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Magnesium rod filler for TIG welding - AZ92A and others



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The Harnessing of Heat: A Welding History

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As metalworking goes, welding history is relatively recent starting in approximately 1000 B.C. The history starts with the discovery and shaping of metals in ancient civilizations with a progression from copper, bronze, silver, gold and iron. Metalworking then progressed on to steel. The first welded pieces are thought to be gold ornaments.

Technology stayed pretty much the same until the Industrial Revolution in the 1700's to 1800s. At this time forge welding technology was developed which uses heated metal to join two pieces together. This was similar to the familiar blacksmith shop.

At the beginning of the 19th century acetylene was discovered, providing a controllable source of heat for welding. Modern welding didn't start until the widespread availability of electricity at the start of the 20th century. The need for military related welding in World War I and II accelerated welding technology and methods. Prior to WWI welding wasn't trusted to join metals in critical objects such as ships due to cracking. The welding history timeline below details how the technology developed.

Orbital Welding Machine

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Metalworking and Welding Timeline

Welding B.C.

The first metal to be shaped in welding history is thought to be copper since it can be hammered and bent.

4000 B.C.



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Types & Positions

Aluminum

Aluminum Brazing
Aluminum Welding

Cast Iron

Cast Iron Welding
Cast Iron Brazing

Plastics

Plastic Repair

Other Methods

Metal Plating
Metal Sculpture
Metal Casting

- Welding history is thought to begin in Egypt in starting in 4000 B.C. In general, civilizations started with copper and then progressed to bronze, silver, gold and iron.

3500 B.C.

- Discovery of Tin

3000 - 2000 B.C.

- Humans started working with bronze between 3000 and 2000 B.C. During the bronze age small gold circular boxes were made by pressure welding lap joints together.
- During this period metal is shaped into jewelry, dining utensils and weapons.

3000 B.C.

- The Sumerians made swords that are produced using hard soldering.
- Egyptians use charcoal generated heat to turn iron ore into sponge iron. Particles produced are hammered into together producing first instance of pressure welding (also called solid phase)
- Queen Pu-abi tomb contains a gold bowl with a handle that is brazed to the bowl wall. Gold goblet also discovered that has a braze fillet on the outside of the goblet.

2250 B.C.

- Cobalt used by Persians to color glass

Ancient Example of Soldering

This is an example of soldering in 2600 B.C. in Mesopotamia (Iraq) using metal that combined silver and gold.

1500 B.C.

- Discovery of Mercury
- Instances of iron smelting (becomes more common in 1200 B.C.)

1475 B.C.

- Painting discovered of brazing in tomb of Vizier Rekh-mi-re

1330 B.C.

- Egyptians used solder and a blow pipe to in 1330 B.C. for metal soldering.



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Info

Egyptian Soldering - 1330 B.C.
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Golden Death Mask of Tut-Ench-Amun

Welding and Cutting Journal 2005

1000 B.C.

- Iron work started in 1000 B.C., bending the metal with the use of furnaces to produce swords and spearheads. (one type called the Catalan furnace)
- Gold boxes found in Ireland that were fabricated by hammering lapped joints (form of pressure welding)

900 to 850 B.C.

- The Egyptians followed with iron tool making in 900 to 850 B.C. In this era iron grew slowly in popularity due to the familiarity and usefulness of bronze and copper.
- Iron weapons have been found and traced to the Babylonians to about 900 B.C.

589 B.C.

- The Chinese during the Sui Dynasty developed the ability to turn wrought iron into steel in 589 A.D. The Japanese manufactured steel through a welding and forging process to produce Samurai swords.

A.D. Welding History**60 A.D.**

- First time in welding history that gold brazing process is recorded by Pliny. He describes how salts acted as a flux and how metal color determines brazing difficulty (color indicated s the presence of oxides).

The Iron Pillar in India

The Iron Pillar of Delhi is fabricated using iron billets. Blacksmiths forge welded the structure that is approximately 25 feet high and weighs 6 tons.

310 A.D.

- Welding was used in the Iron pillar in Delhi, India, about 310 AD, weighing 5.4 metric tons. (pictured above). Other structures with similar construction found in England, Scandinavia and Rome. Source of iron was meteors.

