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The Development of TIG Welding

Abstract: The article discusses the development of inert gas-shielded welding using a non-consumable electrode (TIG welding), outlines the history of shielding gases and tungsten electrodes, presents the primary accomplishments and patents related to the evolution of the TIG method worldwide and describes the first welding equipment produced in Poland and the attempted use of the TIG method.

Keywords: argon, helium, TIG method

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Introduction

Arc welding, in common use today, was first used in 1860 by Henry Wide. The machine was based in rather a primitive electric generator and two leads of "significant size" connected to each other [1]. In 1866, H, Wide patented his method, named "Producing and applying electricity", in Britain [2]. This was the first patent in the world concerning arc welding [3]. Twenty years later, a Frenchman Auguste de Meritens used electric arc when making battery (accumulator) plates. The process was performed in a special chamber (Fig.1), where the plates were placed on a copper table connected to the negative pole of a generator, whereas a carbon electrode, fixed on a copper torch ending with a wooden grip was connected to the positive pole. Welding fumes emitted during the process were pumped out through an opening in the chamber. In spite of the low power of the generator and heat losses to the environment, the welding process itself was quite unproblematic because of the low melting point and the low heat conductivity of lead [4]. The method developed by A. Meritens constituted the first fully documented application of electric arc for welding purposes.

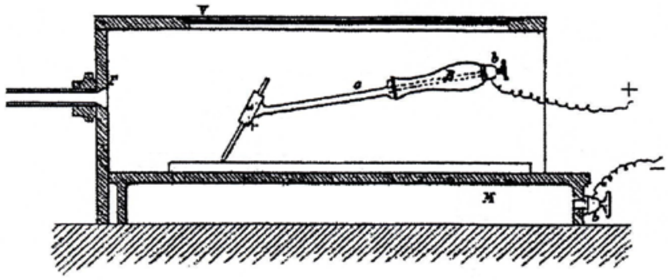

Fig. 1. Machine for the arc welding of battery plates invented by Augusta de Meritens [4]

In 1881, a Polish engineer Stanisław Olszewski and a Russian researcher Nikolay Benardos presented an arc welding method involving the use of a carbon electrode (Fig. 2). The method, named "Elektrogefest" was patented in France in 1885 and, afterwards in many other countries in Europe and the USA [5]. It was then that the history of arc welding started.

Undoubtedly, Hugo Zerener, who in 1889 patented welding by means of two carbon electrodes (Fig. 3) angled towards each other, holds an important place in this history. Burning arc was deflected by a magnetic field generated by an electromagnet located between the electrodes. It should also be noted that H. Zerener was the first to indicate the necessity of protecting welder's eyesight against radiation [6].

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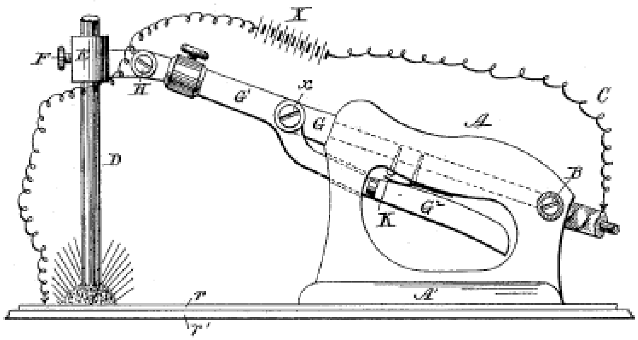

Fig. 2. Movement of the carbon electrode in the patent by Benardos-Olszewski [5]

At the same time, a Russian engineer Nikolay G. Slavyanov patented, first in Russia, and next in England, Germany, Austria-Hungary and Belgium, a method where a non-consumable carbon electrode was replaced by a metal electrode, the chemical composition of which was consistent with that of a material subjected to welding [6]. Gas metal arc welding was also patented by an American Charles L. Coffin in 1890 [7].

