about Plasmas
from the Coalition for Plasma Science

Plasmas for Welding

PLASMAS HOLD OUR WORLD TOGETHER. That may be a bit of an overstatement, but not by much. Cars, bridges, ships, pipelines, hot-water systems, the metal framework of buildings, in fact most manufactured goods depend on thousands of metal-to-metal joints. Many of those joints are welded using plasmas — gases made so hot that many of their atoms are broken apart and electrically charged.

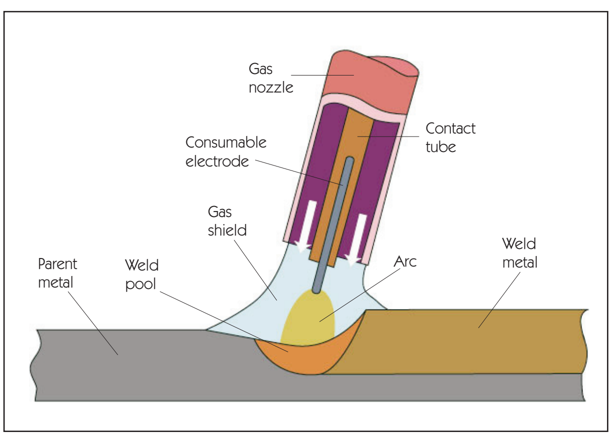

A welding helmet and flame retardant clothing protect a welder from sparks, heat and ultraviolet rays.

We have been surrounded by electrical plasmas since time began. The light from the sun, the stars, lightning and the Aurora Borealis (the Northern Lights) are all produced by plasmas. Benjamin Franklin studied lightning and discovered that it was composed of charged particles, even before other scientists knew of the existence of electrons. However, only recently have we learned to harness the power of plasmas to work for us.

A plasma is a gas containing a large number of positively and negatively charged particles. Since the interaction of these particles produces forces many thousands of times greater than gravity, plasmas have the ability to concentrate and focus energy in many useful ways.

The first man-made plasmas consisted of spark discharges from static electricity. Aristotle was fascinated by the static electricity generated by rubbing amber against fur or wool. The first artificially produced high-power plasma was generated by Sir Humphrey Davy in the early 19th century. It was Davy who coined the term electric "arc," because the bright light emitted in his laboratory formed an "arch" as the air heated by the electric current rose between the two horizontal electrodes. Yet it was not until the late 19th century that industrial uses of electrical arcs or plasmas became prevalent, due to the ready availability of electricity created by Thomas Edison and George Westinghouse.

Because the electrons in plasmas move very easily, a plasma can carry very large electric currents and can concentrate the electric energy in a very small volume. This makes plasmas very efficient sources of heat for melting metals. Approximately one-third of all the steel produced in the United States is melted in electric arc furnaces. The steel furnace electric arc concentrates the energy necessary to operate 1000 homes into a volume equal to that of a basketball and can melt 100 tons of steel in half an hour. On a smaller scale, this same type of electric arc is used to weld metals together.



An electrical current bridges the gap between the electrode and the metal to be welded.

In arc welding, an electrode is connected to one end of an electrical power supply and the metal to be welded is connected to the other end. The welder touches the tip of the electrode to this metal, then draws it away to produce a short gap, a fraction of an inch in length, between the electrode and the metal. The voltage in the power supply causes an electrical

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current to bridge this gap. The current heats the air to create a plasma, which emits a very intense light. This is the welding arc.

In a high-power welding arc plasma, all the particles – the negatively-charged electrons, the positively-charged heavier particles ("ions") and the remaining neutral atoms – are at nearly the same temperature. And that plasma temperature exceeds 11,000°F, which is far above the melting temperature of all known materials. Everything held in contact with this intense plasma melts or vaporizes. The edges of the metal pieces to be joined melt and form a liquid pool. The tip of the electrode also melts, and the resulting liquid metal transfers across the arc to the weld pool as drops of liquid to combine with and enlarge that pool. As the arc is removed, the weld pool cools and solidifies to form a weld. The electrode material melted into the weld is called "filler" metal, as it fills the gap between the metals being welded. Over 100,000 tons of filler metal are used each year to construct nearly all forms of bridges, buildings and transportation systems.

Electromagnetic forces in the arc produce a plasma jet — or plasma wind — at the tip of the electrode. The jet moves at a velocity of over 500 miles per hour. The force of this plasma jet exceeds the force of gravity and carries the molten metal drops from the tip of the electrode into the weld pool. That force also creates a stiff arc, which allows the welder to direct the heat as the electrode is tilted and turned to any angle or position, even overhead. The jet also helps protect the liquid metal from oxidation by the surrounding air – and it pushes aside the melted weld pool, permitting deeper and stronger welds. The intense heat created by the plasma produces a pressure within the plasma that is high enough to counteract the pressure produced by over 300 feet of water, allowing arc welding to be performed deep under water for offshore oil rigs or ship repair.

Plasma can be manipulated to cut through metals at high velocity.

Although most welding arc plasmas operate in the open atmosphere, an even stiffer and more intense arc can be produced by operating the arc in a small copper cavity which is cooled by either water or air. The plasma, which is heated and expands in this confined space, exits a small hole in the cavity with even higher velocities than an arc that is produced in the open atmosphere. This higher velocity and much stiffer plasma jet not only melts metal very quickly, but has enough force to blow the molten metal away, causing a very rapid cutting action. With a nitrogen plasma, metal plates up to three inches thick can be cut at speeds up to 15 inches per minute; with an oxygen plasma, half-inch steel can be cut at 160 inches per minute. Thinner plates can be cut at over 20 feet per minute, making the plasma arc process the fastest and most economical method of cutting virtually any metal. In large production facilities the cutting is done under several inches of water, eliminating smoke and fumes, thus making the plasma cutting process the most environmentally friendly method of cutting metals.

Plasma arcs, used for both welding metals together and cutting metals apart, have revolutionized the way we construct bridges, buildings, pipelines, energy generation facilities, cars, trucks, ships and airplanes. We can fabricate these and other metal structures more quickly, more safely, more economically, and in greater quantity and size than would otherwise be possible. These compact plasmas work more efficiently than anything else available and have been harnessed to create much of the man-made world around us.

References and Suggested Reading: Thomas Eagar Website: http://web.mit.edu/3.37/www/; H.B. Cary, Modern Welding Technology, 2nd Edition, Prentice Hall, 1989; A.C. Davies, The Science and Practice of Welding, Vols 1 and 2, 8th Edition, Cambridge University Press, 1984; R.J. Sacks and E.R. Bohnart, Welding:Principles and Practices, 3d Edition, McGraw Hill, 2005

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