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The Origin of Gas-Shielded Welding

Abstract: The article presents welding techniques developed in the 1930s, giving rise to modern methods of gas-shielded welding, i.e. reducing gas-shielded (methanol or hydrogen vapour), arc-hydrogen welding and arc-gas welding. The above-named methods have contributed to presently applied gas-shielded welding techniques.

Keywords: electric arc, welding, methanol, hydrogen

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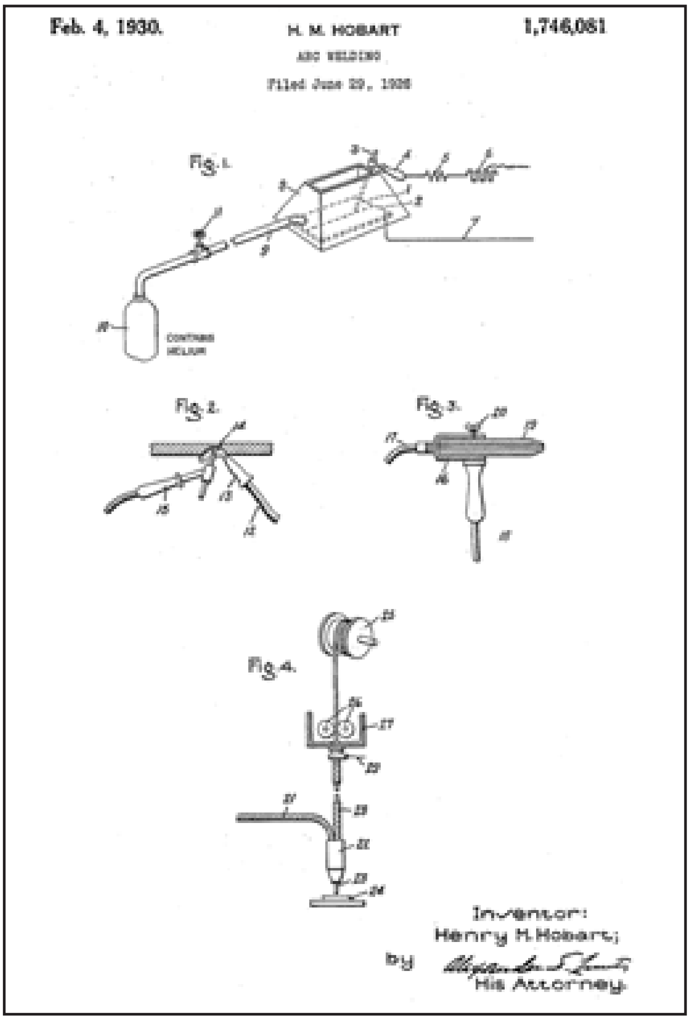
The practical application of shielded gases dates back to the turn of the 1940s and 1950s, i.e. the time marking the development of the TIG welding method (argon or helium-shielded welding process performed using a non-consumable electrode) [1]. As early as in the late 1890s, H. Zerener patented a method enabling the argon-shielded welding of metals (German patent no. 154335, 1899) [2]. However, the above-named method was not applied industrially, most likely because of the intense development of oxy-acetylene welding. The idea concerning the application of shielding gases regained its significance in the 1920s, which was partly related to attempts at improving welding processes in order to obtain welds characterised by the highest possible properties [3]. In 1920, H. M. Hobart used helium as the arc shielding gas and patented this method in 1926 (Fig. 1) [4]. Also in 1926, P. K. Devers patented argon-shielded welding [5]. At the same time, other gases, i.e. methanol and hydrogen vapours, were tested as potential shielding gases, which led to the development of two welding methods, i.e. reducing gas-shielded welding and arc-hydrogen welding. Although today the above-named techniques are little known and disused, they laid foundations of presently applied welding methods.



Methanol vapour-shielded welding, also

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known as the **Alexander method** (after its creator) was patented in 1924 (Fig. 2) [5]. Methanol, contained in an evaporating dish, was heated up to a temperature of 100°c. Afterwards, methanol vapours were fed to a nozzle located concentrically with a metal electrode (Fig. 3) [6].

