

A HISTORY OF WELDING

FROM HEPHEASTUS TO APOLLO

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1800-1850s

- Scientists are using the oxy-hydrogen blowpipe as a laboratory tool to examine refractory metals to the extreme temperature of 4468°F.

1800

- Alessandra Volta discovers that two dissimilar metals connected by a substance became a conductor when moistened, forming a 'Voltaic Cell'.

1801

- Sir Humphrey Davy (1778-1829) of London England, experimented and demonstrated the arc between two carbon electrodes using a battery. This was the forerunner to electric-arc lighting.
- Vanadium was discovered in Mexico and was thought to be a form of chromium for the next three decades. In 1830, it was rediscovered by N.C. Sefstrom, and in 1887, H.E. Rosco isolated the element from its compounds, mainly vanadite and carnotite. It was named for the Scandinavian love goddess Vanadis.

1808

- Magnesium is discovered as a chemical element by Sir Humphrey Davy.
- Sir Humphrey Davy proved the existence of aluminum.

1818

- Robert Hare, a professor of Chemistry at the University of Pennsylvania invents the hydrogen blowpipe.

1820

- Hans Christian Oersted established connection between electricity and magnetism.
- Andre-Marie Ampere pioneered the field of electromagnetism.

1823

- Charles Macintosh opens a rubber factory in Glasgow Scotland.

1827

- Friedrich Wholer discovers aluminum in 1827

1828

- Wallaston produced sponge platinum and welded it together by cold-pressing, sintering and then hammering while the metal was hot.

1831

- Michael Faraday invents the Dynamo creating electricity from magnets

1835-1836

- English chemist Edmund Davy (1785-1857), a cousin of Sir Humphrey Davy described the properties of acetylene, but was unable to give correct formula.
- Frenchman Sainte Claire Deville invents the oxygen-hydrogen blowpipe. Used mainly as laboratory equipment for melting platinum and producing enamel.

1838

- Charles Goodyear discovers the vulcanization of rubber, giving rise to the development of rubber hoses for welding gases.
- Eugene Desbassays de Richemont patents a process of fusion welding

1839

- Michael Faraday discovers the homopolar device that generates voltage.

1840

Frenchman E. Desbassayns de Richemont invents the first air-hydrogen blowpipe.

- de Richemont coins the phrase "soudure autogène", improperly translated into English as "autogenous welding". Welding implies solid state whereas fusion welding implies a liquid state.

1841

German H. Rossier used the air-hydrogen blowpipe for soldering lead.

1846

- James Nasmyth, while investigating the proving of ship chain for the British Admiralty, discovered and gave the reason for the convex forge welding "scarf". By preparing the surfaces to be welded with a slightly convex surface the flux and swarf are squeezed out of the joint. Otherwise they are trapped in the joint weakening it. This was the first improvement in the forge welding process in 3000 years. Prior to this time the shape of the joint was randomly flat concave or convex.

1856

- James Joule, an Englishman, first experimented with a bundle of wire in charcoal and welded the wires by heating with an electric current. This was the first example of heating by internal

resistance to produce a weld. Years later, Elihu Thomson perfected the process into what will then be known as resistance welding.

1860s

- An Englishman named Wilde successfully used the theories of Volta and Davy and the primitive electric sources of the time to make "Joins" and received a patent for the earliest form of the art now known as "electric welding".

1860

French chemist Berthelot (1827-1907) accurately gave the correct formula of C_2H_2 to acetylene. Also found it to be unstable (1863) under certain pressure and temperature.

1862

- A German, Friedrich Wohler (Woehler), produces acetylene gas from calcium carbide.

1863

- The first successful oil pipeline was built by Samuel Van Sickle at Titusville, Pennsylvania where 2-1/2 miles of 2 inch diameter cast Pipeline was laid for the transfer of 800 barrels of crude oil. The pipe was screw coupled and hammered since welding was not yet invented for pipe joining. The Dresser coupling, invented in 1891 was the first time a mechanical joint could be assembled without excessive leaking. This method was the standard for pipelining until the mid-1930s, when welding overtook the assembly process.

1865

- John Motley Morehead, a graduate of North Carolina State University in 1891, was working as a chemist for Willson Aluminum Company determined that when heating slacked lime mixed with coal tar and immersed in water would produce acetylene gas. Acetylene is formed when bicarburet of H_2 and ground carbon produces a solid of calcium carbide when immersed in water. This was originally discovered 56 years earlier by Edmund Davy.

1876

- Otto Bernz of Newark New Jersey founded the Otto Bernz Company selling plumber's tools and the gasoline torch "Alway's Reliable".

1877-1903

- Development of gas welding and cutting, carbon arc and metal arc welding.
- Elihu Thomson invents a low-pressure resistance welding machine which was accomplished by causing internal resistance enough to reach the plastic stage of a metal. Later, it was referred to as Incandescent Welding.

1877

During a lecture at the Franklin Institute (Philia), E. Thomson reversed the process of (...)

1881

- Auguste DeMeritens working at an associated laboratory founded by the periodical "l'Electricien" - Cabot Laboratory (Cabot), France was using arc heat to join lead plates for storage battery. French Patent Number 146010 was issued.

1885

Nikolai N. Benardos (Bernados) and Stanislav Olszewaski (Olszewaski) secured a British patent with carbon arc welding. Both men were working under the direction of A. DeMeritens with the arc lighting industry at the Cabot Laboratory (Cabot) in France. Carbon was oxidized at the carbon tip and created CO₂ at the arc for shielding. Both men had to generate their electricity using a steam-engine (prime-mover) to turn the generator and produce electricity. The alternative was to use batteries which did not last long because of the short-circuiting involved. Patents applied for and received besides Britain: Belgium, Germany, Sweden, and France.

