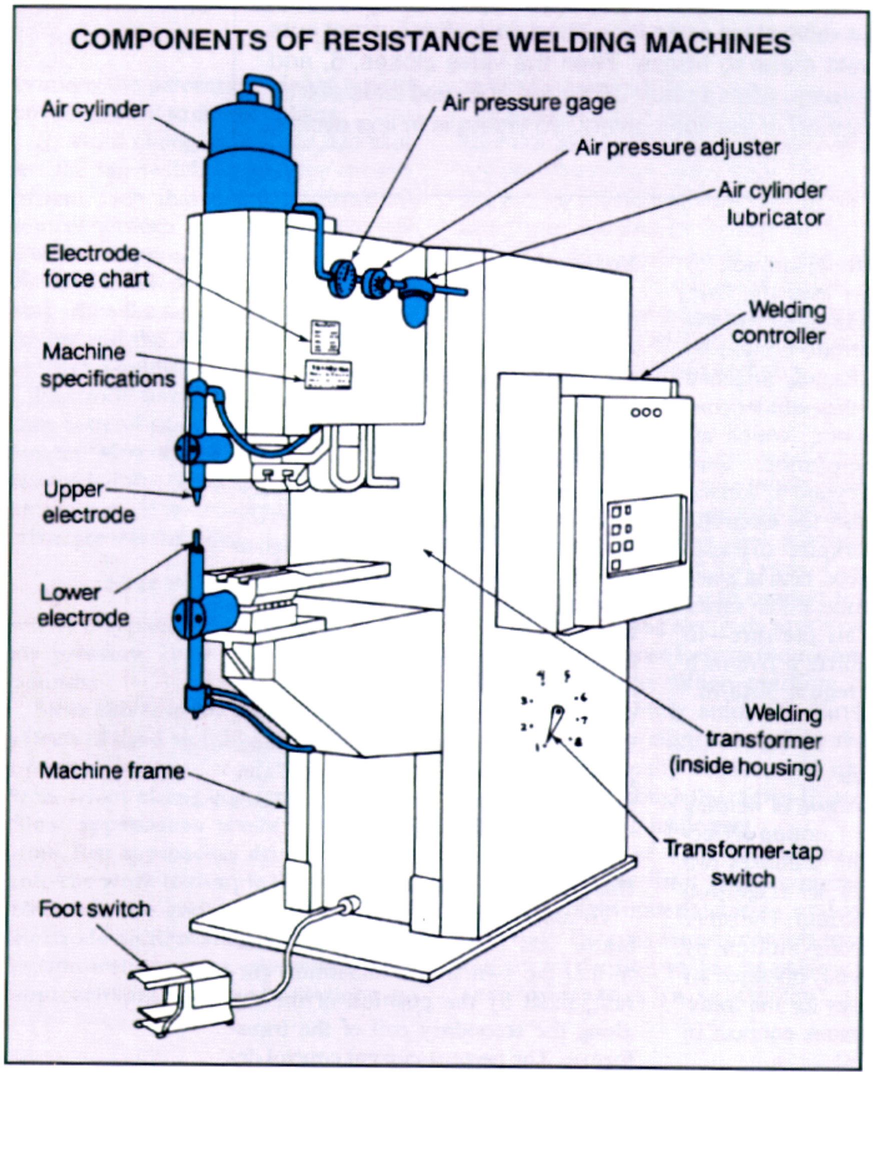
product knowledge

The ABCs of resistance welding

Resistance welding machines convert line current to welding current, using transformers, split-second controlled by electronic timers. Air-operated electrodes, also closely controlled, drive high currents though workpieces, melting weld zones by electrical resistance.

by Robert J. Bonebrake

Used on sheet metal production lines around the world, resistance welding (RW) joins two or more pieces of metal without using filler metal. Water-cooled electrodes, usually of dispersion-hardened copper, squeeze metal sheets together, then pass electric current through to heat them by electrical resistance until they melt at contacting faces. Current shuts off and metal solidifies, forming a solid weld between the pieces.



Amperage, time of current flow, and squeeze force determine weld size and strength. For low-carbon steel sheet, 1/16 inch thick, a 10,000-amp current flowing for 1/4 second under 600 pounds of electrode force produces a sound resistance weld. Parameters vary with material and thickness, as reflected in resistance welding schedules available from American Welding Society, Resistance Welder Manufacturers Association, and manufacturers of RWmachines.