1000 - 1099 A.D. (11th Century)

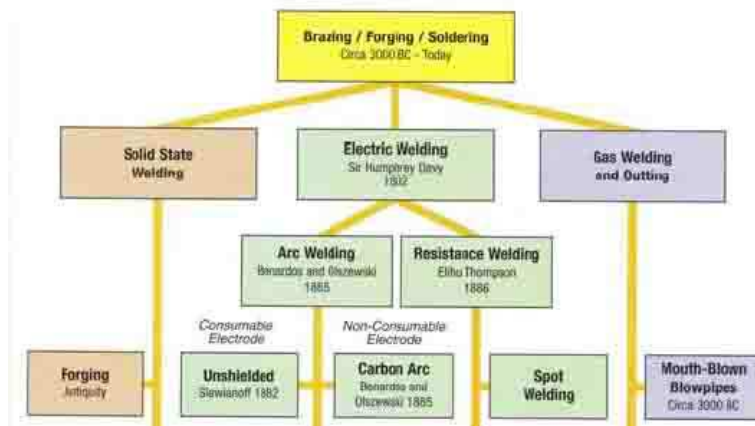
- The manuscript written by monk Theophilus has a description of mixing flux for silver brazing. He indicates the use of Sodium Chloride and Potassium Tartrate. Metals are 66 percent Silver-Copper.

1375

- Discovery of the metal Zinc

The Middle Ages (5th to 15th century) brought a phase in welding history where forge welding was front and center. Blacksmiths pounded hot metal until it bonded.

Diagram of Welding History



Visual Welding History

Photo Credit: Welding - A Journey to Explore Its Past

14th Through 17th Centuries

1540:

- Vannoccio Biringuccio released *De la pirotechnia*, which includes descriptions of the forging operation.
- Renaissance craftsmen gained skilled in the process, and the welding continued to grow during the following centuries.

1568:

- Benvenuto Cellini, an Italian goldsmith, writes about brazing a silver/copper alloy using a soldering process

1599:

- First instance of the root of the word weld (originally well)

16th century: the first cast iron cannon is produced

18th Century

Most innovations during this time in welding history used blast furnaces. This small incremental progress lasted until the middle of the 18th century and the beginning of the industrial revolution. Even then the progress was more in how work was performed. Instead of one person completing an entire project, work was divided in smaller parts and assigned to semi-skilled labor.

1735:

- Evidence that platinum used by pre-Columbian Indians in Ecuador

1751:

- Pure nickel created by Axel F. Cronstedt, a Swedish chemist using German Ore.

1766:

- Hydrogen gas properties described by Henry Cavendish, an English chemist and physicist

1774:

- Discovery of oxygen

1776:

- Principles of oxygen cutting established by Lavoisier (French).

19th Century

1800:

- Sir Humphrey Davy invented the electric arc. The arc was created between 2 carbon electrodes that were powered by a battery.
- Voltaic cell is discovered by Alessandro Volta where two different metals can be connects and become a conductor when wet.

1808-1827:

- Sr. Humphrey Davy proves that aluminum exists. It is actually discovered by Friederich Wohler in 1827.

1828:

- Sponge platinum is welded together via cold-pressing and then hammering when hot.

1836:

- Acetylene was discovered in 1836 by Edmund Davy, but was not practical in welding until about 1900, when a suitable blowtorch was developed.

1838:

- Patent issued to Eugene Desbassayrs de Richemont for fusion welding

1839:

- Discovery of voltage generation with a homopolar device by Michael Faraday.

1841:

- Air hydrogen blowpipe developed by German H. Rossier for soldering lead.

1846:

- Key moment in welding history with a major improvement made in the forge welding process. James Nasmyth while working for the British Admiralty discovered that preparing welding surfaces with a slightly convex surface, the swarf and flux are squeezed out of the joint. This improves the strength of the joint.

1850s:

- Workable and practical electrical generating devices were invented and developed by 1850. Credit goes to Ampere, Oersted, Wheatstone, Faraday Ohm and Henry for advances in electric current research.
- By the middle of the 19th century workable electrical generating devices were available.

1856:

- James Joule welded a bundle of wires by using an electric current and internal resistance to create heat. The resistance welding process was later perfected by Elihu Thomson.

1860:

- Wilde develops electric welding. Issued a process patent in 1865.

