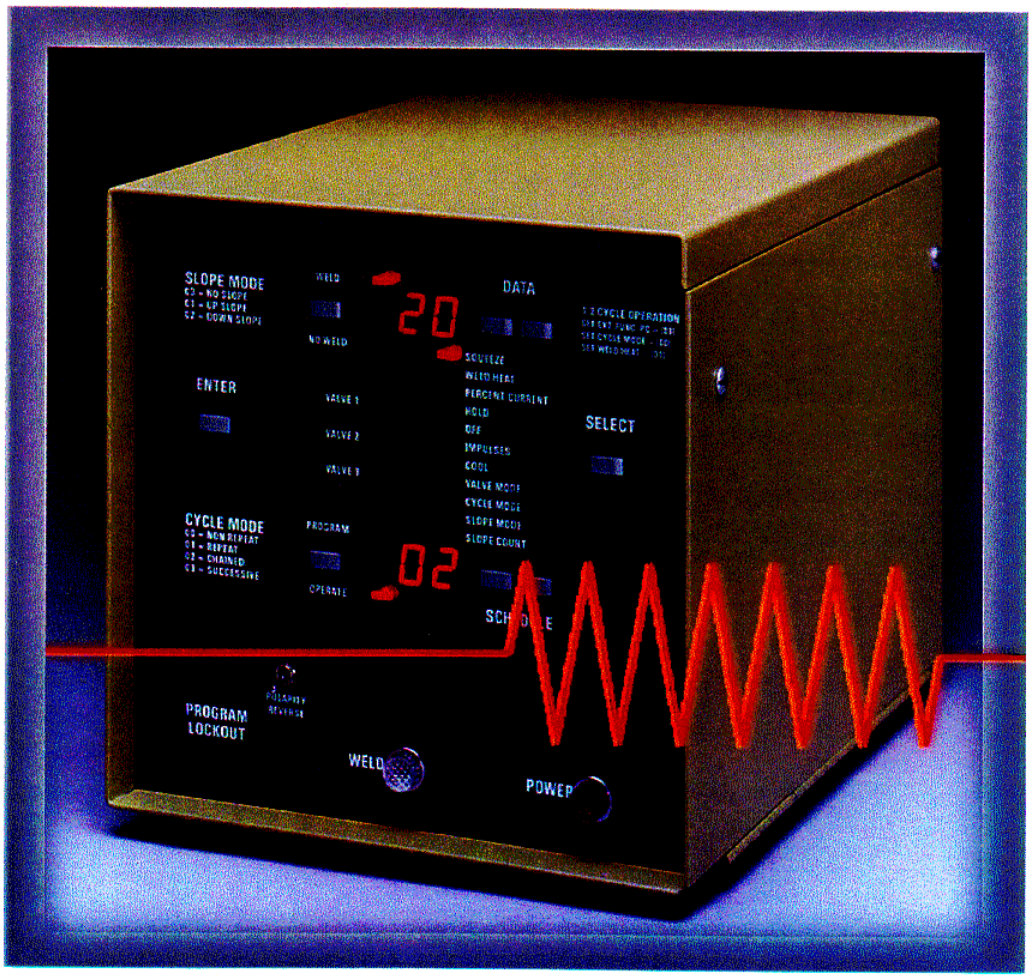
CONTROL FEATURES



FOR RESISTANCE WELDING

Solving application problems with the right option

By Bob Cuff

Resistance welding is a process for joining metals with heat and pressure. Over the years, several advancements have been made in resistance welding control technology. Manufacturers have developed control options to help users of resistance welding machines produce better welds, even under some rather adverse conditions.

Most microprocessor-based weld controls manufactured today incorporate many, if not all, of the National Electrical Manufacturers Association (NEMA) weld control options in the control programs. This article explains how these options can be applied to the resistance welding process.

Spot Sequence

The most commonly used weld control is the spot sequence control, which covers the basic four function weld schedule: squeeze, weld, hold, and off times (see **Figure 1**).

