year filed a petition for dismissal and entered Voronezh gymnasium, which he graduated with a gold medal. In 1872 the young man entered St. Petersburg Mining Academy. His mother, troubled by the cares of a family (his father died in 1868), could not help financially her eldest son. He had to relay ovens and give private lessons in mathematics, drawing and music. Student perfectly carried out training projects that provided original and practical value. For the project of a machine with a special steam distribution made in the last year, he was awarded the Council of the Institute reviews.

After a brilliant graduation in December 1877 a young metallurgical engineer of the first category was ordered at Votkinsky official mountain plant (now in Udmurtia, 50 km east of Izhevsk), where at first he was an intern, and then he was appointed caretaker of mechanical plants and plant mechanic. In 1881 he was transferred to Omutninskie private factories of Pastukhov brothers (now Kirov region, 180 km from the regional center), and in December 1883 – to the workers› village Motovilikha (later joined Perm) on state gun cannon factories as a disposer of gun and mechanical factories. These factories employed more than four thousand people. Factories, equipped with new appliances and staffed by experienced specialists, produced steel guns, artillery shells, steam engines and boilers, steamers and parts. In 1884 Slavyanov designed a special furnace for rolling of sheet iron.

From 28 May to 28 September of the following year Nicholay Gavrilovich was sent to Germany and Belgium to become familiar with production of plants of Kokeril and Krupp society in Witten on Ruhr and Bochum, as well as to explore the World Expo in Antwerp and Electrical Exhibition in K nigsberg (now Kaliningrad).

To learn more about the production, he worked at Belgian factories as a worker. Meeting with the world advances in technology have contributed to the emergence of his inventions. He became interested in electrical engineering, and began its own study, drafted a power station and supervised its construction. On the basis of constructed by him in 1885, electrical appliances and generator 300 A at a voltage of 60 V was created the first at Ural factories and in Perm power plant driven by a steam engine.

Since 1887 production buildings of plants on which he elaborated wiring system of a flat iron steel were exposed by arc lamps with regulators, were made again on his project. Total in thousands of production units burned 2, 5 arc lamps. Generator, arc lamps with regulators and various electric devices of the engineer, were exhibited at Ural-Siberian scientific- industrial exhibition in Yekaterinburg. The expert commission awarded Slavyanov with a large silver medal «For merits of objects represented at the exhibition».

By the end of the 1880s with rapid development of manufacturing engineering, shipbuilding, energy and other sectors of the economy the demand for steel castings has increased. Elimination of defects of large metal workpieces became more and more expensive. To improve the quality of steel bar chemical and mechanical (compression) methods were used. They, however, did not reach fully the purpose, or were complicated and expensive. As a result, often massive large workpieces and products became subjects of remelting.

Slavyanov after a series of experiments proposed in 1890 to use arc heating to seal large metal castings and improve their structure, in particular steel bars, used for production of artillery shells. Use of energy of power plant for industrial heating was carried out as follows: molten metal immediately after pouring into a mold was preheated in the upper part to melting temperature of steel by a strong electric arc generated between non-metallic (graphite, coke) negative electrode disposed near the cast surface, and metal, connected to the positive contact terminal of the DC generator. Under such conditions the metal solidifies gradually from the bottom upwards. All formed gases were freely disposed of and shrinkage voids, arising during the solidification, were filled with metal available at the upper part of stock of molten metal. Without arc seal large upper part of steel bar, which contains gas cavities and shrinkage voids, would go to waste.

In case of adding to the casting of a melted by electrocution metal or alloy, similar in chemical composition to the product, the electrodes were prepared in the form of rods (iron or steel – rolled or forged, cast iron and copper alloys – molded) of different thicknesses depending on the current strength and the size of the cast details. Rods were inserted into the welding automatic controller, designed and named by inventor «Electric melter», which was in principle similar to the differential regulator for arc lighting lamps and maintained the constancy of the arc between the electrode and the workpiece.

Rods under the influence of an automatically controlled electric arc melted quickly. Molten surface of the metal parts joined (merged) with poured metal.

Slavyanov applied his invention for repair. In particular, cover from the slide valve of a three-ton hammer and the frames of the machine steamer were repaired.

His invention began to be used in factories in Russia and abroad. Electrical seal of metal castings with Slavyanov`s method allows now to receive high quality ingots of alloy steels produced by electroslag, plasma-arc and electron- beam melting. The service life of the parts of such steels increases three-fold.

Work with metal electrodes made it possible to use them for welding of metal parts. In 1888 Slavyanov, seven years after the discovery of N. N. Benardos of electric arc welding with carbon electrode critically evaluated and developed his idea, developed and applied welding with consumable metal electrode with pre-heating and protection of a product with molten slag layer.