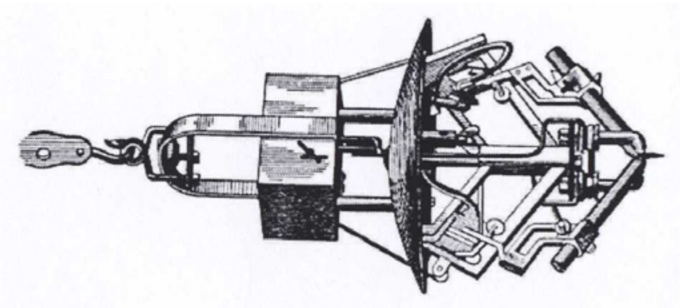

Fig. 3. Arc welding torch designed by H. Zerener [6]

The 19th century saw the development of knowledge about electricity and witnessed the advent of the arc welding of metals, whereas the 20th century was the time when the method was improved and put into industrial practice. The improvement of the method was necessary because welding in air entailed strongly oxidising arc atmosphere responsible for the intense burnout of the ingredients of the weld deposit and those of a material being welded, resulting in the lower properties of welds in comparison with those of the base material.

A method patented in 1899 by H. Zerener [8], where arc was shielded by hydrogen, did not find applications in industrial practice, probably because of the invention and the development of oxy-acetylene welding.

Research works concerning the use of shielding gases lost momentum after Oskar Kjellberg invented a covered electrode in 1907 [9]. However, slag formed during welding with the covered electrode impeded welder's work and often led to the formation of welding imperfections. As a result, after 25 year the idea of applying gases shielding the zone of arc and the liquid metal of the weld regained its place in welding engineering. The first attempts at the use of shielding gases, i.e. methanol and hydrogen vapours, are discussed in one of the articles published in Biuletyn Instytutu Spawalnictwa no. 2/2019.

Inert gas-shielded welding with a tungsten electrode – TIG

Presently applied inert gases, i.e. argon and helium, were first used in the early 1920s. Argon was isolated in 1894 by L. Rayleigh and W. Ramsay, who, when testing hydrogen, discovered that the gas obtained in the laboratory was by 0.5% lighter than that obtained from atmosphere. Having made that observation, the scientists removed oxygen, nitrogen, carbon dioxide and hydrogen from the sample of pure air and discovered the presence of another gas, named argon by them [10]. Argon is obtained industrially through fractional distillation and the isolation of nitrogen and oxygen from liquid air in a cryogenic process [11].

The history of helium started in 1868, when an English astronomer Norman Lockyer observed a yellow line in the solar spectrum. Stating that the observed element was unknown on Earth, he named it Helios, meaning "the sun" in Greek. In March 1895, a Scottish chemist William Ramsay, when searching for sources of argon, isolated helium by heating a mineral containing uranium (cleveite) and the purification of the gas obtained in the above-presented manner. However, the practical use of helium obtained using the aforesaid process was impossible. Only in 1903, in Kansas, when searching for crude oil, non-flammable gas containing 72% of nitrogen, 15% of methanol, 1% of hydrogen and 12% of then unidentified gas was discovered. The further analysis of the gas revealed it also contained 1.84% of helium [12]. In 1918 in the USA, the production of helium through the extraction of natural gas was initiated [13].

Another crucial element used in the TIG method is a tungsten electrode. Tungsten was discovered in 1793 by two Spanish aristocrats Juan and Fausto D`Elhuyar who reduced tungstic acid (using charcoal) contained in wolframite [14]. A hundred and twenty years after that Alexander Just and Franz Hanaman created the first tungsten fibres, whereas M. Pirani and A. Meyer identified the melting point of tungsten at 2965°C (approximately 450° below the actual value) [15].

Reference publications do not contain information when a tungsten rod was used during welding for the first time. Most probably, the pioneers of the solution were P. Alexander and I. Langmuir, who performed research on the use of hydrogen as shielding gas [16]. Hydrogen provided effective shielding and because of that the method could be classified as relatively inert gas-shielded welding.

Presently used gas-shielded welding techniques originated in 1920 at Lehigh University, where workers of General Electric Co., i.e. H. Hobart and P. Devers, investigated the possibility of using argon and helium as shielding gases. The researchers patented their technologies in 1926 [17, 18], naming them as "Heliarc" (helium-shielded welding) and "Argonarc" (argon-shielded welding). Because of high costs of both gases, the methods were not applied until the outbreak of WW2, i.e. when it became possible to weld magnesium alloys [19]. The alloys, used in the production of aircraft fuselages, heated up above a temperature of 700°C, self-ignited when coming into contact with air and, because of this, could not be welded using the gas method, commonly applied in aviation. As a result, in 1940, in aircraft factories of Northrop Aircraft Co., Russel Meredith and Vladimir Pavlecka started research aimed to develop a method enabling the welding of the above-named alloys. Based on experiments performed by H. Hobart and P. Devers, Meredith and Pavlecka used helium as arc-shielding gas. However, the first tests involving the use of electrodes made of magnesium alloys and the side blow-in of helium proved unsuccessful. The foregoing led to the development of a solution involving the use of a tungsten electrode placed in a regular welding torch. The electrode tip was inserted into an opening in a special end of a gas-supplying conduit (Fig. 4) [23].