1886

- N. N. Benardos obtained Russian Patent (No. 11982) electric arc welding with carbon electrode called ""Elecktrogefest" or "Electrohephaestus". The methods of cutting and welding metals by the arc was termed "Electrohefest" in memory(sic) of Hephaestus, the ancient Greek god of Fire and Blacksmith work. (The Romans renamed Hephaestus to Vulcan and which is shown on the title page, giving instruction to the craftsmen forging metal.)
- Benardos receives permission from the Russian Government to organize production in 1885 for "The production of this plant is based on welding and brazing by electricity and also producing devices for electrical illumination" (Note: emphasis mine)
- Electric furnace installed for production of aluminum alloys. An important step in early development of the Aluminum industry.

1887

- N.N. Benardos and S. Olszewaski secured an American Patent for the welding apparatus. (U.S. Patent No. 363320, May 17)
- The "blowpipe" or "torch", using the gases acetylene and liquefied air or oxygen, was developed.
- Thomas Fletcher develops blowpipe that could be used with either hydrogen or coal gas and oxygen
- An English shop began making tanks, casks, and iron garden furniture with the electric arc process.

1888

- Benardos/Olczewski granted patent 12984 for Carbon Arc Welding.

1889

Hans Zerner is issued German Patent 53502.3.12.1889 for the Twin Carbon Arc welding process?.

- C. Coffin is issued patent 395878, 'Process of Electric Welding'.
- The US Commissioner to the 1889 Paris Universal Exposition upon seeing the arc welding process demonstrated wrote in a report "...As the metal is burnt and brittle where it is welded, the process is not a success."

1890

C. L. Coffin in Detroit Michigan awarded first U.S. Patent (No. 419032, Jan 1) for metal electrodes. This was the first record of metal melted from an electrode and actually carried across the arc to deposit filler metal in the joint to make the weld. One electrode was carbon and the other electrode was filler material.

- Coffin also described the GTAW beginnings when a weld was made in non-oxidizing atmospheres.

A bank robber in Great Britain used the newly developed "blowtorch" to gain access to bank vaults.

1892

Canadien Thomas 'Carbide' Willson and American James Turner Moorhead begin to commercially produce acetylene as a product from calcium carbide in Spray, North Carolina.

- Slavianoff suggests that a bare metallic electrode could be substituted for the carbon electrodes of the Benardos process.
- Concurrently, C. L. Coffin is also credited with introducing the bare metallic electrode in the US
- Baldwin Locomotive Works was using Carbon Arc Welding (CAW) for locomotive maintenance. The weld joints were hard and brittle because of the carbon flaking off into the weld puddle.

1886-1898

- Elihu Thompson of the Thompson Welding Co. invented Resistance Welding (RW).

1895

- The combustion of Oxygen and Acetylene was discovered by Henri LeChatelier in his home country of France. Describes combustion of acetylene with equal volume of oxygen proceeds in two stages:

Step 1:	$4 \text{ CO} + 2\text{O}_2 = 4\text{CO}_2$
Step 2:	$2 \text{ H}_2 + \text{O}_2 = 2\text{H}_2\text{O}$

Machine for liquid air generation placed in operation

Lord Reyleigh and Sir William Ramsey discover Argon (Ar).

- Konrad Roentgen (Bavaria) observed the effects of x-radiation while passing electric current through a vacuum tube.

1895-1905

During a 10 year period in the U.S. and at a rate of one accident per day, boilers were exploding with the loss of life from the accidents at twice that rate.

1900

- E. Fouch and F. Picard develops oxyacetylene torch in France.

1901

- Menne invented the Oxygen Lance in Germany.
- Soon after Charles Picards invention of the oxyacetylene blowpipe in Paris France, this invention was called upon to repair a cast iron part on an acetylene pump. Quite by accident, the filler metal had enough silicon present to prevent the formation of the excessively hard white iron.

1902

- President Teddy Roosevelt took over the Panama Canal project from the French.

1903

- Hans Goldschmidt of Essen, Germany invented Thermit Welding (TW), an exothermic reaction between aluminum powder and a metal oxide.. Used to weld railroad rails together.
- Oxyacetylene is applied commercially.

1904

- Concentrated Acetylene Company invents the portable cylinder for the auto headlights.

1905

- L. W. Chubb of Westinghouse Electric & Manufacturing, East Pittsburg, PA, experiments with electrolytic condensers and rectifiers and found that wires could be connected to aluminum plates. Also found that copper could be joined in a like manner. When the cells discharged, sparks were formed.

1907

- Two German welders came to the U.S. and formed Siemund-Wienzell Electric Welding Co. and patented a metal arc welding method. Another German formed company, Enderlein Electric Welding Co. also started up. This was the beginning of the arc welding industry in the U.S.
- Lincoln Electric Company of Cleveland Ohio began by manufacturing electric motors in 1895. By 1907, Lincoln Electric were manufacturing the first variable voltage DC welding machine.

1907-1914

- Oscar Kjellberg (pronounced 'Shellberg') of Sweden and the ESAB (Elektriska Svetsnings-AtkieBolaget) Company invented the covered or coated electrode by dipping bare iron wire in thick mixtures of carbonates and silicates. The purpose of the coating was to protect the molten metal from oxygen and nitrogen. His pioneering of covered electrode development paved the road during the next twenty years in the research of reliable flux coated electrodes.

1908

- Oscar Kjellberg received Patent No. 231733 for the coated welding electrode.
- N. N. Benardos develops electroslag welding process.

1909

- Strohmenger developed the Quasi-arc electrode which was wrapped in asbestos yarn.
- The keel of the H.M.S. TITANIC was laid on March 31 at Harland and Wolff shipyard.
- Schonner, a physicist with BASF (Badischen Anilen und SodaFabrik) invents the plasma arc system using a gas vortex stabilized arc.
- First industrial application of plasma at BASF (Badische Anilin und Sodafabrik) by a physicist manufacturing nitrogen dioxide (NO₂).