1862:

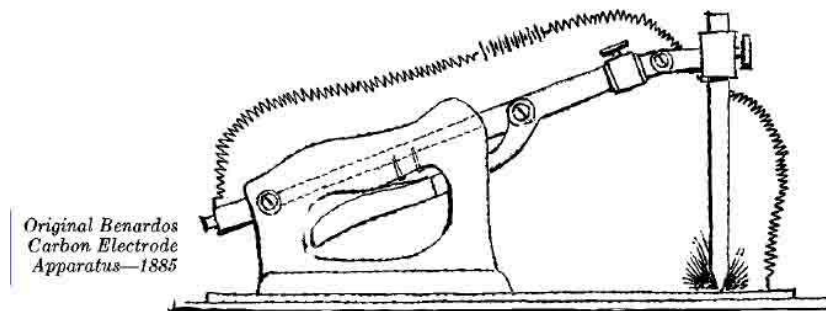
- Friederich Wohler uses calcium carbide to create acetylene gas

1876:

- Otto Bernz Company develops and sells a gasoline powered torch.

1881:

- The first documented use of fusion welding was in 1881 by Auguste de Meritens where he welded lead battery plates together with a carbon electrode. Welding took place in a box with a fixed electrode.

Original Benardos Carbon Electrode Apparatus - 1885

Advances in welding continued with the invention of the metal electrode by a Russian, Nikolai Slavyanov, and an American, C.L. Coffin late in the 1800s. They were not aware of each others work.

Credit also goes to Eli Whitney who invented the idea of interchangeable parts . This led to the manufacture of iron dies and molds.

1882:

- The discovery of bare metal electrode welding was recognized in Europe in 1892. It was introduced in 1888 by N.G. Slavianoff. Slavianoff is credited by most historians for discovering the use of bare metal electrodes for arc welding.

1885:

- Two students of Auguste de Meritens, N. Benardos and S. Olszewski continued his work, and were issued a patent for a welding process that used carbon electrodes (carbon arc welding) and an electric power source in 1887/88. Carbon arc welding uses an arc between a carbon electrode and the weld pool. The process is used with or without shielding or the application of pressure. The primary stated use was repair welding.

The patent issued in 1885 to Auguste and N. Benardos notes that the carbon welding

process can be used for welding two metals, for severing metals and to punch holes in metal. The patent described both a solid carbon electrode and a hollow electrode that would be filled with powdered metals. Since they intended the powder to melt and flow to the weld, they are credited by some with inventing metallic arc welding. Ultimately because of the limitations of this approach, they are not credited with this accomplishment by most historians.

1886:

- Elihu Thomson applied for 2 process patents for "Apparatus for Electric Welding." Invention of resistance welding (RW) with the first patents going to Elihu Thompson in 1885. He produced advances over the next 15 years.

1888:

- A patent is issued to Olczewski and Bernardos for carbon arc welding.

1889 - 1892:

C.L. Coffin is considered to be the pioneer of welding in the United States:

- 1889: received patent for flash-butt welding, equipment and process
- 1890: 2 patents for spot welding. Awarded first patent for metal electrodes.
- 1892: patent for bare metal electrode arc welding process is awarded

1890:

- First known instance of a "torch" being used to break into a bank vault

1892:

- Commercial acetylene is produced in North Carolina by mixing water and calcium carbide
- Baldwin locomotive starts to use Carbon Arc Welding to repair locomotives

1895:

- Combustion of acetylene and oxygen discovered by Henri LeChatelier.
- Argon discovered by Sir William Ramsey and Lord Reyleigh

1897:

- Kleinschmidt introduced the use of copper electrodes

20th Century Welding**1900:**

- Foresche and Charles Picard developed the first commercial oxyacetylene welding torch. The process is used without the application of pressure (AWS).
- Around 1900, A. P. Strohmenger developed a coated metal electrode in Britain, which had a more stable arc.

1901:

- Oxygen Lance invented by Ernst Menne

1903:

- Thermite welding is invented, another process, oxyfuel welding, also became well established as a commercial process.
- First machine for resistance butt welding after merger between Allgemeine Electricitats-Gesellschaft (AEG) and Union-Electricitats-Gesellschaft (UEG).

1906:

- First resistance spot welding machines are produced. Up to 1910 approximately 367 spot and seam welding machines are produced.
- The LaGrange-Hobo welding method is introduced. In this method one end is connected to a current producing machine and the other end is immersed under water. The current that flows through the part causes partly ionized gas to form in the water. The resistance of the part to the electrical flow and the gas created energy which created heat at the weldment. When the part to be welded hit welding heat, it was taken out of the water bath and welded.

