

“Downsizing” in the World of Resistance Welding

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General Comparisons Between Large, Small, and Micro-Scale Resistance Spot Welding

Large Scale Resistance Spot Welding

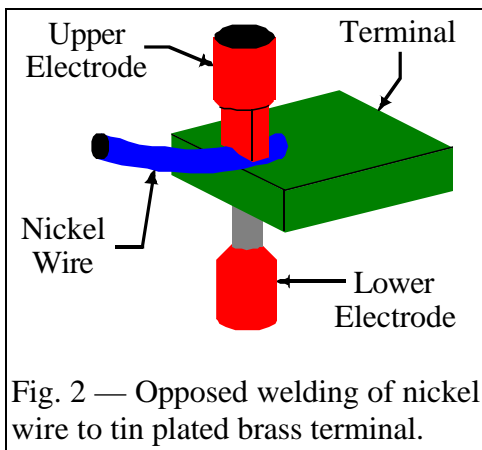
When most welding engineers think about spot welding, the typical picture that immediately comes to mind is a large robotic arm swinging around in space with streams of sparks flying everywhere as a car body is assembled or large panels of sheet metal are joined together to make a refrigerator or an industrial piece of machinery — Fig.1. Galvanized steel sheets ranging in thickness from .016 inches (0.41 mm) to .125 inches (3.18 mm) are routinely joined using resistance spot welding.

Fig. 1 — Photo of car body being welded by robotic resistance spot welding.

(Use AWS stock photo)

The extensive use of standard thickness sheet metal panels, made from common, well characterized steel alloys, and plated with standardized zinc coatings, makes life more manageable for our large scale welding engineer. Materials standardization in fact has permitted the creation of spot welding tables that define what spot welding technology should be used, exactly how much weld current, time, and force are needed, along with what electrode alloy and tip shape are required to make a good spot weld.

Small Scale Resistance Spot Welding - Life just became complicated



Now picture our welding engineer being faced with the task of resistance welding one end of a .015 inch (0.38 mm) diameter nickel wire onto a tin plated brass alloy terminal that is .025 inches (0.64 mm) thick by .187 inches wide (4.75 mm) inside of a modern automotive ignition module — Fig.2. Problems like automatically holding and placing the wire over the terminal on a repeatable basis become significant. The plastic housing, with its embedded terminals, must be designed to provide access for the welding electrodes. After solving the parts handling and electrode access problems, our welding engineer finds that there are no welding tables that define what type of spot welding technology should be used for his application, let alone any starting set of process parameters.

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To complicate matters, the opposite end of the nickel wire must be automatically positioned and parallel gap welded to a .020 inch (0.5 mm) thick by .15 inches (3.8 mm) square nickel pad that had been fused to the electronic control printed circuit board — Fig.3. Once again, our welding engineer has no welding table for selecting the appropriate spot welding technology and starting process parameters.

At this point, it is becoming apparent to our welding engineer that there is something very different between large scale and small scale resistance spot welding.

Micro Scale Resistance Spot Welding - Life just became very complicated

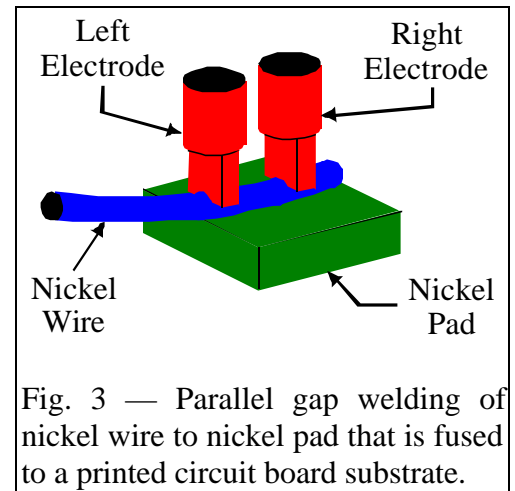
Our welding engineer decides to escape his small scale resistance welding problems by changing jobs. The medical products field is growing so he takes a position with a company that is developing a new implantable bio-sensor. His first task is to develop a resistance welding process for joining a .002 inch (50 micron) diameter platinum wire to a .010 inch (0.25 mm) square by .001 inch (25 micron) thick gold plated copper pad on a flexible printed circuit board. Like the small scale resistance welding problem, there are no welding tables to help our welding engineer select the appropriate welding technology and provide him with starting process parameters.

The Differences Become More Apparent

The size of the large scale resistance spot welding application market is easily an order of magnitude greater than small and Micro-Scale resistance welding applications. Large scale resistance spot welding is well over 100 years old and represents a mature joining process. There has been ample time for materials to become standardized as to alloy types, plating, and thickness. These factors have driven the creation of welding tables that clearly define the large scale resistance spot welding process.

Small and Micro-Scale resistance spot welding on the other hand is being fueled by the explosion to make everything smaller, from automotive electronics, to telecommunications components and medical products. The only thing that these applications have in common is their lack of commonality. Even within a single applications sector such as automotive electronics, the alloys, plating, part geometry, and thermal loading are vastly different from application to application, making the creation of standardized welding tables almost impossible.

This article provides the welding engineer familiar with large scale resistance spot welding with some basic knowledge about materials, weld energy controls, weld force controls, electrodes, and parts fixtures to help ensure his joining success as he “downsizes” into the realm of small and Micro-Scale spot welding.