1910

- Charles Hyde of Great Britain is issued a patent for brazing steel tubes. By clamping two pieces into position, copper is placed in the joints as metallic strips, plating or powder mixed in a paste. Heated in a hydrogen furnace (oxygen-free atmosphere) and by capillary attraction flows copper into the joint

1911

- H.M.S. TITANIC is launched on May 31.
- First attempt to lay 11 miles of pipeline using oxy-acetylene welding near Philadelphia, Pennsylvania.
- American physicist (Matters) developed a plasma arc torch for heating a metal fusing furnace.

1912

- Lincoln Electric Co. introduced the first welding machines after experimentation started in 1907.
- E. G. Budd Spot Welds (SW) the first automobile body in Philadelphia, Pennsylvania.
- Langmuir gives the "plasma" to a gas or gas mixture brought to such a high temperature that all diatomic molecules are dissociated and the atoms partially ionized and where all monotomic gases are fully ionized.
- Firecracker welding technique, a version of shielded metal arc welding is patented in Germany.
- Strohmenger introduced coated metal electrodes in Great Britain. The electrodes had a thin wash coating of lime or clay resulting in a stable arc.
- Strohmenger obtained US patent covering an electrode coated with a blue asbestos with a binder of Sodium Silicate (NAXX). This was the first electrode which produced weld metal free of impurities.

1913

- Avery and Fisher develop the acetylene cylinder in Indianapolis, Indiana.

1914

- A 34 mile pipeline was laid near Enid, Oklahoma using oxy-aceylene welding for the oil industry.

1915-1916

- Underwater cutting was carried out but interest did not come about until 1926.

1916

- Companies licensed resistance welding equipment, mostly spot welding was the intended use.

1917

- Because of a gas shortage in England during World War I, the use electric arc welding to manufacture bombs, mines, and torpedoes became the primary fabrication method.

1918

- Admiralty testing of metal-arc welding on Barge Ac 1320 leads Lloyd's Register to permit metal-arc welding in main structures on an experimental basis.

1917-1920

- During World War I, a Dutchman, Anthony Fokker, began using welding in the production of Fuselages in German fighter planes.
- HMS Fulagar (Fullagar) was first all welded hull vessel - Great Britain.
- The repair of sabotaged German ships in New York Harbor highlighted the first important use welding because the German merchant marines tried to destroy the ships boilers on 109 ships. A team of engineers from a railroad company (possibly the Rock Island Line) was tasked to the repair. Later, 500,000 troops were delivered to the European War in France using these repaired ships. The success of the weld repairs catapulted welding to the arena for manufacturing and repair and dashed its sordid past as a controversial operation.

1919

- President Woodrow Wilson established The United States Wartime Welding Committee of the Emergency Fleet Corporation under the leadership of Dr. Comfort Avery Adams.
- Dr. Comfort Avery Adams, held a meeting on January 3rd to form the "American Welding Society ". The Constitution of this meeting was approved on March 27.
- C. J. Holslag used Alternating Current (AC) for welding, but this was not popular until 1930.
- The AWS Constitution of the January meeting was approved on March 27.
- Reuben Smith developed and patented the paper-coated electrode. The weld did not leave a slag and produced an acceptable weld.

1920s

- Various welding electrodes were developed:
 - Mild steels electrodes for welding steels of less than 0.20% carbon;
 - Higher carbon and alloy electrodes; and
 - Copper alloy rods.

- Researchers found that Oxygen (O₂) and Nitrogen (N₂) when in contact with molten metal caused brittle and porous welds.
- Alexandre and Langmuir, from General Electric Co., used Hydrogen in chambers to weld. Began with two carbon electrodes and later switched to Tungsten.
- Bundy-Weld of Bundy Company, Detroit Michigan uses sheetmetal coated with a copper paste and is rolled tightly around itself and placed in a furnace. The brazed joint is formed into one piece tubing.
- The automotive industry began using Automatic Welding with a bare wire fed to the workpiece to the production of differential housings.
- Poughkeepsie Socony (1235 tons), the first all-welded tanker was launched in the USA.

1920

- P.O. Nobel of General Electric Company developed automatic welding, using Direct Current (DC) using the arc voltage to regulate feed rate. Primary use was to repair worn motor shafts and crane wheels.
- The British ship "Fulagar" was constructed by the Cammell-Lairds and launched. In 1924, the ship grounded. A report in the British "Journal of Commerce" (July 17, 1924) reported that she held steadfast and if rivets were used in the construction, the ship would surely have opened up and not be able to get off the bank.
- After WW I, the Treaty of Versailles limited the Germans from designing and building ships in excess of 10, 000 tons for armored ships and cruisers not to exceed 6,000 tons. Welding was an experimental production option before WW I but the Germans used it to develop the next stage of warships by saving weight whereby the ship could then carry more armament or armor plating in selected areas.
- Torch brazing is in full swing using silver and gold filler metals and mineral fluxes as protective cover.
- Electrification of Russia begins utilizing hydroelectric power sources.

1921

- Leslie Hancock pioneered flame cutting machine where the burner followed the path of a magnetized stylus tracking around the contour of a metal template. The stylus is propelled by a gramophone motor.

1922

- "No longer in the tones of a Walt Whitmanesque muscular America, the skyscraper celebrated the technology that was bringing the world together."
- The first issue of the "Proceedings of the American Welding Society" was published in January (Vol. 1, No. 1). The name was changed in February, the next month, to "Journal of American Welding Society".
- The Prairie Pipeline Company weld an 8 inch diameter pipeline 140 miles long to carry crude oil from Mexico to Jacksboro, Texas. The advantage of welding over fittings saved the project 35 percent and the cost of weld, labor and material was \$2.00 per welded joint.

