Eugeniusz Turyk, Wojciech Grobosz

Beginnings of submerged arc welding

Abstract: On the basis of available publications and patent descriptions it was possible to put together facts related to the beginnings of submerged arc welding in Poland and worldwide. The overview of reference publications confirms the information according to which the authorship of welding under a flux layer providing a metallurgical shield for the welding zone should be ascribed to D.A. Dulczewskij, whose patent was published in 1929. The article presents the issues of the first research, structural and implementation works connected with submerged arc welding and surfacing carried out at Instytut Spawalnictwa in early 1950s.

Keywords: submerged arc welding, history, D.A. Dulczewskij, Nikolay Benardos, Stanisław Olszewski, patents, research works, devices;

Information related to the invention and development of submerged arc welding in various publications is incomplete or even contradictory. For instance, the authorship of this method is ascribed to D.A. Dulczewskij, 1929 [1], B. Robinoff, 1930 [2] or J. Kennedy (*"J. Kennedy developed machine submerged arc welding"*), 1936 [3]. It is also possible to encounter information providing a later date attributed to the invention of this method – *"Submerged arc welding method has been invented"*, 1937 [4]. National reference publications contain only short mentions about the beginnings of submerged arc welding, e.g. in the publication [1]. There are no publications presenting the history of the development of this method. For this reason it has become necessary to attempt to complete and systematise historic facts about the beginnings of submerged arc welding both in Poland and worldwide. To this end, available publications and patent descriptions have been used.

Development of submerged arc welding worldwide

Arc welding began with inventing arc welding of metals using a carbon electrode, presented by Nikolay Benardos at the World's First Electric Exposition in Paris in 1881 and patented together with Stanisław Olszewski in various countries in 1885-1887 (so-called Elektrohefest process) [2]. Next, in 1890 Nikolay Slavanov patented welding with a metal electrode, instead of a carbon one, which provided both the heat source and a filler metal at the same time [2]. Oscar Kjellberg, the founder of Elektriska Svetsnings-Aktiebolaget (ESAB), trying to improve this method, invented a covered electrode produced by immersing an iron wire in a thick mixture of carbonates and silicates (patented in 1907) [2]. All these solutions were concerned with manual welding.

The development of mechanised, i.e. so-called automatic arc welding started in 1920s. Devices for welding with a consumable electrode and

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electric arc burning in the air were referred to in contemporary patents:

- *Apparatus for arc welding*. Author: Paul O. Noble from General Electric Company. USA, United States Patent Office. Patent no. 1,508,711, filed on 27.07.1921 and published on 16.09.1924 (Fig. 1) [5];
- *Automatic arc welding machine*. Author Frank A. Haughton. USA patent no. 1,676,985, filed on 14.09.1925 and published on 10.07.1928 (Fig. 2) [6].

A significant disadvantage of automatic welding with an open arc was the porosity of welds resulting from metallurgical reactions taking place at the interface of air and liquid metal drops transferred in the arc as well as in the weld pool zone, on the surface and within a liquid metal.

A mention related to the first publication about submerged arc welding by D.A. Dulczewskij in 1923 [7] can be found in the article [8]. A document detailing the principle of welding under a powder (flux) layer, providing metallurgical coating of the welding zone, is Dulczewskij's patent for arc welding of copper, filed on 28.12.1927 and published on 31.07.1929 (Fig. 3) [9].

In the patent description D.A. Dulczewskij stated that satisfactory arc welding had been considered impossible due to the strong oxidation of copper and the fact that during melting of copper by an electric arc and with the free access of air hydrogen and other gases mixed with copper. In order to protect the place of welding and the arc against the effect of air oxygen the author suggested using a layer of powder based