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Part Materials

Alloys, Thickness Range, and Applications - Large Scale Spot Welding

The majority of large scale resistance spot welding applications use parts fabricated from galvanized low carbon 1010 and 1100 cold roll steel along with 304, 316, and 400 series low carbon stainless steels, ranging in thickness from .016 inches (0.41 mm) to .062 inches (1.57 mm). The effects of spot welding on these common materials is well known and documented. The American Welding Society (AWS), 800-443-9353, Resistance Welding Manufacturers Association (RWMA), telephone 215-564-3484, and spot welding suppliers like Contacts Metals Welding (CMW), telephone 317-634-8884, all publish spot welding parameter tables for large scale resistance spot welding of the most common steel alloys sheets. Table 1 provides a list of the most common materials, thickness range, and applications joined by large scale spot welding.

Table 1 - Large Scale Spot Welding

Typical Materials	Plating Types	Common Applications Thickness Range: .016 to .062 inches (0.41 to 1.57 mm)
1010 & 1100 Cold Roll Steel	None, Tin, Zinc	Appliances, auto body panels and frames, boxes and enclosures, Steel furniture
304, 216, 410 Stainless Steel	None	Boxes and enclosures, steel furniture, supporting brackets and structures

Alloys, Thickness Range, and Applications - Small Scale Spot Welding

In addition to using many of the same stainless alloys used by large scale spot welding, small scale spot welding uses a wide variety of brass, copper, inconel, nichrome, and nickel based alloys. Difficult to join materials such as molybdenum and tungsten are also used in making high intensity vapor arc lamps for automotive headlamp, street, and security lighting. Typical plating materials include tin/lead solder over brass and copper, pure tin, nickel, silver, and gold. There are no detailed published resistance spot welding guides or tables for joining these materials since the part size, geometry, plating type and thickness vary substantially from application to application. Table 2 provides a list of the most common materials, thickness range, plating types, and applications joined by small scale spot welding.

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Table 2 - Small Scale Spot Welding

Typical Materials	Plating Types	Common Applications Thickness Range: .005 to .020 inches (0.125 to 0.51 mm)
Brass Alloys	None, Tin/lead, Tin, Nickel, Silver	Electronic terminals, relay supports
Copper	None, Tin/lead, Tin, Nickel, Silver	Electronic terminals, relay supports
Copper Alloys	None, Tin/lead, Tin, Nickel, Silver	Electronic Terminals, relay supports, bi-metal components
Inconel	None	Aircraft components
Molybdenum	None	Auto headlamps, street lamps, medical lamps
Nichrome	None	Bi-metal sensors, detonating devices
Nickel	None	Rechargeable battery packs, electronic circuits, bi-metal sensors
Silver Alloys	None	Relay contacts
Stainless Steel	None	Medical catheters, small surgical instruments and devices
Tungsten	None	Auto headlamps, street lamps, medical lamps

Alloys, Thickness Range, and Applications - Micro-Scale Spot Welding

The world of Micro-Scale spot welding begins at a part thickness of .005 inch (0.125 mm) and goes down to about .0005 inches (12 microns). The most common materials found in Micro-Scale spot welding are 304L and 316L stainless steel, copper wire, nickel, platinum, and titanium. Table 3 provides a list of the most common materials, thickness range, plating types, and applications joined by Micro-Scale spot welding.

Table 3 - Mciro-scale Spot Welding

Typical Materials	Plating Types	Common Applications Thickness Range: .0005 to .0050 inches (12.5 um to 0.125 mm)
Copper	None, Tin/lead, Tin, Nickel, Silver	Electronic circuit connections
Gold	None	Electronic circuit connections
Nickel	None	Electronic circuit connections
Nitinol	None	Medical guide wires and stents
Platinum	None	Electronic circuit connections and medical device sensors
Stainless Steel	None	Medical catheters, guide wire, micro- cutting instruments and devices

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Part Geometry and Thermal Loading

Part shape or geometry on small and Micro-Scale size parts can make or break the possibility of achieving a successful spot weld through the creation of large thermal imbalances, particularly if thermally mismatched parts are being welded together. For example, spot welding the .015 inch (0.38 mm) diameter nickel wire to the .025 inch (0.64 mm) thick brass terminal described earlier is potentially a big problem because of the large heat sinking capability of the brass terminal in comparison to the limited heat absorption capability of the small nickel wire.

To compensate, the knowledgeable welding engineer will work with the terminal designer to create a “thermal island” in the brass terminal. This task can be accomplished in several ways. A hole can be placed in the terminal, slowing down the loss of heat from the welding area to the larger thermal mass portion of the terminal. A projection can be stamped into the brass that has a small contact area and smaller cross sectional thickness compared to the larger area and cross section of the brass terminal — Fig.4. In summary, the primary goal of part design for weldability is to use geometry to effect a heat balance between thermally disparate parts.