One major drawback of the Bernandos› method was the danger of metal spoilage under the influence of high temperature of carbon electrode. Without metallurgical flux welding of steels containing alloying components and impurities does not always succeed. Oxide inclusions fell in the seam of the air. It accumulated sulfur and phosphorus.

Electric casting invented by Slavyanov (as he called the method of welding by electric fusion)

was the pouring of molten metal on the surface of metal products and its conversion after turning off of an electric arc into a stable compound. Such a method (in modern terminology – electric arc welding by metal electrode) differed from the previously proposed «electrogefest» of Benardos in that way that one or both electrodes were rods of the material to be cast.

The inventor pointed out: «As the source of electricity may serve dynamo without the aid of batteries, but in this case it must have fireproof armature and develop the current strength of not less than 200 A at a voltage of at least 50 V. It is possible to apply a weaker dynamo or of improper design, but then electric battery is required». He created a dynamo, which was the world's first electric welding DC generator, which simplified as compared to the batteries installation scheme and gave an impetus to the creation of new, improved and modified welding power sources, which in turn contributed to further development of welding.

In 1888 Slavyanov was appointed deputy chief of the mountain (the Director). Electrocasting factory with an electric generator was organized. It was the world's first welding department where great details were brought by narrow gauge railway and Slavyanov on 18 October for the first time publicly in the presence of the state commission, which included metallurgists and electricians from St. Petersburg, successfully tested his method of welding shaft of the steam engine by a metal consumable electrode. The Commission wished wider distribution of electrical casting method.

The inventor designed the machine with automatic regulator of the arc length, which was the ancestor of modern welders. For convenience melter was hung on the special device. It was possible to weld with two series-connected melters.

For his work he applied currents from 200 to 1000 A at a voltage of 50–75 V. Melting metal electrode`s diameter was 7–12 mm. These values are very close to the modern parameters of welding electrodes. When the thickness of the welded metals is 1–2 mm electrode`s diameter is chosen equal to 2–2.5 mm, with a thickness of 2–2.5 mm – diameter is 3–5 mm, with greater thickness – 5 mm or more. Amperage is taken 30–50 times larger than the diameter of the electrode, if these values are considered as abstract mathematical relations.

Slavyanov could work as a master on all metal-working machines. In his cabinet he had a small lathe tool in order to be able to carve a necessary detail at any time. He himself made many parts for welding machine. He taught the world's first electric molders (electric welders), which later became themselves teachers for other workers. In fact, at that time he created a real school of primary professional education for electric welders.

In the years 1889–1890 electric welding with consumable metal electrode instead of riveting of a body was first used in the shipbuilding industry on the stocks of Motovilikhinskaya shipyard during construction of a body of the largest tug-boat in Russia and Europe «Rodedya – Prince Kossogsky».

Slavyanov on the Permian cannon factories began to use his new method to correct and eliminate casting defects, which were considered as insurmountable by metallurgists, repair of frames of steam engines and their cylinders, housings of steam hammers and rolling shafts, gears, artillery carriages weighing 180–425 pounds (2948,4–6879, 6 kg).

Later major inventions and scientific works in the field of arc welding appeared, which were based on the ideas of Slavyanov. Inventors conducted jointly research in many countries to improve the quality of the weld metal. Successful solutions were put into practice, were developed and served as a stepping stone to improve welding practice.

Swedish engineer O. Kelberg offered to cover melting metal electrodes with heat-resistant non-conductive material to prevent runoff of electrode material and to weld in the overhead position. The coating to some extent protected the molten metal from oxygen and nitrogen of air.

In 1917, American scientists O. Andrus and D. Stress invented a new electrode. Their steel rod was wrapped with a strip of paper glued by sodium silicate – liquid glass. The arc stroked immediately, with the first touch and did not fade with slight removal due to the presence of sodium in the coating. Paper has become a source of smoke, pushing back the air from the welding zone.

In our country, in 1928 the serial production of the coating -covered electrodes for manual arc welding was established. Coating contained sponging (starch, cellulose, marble $CaCO_3$), stabilizing with a low ionization potential (chalk, potash) and dopant agents. They have improved the structure and composition of the weld metal and slag components (quartz SiO_2, fluorspar CaF_2, aluminum oxide Al_2O_3, titania oxide TiO_2, Mn oxide MnO, calcium oxide CaO, etc.), reducing agents (FeSi, ferromanganese FeMn, ferrotitanium FeTi). Changing the composition of the coating components, electrodes were received with special properties. When welding of structural steels of different brands the desired properties of the weld metals were provided (heat resistance, corrosion resistance, heat resistance, etc.), the tensile strength of the weld joint is to 8,5 MPa, bending angle is up to 180 degrees.