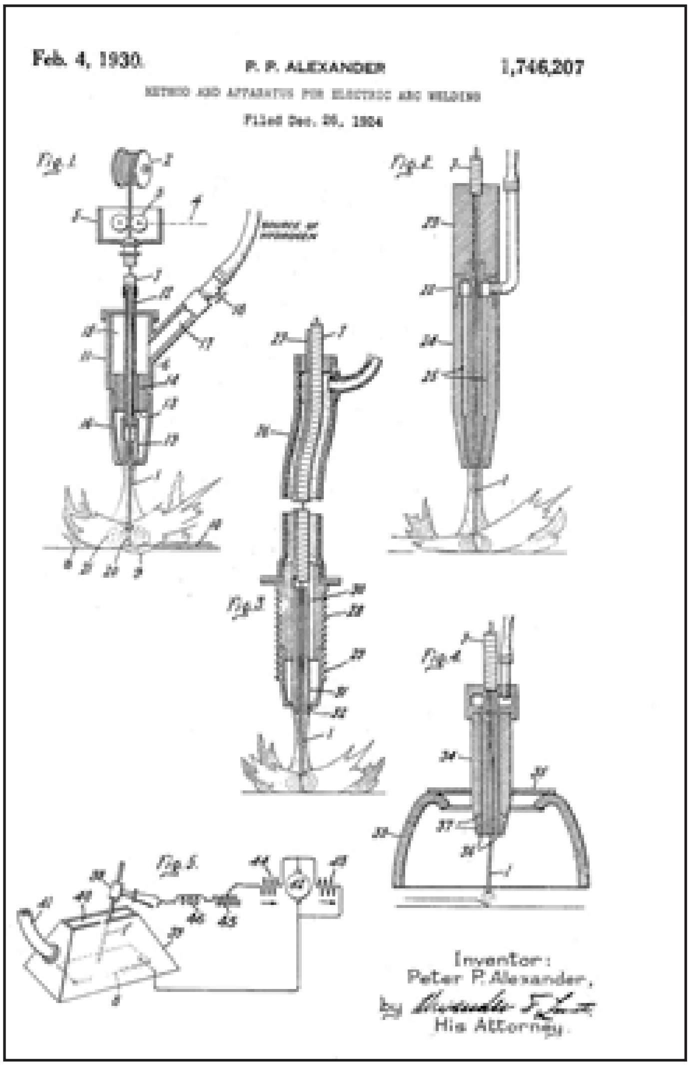

Fig. 2. Patent by P. Alexander: no 1746207 *Method and apparatus for electric arc welding*; 20.12.1924 [5]

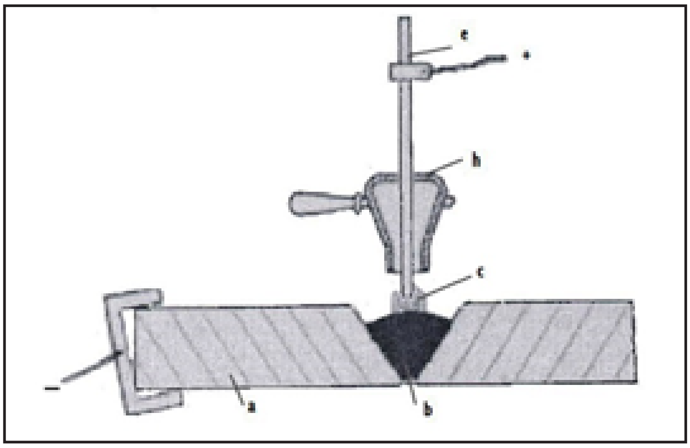

Fig. 3. Schematic diagram presenting the Alexander [7]; a: material being welded, b: weld, c: electric arc, h: nozzle, e: electrode

After coming into contact with electric arc at a temperature of approximately 700°C, methanol vapours decomposed into hydrogen and carbon oxide, preventing oxygen and nitrogen from accessing the weld [8].