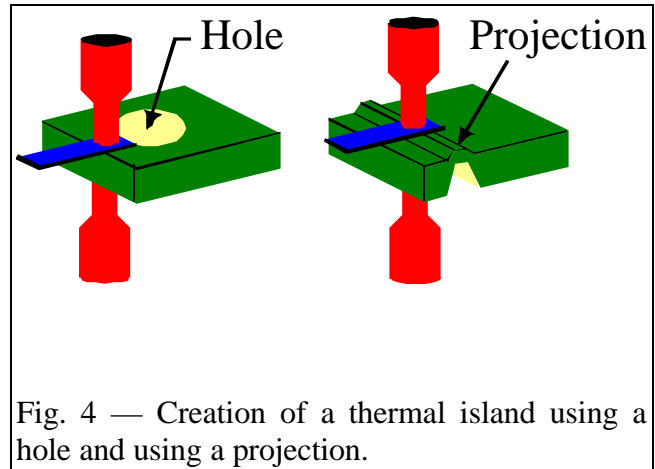


Fig. 4 — Creation of a thermal island using a hole and using a projection.

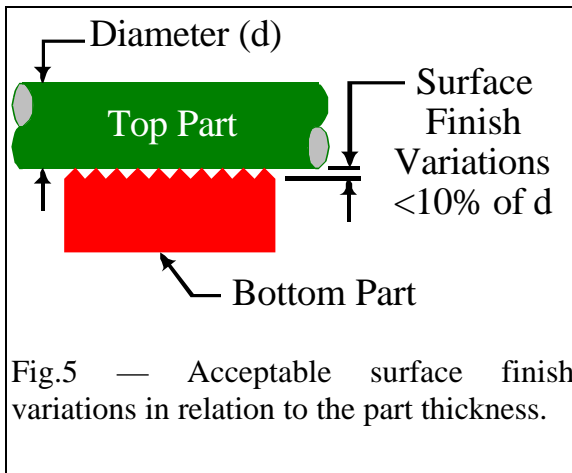
The same techniques of creating “thermal islands” also apply to large scale resistance spot welding. However, the absolute size of these “thermal islands” and their fabrication tolerances exceed small and Micro-Scale applications by a factor of ten times or more.

Surface Finish

As the size of the parts to be resistance spot welded decreases, the surface finish quality of each part takes on more importance. For example, squib or detonating wire used in making automotive airbag or aircraft canopy and ejection seat detonators can range in size from .0005 inches (12.5 microns) in diameter to .0020 inches (50 microns) in diameter and are made from platinum iridium, platinum-tungsten, nichrome, or stainless alloys. One side of the squib wire is typically welded to the top of a connecting pin made of nickel-iron or stainless steel while the other end is welded to a header surface made from a stainless steel alloy. In the case of the .0005 inch (12.5 microns) diameter wire, the mating surface finish peak-to-peak variations should not exceed .00005 inches (1.2 microns) or the welding process will not be repeatable. Variations in peak-to-peak surface finish approaching .00025 inches (6.4 microns) can actually cut the wire during welding and definitely create an inconsistent electrical contact resistance which in turn translates into “unexplained” blow-outs and inconsistent welds.

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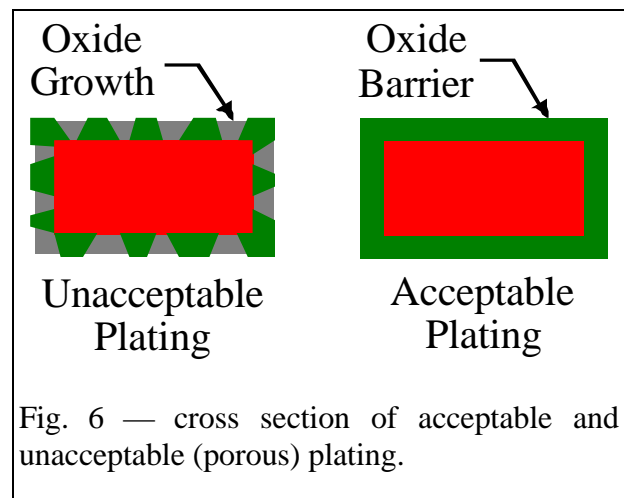
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As a general rule of thumb, the peak-to-peak surface finish variations for small and Micro-Scale parts should not exceed 10% of the part diameter or thickness — Fig.5. As parts increase in diameter or thickness, the surface finish peak-to-peak variations become a non-issue. Thus, surface finish variations are rarely a problem with large scale resistance spot welding.

Plating Issues

Plating is the nemesis of both large, small, and Micro-Scale resistance spot welding. Plating materials, particularly lead, cadmium, tin/lead solder, tin, and zinc melt at temperatures that are substantially lower than the melting temperature of the base materials, resulting in weld splash and severe electrode sticking. In addition, poor quality plating results in inconsistent weld strength due to the growth of base material oxides through microscopic holes in the plating surface — Fig. 6. Oxide contamination reduces the tensile or peel strength of the final joint and causes weld strength inconsistencies, regardless of the spot welding scale. Plating quality can be measured in terms of plating thickness consistency and the degree of surface porosity.