1923

- Institute of Welding Engineers was formed and headquartered in New York City.
- Naval Research Laboratory (NRL) was formed by the US Government which was motivated by Thomas Edison's belief that history demonstrates a relationship between technological innovation and national security.

1924

- 1st all-welded steel buildings constructed in U.S. by General Boiler Co. "to the exclusion of rivets".
- Resistance, gas and metallic arc welding in the manufacturing of all steel automobile bodies at the E.G. Budd Manufacturing Company.
- Mechanical flash welder used for joining rails together.
- First recognition of welding design was presented in papers written by: J. C. Lincoln, S. W. Miller, C. J. Holslag, H. A. Woofter, and J. H. Deppler.

1925

- ASME Boiler Code Construction Code Section VIII is issued for unfired pressure vessels.
- AWS Board of Directors approves "Standardization of Hose Connections for Welding, and Cutting Torches and Regulators"
- AWS held First Welding Show with the National Fall Meeting, 21-23 October, in Boston.
- A.O. Smith fabricates a single-piece heavy walled pressure vessel entirely by welding and was PUBLICLY tested then placed in an oil cracking service.

1926

- H.M. Hobart and P.K. Devers used atmospheres of Helium and Argon for welding with a bare rod inside the atmosphere. Due to the impurities of the inert gases and the corresponding high cost along with a lack of knowledge about current density, commercial applications were not realized at this time.
- UNA-METHOD - Trade name for the rail joint welding process, arc welding apparatus, electrodes and supplies. UNA Welding & Bonding Co. Cleveland Ohio.
- FUSARC - (need info)...?
- Irving Langmuir, a noted chemist with General Electric Co. developed the Atomic Hydrogen Welding (AHW) Process. Co-authored with R. A. Weinman the paper was "Atomic Hydrogen Arc Welding"
- Naval Research Laboratory (NRL) employee, P. W. Swain authored a paper "X-ray tests of weld " which was to have an impact with the welding industry much longer than the introduction of Atomic Hydrogen Arc Welding. The technique used a gamma-ray radiation as a shadow method to detect flaws in cast or welded steels. The techniques was used to detect flaws on the US Navy 9000 tonne heavy cruisers. The process was later identified as a Nondestructive test method and contributed to the success of developing improved steel castings for the U.S. Navy.
- Landstroth and Wunder of A. O. Smith Co. solid extruded heavy coatings for metal-arc welding electrodes.

1927

- Lindberg's Ryan monoplane fuselage was manufactured with welded steel alloy tubing.
- Soviet Union production of Resistance Welding machines at Elektrik Works called the "AT-8" and the "ATN-8: apparatus's for spot-welding and the "AS-1" and the "AS-25-1" for butt welding.
- John J. Chyle of A. O. Smith Corp. invented and patented the first extruded, all-position, cellulosic, titanium dioxide later classified as E6010 type welding electrode.

1928

- In East Pittsburgh, Pennsylvania, on the Turtle Creek, America's First All-Welded Railroad Bridge was erected by Westinghouse Electric and Manufacturing Company. Westinghouse used the bridge to transport the large generators from facilities to the rest of the country by way of the railways. Weighing in at 20,000 pounds and at 62 foot long, the bridge was manufactured without the use of rivets, a common method of bridge construction of those days. The testing of the bridge was completed by driving a locomotive on the bridge. (Information Courtesy of Mr. LaFave)
- Code for Fusion Welding and Gas Cutting in Building Construction (predecessor of AWS D1.1) was issued by the American Welding Society.

1929

- Lincoln Electric Co. started production of heavy coated electrodes (Fleetweld 5) and sold the electrodes to the public. Sues A.O. Smith and wins.
- 1st European All-Welded bridge in Lowicza, Poland. Designed in 1927 by Professor Stefana Bryly and spanning the Sludwie River this bridge was still in use as late as 1977, whereby it was being replaced with a newer highway and bridge which is designed for wider traffic. The Polish Government planned to move the bridge 80 meters up stream and establish the bridge as a historical monument. In 1995, AWS President ED Bohnart presented to the Government of Poland, the AWS Historic Welded Structure Award.
- Welding symbols are established by the American Welding Society
- General Electric experiments with "Controlled-Atmosphere brazing", using hydrogen gas for copper to steel brazes.
- Welding conferences are held on the campuses of Lehigh and Syracuse.

1930-1940s

- Atomic hydrogen arc welding process developed. Found that hydrogen was liberated releasing heat, which was 1/2 of the BTU of acetylene. Used primarily for tools steels. Development included an automatic version of the process.

1930

- Specifications for welding electrodes were beginning to be written.
- H. M. Hobart issued Patent Number 1746081, for "Arc Welding" and P. K. Devers was issued Patent Number 1746191 for "Arc Welding" on Feb 4 for using a concentric nozzle with a wire feed. This became known later as Gas Metal Arc Welding (GMAW). Work was based on various atmospheres in 1926.

- Germany started development work to find a suitable substitute for their dwindling supply of critical alloys. Experiments in the U.S. and Germany found that Thermoplastics when heated could be pressed together and obtain a permanent bond. In 1938 this principle was incorporated into "Hot Gas" welding technique. Thermoplastic rod and sheet were heated simultaneously by a stream of hot air while the rod was pressed into the sheet causing a bond. World War II forced Germany to further develop and use welded Thermoplastic as a corrosion resistant structural material.
- Stud Welding (SW) was developed by the New York Navy Yard to fasten wood to steel.
- Submerged arc welding developed by National Tube Co. in McKeesport, PA by Robinoff. Later sold rights to Linde Air Products and renamed UNION-MELT. Used in late 30s and early 40s in shipyards and ordnance factories.
- 1st all-welded merchant ship was built in Charleston, South Carolina.
- Advancements in protective atmospheres that dissociate chromium oxide from the surface of stainless steel are performed in furnaces without the mineral flux and were found in laboratories with no commercial equivalence.

