Shunt currents in the secondary circuit of a resistance welding machine

How Kirchoff's Law of Distributive Networks applies

By Robert Cuff

An understanding of some of the basic laws of physics and mechanics is necessary to help make the resistance welding process work well consistently. One of these basic laws is Kirchoff's Law of Distributive Networks as it applies to the current flowing in the secondary circuit of a resistance welding machine.

This article discusses this law and how it relates to the creation of shunt currents in resistance welding machine secondary circuits.

Shunt Current Paths

By definition, joining metals using the resistance welding process requires clamping together the parts to be welded and passing an electrical current through them for a period of time. This definition of resistance welding assumes that all of the current provided in the secondary circuit of the welding transformer is flowing through the parts to be welded. However, this may not always be true. Some current may be diverted through other paths in the machine's secondary circuit.

In a machine that is set up properly, all of the current in the secondary circuit passes through the electrodes and the workpieces to form a proper size weld nugget at the interface of the workpieces (see **Figure 1**). There is only one current path through the parts.

If, for some reason, some current is flowing through other paths in the secondary circuit of the machine, there may not be enough current flowing through the welding electrodes to form a high-quality weld nugget between the parts to be welded. The other current paths in the secondary circuit—shunt current paths—may divert enough current to prevent the formation of a good weld nugget.

These shunt paths usually are formed unintentionally and often are not easily or readily recognized. The current through these shunt paths is described and defined by Kirchoff's Law of Distributive Networks :

> The magnitude of the current in a circuit is the sum of the currents in the respective branches of the circuit.

As an example, in a welding machine secondary circuit with a shunt current path across the welding electrode circuit, some current will flow through the shunt path, reducing the current through the welding electrodes. The shunt path may be formed by an electrode touching the part to be welded at a point other than the electrode face or a weld spacing that may be too short.

Kirchoff's Law is diagrammatically illustrated in **Figure 2**. In this figure, the total current in the circuit, I_T, remains the same; however, it is now equal to the sum of the current through the weld, I_W, plus the current through the parallel shunt path, I_{R1}.

In this example, the welding current selected is 10,000 amps for welding two 16-gauge mild steel parts. However, if a shunt path runs parallel with the weld, some current will flow through the path, reducing the current at the weld. Assuming that the shunt path is of a resistance that would cause 2,000 amps to flow through the shunt path, I_1, then only 8,000 amps would pass through the parts to be welded, possibly an insufficient amount to form a proper weld nugget.

The current in the secondary is the current in the secondary, but how it is distributed determines the quality of the weld being made. The weld control can provide switching only for the total current in the secondary circuit; it cannot redistribute the secondary current. The total current in both illustrations in Figure 2 is the same, but the weld current in the second illustration has been reduced by shunt current.