R. Meredith, while continuously improving his method, designed a new welding torch, patented in 1942 in the USA under number 22 74631 (Fig. 5) [20]. The patent contained the description of the welding torch design and the efficiency of making butt welds in sheets having thicknesses restricted within the range of 1.2 mm to 4.6 mm, using current restricted within the range of 65 A to 140 A. In the method, arc was powered by reversed polarity DC, as in MMAW [21]. Three years later, R. Meredith received another patent for the subsequent modification of the welding torch (Fig. 6) [22].

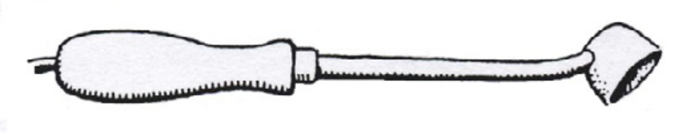

Fig. 4. Shape of the first TIG welding torch [23]

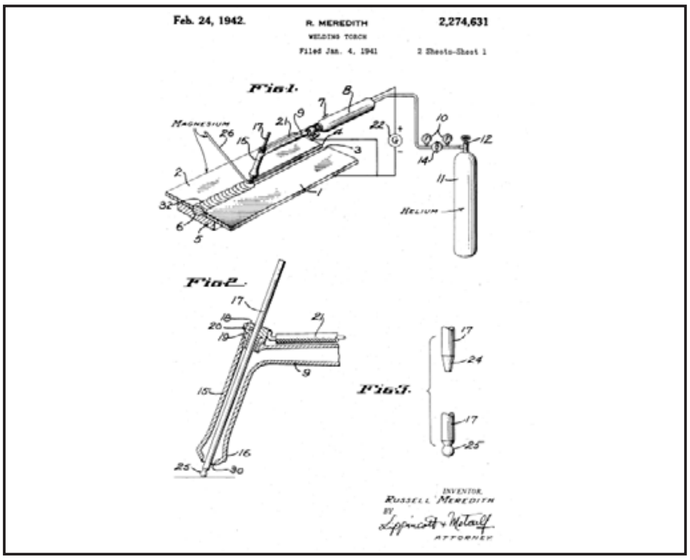

Fig. 5. Patent by R. Meredith; no. 2274631 "Welding Torch"; 24.02.1942 [20]

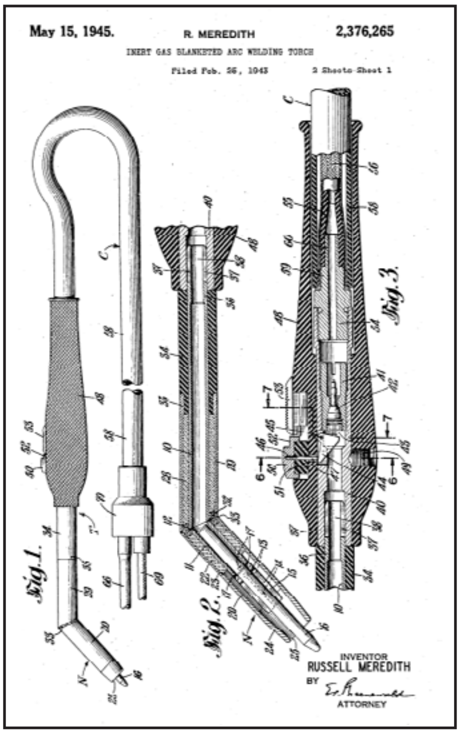

Fig. 6. Patent by R. Meredith; no. 2376265 “Inert gas blanketed arc welding torch”15.05. 1945 [22]