1931

- E. G. Budd Manufacturing Company of Philadelphia spot welded stainless steel (18-8) and built the Privateer. The spot-welding was a process called "shotwelding" a proprietary process developed by E.G. Budd.
- Combustion Engineering shipped the first commercial land boiler fabricated by ASME welding code to Fisher Body Div. of General Motors Corporation.

1932

- Submerged Arc Welding (SAW) developed by National Tube Co. in McKeesport, PA by Robinoff. Later sold rights to Linde Air Products and renamed UNION-MELT. Used in late 30s and early 40s in shipyards and ordnance factories.
- British Corporation Register and Lloyd's introduce revised rules and approvals for the use of welding on ships.

1933

- Lincoln Electric Co. published 1st edition of "Procedure Handbook of Arc Welding Design and Fabrication" with the purpose to have its customers use arc welding efficiently. As a full service company, this book provided the customers a knowledge of welding education and training.
- English Antiquarian, H. A. P. Littledale patents the "Littledale Process (British Patent No. 415,181)", following the same approach that Pliny and Theophilus wrote about from the past two millenniums. Mixing copper salts with seccotine glue ultimately would produce the following reaction $\{CuO+C \rightarrow Cu + CO\}$ which is where brazing would theoretically be reached. The temperature the reaction takes place: 850C.

1934

- 1st All-welded Excavator - HARNISCHFAGER Corp.
- 1st All-welded British bridge - Middlesborough, England
- Lloyd's Rules for pressure vessels permits inspection using X-Ray technology.

- In Scotland, welding was beginning to be recognized as a separate crafts trade and the Trade Unions were opposed to this recognition. The General Secretary of the Boilermaker's Union argued that it was unfair to condemn any young man to a lifetime of welding. (Scotland). The Shipbuilding Employers insisted on the separate recognition.
- Westinghouse introduces the "Ignitron" which would become the basis for resistance welding timing controllers.
- American Welding Society presents John C. Lincoln the Samuel Wylie Miller Medal for "Meritorious Achievement". The award cited him for his work on the variable voltage machine, the ductility and strength of welds, the carbon arc automation process, and his efforts to expand the use of welding in many industries.

1935

- Granulated flux developed in 1932 and a continuous bare wire feed became known as "Submerged Arc Welding (SAW)" and saw major applications in shipbuilding and pipe fabrication (see 1932 for a different account).
- Solid extruded electrodes are introduced in Britain and subsequently the first British welding electrode standard written.
- Welding has "Arrived" when London, England hosts 900 attendees at the "Great Symposium" on the "Welding of Iron and Steel"
- Solar Aircraft Company of San Diego California develops a flux to combat welding problems with stainless steel manifolds for the U.S. Navy and was regarded as a closely-guarded military secret. Where flux is applied to the front of the weld, this was placed on the backside of weld, protecting from oxide formation. Later, the product was developed further to accommodate the Heliarc process.

1936

- 1st All-welded Box Girder Crane by HARNISCHFAGER Corp., Milwaukee WI.
- 1st All-welded Gear were fabricated by HARNISCHFAGER Corp. Milwaukee WI.
- First Specification for Design, Construction, Alteration and Repair of Highway and Railway Bridges by Fusion Welding was issued by the American Welding Society.
- Tentative Rules for the Qualification of Welding Processes and Testing of Welding Operators was submitted by AWS.
- The Soviet Union at the Elektrik Works started using the electronic control gears as the first valve timer with a thyristor contactor (RVE-1) for resistance welding.
- Japan Welding Society stipulates the rules of qualification testing in "The Standard of Qualification for Arc Welding Operator".

1937

- BS 538: Metal arc welding in mild steel, was issued, legitimizing arc welding structural applications.
- Norman Cole and Walter Edmonds, metallurgists from California are granted a patent for their product named "Colmonoy". Derived from COLe and edMONds and alloY.

1938

- The Welding Handbook, First Edition was printed and edited by William Sparagen and D. S. Jacobus.
- Pressure vessel industry began implementing the high production value of Automatic Welding.
- The German Shipbuilding Industry uses welding extensively to reduce the weight of warships and increase the overall size of the ship. This restriction was put in place after World War I.
- K. K. Madsen of Denmark describes Gravity Welding as a specialized electrode holder and the mechanism which will maintain a covered electrode in contact with the workpiece.
- A.F. Wall purchases Colmonoy and renames to Wall-Colmonoy (Detroit).

1939

- Floyd C. Kelly of General Electric publishes "Properties of Brazed 12% Chrome Steel" as an early investigation of the strength of brazed joints.⁴ Aluminum Spot Welding saw application in the Aviation Industry. He describes:
 - Single lap tensile specimens
 - 45 degree vee-type tensile specimen
 - Butt brazed tensile specimens.
- Aluminum Spot Welding saw application in the Aviation Industry.
- Ultrasonic Fluxless soldering patented in Germany. Process is conceived in 1936.
- Air Arc Gouging is developed (USA).
- Stud Welding (Nelson Stud Welding Co.) used by the US Navy to reduce time installing studs during fabrication of ships and aircraft carriers.

1940s

- With World War II GTAW was found to be useful for welding magnesium in fighter planes, and later found it could weld stainless steel and aluminum.
- Canadian Welding Society (CWS) formed.
- Exchequer, first all-welded ship built at Ingalls Shipyard in Mississippi.
- J. Dearden and H. O'Neill (UK) discuss "Weldability" in terms of carbon equivalencies.
- Sun Shipbuilding Company builds the world's largest ocean-going tanker, I. Van Dyck (11650 DWT). This was the first large scale use of automatic welding applied in shipyard work.
- First mass soldering technique, Dip Soldering, is used for Printed Wiring Boards (PWB) to keep up with the development of electronic equipment such as, Television, radios, etc.
- Little advancement was made in brazing and there were no dry-hydrogen facilities, except for laboratories, for brazing Stainless steel and there were no vacuum furnaces.
- Germany was using 85Ag-15Mn brazing alloys as the best high temperature filler metal available. Used for brazing hollow sheet metal blades used in the turbine engines and stators.