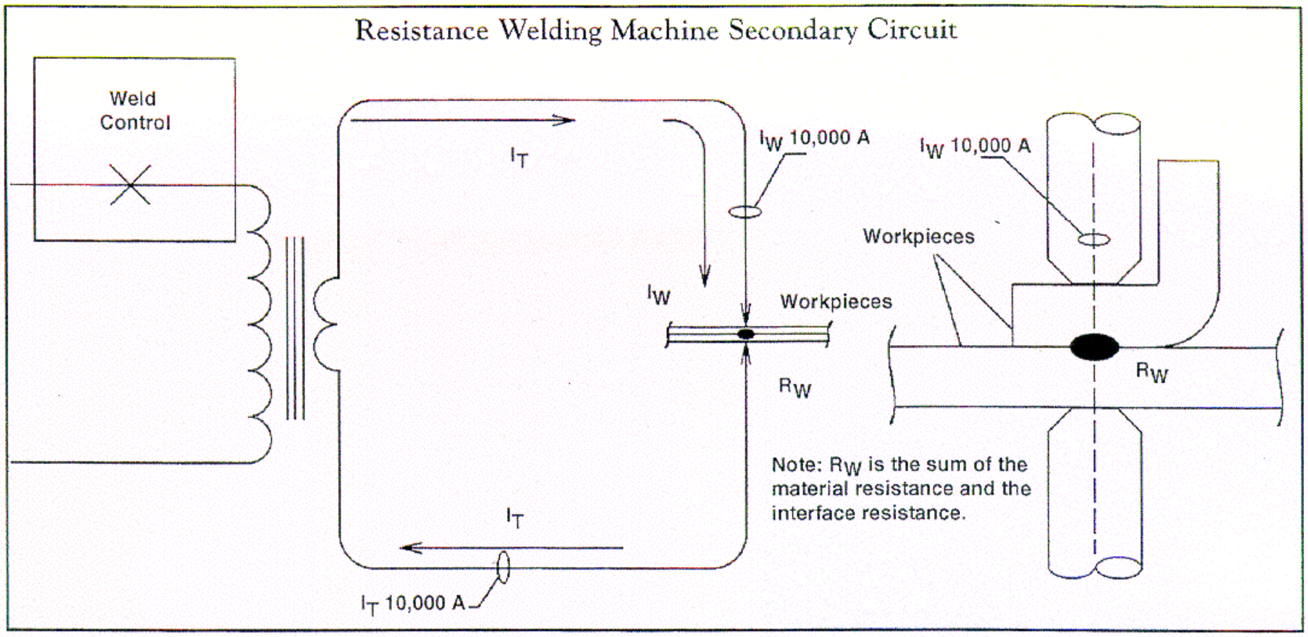


Figure 1

All of the current in the secondary circuit should pass through the electrodes and the workpieces to form a proper size weld nugget at the interface of the workpieces. No shunt currents paths are present.

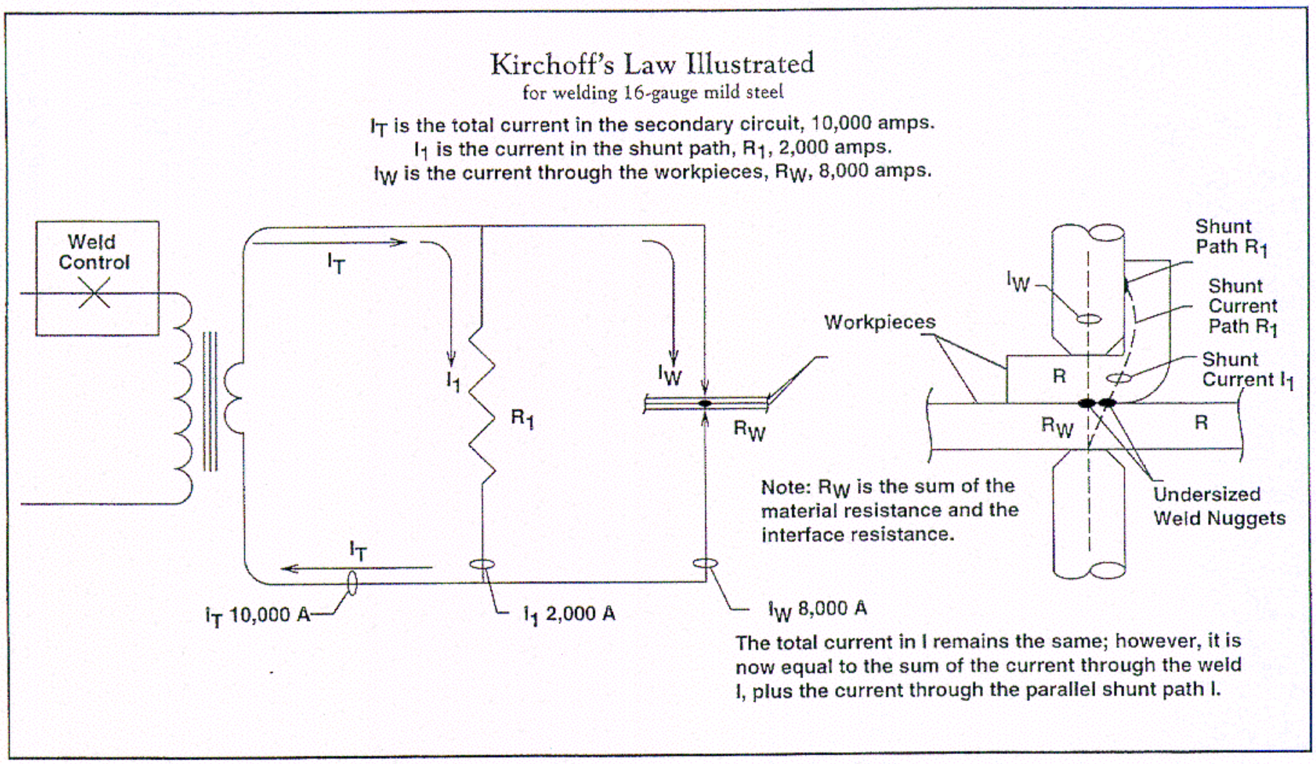


Figure 2

When the electrode touches the piece at a point other than the electrode face, a shunt current path exists that will produce a poor weld—even when the current is correct.