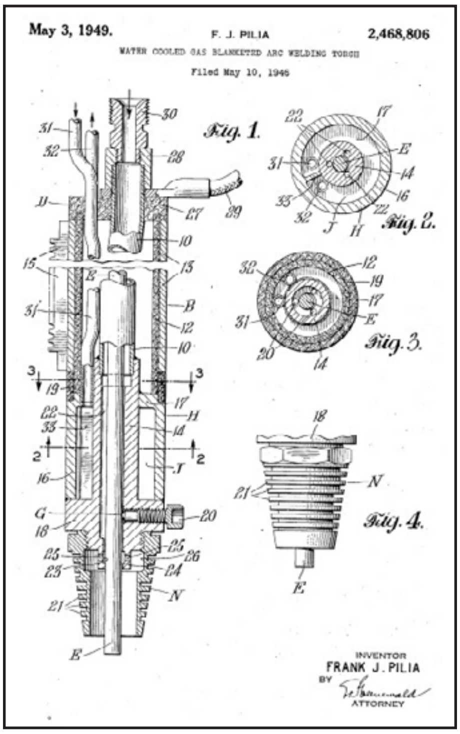

Fig. 7. Patent by F. Pilia; no. 2468806 “Water-cooled gas blanketed arc welding torch” 03.05.1949 [24]

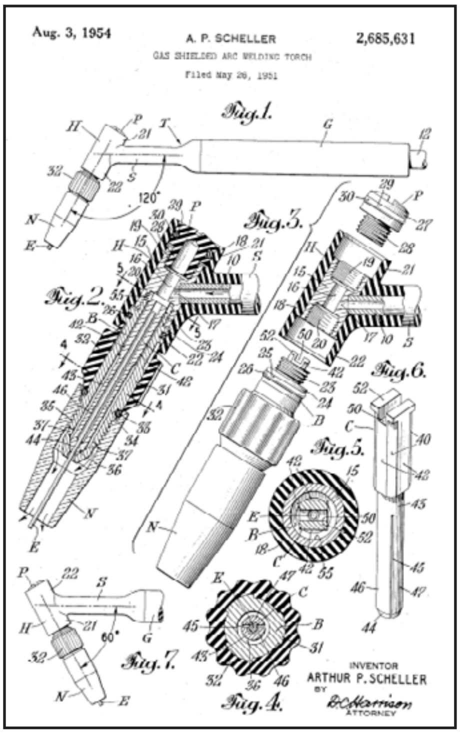

Fig. 8. Patent by A. Scheller; no. 2685631 “Gas shielded arc welding torch” 03.08.1954 [25]

R. Meredith and the Northrop company named the method “Heliarc” and, in 1942, sold the patent rights and trademarks to Linde, i.e. a company manufacturing and selling inter gases [23].

Having obtained the aforesaid rights, the Linde company initiated the development of the new method. Only after three years following the implementation of the method in industrial practice, Linde proposed 46 solutions including the welding of magnesium, aluminium, and stainless steels as well as copper and nickel-based alloys. The range of works was extensive, ranging from jet engine models through coffee jugs and household cooker rings [21]. Simultaneously, welding torch designs were improved as well; Frank Pilia invented and patented a water-cooled welding torch (Fig. 7) [24], whereas Arthur Scheller invented and patented a torch featuring a bent head, making it easier to reach poorly accessible areas (Fig. 8) [25].

The mid-1940s saw helium replaced with argon (more available outside the USA [21]) and the use of ionisers facilitating the striking of arc (Fig. 9) [26]. Soon, alternating current started being used in the welding of aluminium and magnesium alloys [27].