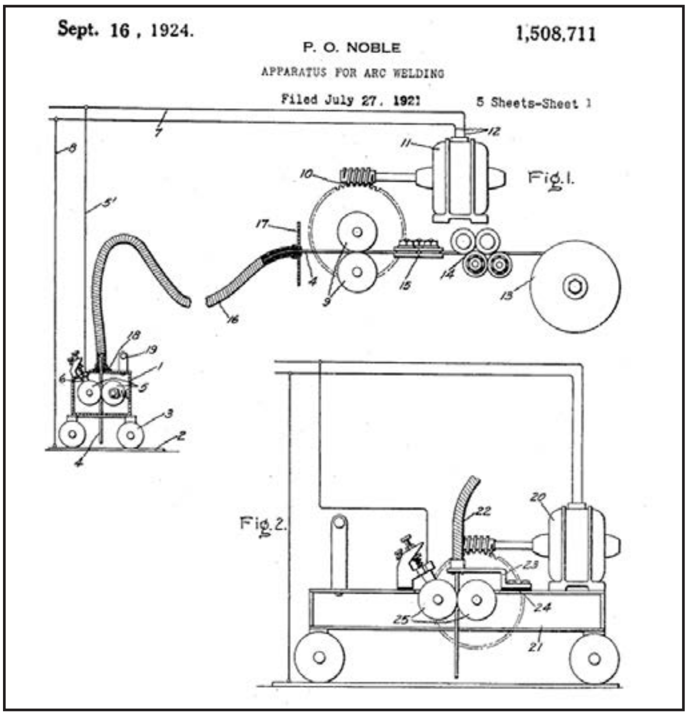


Fig. 1. Scheme of the arc welding machine according to US patent no. 1,508,711 [5]

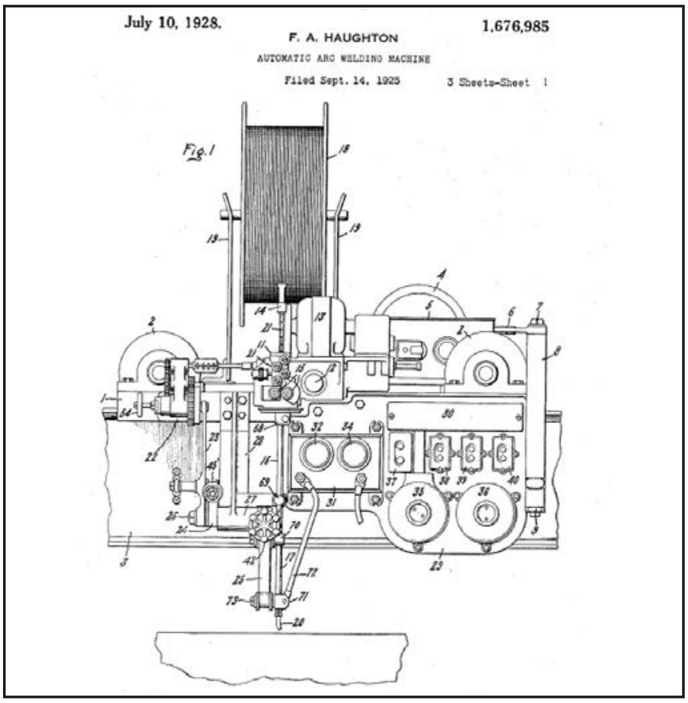


Fig. 2. Automatic welding machine according to US patent no. 1,676,985 [6]

Класс 21 h, 29 № 10578

ПАТЕНТ НА ИЗОБРЕТЕНИЕ

БИБЛИОТЕКА Комитета по изобретательству при СТО Союза ССР.

ОПИСАНИЕ

способа дуговой электрической сварки меди.

К патенту Д. А. Дульчевского, заявленному 28 декабря 1927 года (заяв. свид. № 22693).

О выдаче патента опубликовано 31 июля 1929 года. Действие патента распространяется на 15 лет от 31 июля 1929 года.

Удовлетворительная электрическая сварка меди при помощи вольтовой дуги до настоящего времени считается невозможной, вследствие сильного окисления меди и поглощения ею водорода и др. газов, в процессе ее плавления дугой, и потому в ответственных случаях сварка меди производится кислородно-ацетиленовым пламенем с применением сварочных брусков из электролитической меди в сплаве с фосфором, серебром и другими восстановителями.

Предлагаемым же способом дуговой электрической сварки меди имеет целью устранить недостатки по вышеупомянутому способу сварки дугой со свободным доступом воздуха, путем применения слоя порошкообразных горючих для защиты места сварки и дуги от воздействия кислорода воздуха.

На чертеже изображен вид свариваемых частей по предлагаемому способу.

Отрицательным электродом дуги служит медный прут 1, а положительным служат свариваемые части 2. Плавящийся под действием дуги прут 1 превращается в жидкий припой 3, при чем конец прута находится под слоем порошкообразных горючих 4 (древесного угля, опилок, сажи, крахмала и т. п.). При этом плавление происходит в атмосфере восстановительных паров вещества порошков, испаряющихся вокруг дуги под влиянием высокой температуры последней. При повышенном давлении этих паров и паров меди образуется вокруг отрицательного электрода кратер *A*, дающий возможность наблюдать за сваркой. С прекращением дуги кратер сам собой закрывается. Стенки 5 и подкладка 6 у места сварки служат для предохранения от рассыпания порошкообразного горючего и от растекания жидкого припоя.

Предмет патента.

Способ дуговой электрической сварки меди, характеризующийся тем, что сварку производят под слоем порошкообразных горючих, как напр. древесного угля, опилок, сажи, крахмала и т. п.