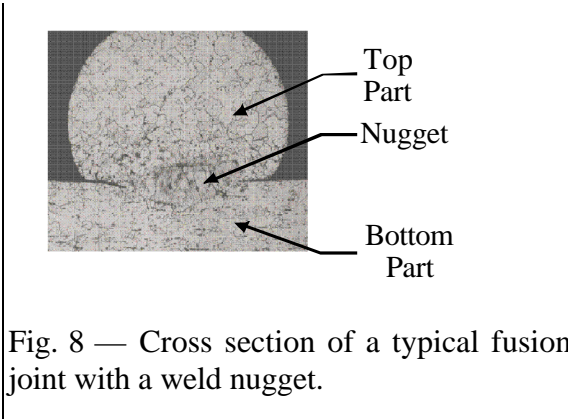
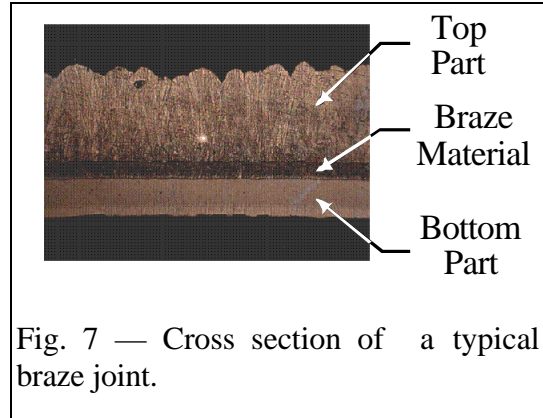
Plating thickness control is everything in small and Micro-Scale spot welding. Always use the thinnest plating possible. Allowing the plating thickness to vary by as much as .0002 inches (5 microns) on a part that is .005 inch (125 microns) thick will result in a totally uncontrollable welding process. Plating thickness control in large scale spot welding is not as quite as critical and is typically dealt with by using excess weld energy to blow away the plating in the interface area.

When possible, use plating that has the same thermal conductivity as the base material. For example plating a gold flash over copper protects the copper from oxidizing but has a negligible effect on the welding process. However, plating nickel over copper can result in a weak plating-to-plating weld because of the difference in heat absorption between the nickel and copper during the melting process. The nickel can not dissipate the weld heat as quickly as the copper so the nickel plating tends to vaporize and throw off bits of nickel in the form of sparking. The copper base material never reaches adequate melting temperature. A strong copper-to-copper weld can only be achieved at the expense of excessive nickel plating expulsion which in turn causes electrode sticking and rapid electrode wear.

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Cadmium, lead, silver, tin/lead solder, tin, and zinc plating will most often create a braze joint which is defined as the joining of two materials by using a third interface material. For many applications, a braze joint may produce perfectly satisfactory weld strength — Fig. 7.



In other applications where a fusion or nugget weld is desired, these plating materials will always remain in between both parts, even on a microscopic scale, thus preventing the creation of a fusion nugget — Fig. 8.

Weld Energy Controls

Weld Energy Control Systems - Large Scale Resistance Spot Welding

Most large scale spot welding applications are joined using a controlled alternating welding current (AC) that ranges from 2,000 amps to about 20,000 amps. This weld current creates weld heat that is proportional to the weld current (i) squared times the total electrical resistance (R) of the parts to be welded times the time (t) that the weld current is on: $\text{Weld Heat} = i^2 \times R \times t$.

A complete AC welding system includes a “Timer” for controlling the phase angle and duration of the weld current, a power transformer to convert high voltage, low current energy to a high weld current at a safe, low operating voltage, and a weld head for applying weld force and conducting the weld current into the parts to be welded.

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The majority of large scale AC controls are “open loop” controls, meaning that the operator can not directly set the actual weld current. The actual weld current will depend on the output voltage setting of the weld transformer, the part electrical resistance, and on the percentage of weld current that is allowed by the control to flow during the positive and negative portions of the power line cycle — Fig. 9. In the USA, one complete power cycle is 60 Hz, which is 16.67 milli-seconds (.01667 seconds) in duration. Most of the world uses a 50 Hz power cycle which is 20 milli-seconds (.02 seconds) in duration. These open loop systems are inexpensive and work well for most large scale applications.

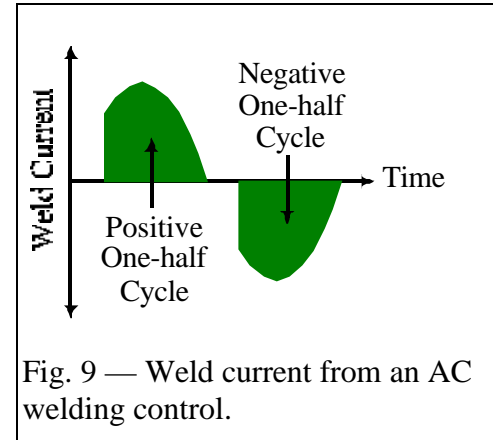


Fig. 9 — Weld current from an AC welding control.

As the push from worldwide competition increases to improve weld quality and consistency, new AC welding technology that provides “closed loop” control over weld current has appeared. These new systems dynamically control the weld current to a user programmed value, thus improving spot welding consistency.

Weld Energy Control Systems - Small Scale Resistance Spot Welding

While many small spot welding applications can be successfully welded using scaled down versions of the large scale AC spot welding control systems, the six-sigma oriented manufacturer has found that these open loop AC welding systems can not offer the degree of welding consistency that the manufacturers are trying to achieve. Instead, these quality oriented manufacturers are turning to high frequency inverter and linear DC technologies. These two new technologies offer precise, high speed, closed loop control over weld current, weld voltage, or weld power — Fig.10 and Fig. 11.