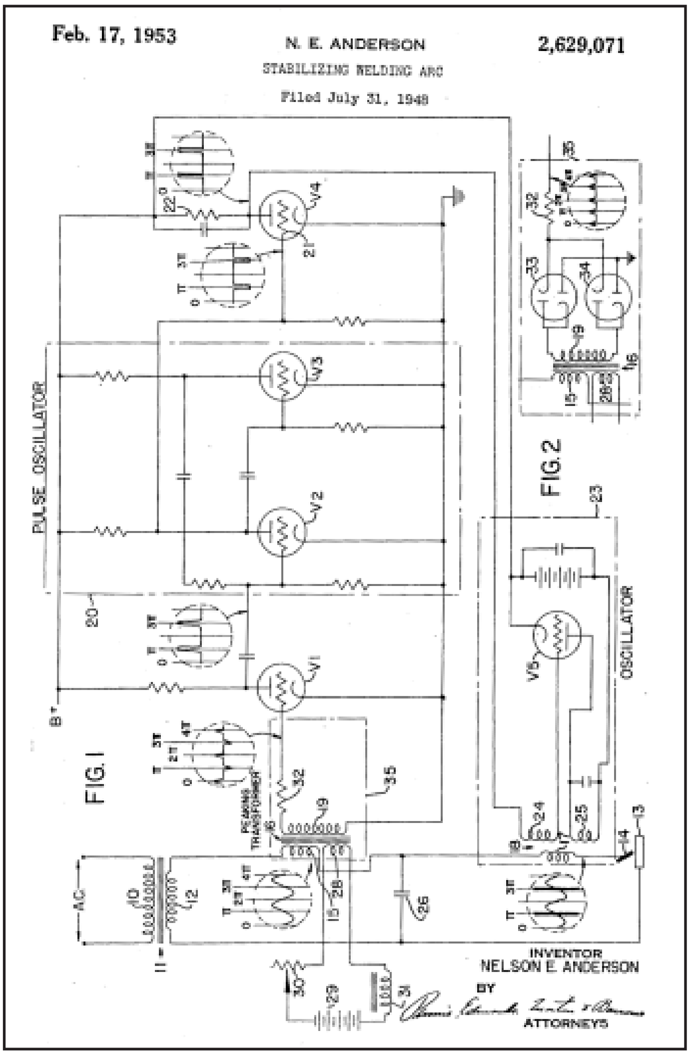

Fig. 9 Patent for welding involving the use of the ioniser; patent by N. Anderson, no. 2629701 “Stabilizing Arc Filet” 17.02.1953 [26]

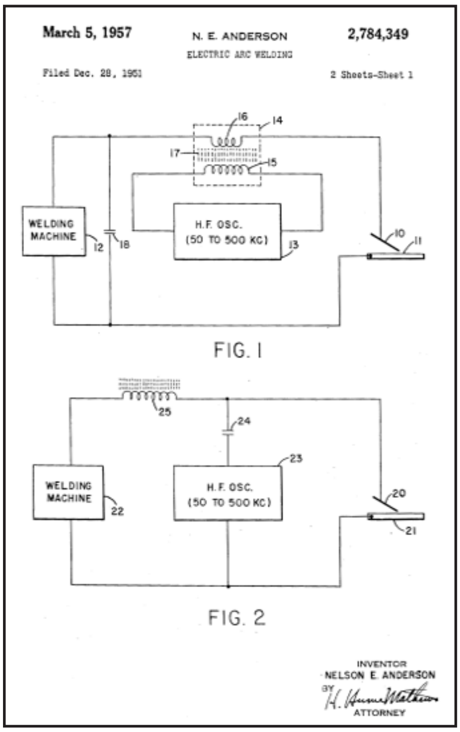

Fig. 10. Patent by N. Anderson: no. 2629701 "Stabilizing welding arc"; 03.1957 [28]

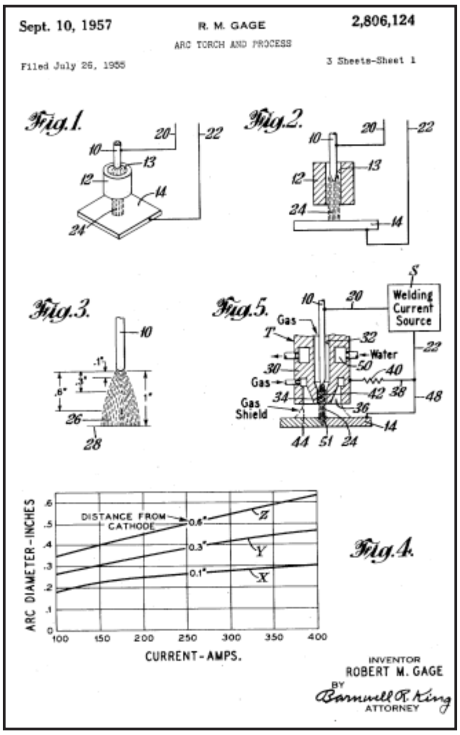

Fig. 11. Patent by R. Gage; no. 2806124 "Arc torch and process"; 10.09.1957 [29]