Fig. 3. USSR patent no. 10578 for arc welding of copper, page 1 of the description [9]

on charcoal, sawdust, soot and starch (it can be assumed that starch acted as an agent binding powder by drying – for this purpose it is used in foundry engineering). Metal melting takes place in an electric arc burning under the layer of powder in the reducing (deoxidising) atmosphere formed around the arc during burning of coal and other loose components (Fig. 4).

Works on providing the metallurgical shielding of the welding zone were conducted also in the USA. In 1930 Boris S. Robinoff, Sumner E. Paine and Wrignol E. Quillen obtained US patent no. 1,782,316 (filed on 10.05.1929 and published on 18.11.1930) entitled “Method of welding” related to arc welding under a flux layer (Fig. 5) [10].

In 1934, working on automatic welding with a bare wire, General Electric used flux developed by W. Miller. The flux contained feldspar (basic components 63÷76% SiO_2 and 13÷21% Al_2O_3) and titanium dioxide. Powdered components were wetted with water and, in the form of a paste, were applied on a product before welding [11]. In 1930s a factory of automatically arc welded pipes using dry fluxes, i.e. Western Pipe and Steel Company was established in the USA.

In 1935 the title to patent no. 1,782,316 was purchased by the Linde Air Products Company, which named the method of welding under flux as the “Union-melt” process. Next, the company developed a method of automatic arc welding under a flux layer - U. S. Patent 2,043,960, authors L.T. Jones, H.E. Kennedy and M.A. Rothermund; the patent was filed on 9.10.1935 and published on 9.06.1936 (Fig. 6) [12]. The method was used for welding steel sheets having a thickness of up to several dozen mm at a welding rate of up to 10 m/h [11]. The years which followed saw quickly developing automatic submerged arc welding. The scale of the development can be demonstrated by the fact that in 1944 over 3 thousand automatic welding machines were used in American industry [17].

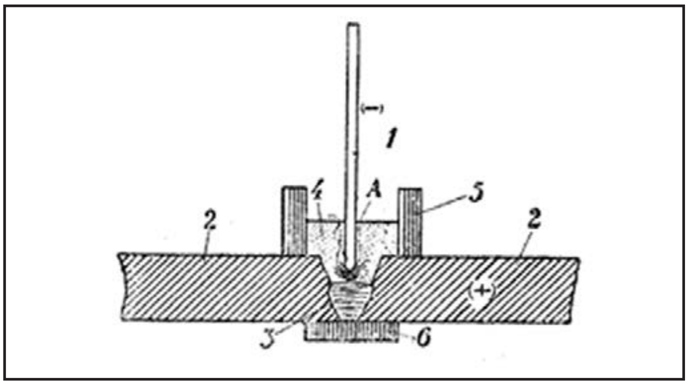


Fig. 4. Scheme of welding copper under a powder layer according to USSR patent no. 10578:
1 - copper rod (pole “–”); 2 - elements being welded (pole “+”); 3 - liquid metal formed from melting the rod in the electric arc (weld pool); 4 - layer of powder; 5 - wall preventing powder spilling; 6 - washer forming the root of a weld; A - crater enabling the observation of a welding process (page 2 of the patent description [9])

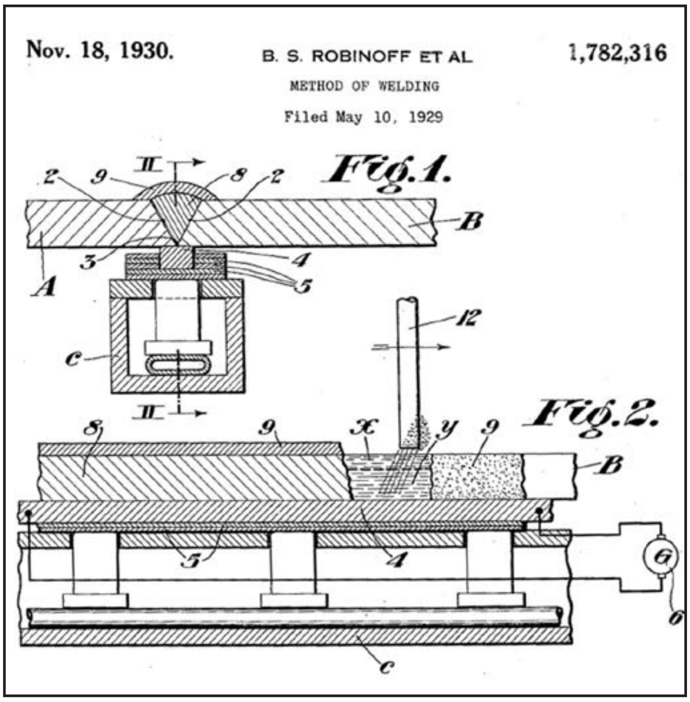
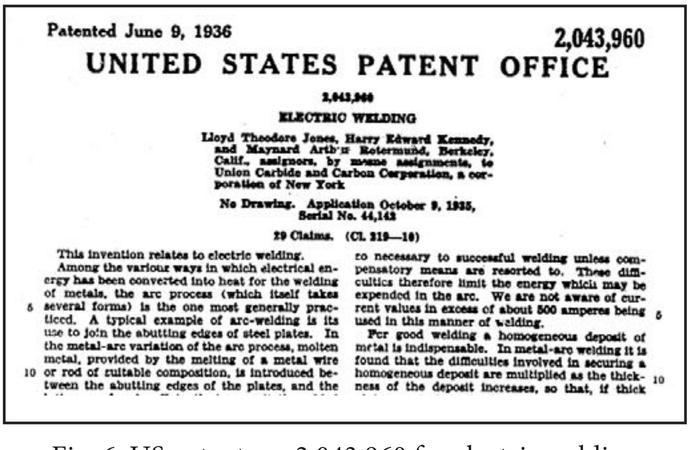