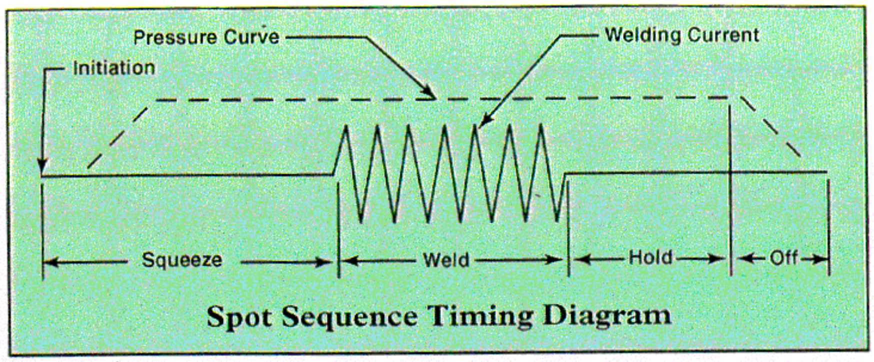


Figure 1
The most commonly used weld control is spot sequence control.

The spot sequence as a control, or as a sequence selection in a microprocessor-based control, represents about 80 percent of all welding control sequences used. The spot welding sequence can be used for welding mild steel, most copper-based alloys, nickel-chromium alloy steels, and nickel-based alloys. With optional accessories or programs, high-carbon steel, aluminum, and coated steels can be welded.

The spot sequence can be used for basic spot welding, projection welding, and crosswire welding. However, some special conditions may require optional control functions to produce welds of good quality, easily and consistently.

Pulsation

The multi-impulse (pulsation) sequence control, with percent current adjustment, is probably the second most widely used sequence for welding control applications.

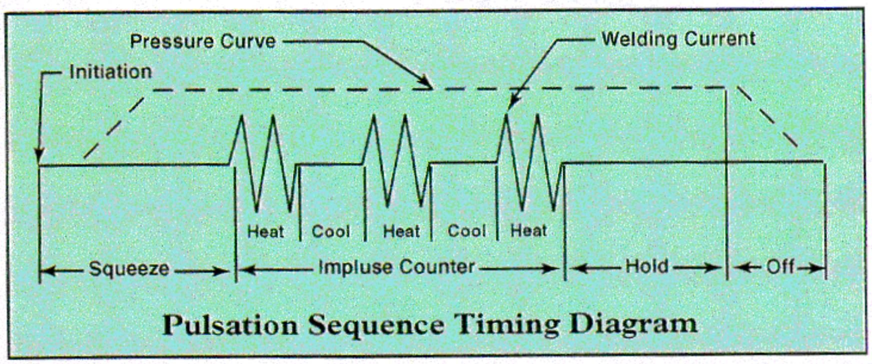


Figure 2
The pulsation sequence can interrupt the weld current with a cooling period to achieve a specific number of weld (heat) impulses.

The pulsation sequence is similar to the spot sequence, except that it can interrupt the weld current with a cooling

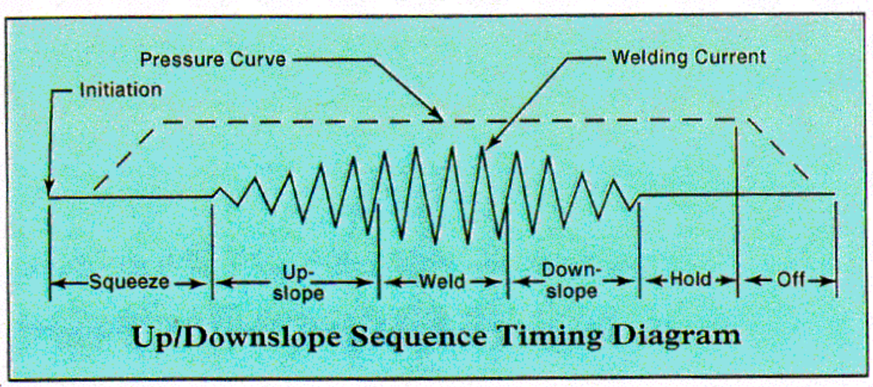


Figure 3
Upslope and downslope are useful for welding aluminum.

period to achieve a specific number of weld (heat) impulses (see **Figure 2**). The interrupted weld sequence times are defined as heat (when the weld current is on) and cool (the interval between heat impulses).

The heat and cool times and the number of heat impulses can be predetermined and set via front panel switches. Some older, analog controls had a weld interval timer instead of the impulse counter. Digital controls usually include selection of both the spot and multi-impulse sequences.

Projection Welding with Pulsation. Pulsation welding techniques can be applied to projection welding, particularly to help set down large or multiple projections.

For these projections, the current requirements may be quite high. Unfortunately, the welder's pressure system might not be adequate to follow up and properly set down the larger projection as fast as the current at the projection is melting the material. The result is often a poor weld with a large amount of metal expulsion (flashing).