Welding performed using the method developed by P. Alexander was problematic as the welder had to move the electrode and the gas nozzle at the same time, yet welds obtained using this technique were characterised by higher ductility than those made using Slavianov method and were free from oxides and porosity. Sometimes, particularly during the welding of copper and aluminium using a carbon electrode, methanol was replaced with ammonia [6]. The development of covered electrodes made the Alexander method gradually go out of use.

At the same time, P. Alexander developed a hydrogen-shielded welding method [9]. In the above-named method (Fig. 4a), the wire unwound from the reel was fed through the torch (Fig. 4b) to the nozzle. At the same time, the stream of gas flowing out of the nozzle shielded arc and the liquid metal pool, preventing the oxidation of the weld [8].

The welding rate obtainable using the above-presented method was significantly higher than that typical of welding in air, even in relation to slightly higher current values. The foregoing resulted from the considerably higher energy of arc and the unnecessity of the bevelling of edges. In relation to a sheet having a thickness of 6 mm, a current of 180 A and a voltage of 60 V, the welding rate amounted to 18 m/h. Welding the same sheet using the same parameters in air slowed the process to 4 m/h [9]. Joints obtained using the above-presented method were characterised by favourable plastic properties and the lack of welding imperfections [8]. The implementation of the aforesaid technology was accompanied by works aimed at the automation of the process. The year 1926 saw the implementation of a new torch (Fig. 5.) and a machine (Fig. 6) enabling the automatic feeding of the electrode wire to the welding area [8].

In 1926, I. Langmuir invented an electric arc welding method referred to as Arcatom [4]. In the aforesaid method (Fig. 7), arc was formed between two tungsten electrodes glowing in hydrogen atmosphere [8].

In the above-named method, hydrogen was used as the shielding gas preventing the oxidising effect of air and, at the same time, constituted an additional heat source during welding. In arc space and at a temperature of 2300°C, hydrogen dissociated and, after coming into contact with the cooler surface of a material being welded, associated, emitting significant amounts of heat previously absorbed during decomposition [11].

The welding torch used in the Arcatom method was composed of two non-contact tungsten electrodes having a diameter of 3.2 mm each, positioned at an angle of 55° in relation to each other and placed on a copper tube having a diameter of 105 mm

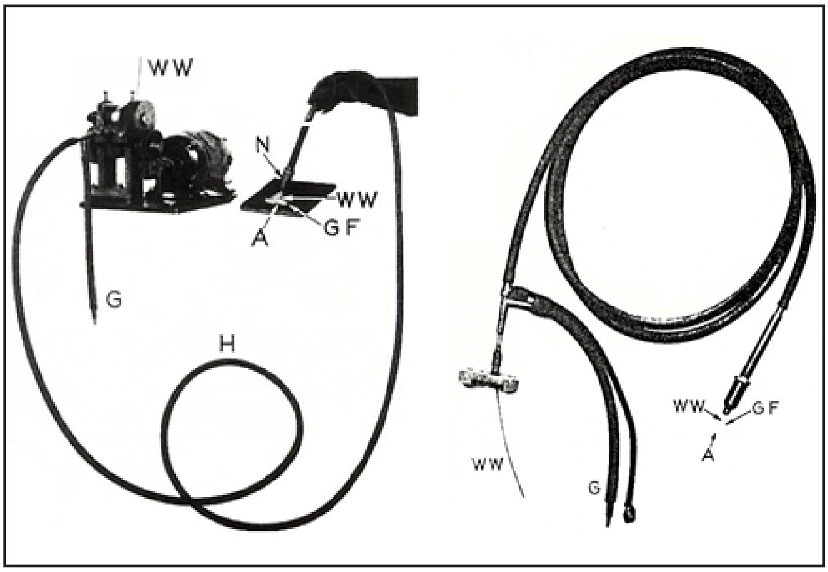

Fig. 4. Hydrogen-shielded welding: a) machine, b) torch [8]
A: arc, G: gas conduit, GF: gas flame, H: conduit feeding gas, power and electrode wire, N: nozzle, WW: electrode (welding) wire