Fig. 5. Scheme of welding under a flux layer according to US patent no. 1,782,316 [10]



Patented June 9, 1936 2,043,960

UNITED STATES PATENT OFFICE

2,043,960

ELECTRIC WELDING

Lloyd Theodore Jones, Harry Edward Kennedy, and Maynard Arthur Rotermund, Berkeley, Calif., assignors, by mesne assignments, to Union Carbide and Carbon Corporation, a corporation of New York

No Drawing. Application October 9, 1935, Serial No. 44,142

29 Claims. (Cl. 219—10)

This invention relates to electric welding.

Among the various ways in which electrical energy has been converted into heat for the welding of metals, the arc process (which itself takes several forms) is the one most generally practiced. A typical example of arc-welding is its use to join the abutting edges of steel plates. In the metal-arc variation of the arc process, molten metal, provided by the melting of a metal wire or rod of suitable composition, is introduced between the abutting edges of the plates, and the

so necessary to successful welding unless compensatory means are resorted to. These difficulties therefore limit the energy which may be expended in the arc. We are not aware of current values in excess of about 500 amperes being used in this manner of welding.

For good welding a homogeneous deposit of metal is indispensable. In metal-arc welding it is found that the difficulties involved in securing a homogeneous deposit are multiplied as the thickness of the deposit increases, so that, if thick

Fig. 6. US patent no. 2,043,960 for electric welding under flux [12]

In Germany the Union-melt welding process was named Ellira-Schweissen (Ellira - from **El**ektrische-**Li**nde-**Ra**pidschweiβung), where in early 1940s it was used in the production of ships, boilers etc. (Fig. 7) [13].

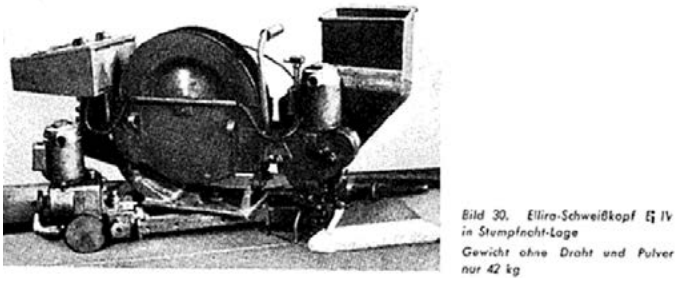


Fig. 7. Device with Ellira E IV welding head [13]

In 1938 in the USSR K.K. Chrenow developed ceramic flux for arc welding [14]. In the following year at the Electric Welding Institute (EWI) in Kiev works on automatic welding under flux were initiated. The team of EWI researchers including W.I. Diatłow, A.M. Łapin, I.I. Frumin and W.S. Szirin developed AN-1 melting flux for welding carbon steels with a silicon-manganese wire [15, 16]. The flux contained a significant amount of silicon and manganese oxides, which was a pre-condition for reducing the porosity of joints in then-dominant unalloyed effervescing industrial steels. In 1939 at the Electric Welding Institute in Kiev, under E.O. Paton's supervision, so-called "high-speed automatic unshielded electrode welding under a flux layer" was developed. The method was demonstrated in June 1940 and its welding rate during the demonstration amounted to 32 m/h. The method of high-speed submerged arc welding was first used in the production of 60-ton rail tankers, and from 1941, among others, for mass-scale welding of tanks (Fig. 8). The implementation of high-speed submerged arc welding decreased the labour consumption of welding the armoured body shell and turret of a T-34 tank eight times if compared with previously used shielded metal arc welding [11]. Submerged arc welded joints passed firing tests including firing a cannon at a tank, and high-quality full penetration welds were called "Paton seams" [16].