Machines use transformers

. . .to convert line currents to the high amperages needed for RW. In a transformer, two coils, a primary and a seconday, wind around an iron core. Power transfers from primary to secondary, current and voltage stepping up or down according to the ratio of the number of wire turns in primary and secondary windings. To turn out 10,000 amps from a 200-amp line current, the primary could have 100 turns, the secondary, two turns, giving a 50/1 ratio: 200 amps $\times$ 50 = 10,000 amps.

Control time and force

Spot welds require split-second current timing, achieved by ignitrons (mercury-vapor tubes) or silicon-controlled rectifiers (scr's), solid-state devices. Small electric currents activate both devices; neither has moving part parts.

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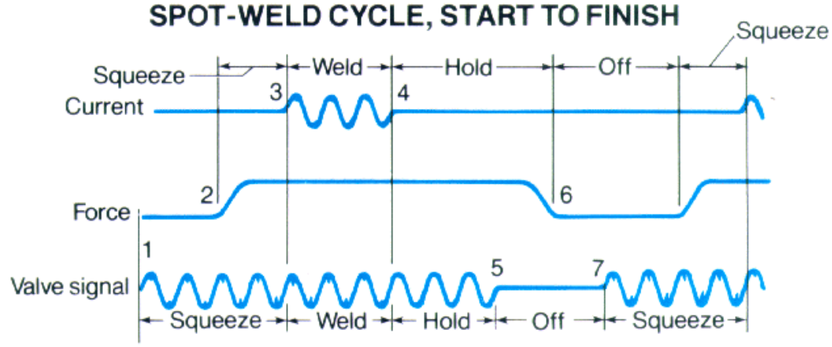
SPOT-WELD CYCLE, START TO FINISH



Making a spot weld, controls turn welding current and air pressure, which actuates electrodes, on and off at preset times. Squeeze timing starts when the air-pressure valve opens, 1, letting air enter the cylinder, which controls electrode force. When pressure rises enough to force the electrode tip against the workpiece surface, squeezing begins, 2. Current starts, 3, when pressure reaches the set force, and continues until enough metal melts at the interface to make the weld, 4. The air valve stays open for a short time after current cuts off, 5, allowing weld metal to freeze. Then the valve closes, 6, and electrode force relaxes. After a short *off* period, the next weld starts, 7. Switches operate off of the line current, so timing is in line cycles, 1/60 second.

Controls time electrode motion to squeeze pieces tightly, assuring firm electrical contact. Most commonly, RW machines control electrode motion by pneumatic cylinders. Rigidly attached to the machine frame, the cylinder contains the movable piston, which attaches to the upper electrode. Compressed air enters the cylinder, forcing the piston down to push the electrode tip against the upper workpiece to clamp it firmly to the lower piece, held in place by the opposing electrode. Force varies with piston area and air pressure—to exert 600 pounds of force, a five-inch diameter piston would require 30 $lb/in.^2$ pressure.

Controlling parameters

To coordinate application of welding current with mechanical motion of electrodes, an RW controller produces two signals. One switches the scr or ignitron on and off, to control current. The other signal controls electrode motion by switching on an electrically operated air valve. Acting as switches for the transformer, scr's and ignitrons connect in series to the primary coil.

Making a weld

During welding, controls turn current, electrode force, and air-pressure-valve voltage on and off in precisely timed sequence. Operating from a 60-Hz line current, controls measure time by line cycles, each cycle representing 1/60 second.

A sequence starts when the air-pressure valve opens to raise pressure in the cylinder. When pressure rises enough to force the electrode tip against the workpiece surface, squeezing begins. Shortly thereafter, the timer activates the current, which stays on long enough to melt metal at the workpiece interface to make the weld. Pressure holds for a short time after current cuts off, allowing the nugget to freeze under compression. Then, the air valve closes, and pressure relaxes until the next weld starts.