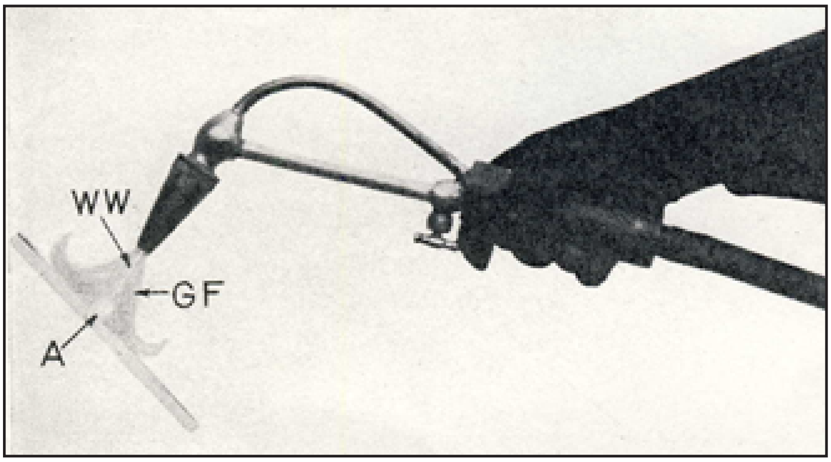

Fig. 5. Torch used in semiautomatic hydrogen-shielded welding [8]

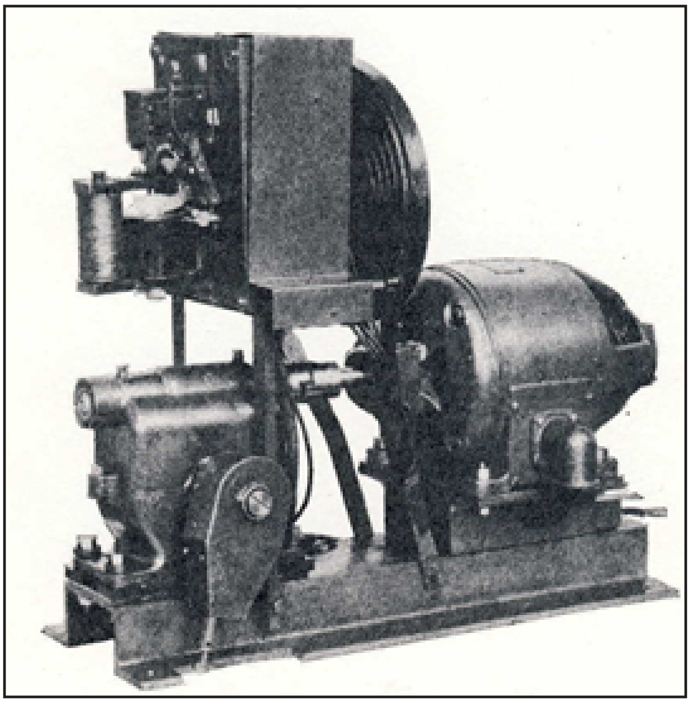

Fig. 6. Machine for semiautomatic hydrogen-shielded welding [8]