Pulsation techniques apply the total heat energy of the weld over a longer time, allowing the pressure system of the machine to provide the follow-up necessary to set down the projection to make a good weld. Upslope control can also be used with projection welding.

With multiple projections, maintaining tooling that will provide absolutely equally shaped projections can be difficult. Although the differences in height or size of the projections may be small, the potential for unequal parallel current paths through the projections is significant. If the current paths are not reasonably equal, the resulting total weld may not meet specifications.

Again, pulsation welding techniques may help to ensure a more equal and uniform set down of the projections to create properly formed weld nuggets at each projection.

Welding Galvanized Steel with Pulsation. Pulsation welding techniques are also successfully used for welding zinc-coated steel.

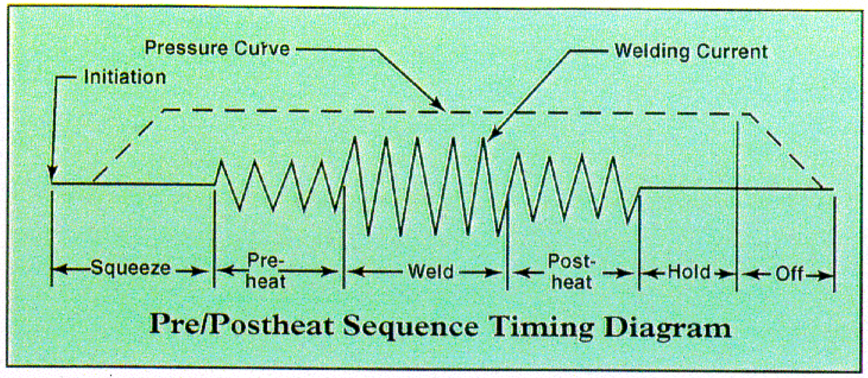


Figure 4

Postheat is helpful when welding aluminum, while preheat is often used to heat larger weldments before the full weld current is applied.

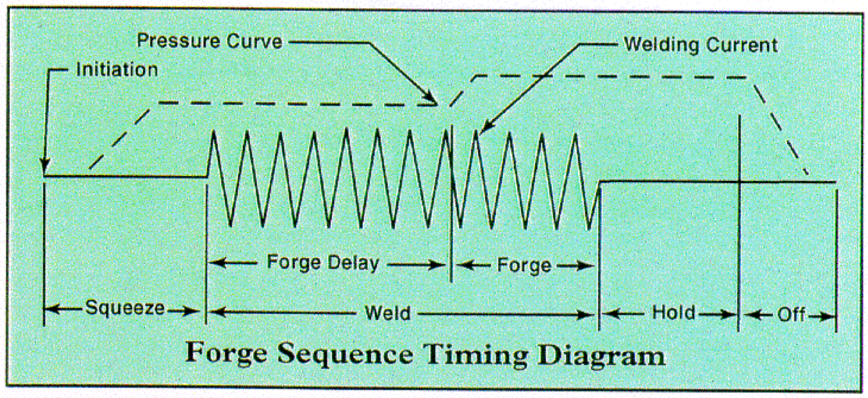


Figure 5

Forge delay is often used in conjunction with upslope for welding aluminum.

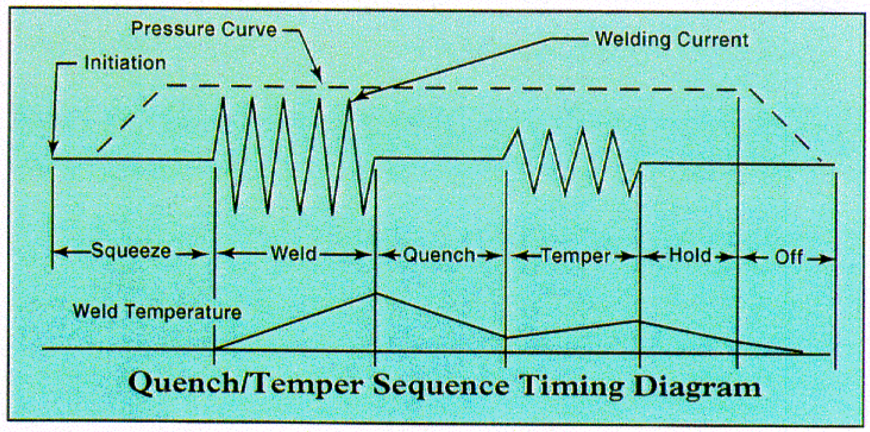


Figure 6

On high-carbon steel, the quench and temper control provides postheat treatment through the cooling period (quench) and annealing heat (temper) to maintain ductility in the weld area.