Using machine switches

To control welding amperage, the operator sets two switches. The transformer-tap switch sets maximum current, fixed by the position of the tap along the secondary coil of the transformer. The percent-current control de-

RW PARAMETERS FOR LOW-CARBON SHEET STEEL

Thickness of thinnest outside piece, in.	Electrode diameter and shapes[a]: Flat face, Max d, in.	Flat face, Min D, in.	Radius face, Radius, in.	Weld force, lb	Weld time, cycles	Hold time, cycles	Welding current, amps	Weld shear strength, lb[b]	Diameter of fused zone, in.	Minimum weld spacing, in.	Minimum overlap, in.
0.010	0.125	1/2	2	160	4	5	4,000	130	0.113	1/4	3/8
0.021	0.187	1/2	2	244	6	8	6,500	300	0.139	3/8	7/16
0.031	0.187	1/2	2	326	8	10	8,000	530	0.161	1/2	7/16
0.040	0.250	5/8	3	412	10	12	8,800	812	0.181	3/4	1/2
0.050	0.250	5/8	3	554	14	16	9,600	1,195	0.210	7/8	9/16
0.062	0.250	5/8	3	670	18	20	10,600	1,717	0.231	1	5/8
0.078	0.312	5/8	3	903	25	30	11,800	2,365	0.268	1-1/8	11/16
0.094	0.312	5/8	4	1,160	34	35	13,000	3,054	0.304	1-1/8	3/4
0.109	0.375	7/8	4	1,440	45	40	14,200	3,672	0.338	1-5/16	13/16
0.125	0.375	7/8	4	1,760	60	45	15,600	4,300	0.375	1-1/2	7/8
0.156	0.500	7/8	6	2,500	93	50	18,000	6,500	0.446	1-3/4	1
0.187	0.625	1	6	3,340	130	55	20,500	9,000	0.516	2	1-1/4
0.250	0.750	1-1/4	6	5,560	230	60	26,000	18,000	0.660	4	1-1/2

a. RWMA Class 2, copper – 2 percent ThO_2. b. For steels of 90,000 lb/in^2. max tensile strength.

termines the percentage of that tapped current needed to do the welding.

To avoid energy waste, the operator sets the tap switch to produce enough current such that the percent-current control between 70 and 90 percent will give the amperage needed for welding. He uses lower percent-current settings only when the tap switch is at its lowest setting and the 70-percent setting gives too high a welding current.

Electrode force varies with air pressure, piston-head weight, and piston diameter. Most RW machines come with electrode-force tables that relate force to air pressure. If the machine lacks such a table, use this formula:

$$Force = 0.78 \times D \times p$$

where D is piston diameter, inches, p is air pressure, lb/in.^{2}, and *force* is in pounds.

Since this formula does not consider effects of dead weight and friction, an operator may need to adjust speed controls when changing electrode force. Slow approaches waste production time. Fast approaches drive electrodes into the work to dimple it, shortening electrode life and risking damage to electrode holders and pistons. On projection-welding runs, excessively high approach speeds flatten projections, resulting in poor welds.

An electrically operated air valve controls pressure in the cylinder that actuates the movable electrode. Signalled by the controller, the valve opens, admitting compressed air into the cylinder to force the electrode tip against the workpiece. To calculate imposed force, given in pounds, divide the air-gage reading, in lb/in.^{2}, by the electrode tip area, in square inches.

RW schedules

. . .tell the operator how to set controls to assure sound spot welds. The table lists settings for welding of SAE 1010, a low-carbon sheet steel, in thicknesses from 0.010 to 0.250 inch. One electrode has a flat face to support the work. The opposing electrode uses a radiused tip to impose force without dimpling the surface. When marking is taboo, as in welding autobody parts, place the flat-tip electrode against the inside sheet, usually thicker, and impose pressure through the radius-tipped electrode on the outside part.

Most tips have a 30-degree angle around faces to limit mushrooming, spreading of tip material during production runs. Excessive mushrooming lowers current density, weakening welds unless operators raise current to compensate. Operators should monitor mushrooming by measuring spot weld diameters periodically. Extend tip life by machining.

Don't skimp on holding times, given in cycles. Otherwise, you risk cracked welds with oxidized surfaces. Overly long hold times do no harm, though they lengthen welding cycles unnecessarily.

Operators should adjust welding currents after making other settings. Starting a run, an operator welds test strips for tear tests, on which technicians measure weld strengths and diameters to make sure current settings are accurate. Tear tests made periodically during runs tell operators when mushrooming starts to lower current density, so that they can boost amperages or dress tips.

Designers should make sure to space spots far enough apart to preclude shunting. Placing welds closer than minimum spacings risks chances for current to bypass the weld zone to go through welds already made. Then too little current passes through the weld, resulting in a weak joint. To ascertain shunting effects, run test strips at spot spacings specified for assembly. ***TWD***