In July 1891 Slavyanov was appointed mining manager at Perm gun factories. Russian cannon fodders could not penetrate the armor of enemy ships. Furthermore, they were expensive. Together with the builder of the first open-hearth furnaces in Russia A. A. Iznoskov, specially invited by him, Slavyanov created new spherical artillery shells from ingot steel, instead of forged one. According to the results of test firings conducted at the firing ground in Motovilikha, they were not inferior in strength to Krupp`s artillery shells and punched a six-inch (152.4 mm) armor.

Then Slavyanov received patents for «Method of electric seal of metal castings» (Russian privilege № 8747) and «Method and devices for electrical casting of metals» (Russian privilege № 8748). The invention is based on the phenomenon of electric arc, discovered in 1802 by an academician of St. Petersburg Academy of Sciences V. V. Petrov. The first patent secured priority recharge in electric ingot replenishment in an important research field of metallurgy to reduce shrinkage cavities and obtaining a homogeneous metal structure of steel

workpieces. Both methods were simultaneously patented in France, England, Austria- Hungary and Belgium; applications were made in the U.S. (patent obtained in 1897), Sweden and Italy.

In 1891 he published at his own expense (director spent most of the huge salary on inventions) the first book summarizing the essence of electrical casting of metals to promote his invention. It became known and was translated into English, French and German languages and published abroad.

A year later, his major printed work «Electric casting of metals. Guide for installation and its practical application» was published. This is the first monograph on the electrical treatment of metals. Slavyanov proposed ways of pouring voids in metal products and merging together two objects or two parts of a broken or cracked parts; methods of correcting worn (erased) surfaces of rubbing surfaces by pouring molten metal on them; increasing layers of metal on metal objects. In this work the author spoke about turning solid white iron in soft gray; casting small products; pouring broken pieces of metal things (like teeth in the wheels, corrected place was put in the mold and poured with liquid metal of electrode) and large amounts of iron to iron parts. This book was reprinted in 1929 by the journal «Welding Bulletin» in Berlin, and in 1954 in Moscow.

In 1892 Slavyanov presented as a separate exposition the largest range of products, welded using his method, at the IV electrical exhibition of Russian Technical Society (RTS), which was held in St. Petersburg. The exhibition was visited by over 50,000 people. It was an undoubted achievement for a specialized technical exhibition.

Several samples of welding of dissimilar metals, delivered by the service of rolling stock and traction of Orel- Vitebsk Railroad (now Moscow and Belarusian), were investigated by professor P. K. Khudyakov in the laboratory of Imperial Moscow Technical School (now Moscow Higher Technical University named after Bauman). All tests were positive. Neither model broke at jointing. Metallographic examination showed excellent quality of structure in welding bronze with copper, copper with steel and copper with brass. Electric arc welding had higher quality than gas welding and carbon arc welding.

On the basis of the tests› results a special commission of the Ministry of Railways approved the use of electric arc welding with metal electrode in the repair of railway rolling stock and mechanical equipment of depots and workshops. It was the first official recognition of the welding process in Russia.

His other work «Electrical seal of metal castings› was presented at the exhibition in St. Petersburg. RTS awarded a mining engineer gold medal and honorary diploma for the successful use of electric arc to the production of metal castings and their subsequent processing to changes in the chemical composition of the metal and improve its mechanical properties.

In the same year at the World Exhibition in Chicago, dedicated to the 400th anniversary of the discovery of America by Columbus, both inventions of Slavyanov and his glass weighing 5.33 kg with a height of 210 mm in a dodecahedral prism with a hole inside were presented among Russian exhibits. This metal bar obtained through consistent surfacing on steel one after the other layers of electrodes made of special bell metal, red brass (alloy of 3–10% brass with copper), nickel, iron, copper, nickel silver (nickel silver, alloy of 5–35% nickel, 13–45% of zinc and copper) and the usual bronze, clearly demonstrated the possibility of electrocasting.

Some Western newspapers expressed the opinion of the inapplicability of electrocasting for welding ferrous metals. Workpiece of 8 layers represented the whole range of technical metals of that time and proved disputable possibility of a strong welding of various metals. For the invention of the original and effective welding process Slavyanov received a medal and honorary diploma with the words «For realized technological revolution». His «sandwich» for many years remained unconquered top in welding art. Now one glass of the inventor is in the Polytechnic Museum in Moscow, the second – in the Perm regional museum.