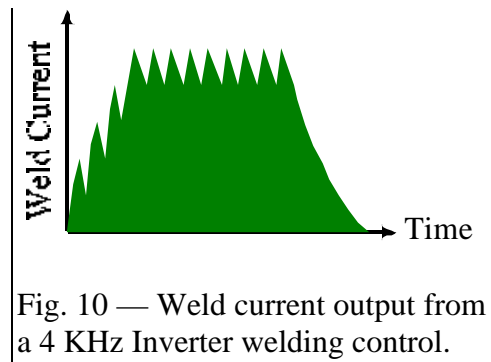


Fig. 10 — Weld current output from a 4 KHz Inverter welding control.

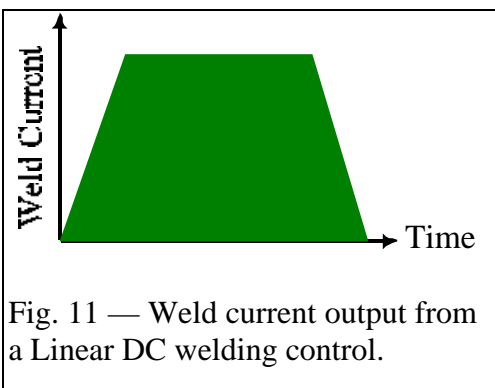


Fig. 11 — Weld current output from a Linear DC welding control.

Weld current for small scale inverter and linear DC spot welding ranges from 500 to 4000 amps. Weld time is typically programmed in fine resolution, one milli-second (.001 second) time increments, as opposed to the older one cycle, 50 Hz (.02 seconds) or 60 Hz (.0167 seconds) time increments found on large scale AC spot welding controls. Welding schedules based on milli-second weld time increments, coupled with constant current, voltage, or power feedback, offer the global welding engineer the ability to duplicate weld schedules around the world without having to worry about compensating for differences caused by 50 Hz or 60 Hz.

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Small scale spot welding applications are also successfully welded using stored energy welding technology (CD). This technology stores the weld energy in capacitor banks before discharging the weld energy into a special pulse transformer which in turn reduces the weld voltage to an operator safe level and then sends the weld energy through the parts to be welded — Fig. 12. Weld energy is controlled in terms of the product of power and time (watt-seconds), while weld time is fixed by the electrical characteristics of the capacitor bank and pulse transformer. At the present time, stored energy welding control technology is “open loop”, meaning that the actual weld energy flowing through the parts to be welded can change from weld to weld. Additionally, weld time selection is very limited. Only by changing the pulse transformer size or internal electrical connections within the pulse transformer can the weld time or “pulse width” be changed to suit the needs of the application.

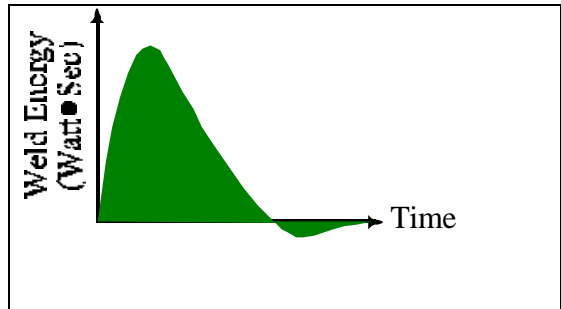


Fig. 12 —Weld power output from a Stored Energy welding control.

At the present time, stored energy welding control technology is “open loop”, meaning that the actual weld energy flowing through the parts to be welded can change from weld to weld. Additionally, weld time selection is very limited. Only by changing the pulse transformer size or internal electrical connections within the pulse transformer can the weld time or “pulse width” be changed to suit the needs of the application.

Weld Energy Control Systems - Micro-Scale Resistance Spot Welding

While open loop stored energy welding controls have been used for a long time to do Micro-Scale spot welding, the trend is to use the newest inverter and linear DC welding controls that provide constant current, voltage, or power feedback and most importantly, can be programmed in 0.1 msec (.0001 second) time intervals. Many of the very small automotive and medical applications require 0.1 msec weld time interval resolution in order to precisely control the generation of weld heat. Table 4 summarizes the range of weld current and weld time resolution for each spot welding scale.

Table 4 - Welding Control Comparisons		
Size	Weld Current Range (Amps)	Weld Time Resolution
Large	2,000 to 20,000	50 Hz: .02 seconds 60 Hz: .0167 seconds
Small	200 to 2,000	1 msec (.001 seconds)
Micro	20 to 200	0.1 msec (.0001 seconds)

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Heat Profiles

All full featured welding controls within each welding scale offer some ability to profile the weld current to match the thermal properties of the application. The *Basic* weld current profile is used to simply turn on a specific amount of weld current for a fixed time. This *Basic* weld current profile works well when heating thermally conductive materials such as copper and brass because these materials require a rapid infusion of weld heat to successfully complete a spot weld. However, the same *Basic* weld current profile can cause weld splash and severe electrode sticking when welding heavily plated materials and materials that are more thermally resistive such as nickel and steel. With thermally resistive materials, it is advisable to slow down the rate of weld heat build-up within the parts. Slowly increasing the weld current from zero or a very low level to the required weld current level is called *Up Slope* and is the most common weld heat profiling technique used to minimize weld splash, thin out heavy plating, and reduce part deformation and electrode sticking — Fig. 13.