1940

- Gas shielded metal arc welding developed by Hobart and Devers at Battelle Memorial Institute.

1941

- Engineers at Northrup Aircraft Co. and Dow Chemical Co. developed the GMAW process for welding magnesium, and later licensed it to Linde Co. with a water cooled, small diameter electrode wires using CV power. Because of the high cost of inert gas, the cost savings were not recognized until much later.
- PLUTO - PipeLine Under The Ocean was created using the Flash Weld (FW) process for 1000 miles of 3 inch diameter pipe, to assist in the invasion of Normandy Beach, France. Once in place, the pipeline began pumping 1 million gallons of petrol per day directly to depots deep in the French country side.
- Friction Surfacing. H. Klopstock and A. R. Neelands "An Improved Method of Joining and Welding Metals" British Patent 572789, October 1941.

1942

- Chief of Research, V. H. Pavlecka, and engineer Russ Meredith of Northrup Aircraft Inc. designed the Gas Tungsten Arc Welding (GTAW) process to weld magnesium and stainless steel. Alternate names are TIG (tungsten inert gas) and Argonarc and Heliarc. Heliarc is the term originally applied to the GTAW process. (Patent Number 2274631, 24 February 1942).
- The invention of GTAW was probably the most significant welding process developed specifically for the aircraft industry and remained so until recently, with the Friction Stir Weld process of the 1990's. Mr. Northrup of Northrup Aircraft Inc. was a visionary who wanted an all-welded aircraft (i.e., manufacturing costs, and light weightness of the aircraft). Meredith was working from research of Devers and Hobart at General Electric (1920s) who had experimented with tungsten arcs in non-oxidizing atmospheres. The high reactivity of magnesium (Northrup's dream metal) would cause problems with more conventional processes, so, Meredith began developing a torch with better handling characteristics and would use inert gas enshrouding tungsten. Thus, the Heli-arc process.
- From the Dec 1942 Welding Journal: "The full importance of arc welding on the future of magnesium alloys cannot be fully appreciated at this time but the fabrication of these strong light alloys has opened the possibilities that were not considered even a year ago. For the man in industry, this method of joining offers simplicity of structure, ease and speed of fabrication and over-all economy."
- US Patent 2269369, Jan 6, 1942 issued to George Hafergut for Firecracker Welding.
- Traveling 285 miles north of Edmonton Canada and barging 1100 miles north to the Norman Well refinery a base camp was setup to build the Canadian Oil (CANOL) project. Working for 20 months, 1800 miles of pipeline was laid along side of 2000 miles of road. The last weld was laid on 1 February 1944. On 1 April 1945 the wells were shut down.
- Second Edition of the Welding Handbook was printed and issued.
- SAW proves its worthiness during World War II with the building of the Liberty Ships.
- G.L. Hopkins of Woolrich Arsenal defines the problem of cracking in alloy steels and hydrogen in welding electrodes.

1943

- Union-Melt is now commonly referred to as Submerged Arc Welding (SAW). The process used rods rather than wire filler metal and could weld work pieces up to 2 -1/2 inches thick.
- Sciaky (USA) markets the three-phase resistance welder.

1944

- 1st Low-hydrogen electrodes used in fabrication of alloy armor tanks vehicles by the Heil Corp in response to the chrome and nickel shortages from World War II for the U.S. Army.
- The Bureau of Navy Aeronautics designed and E. G. Budd Mfg. built the "Conestoga", a stainless steel aircraft. Despite the success of the aircraft, aluminum and rivets became the influencing factor in aircraft design.

1945

- After World War II, the Allies brought from Germany the alloy combination, 85Ag-15Mn which has a 1760°F brazing temperature.
- ElectroBrazing is used for manufacturing shafts to gears.

1946

- Sprayweld Process (US Patent 2361962) issued to Wall-Colmonoy uses an alloy powder spray which produces a smooth, welded deposits.
- General Electric Co. Ltd (UK) invents the Cold Pressure Welding Process.
- High Frequency (HF) stabilized AC tungsten-arc welding is used for aluminum alloys.

1947

- The Final Report of a Board of Investigation, ordered by the Secretary of the Navy, "To Inquire Into The Design and Methods of Construction of Welded Steel Merchant Vessels, 15 July 1946" was issued.
- Canadian Welding Bureau was created as a division of the Canadian Standards Association
- The Austrian Welding Society is formed and publishes a monthly magazine "Scheisstechnik"
- Microbraz, developed by Robert Peaslee of Wall-Colmonoy, is a 2500°F nickel alloy braze filler metal used in hydrogen furnaces. Used for stainless steel fuel supply connecting injectors to injector pumps for 18 cylinder reciprocating engines. The fledgling aircraft engine industry needed something else for engines to experience a hot shutdown without blowing the silver braze filler metal out from the brazed joints. Typical alloy was 85Ag-15Mn (BAg-23).

1948

- The Ohio State University Board of Trustees established the Department of Welding Engineering on January 1 as the first of its kind for a Welding Engineering curriculum at a University. OSU pioneered the Welding Engineering through an emphasis in the Industrial Engineering Department the previous nine years. The advantages of this engineering degree is 1) Enable satisfactory administration of problems relating to education and research in the welding field. 2) Recognition is given to the Welding Engineer as an entity among applied sciences. 3) A degree is authorized which is descriptive of a particular discipline imposed in training for professional work in the field.
- Air Reduction Company develops the Inert-Gas Metal-Arc (MIG) process.
- SIGMA Welding (Shielded Inert Gas Metal Arc) was developed to weld plate greater than 1/8 inch instead of the "Heli-Arc" welding process. The arc is maintained in a shield of argon gas between the filler metal electrode and the workpiece. No flux is used. Licensed by Linde Air Products Co.