Welding under a flux layer was carried out using automatic welding heads, whose principle of operation was the same as in automatic open arc welding – a filler metal feeding rate depended on arc voltage. The constant length of arc was maintained continuously by changing the filler metal feeding motor rotation rate, which was tightly related to arc voltage changes. A rise in arc voltage increased the rate, whereas decreasing arc voltage reduced the rate proportionally, restoring pre-defined arc voltage. Control systems were complicated [1, 17, 18]. Their simplification was possible due to the method of automatic arc welding under a flux layer patented by W.I. Diatłow. This method was characterised by the constant filler metal feeding rate independent of welding arc voltage (Fig. 9) [19]. The principle of this method was described by W.I. Diatłow as the "phenomenon of welding process self-regulation" (USSR patent no. 64207, filed on 15.04.1942, published on 31.01.1945). Presently this phenomenon is referred to as welding arc self-regulation or the self-regulation of inter-electrode space energy state in disturbance effect conditions [18]. The method enabled a simple filler metal feeder drive solution using an asynchronous motor. In this way it was possible to simplify the control system in relation to filler metal feeding control systems depending on arc voltage. The self-regulation of a welding arc was also the basis of control in machines for CO_2 shielded welding,

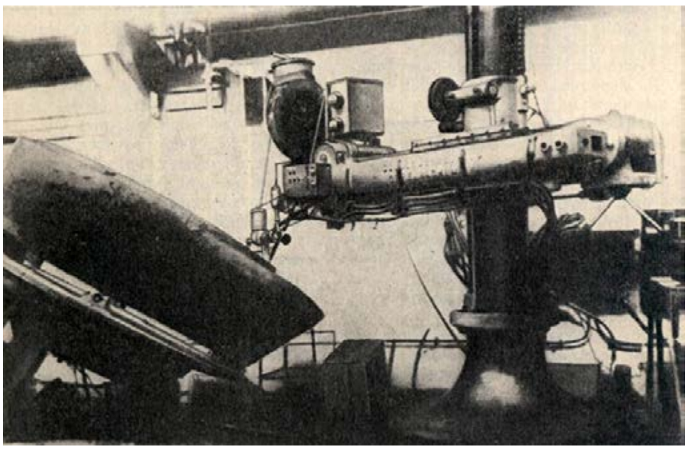


Fig. 8. Submerged arc welding of a ring for a T-34 tank turret using a column and boom station [16]

a method developed by K.W. Lubawskij and N.M. Nowożiłow in 1953 [2].

Класс 21h, 30₁₀ СССР № 64207

ОПИСАНИЕ ИЗОБРЕТЕНИЯ
К АВТОРСКОМУ СВИДЕТЕЛЬСТВУ

Зарегистрировано в Бюро изобретений Госплана СССР [illegible]

В. И. Дятлов

Способ автоматической дуговой сварки под слоем флюса

Заявлено 15 апреля 1942 года в Наркомтавкопром за № 14-184 (309323)
Опубликовано 31 января 1945 года

Для сварки под слоем флюса («Unionmelt» U. S. Patent 2043960, 1936 г.) применяются автоматические сварочные головки, принцип действия которых остаётся таким же, как и для автоматической электродуговой сварки открытой дугой.

Этот принцип заключается в том, что механизм подачи электродной проволоки имеет электрическую связь с напряжением между концами электродов («напряжение на дуге»). С изменением напряжения между концами электродов механизм подачи электродной проволоки изменяет скорость подачи этой проволоки и восстанавливает заданную величину напряжения между концами электродов.

Настоящее изобретение касается нового принципа регулирования сварочной дуги и подачи электродной проволоки при автоматической сварке под слоем флюса, основанного на явлении саморегулирования процесса сварки под слоем флюса, присущем только этому процессу сварки.

Процесс сварки под слоем флюса отличается от обычного процесса электродуговой сварки открытой дугой тем, что, помимо прохождения сварочного тока через сварочную дугу, в определённые периоды времени сварочный ток проходит через расплавленный флюс, который окружает зону сварки и в расплавленном состоянии является проводником электричества.

Периоды горения сварочной дуги и периоды прохождения тока через расплавленный флюс чередуются один за другим. В течение периода горения дуги происходит плавление металла электрода, в течение прохождения тока через флюс происходит плавление флюса.

Изменение величины промежутка между электродами (между электродом и основным металлом) влияет на длительность каждого из указанных периодов, а следовательно, и на распределение энергии, расходуемой на плавление металла и флюса. При увеличении промежутка между электродами, увеличивается период прохождения тока через флюс, сокращается период горения дуги и соответственно увеличивается расход энергии на плавление флюса и количество расплавленного флюса и уменьшаются расход энергии на плавление металла и количество расплавляемого металла электрода.