1907 - 1908:

- Oscar Kjellberg received a patent for the electrode coating process called Shielded metal arc welding. The coating helped to stabilize the arc, producing better welds than bare electrodes. Shielded metal arc welding uses an arc between a covered electrode and the weld pool. The process is used with shielding from the deposition of the electrode covering without the application of pressure, and with filler metal from the electrode.
- Arc welding industry in U.S. starts with two companies: The Siemund-Wienzell Electric Welding Co. is formed in the U.S. and patents a metal arc welding method. A second company also from German founders is started called Enderlien Electric Welding Co.
- Lincoln Electric manufactures the first variable voltage DC welding machine.

1908:

- Bernardos patented electroslog process which enabled the welder to weld thick plates in a

single pass. The process he outlined is popular today.

1909:

- The plasma arc system using gas vortex to stabilize the arc is invented by Schonner while working as BASF.
- The Quasi-arc electrode is invented which is wrapped with an asbestos yarn by A.P. Strohmenger.

1910:

- Patent issued to Charles Hyde for brazing steel tubes.

1911:

- First pipeline created using oxyacetylene welding. Occurs outside of Philadelphia.
- Matters develops the plasma arc torch for heating a metal fusing furnace.

1912:

- Kjellberg received a second patent for an electrode with a heavier coating of asbestos and a binder made out of sodium silicate.
- Lincoln Electric introduces first commercial welding machines
- First auto body is welded by E.G. Budd using spot welding
- Coated metal electrodes introduced by A.P. Strohmenger. Coatings were made from Clay or Lime. Also awarded a patent for an electrode coated with blue asbestos and a sodium silicate binder. First time an electrode produced a impurity free weld.

1919:

- Alternating current welding was invented by C.J. Holslag, but did not become popular for another decade. Electric arc welding was the method used in the United States until 1920. The problem with the method was that the welding arc was unstable and the welds were not as strong as the metal being welded.

At first, oxyfuel welding was the more popular welding method due to its portability and relatively low cost. As the 20th century progressed, it fell out of favor for industrial applications.

It was largely replaced with arc welding, as metal coverings (known as flux) for the electrode that stabilize the arc and shield the base material from impurities continued to be developed.

Welding Circa World War I



Welding For Ships Was Not Reliable Due to Cracking Until World War I

World War I caused a major surge in the use of welding processes, with the various military powers attempting to determine which of the several new welding processes would be best.

1917:

- Gas shortage in England resulted in industry turning to electric arc welding for producing bombs and mines.

1919:

- President Wilson establishes the United States Wartime Welding Committee of the Emergency Fleet Corporation.
- Establishment of the American Welding Society
- Development of the paper coated electrode by Reuben Smith

1920s:

During the 1920s, major advances were made in welding technology, including the introduction of automatic welding in 1920, in which electrode wire was fed continuously.

Shielding gas became a subject receiving much attention, as scientists attempted to protect welds from the effects of oxygen and nitrogen in the atmosphere.

Porosity and brittleness were the primary problems, and the solutions that developed included the use of hydrogen, argon, and helium as welding atmospheres.

The stick welding process advanced quickly due to the improvements in core wire and electrode coatings. X-ray technology made it possible to check the soundness of a weld.

- Research on coated electrodes resulted in better core wire and improved electrode coatings.
- The British primarily used arc welding, even constructing a ship, the Fulagar, with an entirely welded hull. At one point the ship ran aground and stayed whole because it was welded and not riveted.
- The Americans were more hesitant, but began to recognize the benefits of arc welding when the process allowed them to repair their ships quickly after a German attack in the New York Harbor at the beginning of the war.
- Arc welding was first applied to aircraft during the war as well, as some German airplane fuselages were constructed using the process.
- The Germans used electric arc welding on airplanes
- The German merchant marine sabotaged their ships in NY harbor before fleeing. Weld repairs were successfully used, it put welding on the map.
- The auto industry started to use automatic welding.
- General Electric employee P.O. Nobel developed Direct Current automatic welding.
- Before 1920, welding was done with D.C. current produced by batteries. In the late 1920 to early 1930s A.C. welding machines gained in popularity.

During the following decade, further advances allowed for the welding of reactive metals like aluminum and magnesium. This, in conjunction with developments in automatic welding, alternating current, and fluxes fed a major expansion of arc welding during the 1930s and then during World War II.

1923:

- Founding of Institute of Welding Engineers

1924:

- First all welded buildings constructed by U.S. Boiler

1926:

- P.K. Devers and H.M. Hobart test welding using helium and argon as a shielding gas.
- Naval research laboratory releases a paper on the use of X-Rays to test welds.

1927:

- A.O. Smith employee John J. Chyle patents first extruded all position titanium electrode later called the E6010 type.