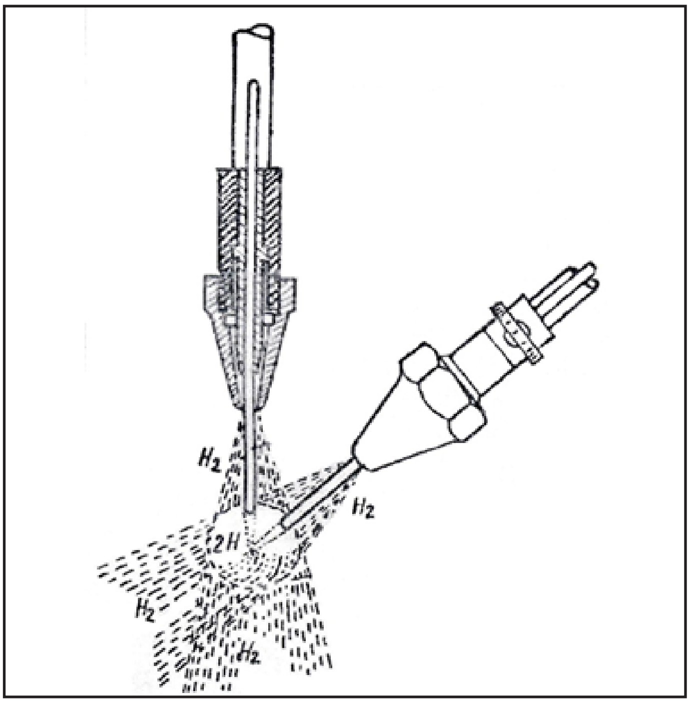

Fig. 7. Schematic diagram of Arcatom welding [10]

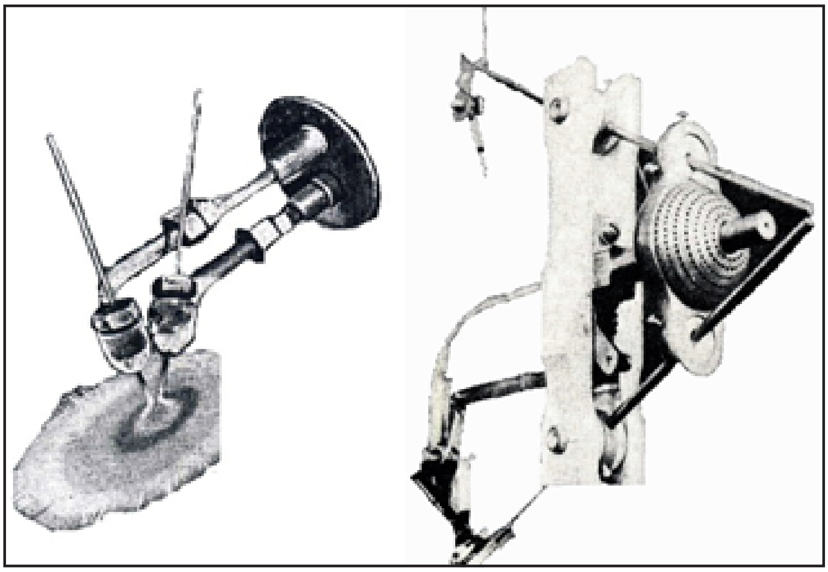

Fig. 8 Welding torches used in the Arcatom method [12,13]

and a length of 98 mm as well as a hydrogen feeding conduit (Fig. 8a) [12]. Another solution involved the use of two electrodes having a diameter of 6 mm each placed on a holder of a semicircular container mounted on a tube and a hydrogen feeding conduit (Fig. 8b) [13].

In order to induce arc striking it was necessary to move apart the electrodes by pushing the lever connected to the handle triggering the flow of hydrogen from the conduit between the electrodes and, at the same time, the flow of hydrogen through the holes in the container [13]. The welding torch design was soon modified and in 1930 hydrogen was fed (via rubber hoses) directly to the nozzles in which the electrodes were installed [14].

The arc-atomic welding station consisted of a welding torch, a transformer and a hydrogen cylinder provided with a regulator and a gas conduit (Fig. 9) [15]. The welding process was performed using alternating current; because of greater difficulty with arc striking in hydrogen than in air, the off-load voltage amounted to 300 V, current was restricted within the range of 20 A to 40 A (in cases of thicker elements up to 70 A), arc voltage was restricted within the range of 60 V to 110 V (up to 140 V) and the flow of gas stood at 14 l/min. [12, 16].