A variety of conditions can contribute to shunting. Some of these conditions are discussed in the remainder of this article.

Workpieces Touching

As demonstrated, Kirchoff's Law of Distributive Networks can work against forming a proper weld when shunt current paths are allowed to exist in the secondary circuit of the welding machine. The workpieces themselves may even be a part of a shunt path.

When an electrode shank or an electrode holder touches the workpiece at the same time that the face of the electrode is in contact with the workpiece, a parallel path is provided for the current to travel through the secondary circuit. This second path decreases the current available for forming the weld nugget (see **Figure 2**).

The total current remains the same, but part of the current is "shunted" through a path that does not contribute to providing sufficient energy to form the weld nugget. The total current is the sum of the current in the path to form the weld nugget *and* the shunt paths.

Shunt paths unintentionally may be built into fixtures. Designers must be sure that proper electrical clearance or sufficient insulation is provided between the noncurrent-carrying parts of the fixture and the parts to be welded. Noninsulated alignment or locating pins in a fixture also may create shunt current paths between the fixture and the parts to be welded.

Burrs and Part Fit-up

Other conditions also can cause a loss of welding current through shunt paths. For example, excessive burrs on parts and poor part-to-part fit-up can create shunt current paths. A large burr touching a mating piece that is near the weld to be made may provide enough of a shunt current path to result in poor weld quality (see **Figure 3**).

Part fit-up in which only portions of the workpieces are touching near the weld area can also provide a shunt path when the parts eventually mate properly. This can lead to a poor weld nugget being formed (see Figure 3).

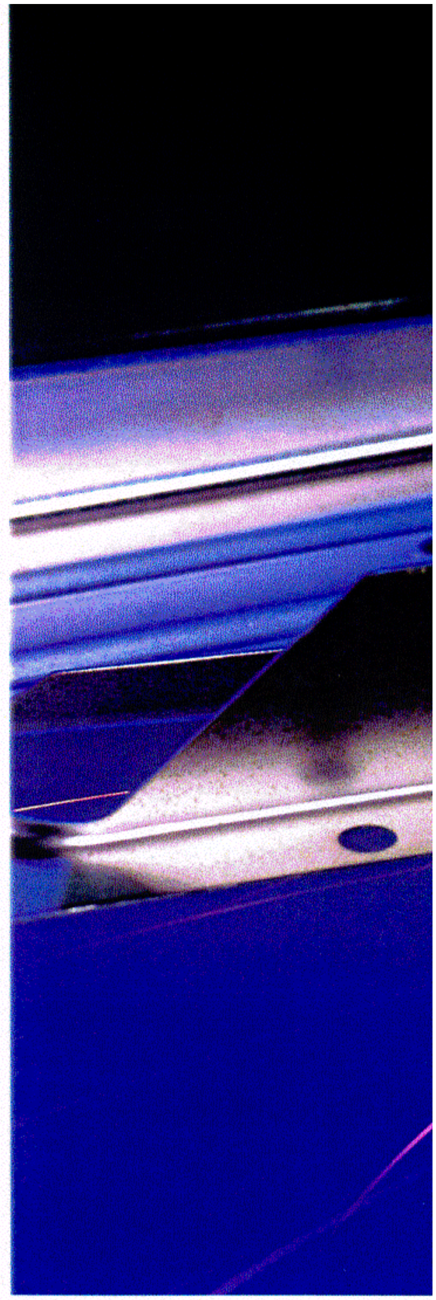
Metal expulsion also may occur, resulting in a poor weld, a personnel hazard, and possibly adherence of the flash to the area at the base of the throat of the machine's secondary circuit. Over time, this buildup can become a shunt current path in the secondary circuit. Some current will shunt across the flash on the pads, resulting in less current at the weld interface.