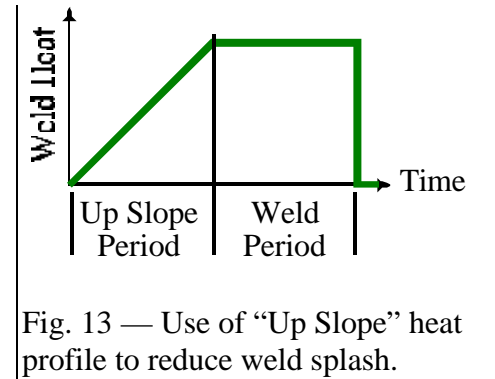


Fig. 13 — Use of “Up Slope” heat profile to reduce weld splash.

Weld Force Controls

Weld Force Control - General Requirements

Of all the resistance spot welding variables, weld force receives the least amount of attention and yet can cause tremendous welding inconsistencies when improperly applied. Our typical welding engineer always assumes that a “magic power supply” will overcome all of the deficiencies caused by poor weld force control and poor inertia follow-up.

Weld force directly controls the magnitude of electrical interface resistance between the parts being welded. A constant weld force is needed to create a consistent electrical interface resistance. A high weld force brings the weld material surface irregularities into closer contact, reducing the electrical interface resistance, thus reducing the amount of weld heat generated. Weld force also controls how the electrodes move up against the parts to be welded as the parts start to melt. This ability to keep the electrodes up against the parts as the parts go through the solid, plastic, liquid, and back to the solid phase, is called “inertia follow-up” and is directly dependent upon the electrode mass. The symptoms of insufficient inertia are severe weld splash between the electrodes and the outer surface of the parts and severe material expulsion from the interface area between the parts.

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Weld Force Control Systems - Large Scale Resistance Spot Welding

Large scale AC welding typically uses a large diameter air cylinder, coupled directly to the electrode drive shaft, to control weld force by varying the air pressure in the cylinder — Fig. 14. Large scale welding forces range from 150 to 3500 lbs (66 to 1548 dN) or more. Inertia follow-up is generally not a problem for two reasons: a) the high weld force creates sufficient electrode acceleration in spite of the large electrode moving mass, and b) the .05 to .10 seconds for the parts to go from solid to plastic to liquid reduces the need for extremely fast electrode acceleration.

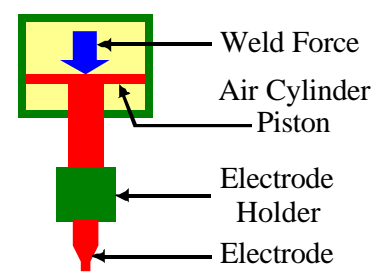


Fig. 14 — Direct air cylinder force control used in large scale spot welding.

Welding engineers “downsizing” from large scale to small scale spot welding do what anyone would expect. That is, they attempt to scale direct air drive weld force control systems to handle small spot welding applications. In creating a robust design with large air cylinder drive shaft coupled directly to a large electrode holder mass, electrode sticking, material expulsion, and non-repeatable welding is virtually guaranteed for the following reasons. One, typical welding forces range from 1 to 20 lbs (0.44 to 8.84 dN), so there is not a lot of weld force to accelerate the large moving mass. Two, the transition from solid to plastic to liquid occurs in .005 seconds instead of the .05 seconds encountered in large scale welding, requiring much higher electrode acceleration. Three, the air molecules in the air cylinder can not expand fast enough to accelerate the air cylinder drive shaft and electrode mass during the rapid melting phase. The only weld force control systems that have a chance at providing the required electrode acceleration are low mass coil spring, leaf spring, and magnetic force systems.

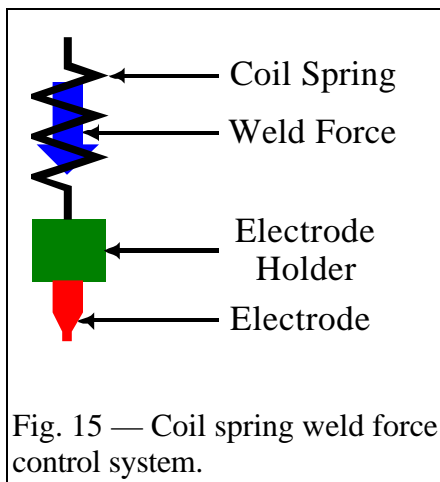


Fig. 15 — Coil spring weld force control system.

Low mass coil and leaf spring weld force systems work quite well for small and Micro-Scale welding — Fig. 15. The downside to these systems can be the difficulty in automatically changing weld force and that when improperly designed, the actual weld force is dependent on electrode length.

Magnetic weld force systems represent the latest in weld force control technology — Fig. 16. These systems can be programmed electronically to create single or multiple weld

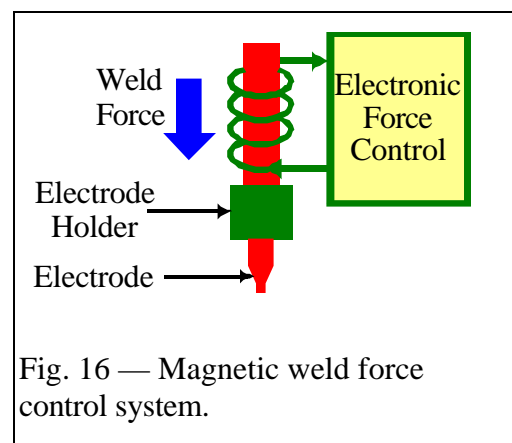


Fig. 16 — Magnetic weld force control system.

force profiles, control the rate of weld force build up, and easily measure or control weld displacement, which represents how much the part being welded is deformed by welding process.