The Arcatom method could be used for the welding of "high-carbon steels as well as high-alloy, i.e. nickel, molybdenum, cobalt, chromium and tungsten, steels". The chemical composition of the filler metal was consistent with that of the base material [16]. In cases of sheets having thicknesses of up to 6 mm, the filler metal was not used, sheets were joined using the overlap welding method and the weld was obtained through the partial melting of edges [15]. Initially, because of difficulty adding the filler metal, the above-named method was only used when welding sheets. With the passage of time, welding tests were extended to include attempts at joining plates having thicknesses of up to 20 mm, which was particularly important in the fabrication of boilers and vessels [15].

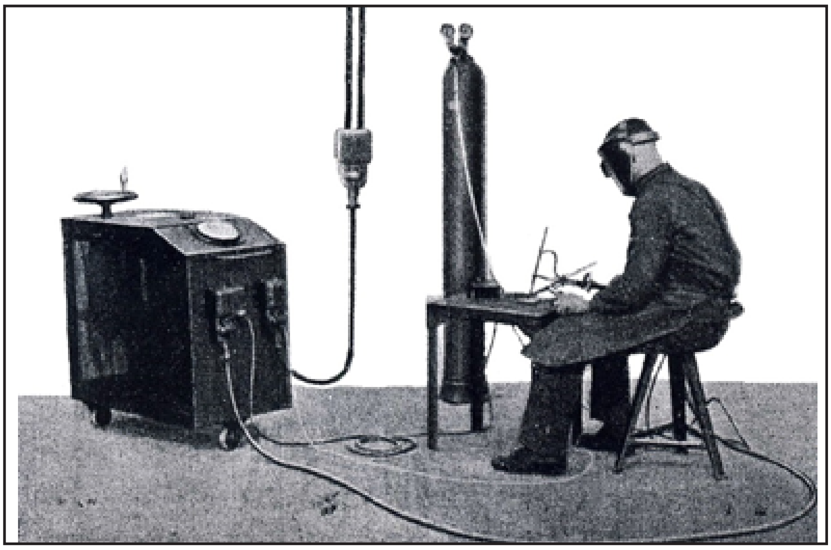

Fig. 9. Atomic welding station [15]

Welding experiments were also performed using a 1:1 mixture of hydrogen and nitrogen as the shielding gas and the replacement of the tungsten electrode with the graphite one. The use of the aforesaid gas mixture made it possible to increase welding current by 10% to 20% and obtain welds characterised by favourable plasticity. The tests did not reveal the effect of the electrode material on the welding process [13].

The CO_2-shielded MAG welding was preceded by a solution proposed by P. O. Nobel, who, in 1920, developed a welding method involving the use of direct current and a solid wire, where the welding rate was adjusted by the controlling of arc voltage and where the shielding gas was not used [17].

The first attempts at CO2-shielded welding were performed by the company of I.G. Farbenindustrie A.G. in Griesheim, Germany, which in 1928 developed an arc-gas welding method referred to as Arcogen [18]. Within the above-named method, welding (Fig. 10) was performed using a metal electrode, an acetylene flame was used to heat up elements to be joined as well as to create a protective shield against the oxidation and nitration of the weld and, by heating the weld, to prevent its excessively fast cooling. The method aimed to preserve the advantages and eliminate the disadvantages of both methods, i.e. the use of the acetylene flame reducing zone, the possibility of obtaining the plasticity of acetylene welds (in those days much higher than that of electrically welded welds), the neutral and strongly concentrated heat of electric arc, a slight heating zone of materials being joined and, consequently, lower stresses induced by metal contraction [19].