Weld Spacing

Another common form of shunting results from weld spacing that is too short for the material thickness being welded. The American Welding Society's (AWS's) *Recommended Practices for Resistance Welding* and the Resistance Welder Manufacturers' Association's (RWMA's) *Resistance Welding Manual* include tables providing minimum weld spacing requirements for various thicknesses and types of material.

After a weld is made, a lower resistance path has been completed between the two workpieces. If an attempt is made to place the next weld too close to the first weld, the total resistance of the material and the formed weld nugget may be less than the resistance through the interface at the new weld location (see **Figure 4**).

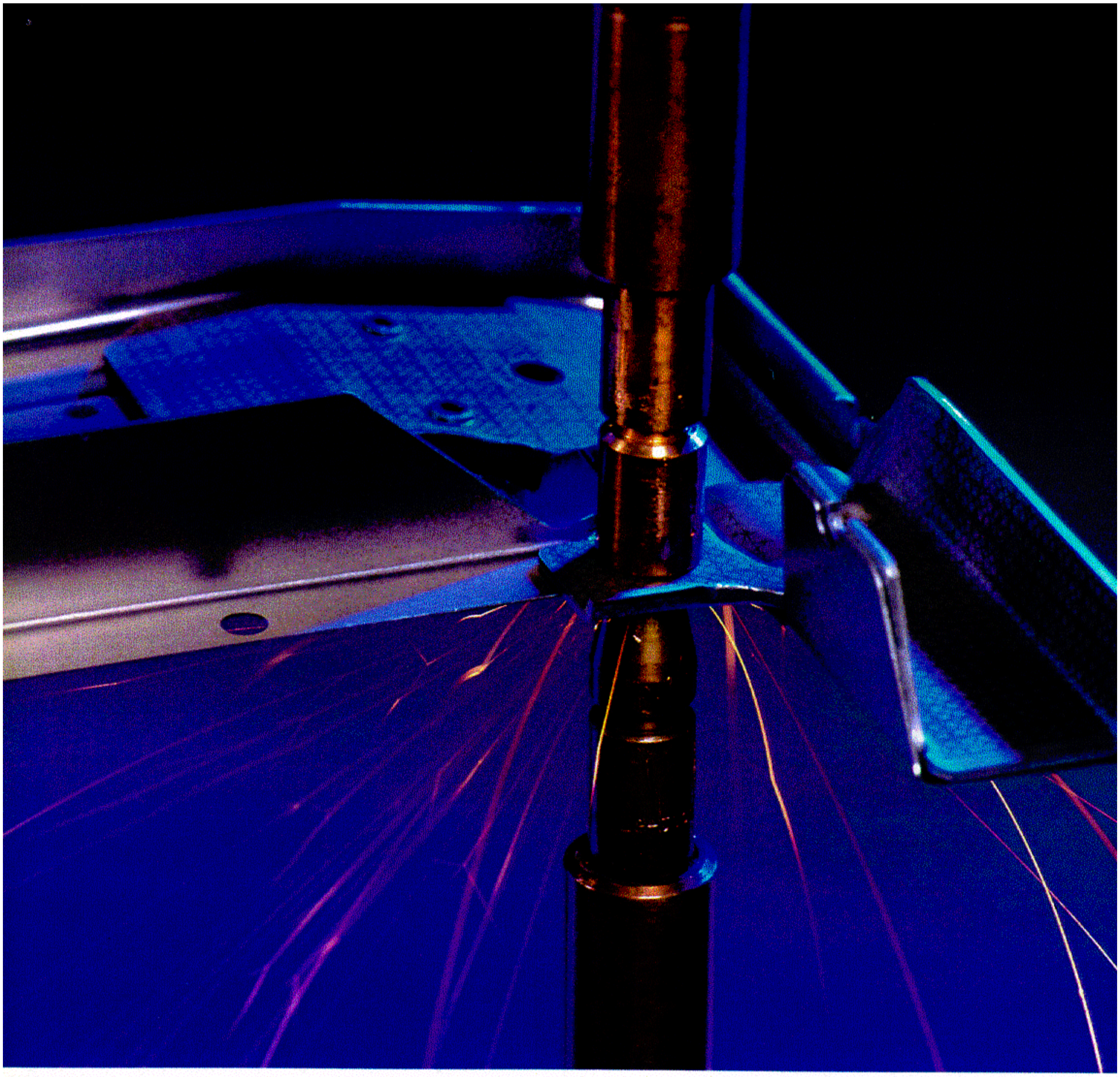
In this case, some current will shunt through the previously formed weld nugget. The result is that the next and subsequent welds, at a similar spacing, will be of lesser quality and may be so poor that they cannot pass a structural strength test. After about the third or fourth weld at this short spacing, the weld nuggets will become uniformly undersized.