The major problem with welding galvanized steel is that the melting points of zinc and steel are dramatically different. Further, the boiling point of zinc is less than the melting point of steel.

When welding steel to steel through the zinc coating, the temperature of the zinc is raised well above its boiling point. At this temperature, the zinc is literally evaporated. The oxidized, vaporized zinc forms a white powder called **zinc oxide**.

Rather severe expulsion of both zinc and steel may also result as the zinc is evaporated. The pressure system of the welder usually cannot "follow-up" to close the secondary circuit fast enough to overcome the gap made by the evaporated zinc.

When welding galvanized steel with copper electrodes, brass can form on the surface of the electrodes as zinc and copper amalgamate with heat under pressure. Unfortunately, brass has a higher resistance to electric current than the copper of the electrode, which quickly creates additional heat at the face.

The increased heat overheats and anneals the copper electrode. The softer copper collapses (mushrooms) at a greater rate, and the electrode diameter expands. Increasing the current helps maintain the correct current density to make the weld, but it creates more heat. The greater heat creates more mushrooming, which requires a higher current to make the weld, which creates more heat, etc.

Pulsation welding allows the first heat impulse to be selected to provide sufficient heat energy to melt through the zinc without creating an oxide or an open secondary circuit. After a short cool interval, the next heat impulse is usually sufficient to make a proper steel-to-steel weld.

Two heat impulses are usually adequate for welding up to 16-gauge steel. 14-gauge steel may require three heat impulses. The result is a better weld and longer electrode life. Metal expulsion can be reduced to zero with pulsation welding.

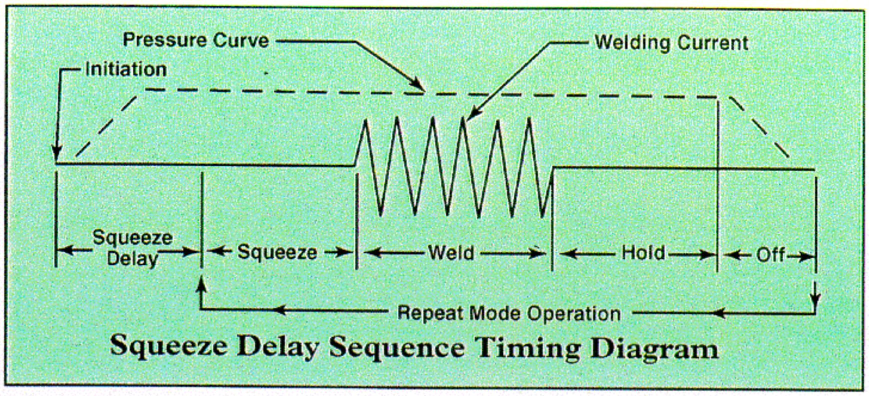


Figure 7
In repeat sequences, squeeze delay can control the air cylinder's return stroke with an off time.

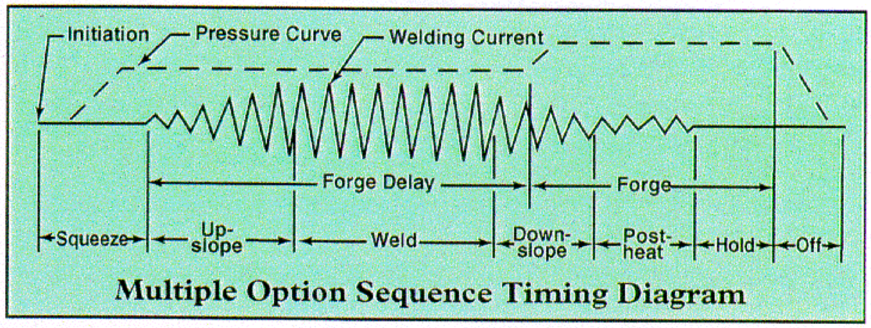


Figure 8
Complex weld schedules may be programmed for applications which require two or more options.