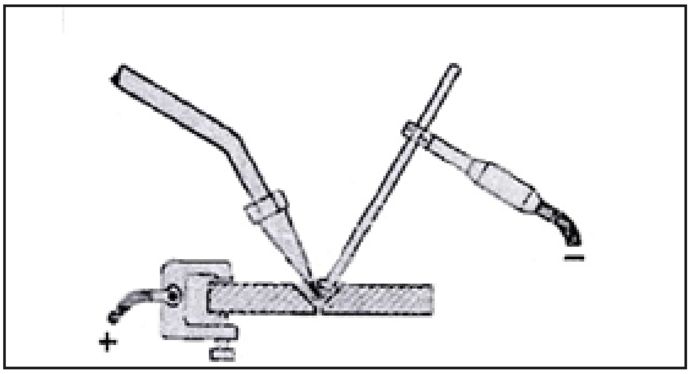

Fig. 10. Schematic diagram of arc-gas welding (Arcogen) [10]

The Arcogen welding station consisted of a welding power source, gas cylinders, an acetylene torch, and electrode and conduits feeding gas and current. The welder held the torch in one hand and the covered electrode in the other (Fig. 11) [6]. The electrode was connected to one of the transformer poles, the second pole of which was connected to an element being welded [20]. By adjusting the inclination of the torch in relation to the electrode, the welder could control penetration depth (Fig. 12). A greater angle between the welding torch and the electrode (Fig. 12a) led to deeper penetration and required a strip under the seam. A smaller angle (Fig. 12b) was used during welding performed without the strip [21].

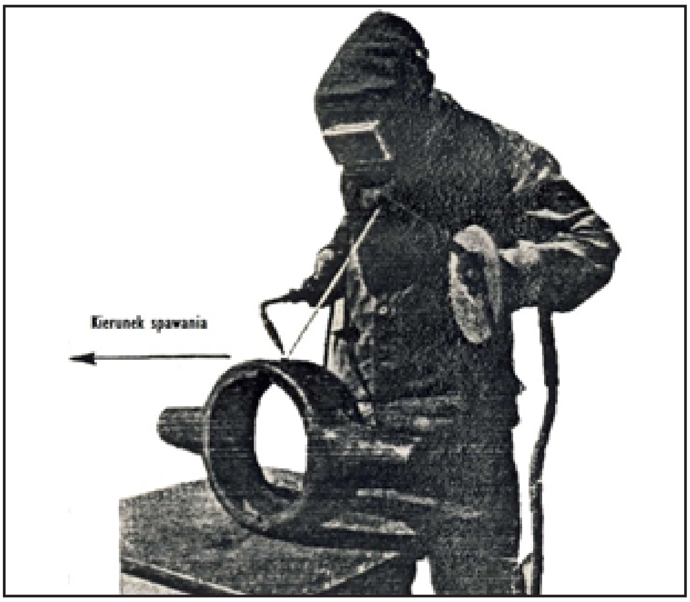

Fig. 11. Manner in which the torch and the electrode were held in the arc-gas (Arcogen) method [22]

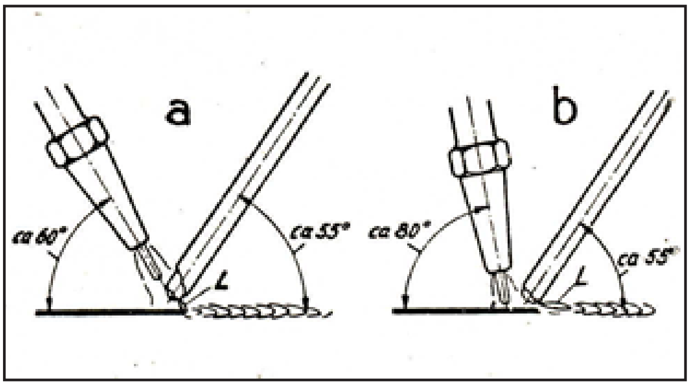

Fig. 12. Position of the welding torch in relation to the electrode in Arcogen welding [21]

In the Arcogen method, arc striking was obtained by heating the electrode with a gas flame, leading to the melting of the coating and the evaporation of its ingredients. The evaporating ingredients of the electrode ionised the space between the electrode and a metal to be welded, resulting in the formation of arc without the necessity of both elements coming into contact [21].