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Weld Force Control Systems - Micro-Scale Resistance Spot Welding

Micro-Scale resistance spot welding force control uses the same weld force control technology as used in small scale spot welding, just the force range is lower and the total moving mass of the force mechanism, electrode holder, and electrode should be less than 0.2 Kg in order to ensure sufficient electrode acceleration at low welding forces. Micro-Scale spot welding can range from 0.1 to 1 lb (.044 to 0.44 dN). Table 5 summarizes weld force requirements for each welding scale.

Table 5 - Welding Force Ranges

Scale	lbs.	dN
Large	150 to 3500	66 to 1548
Small	1 to 20	0.44 to 8.8
Micro	0.1 to 1.0	0.044 to 0.44

Electrode Requirements

Electrode Requirements - Large Scale Resistance Spot Welding

Everything about large scale spot welding is physically large, including the electrodes used to apply the weld force and conduct the weld current through the parts. Shank diameters range from .5 inches (12.7 mm) to more than 1.0 inch (25 mm). Tips are typically convex in shape to help increase the weld pressure and current density on plated parts at the start of the weld cycle. Because of the relatively long welding time and high weld current flowing through these electrodes, it is not uncommon to water cool these large electrodes. Water cooling reduces the nominal electrode tip temperature, which in turn reduces electrode sticking by slowing down plating and parts material build up on the electrode tip.

Large scale electrodes come in variety of copper and other non-ferrous standard resistance welding alloys such as molybdenum and tungsten. The alloy categories are well documented by the Resistance Welding Manufacturers Association (RWMA), telephone 215-564-3484, and spot welding suppliers like Contacts Metals Welding (CMW), telephone 317-634-8884. Pure copper should never be used for spot welding electrodes because of its poor tolerance to mechanical abrasion and plastic deformation due to repeated heat cycling. Special copper alloys, reinforced with chromium or zirconium, are much more durable and tolerate heavy heat cycling. These special copper alloys are used to weld thermally resistive metals such as iron, nickel, and stainless steel. Welding thermally conductive copper and brass alloys requires the use molybdenum or tungsten tipped copper shank electrodes. These electrically resistive materials generate a significant amount of heat that is “drawn” into thermally conductive parts to help with the weld nugget formation.

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Electrode Requirements - Small Scale Resistance Spot Welding

Small scale electrode shanks range in diameter from .125 diameter (3.18 mm) to .25 inches (6.35 mm). They use all of the same copper and other non-ferrous alloys that are used in large scale spot welding and for the same reason, heat balance. In fact, the use of different thermally conductive or thermally resistive electrode tips to create the proper heat balance is very commonly used in both small and Micro-Scale spot welding.

Small scale resistance welding electrodes differ from their large scale brethren in several key areas. One, the actual electrode tip must be precisely machined and maintained or the weld heat will radically change with small changes in tip geometry since the weld heat is proportional to the weld current flow through a given tip area. Severe electrode sticking occurs when the electrode tip area becomes too small to accommodate the required weld heat density.

A second factor, that of tip length, becomes very important since very few small scale electrodes are water cooled. The longer the tip length, the shorter the tip life. In fact, the relationship between tip length and electrode life is exponential — Fig. 17. For example, increasing the tip length from .050 inches (1.27 mm) to .100 inches (2.54 mm) can decrease the tip life by a factor of three or more. This phenomenon occurs because the waste heat generated at the electrode tip can not be as readily absorbed by the larger electrode shank which is now twice as far away from the electrode tip. Keep the distance from the tip face to the shank diameter short and the tip life will increase dramatically. Short tip length also reduces the frequency of electrode cleaning and electrode sticking problems.

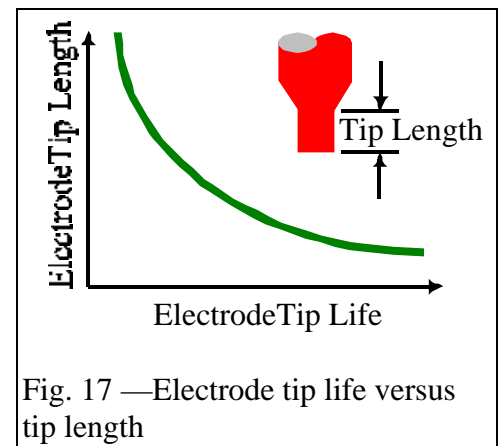


Fig. 17 —Electrode tip life versus tip length

Finally, tip shape is extremely important to maintaining heat balance. Decreasing tip contact area with the parts raises the weld heat density which results in sudden, unexplained “blow-outs” at worst and increased electrode sticking at best. Reduced tip contact area comes from several sources. Welding operators often reduce the outside tip dimensions and thus the tip area by sanding or filing, not realizing the sensitivity of tip geometry changes on heat balance. Operators or maintenance technicians also inadvertently install electrodes in a manner that prevents the tip surface from completely contacting the part surface. As the tip geometry decreases in size, the need to have precisely maintained and controlled electrode tip shape becomes extremely important to achieving welding consistency. Cleaning the electrode tip face using a hand file or sand paper without a parallel supporting block radically alters the tip geometry and surface texture, thus ensuring inconsistent welding, electrode sticking, and those unexplained “power surges” from the welding control that cause tip blow-out, but are in reality reductions in tip contact area with the parts to be welded.