Projection Welding

If the spacing of weld nuggets is required to be closer than that recommended by welding standards, projection welding is a solution to this problem. In this case, Kirchoff's Law can be used to advantage. Fabricating two or more projections into a part, on very close centers, provides parallel current paths through projections in the workpieces. The projections provide point contacts between the workpieces as a path for the welding current.

Each projection is, of course, a sep-



arate weld. The current and pressure requirements for each weld will increase by the number of projections. Two projections require about twice the current and twice the pressure of a single weld. Also, for the current paths to be equal, the projections must be of the same size and shape, and the electrodes must be flat and parallel with the work surfaces.

The resistances at the points where the projections contact the mating workpiece must be the same. If only one projection is making contact initially between the two workpieces, the initial current density at the single projection will be doubled, possibly destroying the projection and resulting in poor weld quality.

When multiple projections are welded, Kirchoff's Law is used in reverse. Equal shunt paths in the workpiece are required to provide equal paths through each projection. If all the projections are not equal, then equal current paths may not exist, and the full current (or at least a large portion) will flow through fewer projections, causing metal expulsion and poor weld quality.

All projections must be of the same size and shape. Also, the electrodes must be flat and parallel with the workpieces. If both of these conditions are not met, there will be increased current flowing through the remaining contact area between the workpieces or between the workpieces and the electrodes, producing unbalanced current flow through the projections (see **Figure 5**).

Kirchoff's Law applies. In spot welding, for example, multiple current paths reduce the current flow to the weld area, resulting in underwelding. However, in multiple projection welding, in which multiple current paths are deliberately designed into the workpiece, reducing the number of projections will increase the flow of current through each projection, resulting in overwelding and possible metal expulsion.

A pulsation welding schedule can help provide the necessary delay in the set-down of the welding machine force system to accommodate minor variations in the projection size or shape.

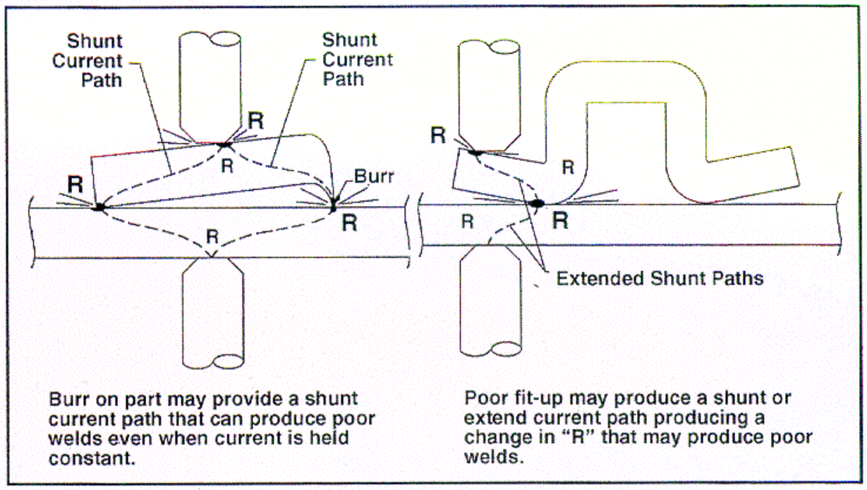


Figure 3

A large burr touching a mating piece near the weld to be made may provide a shunt current path, which would cause poor quality.

Seam Welding

Kirchoff's Law also applies to seam welding. In seam welding, weld nuggets usually are spaced very close together or may even overlap to provide watertight seams. For seam welding applications, higher currents are selected for weld schedules to overcome the losses caused by the shunt current paths created by the very close weld nugget spacing.