Fig. 9. USSR patent no. 64207 for welding under a flux layer using the principle of welding process self-regulation – page 1 of the description [19]

In 1949 G.Z. Wołoszkiewicz, EWI, presented submerged arc welding of thick-walled joints in a vertical position with the forced formation of a single-layer weld and stated that melted slag could be the source of welding heat. In this way electroslag welding was developed [15]. The first special flux for electroslag welding, i.e. AN-8 was developed by G.Z. Wołoszkiewicz and I.I. Frumin in 1950. In the following years, the electroslag welding method almost entirely eliminated submerged arc welding of thick-walled joints in a vertical position.

In 1949 EWI developed double-arc welding under flux at a rate of 160÷200 m/h. The next year saw the development of so-called semiautomatic submerged arc welding intended for manual applications [15]. The method was mainly used to make short curvilinear welds and welds in locations inaccessible for automatic welding due to the size of an automatic welding machine. However, the manual method did not become widespread and for many years has not been used due to difficulty with observing a welding process and low efficiency of semiautomatic welding machines caused by the significant weight of a welding torch with a flux container and a relatively small amount of flux in this container (Fig. 10).

Fig. 10. Semiautomatic submerged arc welding (EWI archive photograph)

The next years brought significant transformations of submerged arc welding machines (welding automatic machines, welding heads, power sources). The process of submerged arc welding started to be used for surfacing and new variants of submerged arc welding appeared: multi-head welding, flux cored arc welding, welding with metallic powder addition, welding with strip electrode and with cored strip electrode, welding with cold and hot electrode, narrow-gap welding, AC/DC submerged arc welding, hybrid laser submerged arc welding etc. Also the range of welding consumables for submerged arc welding increased significantly. In addition to classical welding in the PA and PB positions, submerged arc welding in the PC position was developed. Submerged arc welding was applied not only for making joints in steel but also in copper, aluminium, titanium and in their alloys.

Beginnings of submerged arc welding in Poland

The Polish industry started using submerged arc welding in early 1950s, among others, in shipbuilding and fabrication of welded structures for civil engineering [20÷22]. In 1954 30 automatic submerged arc welding machines [23], i.e. ADS-1000-1, ADS-1000-2 (made in the USSR) UPU (made in GDR by Kjellberg Finsterwalde) were used. Other machines used at that time included PSZ-5 and PDSZ-500 Soviet semiautomatic submerged arc welding machines. The first Polish semiautomatic welding machines, i.e. AS3-500, developed in 1953 by Centralne Biuro Konstrukcyjne Maszyn Elektrycznych CBKME (Central Electric Machinery Design Office) on the basis of PSZ-5 were first used in 1954. Three years later 36 such semiautomatic welding machines were operated in Gdańsk Shipyard [20]. Next machines were used in the production of railway rolling stock, steel structure fabrication and boiler production [24]. In the shipbuilding industry, due to difficulties with making T-joints and welding thin sheets, the AS3/TX-500 automatic welding was developed on the basis of the AS3-500 semiautomatic machine. AS3/TX-500 was extensively used in welding bracing elements during prefabrication works [21]. In 1953 CBKME, in conjunction with Instytut Spawalnictwa, set about adapting the documentation of a licensed Soviet automatic welding machine UT-1250, the Polish version of which was designated as AS1-1250 [22, 23]. Several dozen AS1-1250 machines were produced, yet most of them were used sporadically due to the significant dimensions of the tractor and control cabinet, low stability, troublesome setting of the transverse arm and low mechanical resistance of the whole structure [17, 22]. Further works on automatic submerged arc welding machines were carried out by Instytut Spawalnictwa which designed a prototypical automatic submerged arc welding machine AS7d-1200 powered by an ETb-1000 transformer and featuring remote current control within the 400÷1250 A range. The machine was made in the M-3 plant in Łódź (1957) [17, 22]. The lot production of the AS7d-1200 automatic welding machine was undertaken by Zakład Budowy Prototypów Urządzeń Spawalniczych ZBPUS (Prototype Welding Machinery Production Company) after carrying out trial operation at the "KONSTAL" company in Chorzów and in Gdańsk Shipyard. Afterwards, at ZBPUS, from 1965 known as Zakład Budowy Urządzeń Spawalniczych ZBUS (Welding Machinery Production Company), and from 1977 as Zakład Doświadczalny Instytutu Spawalnictwa ZDIS (Experimental Facility of Instytut Spawalnictwa), further submerged arc welding machines were built including [25, 26]:

- AS8a-600z submerged arc automatic welding machine for welding fillet welds (1961), implemented in a coal wagon welding line at Zaodrzańskie Zakłady Przemysłu Metalowego ZASTAL (Zaodrzańskie Metal Industry Plants) in Zielona Góra;
- OSa device for submerged arc surfacing of rolling stock wheel set flanges with two wires (1961), produced in small lots;
- AS11A-600 prototypical automatic welding machine (small-sized) for submerged arc welding of fillet welds (1963);
- AS14-1200 prototypical automatic submerged arc welding machine (1966), produced next by Opolskie Zakłady Aparatury Spawalniczej OZAS (Opole Welding Equipment Plants), Opole [18].