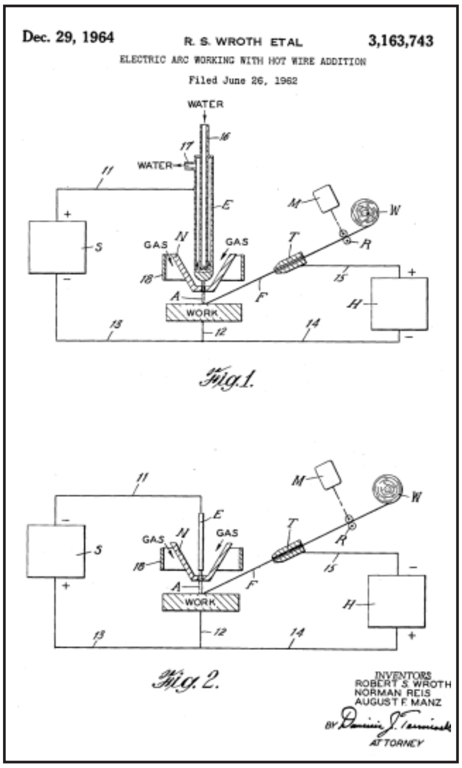

Fig. 12. Hot wire welding process; US patent no. 3163743, 29.12.1964 [27]

The late 1950s saw Nelson Anderson's patent of the pulsed current welding method (Fig. 10) [28] and Robert Gage's invention of plasma arc welding and cutting (Fig. 11) [29].

The TIG process progressed significantly after the application of hot wire welding. The inventors of the above-named method, i.e., Robert Worth, Reis Norman and August Manz, patented it in 1962 (Fig. 12) [27].

The TIG method reached Poland in the mid-1950s. The first attempts at the welding of aluminium and copper were performed at Instytut Spawalnictwa in Gliwice. Because of the lack of welding equipment it was necessary to build a makeshift welding station fitted with an American torch for helium-shielded welding (Fig. 13). Because the above-named welding torch arrived incomplete, damaged and contaminated, it was subjected to a thorough retrofit and repair. [30].

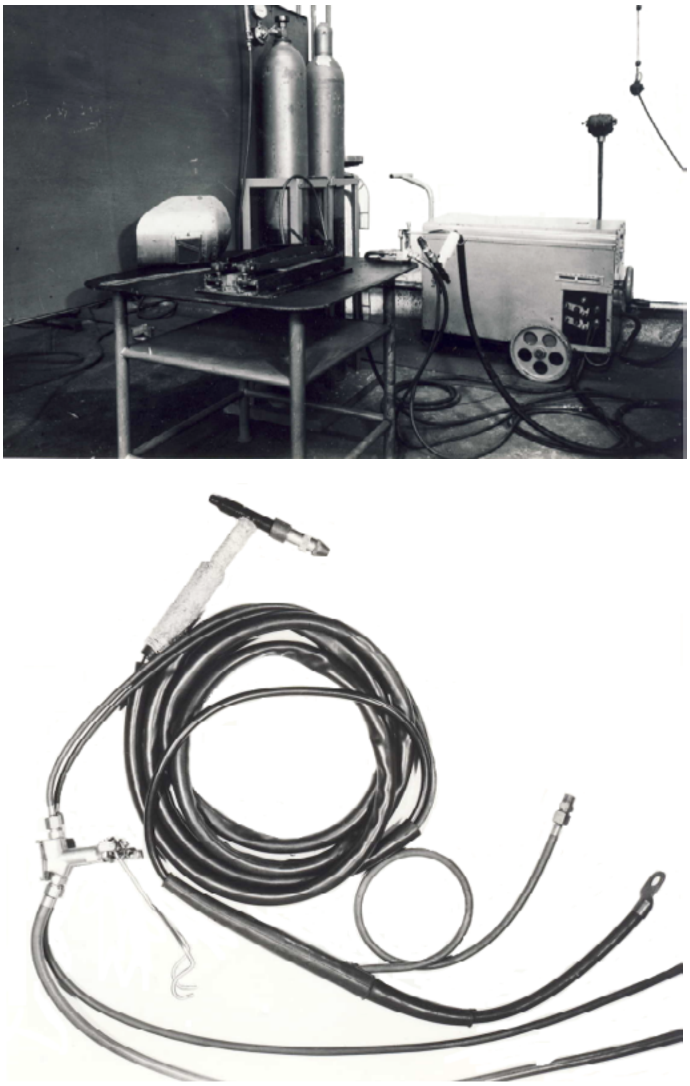

Fig. 13. Makeshift TIG welding station and the welding torch [30]