However, because of the higher current settings selected for seam welding, the heat generated in the first few weld nuggets, possibly three or four, may be excessive and cause overwelding at this point. This overwelding can be caused by the higher currents programmed to overcome the shunt current effects of seam welding and the higher resistance between the seam welding wheels and the workpieces as the wheels meet the edges of the workpieces (see **Figure 6**).

As the wheels roll up over the edge of the workpieces, reducing the magnitude of the current for the first few weld impulses will overcome the problems of initial overwelding and expulsion. There is no shunting effect on the first weld impulse, and the area of the workpieces in contact with the welding wheels initially is very small, resulting in a very high initial contact resistance. Here, Joule's Law ($H = I^2RT$) applies. The larger resistance, R, produces excessive heat, H.

Switches or time schedules associated with the movement of the work to the wheels can be used to preset weld control percent current settings to step the current up to the required seam welding current settings over the first few weld impulses. Many microprocessor-based controls can be programmed for both a change in current and the time delay necessary to reach proper seam welding current levels without damaging the work or the wheels. Usually, reduction in the first three or four initial weld impulses is enough to prevent any damage to the parts or wheels caused by metal expulsion.

Series Welding

Series welding of steel also may be affected adversely by shunt currents if weld spacing is incorrect. For proper setup, the weld spacing for series welding should be the same or slightly greater than the dimensions shown in the tables for weld spacing for like thicknesses of material.

Series welding of sheet metal is usually limited to a maximum of 16-gauge material. In a series weld, two weld nuggets are formed simultaneously, one at each electrode, through the material to be welded and through a common conducting backup. The spot weld spacing must conform to the recommended practices for the material thicknesses being welded.

In a series weld setup, Kirchoff's Law applies. If the electrodes are spaced too close together, current will shunt through the workpiece contacted by the welding electrodes, usually the upper workpiece, and thus reduce the current flow through the interfaces between the workpieces and the common backup conductor. This prevents properly sized weld nuggets from forming at the workpiece interfaces (see **Figure 7**).

Crosswire Welding

Crosswire welding (see **Figure 8**), a form of series welding, can be accomplished when welding a number of cross wires in parallel. Series welding of cross wires is not limited to wire size. Crosswire welding is also a form of projection welding.

Spacing of the parallel wires onto the cross wires is not critical in crosswire welding. With a proper setup, welding cross wires is, as mentioned, a projection weld. Multiple crosswire welding also is analogous to series welding. However, in setup, the orientation of the cross wires is important.