1948-1949

- Curtiss-Wright Corporation looks at brazing as a strong, lightweight process for durable assemblies.

1949

- American Westinghouse introduces and markets welding machines using Selenium Rectifiers.
- US Navy uses inert-gas metal arc welding for aluminum hulls of 100 feet in length.

1950

- The Kurpfalz Bridge in Germany was built as the first welded orthotropic deck.

1950s

- Electron Beam (EB) welding process developed in France by J. A. Stohr of the French Atomic Energy Commission. First Public disclosure was 1957.
- Wave soldering is introduced to keep up with the demand of Printed Wiring Boards used in the electronics age.
- Research on testing of brazed joint begins as serious endeavor for the next ten years.

1950

- Electroslag Welding (ESW) is developed at the E. O. Paton Welding Institute, Ukraine USSR.
- Third Edition of the Welding Handbook is printed by AWS.
- Flash Butt Welding is the standard for welding rail line construction.

1951

- Russia use Electroslag Welding (ESW) process in production.
- The Philip Roden Co. of Milwaukee Wisconsin announces the DryRod electrode oven. This oven is intended to provide a controlled moisture environment of 0.2% moisture standard set forth by the government. This oven provides adjustable temperature control of 200-550 F, vented and holding 350 pounds of electrodes.

1953

- Modifying the Gas Metal Arc Welding (GMAW) process, Lyubavskii and Novoshilov used CO₂ with consumable electrodes. Resulted in hotter arc, uses higher current, and larger diameter electrodes.
- The Ohio State University established a Welding Engineering College curriculum out of the Industrial Engineering Department.

1954

- Bernard develops DualShield (Flux Cored Arc Welding (FCAW))- Shielding comes from Gas shielding outer and with gas generated from the arc welding.

- Lincoln Electric introduces a cored wire without the outer shielding gas (No-gas welding) but the shielding is provided by the flux within the core wire. Lincoln Electric refuses to participate with the Gas Welding industry.

1955

- Brazing Manual (First Edition) characterizes brazed joints as either good or bad.

1956

- Russia invents the friction welding process, a solid-state joining method.
- Dr. W. H. Chang publishes "A Dew Point-Temperature Diagram for Multi-Metal Oxide Equilibria in Hydrogen Atmospheres".
- Friction Welding is used to manufacture rotating bodies.

1957

- Flux Cored-Arc Welding (FCAW) patented and reintroduced by National Cylinder Gas Co.
- Plasma Arc Welding (PAW) Process developed by Robert M. Gage
- Russia, Britain, and USA independently develop a short-circuiting transfer for low-current low-voltage welding in a carbon dioxide atmosphere.
- Braze repair process for cracks in jet engine combustion chambers and transition ducts.

1958

- The Soviet Union introduced the Electroslag Welding (ESW) Process at the Brussels World Fair in Belgium. This welding process had been used since 1951 in the USSR which was based on the concept and work of an American, R. K. Hopkins. Perfected at the Paton Institute Laboratory in Kiev, Ukraine, USSR and the Welding Research Laboratory in Brno, Czechoslovakia.
- AWS Committee on Brazing and Soldering is formed to develop a test for evaluating strength of brazed joints. Robert Peaslee proposes a test in the Welding Journal.

1959

- Electroslag welding process was first used at the Electromotive Division of General Motors in Chicago and was called the "Electro-Molding Process".
- Development of Inside-Outside Electrode which did not require an external gas shielding - Innershield from Lincoln Electric Co.

1958-1959

- Short Arc (Micro-wire Short Arc) developed from refined power supplies and smaller diameter wires.

1960s

- Pulsed Arc Welding...(more to follow)
- Space Program is underway...(more to follow)

- Difficult to stabilize GTAW at below 15 amps, Microplasma is developed to overcome the limitation.

1960

- Development of a cold wall vacuum furnace.
- First laser beam produced using a ruby crystal for the Light Amplification Stimulated Emission Radiation (LASER).
- Explosive welding is developed in USA.
- Hughes Aircraft Company (Mainar) develops the first ruby laser (springtime).
- Bell Telephone Laboratories (Ali Javan) developed and presented the first gas laser using neon and helium (fall time)

1962

- The Mercury Space Capsule is formed using inner and outer titanium shell, seam welded together using a three-phase resistance welder by Sciaky.

1963

- U.S.S. Thresher sinks off the coast of New Hampshire and by December, the U.S. Navy charts the Submarine Safety Program (SUBSAFE) to control the fabrication, inspection and quality control of submarine construction. The presumed failure was with a silver-brazed piping joint, but after the investigation, the whole welding and brazing program was suspect. Included was the material properties of the welding and brazing filler metals.
- Weld testing now has a in-situ method for testing the weldability of welds. The Vareststraint Test, involving a device that permits the evaluation of base metal weldability and determination of the influence of a particular welding process and associated welding variables.
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- Fusewelder Torch (US Patent No 3172605) for sprayweld and surfacing is introduced by Wall-Colmonoy.
- Brazing Manual (Second Edition) re-characterizes brazed joints as either recommended or not recommended.

1965-1967

- CO₂ lasers are developed for cutting and welding.

1967

- H. J. Clarke makes the following Predictions during the AWS Plummer Lecture in Houston as he ties the current state of technology of welding to the future of progress:
 - World's Population would be greater than 5 Billion.
 - Large scale farming of the ocean and fabrication of synthetic protein.
 - Controlled thermonuclear power as a source of energy.