1928:

- First welded railroad bridge created by Westinghouse to transport large generators.

1929:

- Lincoln Electric produces the Fleetwood 5 heavy coated electrode.
- American Welding Society establishes [welding symbols](#).

1930:

- Patent issued to H.O. Hobart for arc welding, and the process that became GMAW ([Gas Metal Arc Welding](#)).
- Submerged arc welding developed by National Tube Company
- All welded merchant ship created
- Release of stud welding, which soon became popular in shipbuilding and construction. Submerged arc welding was invented the same year, and continues to be popular today. By 1930, arc welding was lower in cost than riveting and gas welding.
- Patent issued to Devers and Hobart for use of an electric arc within an inert gas atmosphere. Not well received by the welding industry because of high cost of gas (helium and argon) and unsuitable torch availability

1931:

- Welding of stainless steel (originally called shotwelding) by E.G. Budd Manufacturing

During the middle of the century, many new welding methods were invented.

1934:

- A timing controller for resistance welding is developed by Westinghouse (originally called an Ignitron)

1935:

- SAW (submerged arc welding) process using continuous wire feed and granulated flux is introduced. Process originally called Union Melt.
- British welding electrode standard established and solid extruded electrode released.

1936:

- First A.C. welding machine introduced by Miller Electric Manufacturing. The method had a high rate of metal deposition (ratio of the weight of deposited metal to the net weight of electrodes consumed, exclusive of stubs) and an absence of arc blow (the deflection of an electric arc from its normal path due to magnetic forces).

1937:

- The use of welding is confirmed in structural steel buildings with BS 538 (metal arc welding in mild steel).

1938:

- Gravity welding introduced by K.K. Madsen
- Germans weld ships to reduce weight and to enable the design of larger vessels

1939:

- Use of aluminum spot welding recognize as being useful in aviation

1940 - 1941:

- [Gas tungsten arc welding](#) (GTAW), after decades of development, was finally perfected in 1941 (patent issued in 1942). Invented by Russel Meredith. Developed by the Linde Company. Also called HELIARC or TIG. The water cooled torch was capable of high amperage. Gas Tungsten arc welding uses an arc between a tungsten electrode which is nonconsumable and the weld pool. The process is used with shielding gas and without the application of pressure.
- Army finds usefulness of stainless steel, aluminum and magnesium in equipment such as fighter planes.
- Formation of the [Canadian Welding Association](#).
- Dip soldering technique developed for printing wiring boards. First mass soldering process.

1942:

- Firecracker welding process patent given to George Hafergut.

1943:

- Gas metal arc welding (GMAW) is invented by C.B. Voldrich, P.J. Rieppel and Howard B. Cary. Developed at Dow and Northrup Corporations and then licensed to Linde Corporation.
- The sciaky company starts to sell a three phase resistance welder.

1945:

- Development of an experimental hand-held MIG gun at the Battelle Memorial Institute (Columbus, Ohio)
- Welding replaced riveting as the main method of assembly for ships with 5,171 vessels constructed through 1945.

1948:

- [Gas metal arc welding](#) followed in 1948 (GMAW superseded earlier terms of metal inert gas (MIG) and metal active gas (MAG)), allowing for fast welding of non-ferrous materials, but requiring expensive shielding gases.

The "shielded inert gas metal arc process was introduced by the Air Reduction Company at the AWS show in Philadelphia. Gas metal arc welding uses an arc between a continuous filler metal electrode (consumable) and the weld pool. The process is used with shielding from an externally supplied gas and without the application of pressure.

- The first Department of Welding Engineering department is started at Ohio State University.
- Inert Gas Metal Arc Process (MIG) is developed at the Air Reduction Company.
- SIGMA (Shielded Inert Gas Metal Arc) welding developed to weld thicker plates.

1949:

- Westinghouse introduces Selenium Rectifier welding machines.

1950s:

- Shielded metal arc welding was developed during the 1950s, using a consumable electrode and a carbon dioxide atmosphere as a shielding gas, and it quickly became the most popular metal arc welding process.
- A.C. - D.C. rectifier welding machines were introduced with built-in frequency for GTAW welding. Miller Electric developed the Miller controlled wave a.c. welder which was used for critical welds on missiles and aircraft.
- Electric beam welding process launched by A.J. Stohr
- Printed wiring board process wave soldering is introduced.
- E.O. Paton welding institute develops Electrostag Welding (ESW).

1951:

- DryRod Electrode oven introduced to control moisture levels in electrodes.