Accessory equipment included a CUa flux scraper and a CUb machine for rewinding electrode wire from coils onto reels (1957) [17].

The first research and implementation works on submerged arc welding were initiated at Instytut Spawalnictwa in the early 1950s. Works on fluxes and electrode wires were carried out in Zakład Spoiw i Metalurgii Spawania (Filler Metals and Welding Metallurgy Department) run by Jan Węgrzyn. The research team was composed of Edward Chuchro (the developer of Polish melting fluxes for submerged arc welding [28]), Stanisław Kraszewski and Jerzy Ziemliński. The research involved the development of wires for welding boiler sheets made of effervescing steels, formulas and technologies of producing melting fluxes for welding unalloyed structural steels, low-alloyed steels and acid-resistant steels, fluxes for high-current welding, pumice fluxes for higher speed submerged arc welding (approx. 100 m/h), melting fluxes for surfacing, filler metals for surfacing great furnace tops, electrode wires for surfacing rolling stock wheel rims and ceramic fluxes for welding and surfacing.

According to the Chronicle of Instytut Spawalnictwa "*…1954 was the year in which Instytut started semi-technical production of fluxes for submerged arc welding according to recipes developed by Zakład Spoiw i Metalurgii Spawania (Filler Metals and Welding Metallurgy Department) within programme research work in the years 1952-53. The production required the design and construction of a proper municipal gas-fired tilting furnace along with accessory devices, i.e. a dryer and screen. Due to its shortcomings the furnace was soon replaced by an arc furnace with a production capacity of 300t/year. (…) Initially, the major purchaser of the flux was Huta Ferrum (Ferrum Steelworks). After starting the mass-scale production of the flux by Spółdzielnia «Klejżel» («Klejżel» Co-operative) in Brzezie near Racibórz in 1956, the production of flux at Instytut Spawalnictwa was terminated in 1960.*" [25]. Welding fluxes manufactured at Instytut Spawalnictwa included TK manganese-free flux and TMnII, TMnIIa and TMnIIP manganese fluxes as well as TMn300 and TMn500 fluxes (mixtures of TMnIIa flux and ferroalloys) for hard surfacing [29]. Workers dealing with flux production (Fig. 11) in those days were Andrzej Kachel, Jan Lutkat and Rajmund Jander.

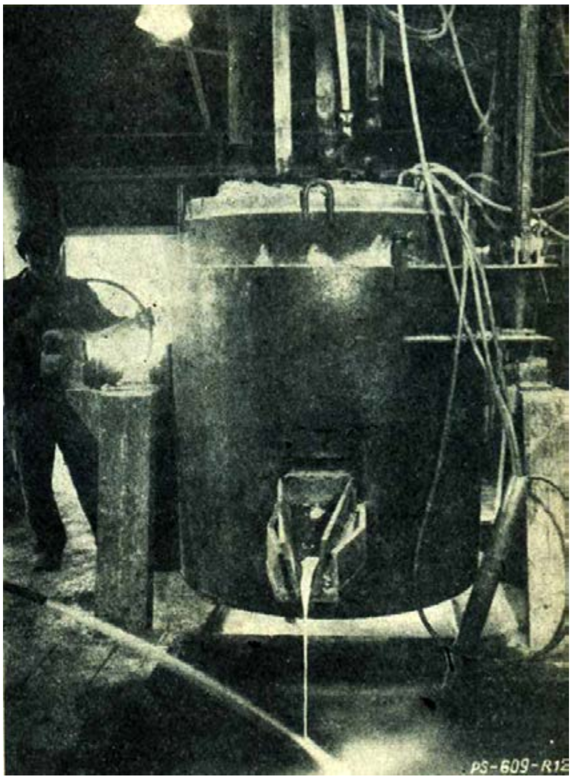


Fig. 11 Arc furnace for the production of welding fluxes [27]