“Downsizing” in the World of Resistance Welding

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Electrode Requirements - Micro-Scale Resistance Spot Welding

Micro-Scale electrode shanks range in diameter from .062 diameter (1.57 mm) to .125 inches (3.18 mm). Like their small electrode cousins, they use all of the same copper and other non-ferrous alloys for heat balance. However, tip geometry tolerances and maintenance becomes even more important. With tip dimensions approaching .005 inches square (0.125 mm) or smaller, the need to fabricate electrode tips with tighter tolerances and precisely maintain tip dimensions becomes very critical to ensure consistent spot welding. For example, reducing just one side of the aforementioned tip by .001 inch (25 microns) reduces the tip contact area by 20%, thus effectively increasing the weld heat by 20%. This 20% increase in weld heat will cause an increase in electrode sticking at best, and tip “blow-out” at worst. Consistent electrode tip contact is everything in both small and Micro-Scale spot welding.

Fixture Design Issues

Fixture Materials

The materials used to fabricate a fixture for holding both parts to be welded can strongly influence the outcome of the welding process. In general, do not use materials such as aluminum (anodized or un-anodized), brass, or copper to support both parts. These materials dissipate heat and therefore can prevent weld heat from building up in the parts, possibly preventing the weld from occurring, regardless of how much energy is pumped into the parts. The fact that these materials are also electrically conductive can cause the weld current to be diverted or “shunted” into multiple paths — Fig. 18. The amount of shunted weld current is not controllable, which means that the basic welding process will never be consistent when shunting happens.

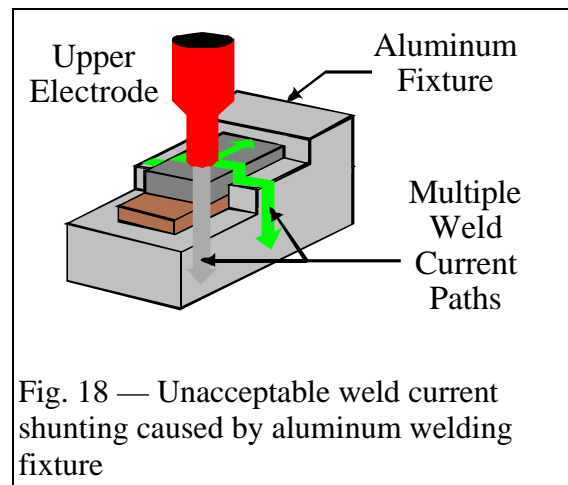


Fig. 18 — Unacceptable weld current shunting caused by aluminum welding fixture

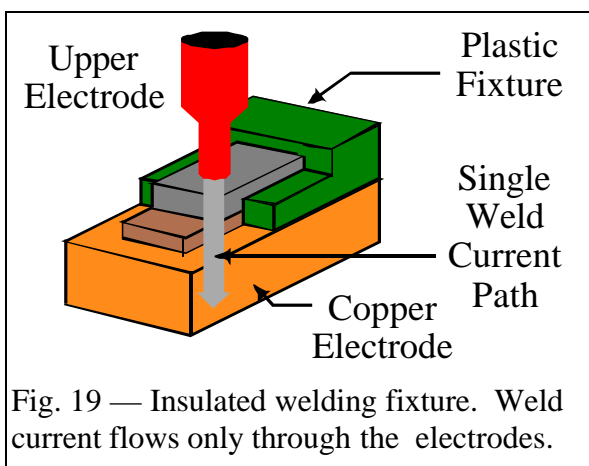


Fig. 19 — Insulated welding fixture. Weld current flows only through the electrodes.

The welding fixture designer should never rely on the fixture to carry the weld current. Weld current flow should be controlled only by the electrodes — Fig. 19. The best materials to use for fixture construction are high temperature plastics that also have good mechanical stability properties.

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Position Consistency

Welding process consistency is the major advantage produced by using a properly designed fixture. The top part will be positioned precisely in relationship to the bottom part, thus creating thermal loading consistency. As parts go from small to Micro-Scale, a change of .001 inch (25 microns) in parts overlap can cause the welding process to go from cold to hot or even blow-out instantly. The same need for positional consistency applies equally to where each electrode tip touches the parts. In the Micro-Scale realm, .001 inch can shift the thermal balance, causing a bad spot weld. As a gross rule of thumb, the electrode tip absolute position on each part should never vary by more than 10% of the tip's smallest dimension. The need for positional consistency also implies that Micro-Scale electrode replacement systems within the fixture should be designed to ensure that positional consistency is maintained after electrode replacement.

Conclusion

“Downsizing” in the world of resistance spot welding can actually be quite fun in spite of the challenges. The key to small and micro-scale resistance welding success is to provide a proportionally tighter degree of process control over materials and welding system variables as you “downsize”.

About the Author

David Steinmeier is an independent metals joining consultant with over seventeen years experience with resistance and YAG laser spot welding and selective soldering. David can be reached for comments or questions at 626-444-9606 or by email at jdstein@pacbell.net.