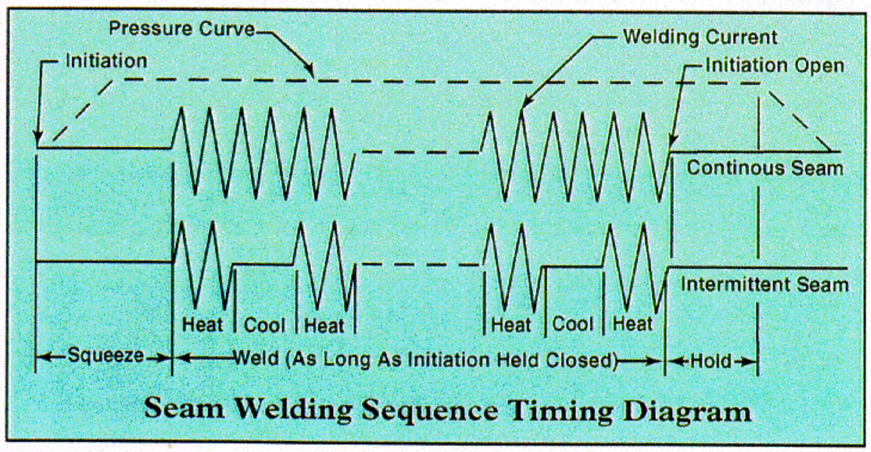


Figure 9
With a seam welding control, the heat impulse and the cool time continue from control initiation until the initiation circuit is opened.

Dispersion-strengthened copper electrode caps can extend electrode life. Weld current steppers are also used to help extend electrode life by advancing the weld current in predetermined increments at predetermined times, empirically matched to increase the current to the change in current density required to overcome the electrode mushrooming.

Upslope control can also be used for welding galvanized steel. The upslope function provides for starting the weld current at a low enough level to melt through the zinc and subsequently increasing the current to make the steel-to-steel weld.

Undersized Machine. Pulsation welding can be used to increase the effective capacity of a welding transformer. A pulsation sequence, heat and cool, provides a cooling period in the transformer that can essentially reduce its effective thermal duty.

In this manner, the capability of a machine designed to weld 16-gauge material could possibly be extended to weld 14-gauge or heavier material without damage to the welding transformer.

Although this may not be the most efficient use of a machine, the technique is used when short production runs are needed in job shop applications that cannot justify the investment in a larger, properly sized machine.

Multiple Schedule

In a single welding setup, welding current is often required for two or more different welding conditions.

Assume, for example, that after setting up for welding two pieces of 16-gauge steel, a 14-gauge bracket is added to the weldment. Rather than setting up two welders or making two separate weld setups, a dual count/dual current option can be added to the control (or the dual function can be programmed into a microprocessor-based control) to provide for two schedules in one control in one setup.

Squeeze, hold, and off times are common to both sequences on most discrete component controls. An extra pilot switch is the only additional hardware required to access the dual function.

Three, four, and five schedules are quite common with most control manufacturers. Some microprocessor-based controls have provisions to access up to 64 sequences and more.

Upslope/Downslope Option

The proper option for welding aluminum is upslope. At first appearance, the welding conditions for aluminum are similar to welding galvanized steel. In both cases, the parent metal is coated on both sides, except that aluminum oxide is an insulator, not a conductor. It is also very hard and abrasive. The oxide coating on aluminum is always present, no matter how well it is prepared before welding.

To weld aluminum, the welder must first mechanically break through the oxide before full welding current can be passed through the aluminum. Upslope is the solution (see **Figure 3**).

Because of the high conductivity (low resistance) of aluminum, a high current of short duration is needed to make a satisfactory weld. When the electrodes first contact the aluminum workpieces, only a small area of metal-to-metal contact may actually be made between the electrodes and the aluminum through the aluminum oxide coating.

Under these conditions, the actual current density may be extremely high, and severe metal expulsion may occur when the weld current is initiated.

With upslope control, the current in the weld can be automatically phase-shifted from a lower value to a higher value for a given period of time while the force applied to the electrodes continues to break through the oxide. The upslope is empirically set to increase the current to coincide with the change in current density as the electrode pressure and the presence of the welding current break through the oxide.

Because aluminum is also a very good thermal conductor, heat is carried away from the weld area quite rapidly through the parent metal surrounding the weld nugget and through the water-cooled electrodes. For this reason, small chill cracks often appear in the aluminum weld nugget after the weld has cooled.

Downslope may be used to continue adding a lesser amount of heat energy to the weld nugget to reduce the chilling factor as the nugget cools (see Figure 3). Postheat may also be used in a similar manner (see **Figure 4**).

Forge Delay

Forge delay is another option often used in conjunction with upslope for welding aluminum (see **Figure 5**). A forging pressure applied near the end of weld time or during the hold time can forge the weld nugget, providing a more homogeneous weld of high strength. Forging can also be applied to other metals to help provide a more homogeneous weld nugget.