- General immunization against bacteria and virile infections, perfected and available.
 - Primitive forms of life will be created in the lab.
 - Automation will have advance for performance of menial chores and complicated functions.
 - Housewives would be ordering groceries and everyday items from central stores linked to the home electronically. (!!!)
 - Children will be receiving education at home - "either by television or with personal teaching machines and programmed instructions"
 - Moon - mining and manufacture of propellant and on Mars, permanent unmanned research stations.
 - Weather manipulation by the military.
 - Effective anti-ballistic missile defense in the form of air-launched missiles and directed energy beams.
 - Libraries will be "computer-run"
- Gravity welding is introduced in Britain after its initial discovery by Japan.

1969

- The Russian Welding Program in Space began by producing Electron Beam welds on SOYUZ-6. Welding an AMG6 and DM-20 aluminum alloys with the Vulkan process. Sponsored by the E. O. Paton Welding Institute Academy of Science.

1970

- As miniaturization developed from the pressure to increase component densities, Surface Mount Technology is developed. This required new ways to make soldered joints, including the development of vapor phase, infrared, hot gas and other re-flow technologies.
- First AWS International Brazing Conference including 24 papers presented created much interest in the brazing process.
- BP discovers oil off the coast of Scotland.

1971

- British Welding Institute (Houldcroft) adds oxidizing gas jet around laser beam to develop laser cutting.

1973

- The American Astronauts used Electron Beam welding process in June 1973 welding Aluminum Alloy 2219-T87, Stainless 304 and Pure Tantalum.
- Welding equipment manufacturers concentrate on equipment refinement instead of new processes.
- Two Supertankers, Globtik Tokyo and Globtik London (476025 DWT) were built for carrying 153 million gallons (3 million barrels) of crude oil.

1976

- First automotive production application of lasers weld begins with General Motors Corporation, Dayton Ohio using two 1.25 kW CO₂ lasers. for welding valve assemblies for emission control systems.

1977

- The US Federal Highway Administration issues a moratorium of Electroslag Welding (ESW) when cracks are discovered during an inspection of a bridge in Pittsburgh, Pennsylvania on an interstate highway. Failure analysis was conducted by Lehigh University on Interstate 79.

1980

- The Fort McHenry tunnel contract, for 750 Million Dollars, is awarded to begin construction, completing Interstate 95 through Baltimore, Maryland. This is the largest tunnel of its kind, 180 feet at the bottom with two separate four lane immersed tunnels removing 3.5 million cubic yards of dredge.

1983

- Homopolar pulse welding variation of the upset welding process research begins at the University of Texas at Austin at the Center for Electromechanics.

1987

- Laser research begins a unique method for depositing complex metal alloys (Laser Powder Fusion).

1991

- TWI of Cambridge England develops the Friction Stir Weld (FSW) process in its laboratory. This process differs from conventional rotary technology whereby a hard, non consumable, cylindrical tool causes friction, plasticizing two metals into a Solid-State Bond. No shielding gas or filler metal is required. Metals joined successfully include, the 2XXX, 6XXX and 7XXX series aluminum. NASA is the first US venture which welded the massive fuel tank for the Space Shuttle.
- Brazing Handbook (Fourth Edition) shows the data of the filler metal/base metal failure transitions between 1T and 2T overlap and is the key for the design data (factor of safety).

1996

- Over 7,00,000 brazements are produced for the aircraft industry in the US and Canada.
- Over 132,010,00 units of brazed automotive parts are produce.

1999

- The Edison Welding Institute develops a solution to obtaining deeper penetration of a GTA weld by introducing FLUX onto the surface of the weld. This FLUX helps drive the welding arc heat deeper into the weld joint and permits 300 percent more penetration.

2000

- Magnetic Pulse Welding (MPW) is introduced by Pulsar Ltd. of Israel using capacitive power as a solid state welding process. Discharging 2 Million amps in less than 100 microseconds this process can create a metallurgical, a non-metallurgical or a mechanical lock, depending on the substrate involved. No heat affected zone (HAZ) is created since only a rise of 30°C occurs.
- Tailored welded blanks of aluminum are used where spot welding was once performed.
- Researchers from Argonne National Laboratory use the energy of the x-ray to weld metal-matrix composite (Ti or Al / Al₂O₃ or SiC) materials.
- Diode laser welding, once limited to compact disks, laser printers, and laser pointers, are now making their way to the manufacturing floor. Welding Type 304 Stainless steel (0.024 inch), Titanium foil (0.005 inch thick) and laser brazing with a silicon-bronze brazing wire.
- Conductive heat resistance seam welding (CHRSEW) is developed. The process uses steel cover sheets placed on top of aluminum butted together. Using conventional seam welding, the heat generated from the steel forms a molten interface on the aluminum and fusion is made at the butt joint. The steel covers are then removed.

2001

- AWS D17.1, "Specification for Fusion Welding for Aerospace Applications" is published in March. The efforts of approximately 50 individuals from a cross-section of the Aviation Industry and government produces the first commercial aviation welding specification.
- Flame brazing 5XXX aluminum alloys using non-corrosive flux.
- Sulzar Elbar introduces laser powder welding technology. Permits rebuilding of substrate material (High Creep Resistance) and reproduction of the single crystal structure.

2002

- From Linde Gas in Germany, a Diode laser using process gases and "active-gas components" is investigated to enhance the "key-holing" effects for laser welding. The process gas, Argon-CO₂, increases the welding speed and in the case of a diode laser, will support the transition of heat conductivity welding to a deep welding, i.e., 'key-holing'. Adding active gas changes the direction of the metal flow within a weld pool and produces narrower, high-quality weld.
- CO₂ Lasers are used to weld polymers. The Edison Welding Institute is using through-transmission lasers in the 230-980 nm range to readily form welded joints. Using silicon carbides embedded in the surfaces of the polymer, the laser is capable of melting the material leaving a near invisible joint line.

2003 Awaiting future developments.

2004 Awaiting future developments.

2005 Awaiting future developments.