Research and implementation works related to submerged arc welding and surfacing were conducted at Zakład Spawania Stali i Żeliwa (Steel and Cast Iron Welding Department) run by Zdzisław Szczeciński, and from 1957 by Karol Śniegoń [28]. The works were concerned with automatic and semiautomatic welding by means of foreign and Polish machines using Polish electrode wires and Instytut's own fluxes. The works included automatic welding of boiler drums made of 50 mm thick sheets, welding with UT-250 and UPU Kjellberg automatic welding machines, welding of push-plate conveyor troughs, welding of thin sheets, surfacing of small diameter elements for motor vehicle and tractor fleet, submerged arc surfacing of P70 steel wheel rims, Thyssen system-based rebuilding surfacing of brake shoe surfaces using strip electrodes, surfacing of cement mill lining plates using strip electrodes, surfacing crane road wheels and caterpillar rollers etc.

The design of specialised mechanised and automatic welding stations, including submerged arc welding stations, was the domain of Zakład Mechanizacji Spawania (Welding Mechanisation Department) run by Alojzy Zawitniewicz [25]. Zakład Konstrukcji Spawanych (Welded Constructions Department) run by Tadeusz Robakowski dealt with, among others, testing mechanical properties and fatigue strength of submerged arc welded joints [30].

In 1955 PWT (National Technical Publishing House) published the first book entitled "Automatic Submerged Arc Welding" written by Jan Węgrzyn and Roman Korkiewicz. In 1959 at an IIW Congress in Opatia (Yugoslavia) the delegation of Instytut Spawalnictwa presented, among others, a paper by Edward Chuchro entitled "Ceramic Fluxes for Submerged Arc hard Surfacing" and a paper by Karol Śniegoń entitled "Rebuilding Surfacing of Metallurgical Equipment" [25].

Research and implementation works on submerged arc welding were also conducted by technical universities and industrial welding centres and establishments, e.g. in shipbuilding, civil engineering and railway engineering [23÷25, 31÷33].

Summary

As regards mechanised welding processes it is possible to assume that they originated with the invention of a mechanised welding device using an electrode wire continuously fed to the zone where an electric arc was burning in the air. Such a machine was invented by Paul O. Noble from the General Electric Company, whose patent was published in 1924 [5]. A disadvantage of open arc welding was the porosity of welds caused by the lack of an arc and weld poll metallurgical shield. The idea of process mechanisation (mechanised electrode wire feeding and the movement of a welding head in relation to an element being welded) was used in devices (in chronological order) for submerged arc welding, MIG/MAG welding and welding with a self-shielded flux-cored wire.

The overview of reference publications confirms the information according to which the authorship of welding under a flux layer providing metallurgical shield of a welding zone should be ascribed to D.A. Dulczewskij, whose patent was filed in 1927 and published in 1929 [7]. The principle referred to in this patent constitutes the essence of submerged arc welding. The patent for arc welding under a flux layer, referred to in the study [2] and developed by a team composed of B.S. Robinoff, S.E. Paine and W.E. Quillen appeared later (filed on 10.05.1929 and published on 18.11.1930) [10]. In turn, the information [3] ascribing the authorship of welding under a flux layer to J. Kennedy in 1936 probably refers to a patent developed by a team consisting of L.T. Jones, H.E. Kennedy and M.A. Rothermund, published in the same year [12]. Obviously, the studies of subsequent inventors and researchers related to welding consumables, welding methods and equipment significantly contributed to the development of submerged arc welding, yet particular attention should be paid to W.I. Diatłow's invention of arc welding self-regulation [17], used not only in submerged arc welding machine control systems but also, later, in MIG/MAG welding devices.

In Poland, the beginnings of submerged arc welding are related to the following:

- industrial implementation of imported automatic and semiautomatic welding machines,
- development and production of automatic and specialised stations for submerged arc welding and surfacing by Zakład Budowy Prototypów Urządzeń Spawalniczych (Prototype Welding Machinery Production Company) of Instytut Spawalnictwa,
- Instytut Spawalnictwa's development of welding consumables and technologies for welding and surfacing applied in a number of industries,
- production of melting fluxes by Instytut Spawalnictwa and next by Spółdzielnia "Klejżel" ("Klejżel" Co-operative) in Brzezie near Racibórz (later named as Zakłady

Elektrochemiczne w Raciborzu (Electrochemical Plants in Racibórz) on the basis of Instytut Spawalnictwa's recipes,
- research and implementation works conducted by technical universities and industrial welding centres and establishments,
- submerged arc welding implementations in shipbuilding industry, military industry, metallurgical industry, railway engineering, chemical industry, welded constructions industry, power engineering etc.

The presented overview of publications related to the history of mechanised submerged arc welding and patent descriptions definitely has not exhausted the subject, yet it has enabled systematising facts related to the beginnings of this method in Poland and worldwide.

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