At the train station Levshino of Ural metallurgical line (now Sverdlovsk Railways), located 10 km north of Motovilikha, the bell was ringing unusually. But after impact bar broke, the station workers began to call with a fragment of a rail. Bell cracked. Slavyanov, the first in the world, welded the broken piece of a bell using his method. Method of electric arc welding with consumable metal electrode preserved the purity of bell voice.

In «Perm province news» article appeared which advised to carry the broken church bells in Motovilikha for repair. The factories had to open a special eletrocasting factory. It restored 34 bells with a total mass of 26.5 tons

On the basis of gained experience of electric arc welding of bells Slavyanov in 1893 in a pamphlet «On the possibility of correcting the Moscow Tsar Bell» proposed overhaul of Tsar Bell, located in the Moscow Kremlin, preserving individual sound. After the controversy in the press, it was decided that the Tsar Bell had a status of a monument and split off part should not be welded.

Basic principles of the theory of electric-heating of the upper parts of castings designed by Slavyanov have been applied in France since 1914, and by the 1930s – in the U.S., Germany and Sweden. The method of electric arc sealing of steel ingots, proposed by Slavyanov, has not lost its value at the present day.

Reports of Nicholay Gavrilovich about the electric welding process and casting metals were presented at the general meeting of members of RTS in 1892 and 1895 respectively. Extensive articles in Russian and foreign journals (in particular, numerous articles of professor M. A. Chatelain in the journal «Electricity») were dedicated to his works.

For exploitation of Slavyanov`s inventions in October 1895 in St. Petersburg was founded an association «Russian partnership of electric metalworking». Electric welding has been applied at the locomotive plant in Kolomna, Society of Shipping and Trade in Sevastopol, Nizhny Novgorod and Sormovskiy ship repair workshops, St. Petersburg, Warsaw, Izhevsk, Votkinsk, Lugansk, Zlatoust plants. The same support had the innovation at factories in Germany (Krupp`s in Essen), England, France, the USA

(engineering and railway workshops) and other foreign countries.

First World War gave additional impetus to the development of electric arc welding with consumable electrode. It began to be used instead of riveting in the construction of iron frames of buildings and ship bodies and instead of casting of very heavy pieces of large machines.

Intended use of electric arc welding with consumable metal electrode expanded. It was applied in the production of cars, electric locomotives, diesel locomotives, boilers, in the construction of metal structures, railways, pipelines for various purposes, etc. Its application made it possible to manufacture in engineering, marine and river shipbuilding such orders that were previously considered impractical reduced the time of their production.

Thermal power of electric arc is easily adjusted by adjusting the welding current. The main advantages of electric welding as a method of ferruminating metals as compared to riveting were increased productivity and improvement of working conditions, saving of metal, lighting of structures, reduction of required production areas, etc. The complexity of the designs executed by manual arc welding in the production of principals with span 12–18 m reached 0.85 m as compared to riveted construction.

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After lengthy welding in the winter outdoors Slavyanov caught his death of cold and got ill. This was followed by rheumatic heart disease. He died in Motovilikha on 17 (5 old style) of October 1897 of a heart attack at age 43 at the height of creative activity.

His untimely death interrupted his brilliant works on implementation of arc welding in industrial enterprises of Russia. As director of two major gun factories, head of huge number of engineers, supervisors and workers, and having great physical resources to experiment on a large scale, he managed before others to do what only decades later appeared abroad.

Revival of the inventor`s ideas in Russia began 30 years after his death. He proposed methods, which provided to create modern high-performance industrial ways of automatic electric arc welding.

Welding as a fabrication process of permanent connections found massive use in the manufacture of metallurgical, chemical, power and transport equipment, pipelines, transport engineering, construction, railway and other constructions. Without it, it is impossible to manufacture ships, trucks, tractors, aircraft, railway rolling stock, turbines, boilers, bridges.

Prospects of welding are endless. At the present time electric arc welding with consumable metal electrode is one of key processes in many industries, it runs about 95% of welding in the manufacture of metal products.

Scientist in the field of metallurgy and welding, academician B.E Paton. wrote: «Being metallurgist, N. G. Slavyanov developed the basis of metallurgical processes that occur during welding. He made a lot of improvements in the methods of electric welding and is considered the founder of modern welding metallurgy».

Detail is important in an era of global networks: in Perm in the house, designed by the inventor, there is a memorial house-museum of N. G. Slavyanov. Apparently, there are no obstacles to visit it to any of us.

Key words: history, Slavyanov, arc welding, transport infrastructure, technological revolution.

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