The Arcogen welding process was performed using alternating current. Voltage used in the process was higher than that applied in classical arc welding, yet current was significantly lower. For instance, during the welding of a 5 mm thick sheet, the current amounted to 58 A, whereas during the welding of the same sheet using an electrode having a diameter of 4 mm the value of current could reach up to 180 A. The consumption of power was by twice lower in relation to the "|combined" method. Current density was also by half lower (Fig. 13) in terms of the Arcogen method (6-2 A/mm2) [20] than during arc welding (16-6 A/mm2). In turn, the Arcogen welding rate was by twice higher than that obtained during acetylene welding (Fig. 14). As a result, a welding time was by 30% shorter, the dissipation of heat was lower and so was the distortion of elements being joined [21]. Arcogen welding was used when joining steels and materials characterised by high heat conduction, e.g. copper and aluminium [6].

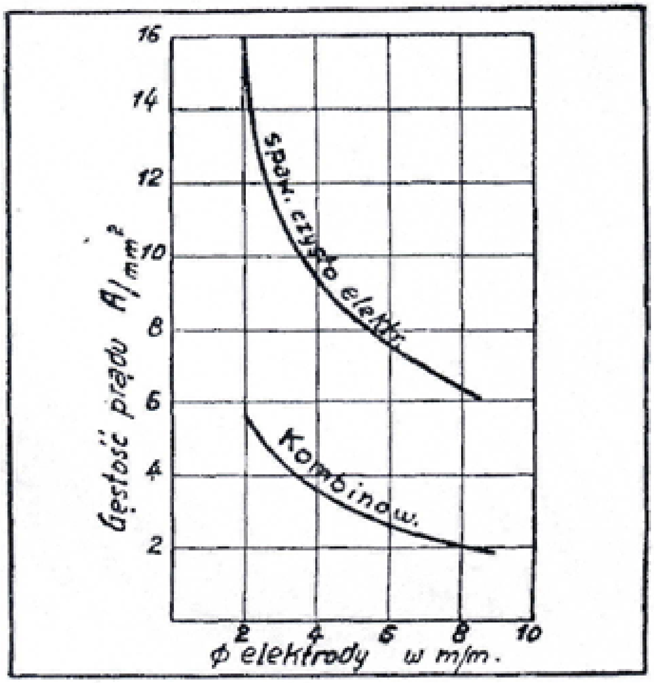

Fig. 13. Correlations between current density and the electrode dimeter in electric welding and arc-gas (combined) welding [20]

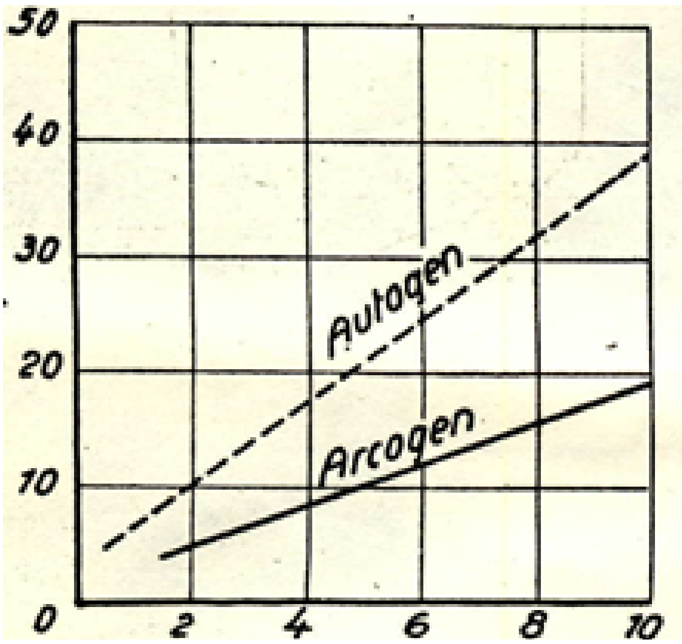

Fig. 14. Correlation between the welding rate and the sheet/plate thickness in the oxy-acetylene welding (Autogen) and arc-gas welding (Arcogen) [21]

Although the above-presented methods were not commonly applied, they undoubtedly contributed to the development of new gas-shielded welding methods extensively used today.

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