Preheat

Preheat functions are most often used to preheat larger weldments before the full weld current is applied. At times, to form an acceptable weld nugget, the temperature of a weldment must be raised 200 to 300 degrees Fahrenheit above room temperature before welding. This ensures that the weld current, when applied, will bring the work temperature up to the temperature of the material's latent heat of fusion (see Figure 4).

Quench/Temper

The quench and temper option is used almost exclusively for welding high-carbon steel.

The carbon content of mild steel, such as 1010, is not adversely affected by the heat of a resistance weld. Even 1015 or 1020 steel will usually produce an acceptably strong, ductile weld without additional postheat treatment.

Type 1025 and higher carbon steels usually require some form of postheat treatment to partially cool and anneal the steel to maintain ductility in the weld. The quench and temper control provides postheat treatment through the cooling period (quench) and annealing heat (temper) to maintain ductility in the weld area (see **Figure 6**).

Retraction

The retraction option can simplify the handling of large and bulky parts. Often, these parts cannot be welded with a typical welder because they are too large to fit between the electrodes of the machine or have a large lip that must clear the electrodes before welding. The retract valve is connected so that the electrodes can be opened much farther than normal, allowing the operator to easily position the part.

A separate foot switch initiates the retraction valve, allowing the electrode to be brought down to the normal weld position for a normal weld sequence. At the end of the weld sequence, the electrodes are brought to the full open position by releasing the retraction valve, allowing part removal.

The operator can then get the electrodes into an otherwise inaccessible area and make one or several welds before retracting the electrodes and placing a new part in the machine.

Squeeze Delay

This option is used with guns that incorporate standard air cylinders and valves without retraction features. Squeeze delay provides a longer "squeeze time" when first initiated in a repeat sequence. If the initiation is held closed, subsequent weld sequences will not go through squeeze delay. This allows a cylinder to pass through a longer distance when first actuated.

In subsequent repeat sequences, the cylinder's return stroke can be controlled with an off time. Off time is adjusted so that the return stroke will only allow the cylinder to return a short distance before the next repeat sequence is started (see **Figure 7**).

Complex weld schedules may be programmed for applications which require two or more of the previously described options. **Figure 8** shows a schedule which combines upslope, downslope, postheat, and forge.

Seam Welding

Seam welding controls are used on seam welding machines to provide continuous current or intermittent current. The intermittent mode is similar to pulsation, but without an impulse counter. The heat impulse and the cool time continue from control initiation until the initiation circuit is opened (see **Figure 9**).

Some machines, such as tube mills and some barrel and drum welders, are built to weld continuously. For these machines, a control with only a percent current adjustment is required. No timing is needed.

Automatic Current Compensation

Automatic current compensation or constant current options are also available for resistance welding. Maintaining a constant current usually provides control over only one of many variables in the welding process.

Although the current in the secondary circuit is the same throughout, the point of greatest resistance to the current is the point at which the heat energy is dissipated. Even with constant current control, this point may not be the interface between the two workpieces.

Constant current controls work, but they are not a cure for improper welder maintenance and setup. The constant current control operation may be able to mask some changes in some process parameters, but it cannot overcome poor setup, shunt current effects, excessive electrode mushrooming, unbalanced secondary conditions, or most fluctuations in the pressure system.

In many instances, the dynamic automatic power factor circuitry offered in most digital welding controls provides most of the adjustment required for changes in the welder's secondary circuit.

Automatic Power Factor Equalization

Almost all digital and microprocessor controls provide for an automatic power factor adjustment circuit. In the weld control, this circuit merely adjusts the weld contactor "turn on" to agree with the power factor of the machine. No improvement in plant power factor is actually attained; the power factor of the control is merely equalized to meet the power factors of the welder transformer and secondary circuit.

The power factor circuit of the control is associated with the phase shift heat control. Full heat is attained when the control, or percent current adjustment, is at 100 percent (99 percent on digital controls) and the power factors of the control and machine are equal.

Conclusion

Other options are available with resistance welding controls to meet specific weld requirements which are not of general use. Information on these options is available from the machine or control manufacturer.

Resistance welding is a simple, sure way to join metal. Understanding how these control options can be applied to the resistance welding process is basic to producing welds of consistent, good quality. ■

Bob Cuff is Chairman with Entron Controls, Carol Stream, Illinois, and a member of the Resistance Welder Manufacturers' Association (RWMA). *RWMA's assistance in this article's development is gratefully acknowledged.*