1954 - 1957:

- Flux-cored arc welding process debuted (FCAW), in which the self-shielded wire electrode could be used with automatic equipment, resulting in greatly increased welding speeds, and that same year, plasma arc welding was invented. Patented in 1957 by National Cylinder Gas Company.

1956:

- Friction welding process introduced by Russia

1958-1959:

- Electroslag welding was released in 1958, and it was followed by its cousin, electro-gas welding, in 1961.
- Other recent developments in welding include the 1958 breakthrough of electron beam welding, making deep and narrow welding possible through the concentrated heat source.
- Short arc process introduced. The process uses wires with small diameters and a refined power supply.

1960:

- Following the invention of the laser in 1960, laser beam welding debuted several decades later, and has proved to be especially useful in high-speed, automated welding. Both of these processes, however, continue to be quite expensive due the high cost of the necessary equipment, and this has limited their applications.
- Welding process called explosive welding introduced.

1962:

- Sciaky welds Mercury Space capsule (created with an outer and inner titanium shell).

Mercury Space Capsule

Due to the small size of each titanium sheet, the metal needed to be triple sheet welding, and then welding to other sheets. The TIG process was used without a filler metal

Source: NASA Manual, Welding Procedures for Titanium and Titanium Alloys

1963:

- Marked by developments in weld testing. The Varestraint Test determines if a base metal can be welded and the viability of different welding processes.
- Wall-Colmony introduces the Fusewelder Torch.

Wall-Colmony Fusewelder Torch

The fusewelder is an oxyacetylene torch that is frequently used when a weld needs to be built up and to finish hard surfacing welds.

1965 - 1967:

- Welding and cutting by CO2 laser
- Gravity welding starts in the U.K.

1969:

- Russians weld in space on SOYUZ-6.

1970:

- New soldering technologies are introduced to support electronic miniaturization:
 - vapor phase
 - infrared
 - hot gas

Modern Welding

Today there are over 90 welding processes with constant research on new metals used in the

nuclear, space and shipbuilding industries. Many changes occurred in the 1980's and 1990s where welding moved from art to science.

- Robotic welding
- On-board computers
- State-of-the-art electrodes
- Exotic multiple gas mixes

1991:

- Friction Stir welding introduced by TWI.

1999:

- The Edison Institute develops a method that leads to 300% increase in flux penetration into a weld.

2000:

- Introduction of magnetic pulse welding.
- An X-Ray is used to weld a metal/matrix composite
- Use of diode laser welding expanded to metals such as stainless steel titanium foil.

2008:

- Development of laser-arc-hybrid welding

2013:

- Development of Gas Metal Arc Welding-Brazing, an process for welding steel used in autos. Process uses a filler metal comprised of silicon with a copper alloy.
- Low-carbon steel and aluminum welding using a lap joint and laser technology.

Future Welding Trends

- Welding operations must be more completely integrated into agile manufacturing processes and process control schemes.
Welding will become increasingly automated as it is integrated into the entire manufacturing design and coordinated with improved information systems.
- Future products requiring welded joints will be composed of designed-to-be-weldable materials, such as highstrength steels that are also smart materials containing embedded computer chips to monitor the weldment's lifecycle performance. Such materials could create new opportunities for using welding as a joining technique in the coming decades.
- In the future, the modeling of welding will be part of the new emphasis on integrating welding across the entire manufacturing cycle
- Welding and materials engineers will develop new materials and adapt existing materials, which are specifically designed to be welded into world-class, fabricated products.
- The development of materials that will reduce energy requirements.

For Additional Reading

[History of Welding](#) (PDF Download)

[History of Welding](#) (website)

[Etymology Dictionary on Welding](#)

[History of Welding](#) (Word Document, Source: [History of Welding](#) (PDF Download))

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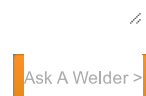
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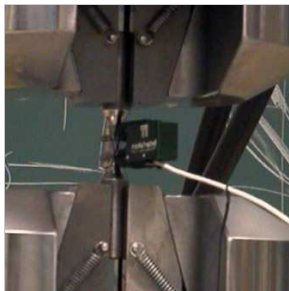
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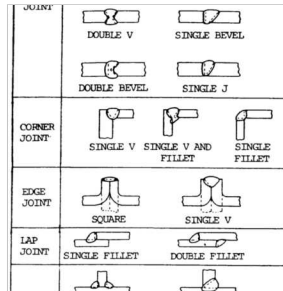
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