The lack of equipment and materials impeded the popularisation of the method. Although, as early as in 1955, the Baildon Steelworks produced electrodes made of pure tungsten (having diameters of 2 mm, 3 mm and 4 mm) [31], it was still difficult to obtain argon characterised by a purity of 99.9%. The purity of argon manufactured by the Polish industry, restricted within the range of 90% to 92%, precluded the use of the gas for welding purposes [32]. In addition, the gas was very expensive as 1 cubic metre of imported argon cost 169 zlotys, whereas the same volume of carbon dioxide only cost 80 zl. [33]. Another issue was connected with gas cylinders, hard to get, extremely heavy (the heaviest gas cylinders in the world) and, worst of all, fitted with untight valves resulting from their improper design and poor workmanship [32].

In the post-war period, rather unmodern welding equipment was produced in few plants and workshops. Imported machines were extremely expensive. The price of an automated welding machine was the same as that of two Volkswagen cars [34]. In 1959, in Poland there were 15 machines for argon-shielded welding (out of which only 10 were operational) [32]. Because of this, in 1955, Instytut Spawalnictwa created the Welding Machinery Production Company / Zakład Budowy Prototypów Urządzeń Spawalniczych/ tasked with the development of new equipment and the retrofit of previously produced machines [34]. The above-named Company designed and made the first Polish machines for manual EGa argon-shielded welding. The machine was provided with three types of welding torches ranging from 20 A to 550 A (Fig. 14). The first half of the year 1959 saw the start of the lot production of the aforesaid equipment [34]. Advantages resulting from argon-shielded TIG welding inspired the attempted joining of

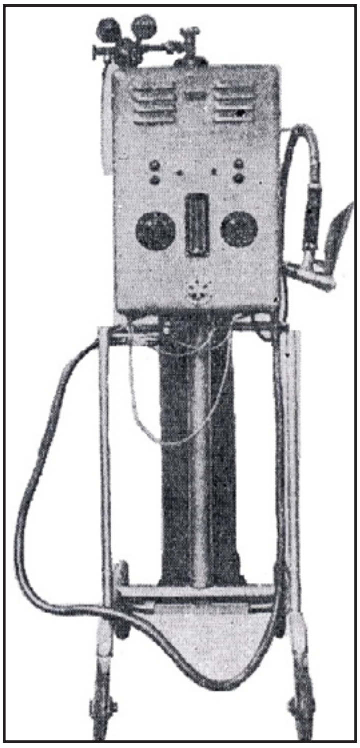

Fig. 14. Poland's first manual TIG welding machine [34]

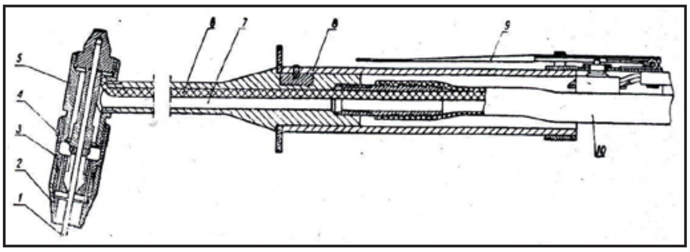

Fig. 15. TIG welding torch designed at the Aviation Institute [35]

austenitic chromium-nickel steels. In 1957, the Aviation Institute /Instytut Lotnictwa/ developed a technology making it possible to weld the above-named steels, a torch enabling the remote switching on/off of welding power (Fig. 15) as well as the dryer and deoxidiser of argon [35]. At the same time, other research works performed at the Institute were focused on conditions enabling the welding of copper, magnesium and aluminium.

The development of inert gas-shielded welding triggered the "emergence" of new welding methods, equipment and consumables, adjusted to modern technological and economic requirements. Increasingly high quality-related requirements combined with the increasing amount of alloyed steels and non-ferrous metals used in welded structures fuelled the growing interest in TIG welding equipment and the popularity of mechanised, automated and robotic processes (at the expense of manual processes).

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