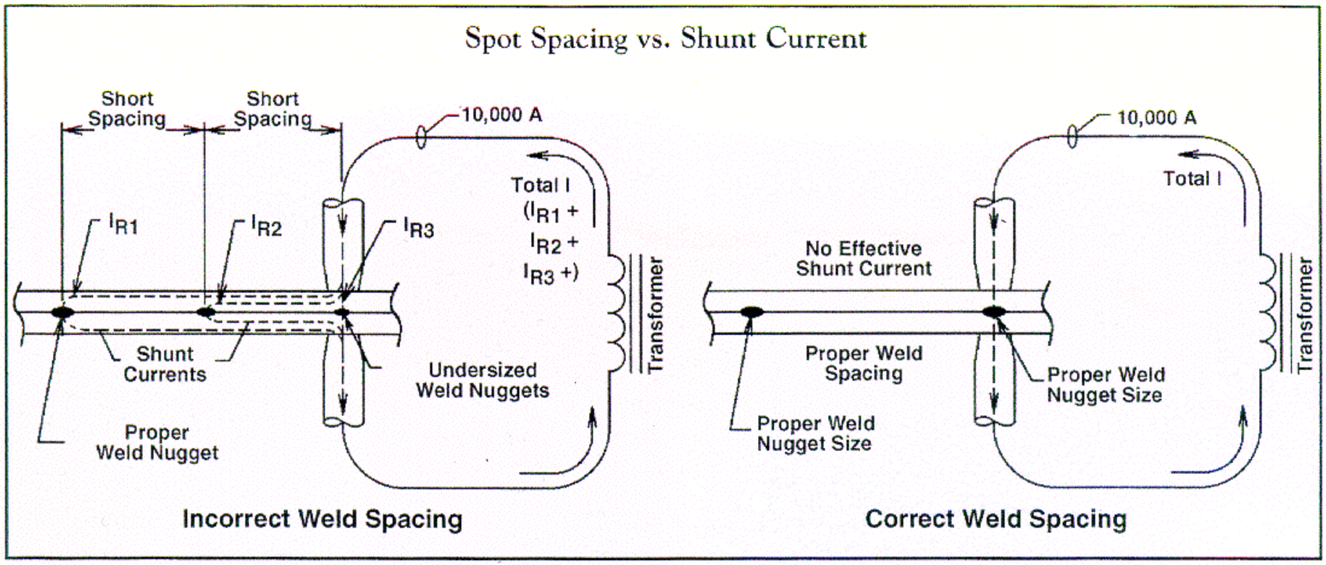


Figure 4

If an attempt is made to place the second weld too close to the first, the total resistance of the material and the formed weld nugget may be less than the resistance through the interface at the new weld.

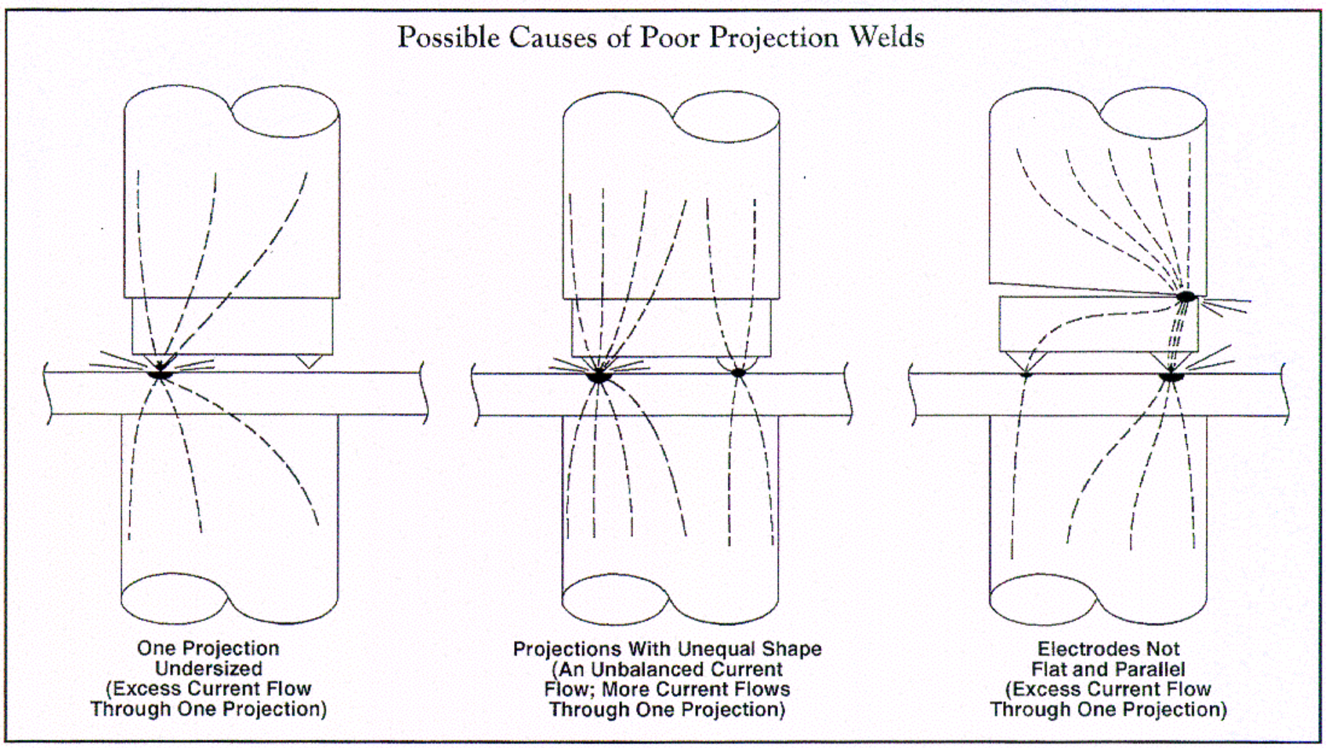


Figure 5

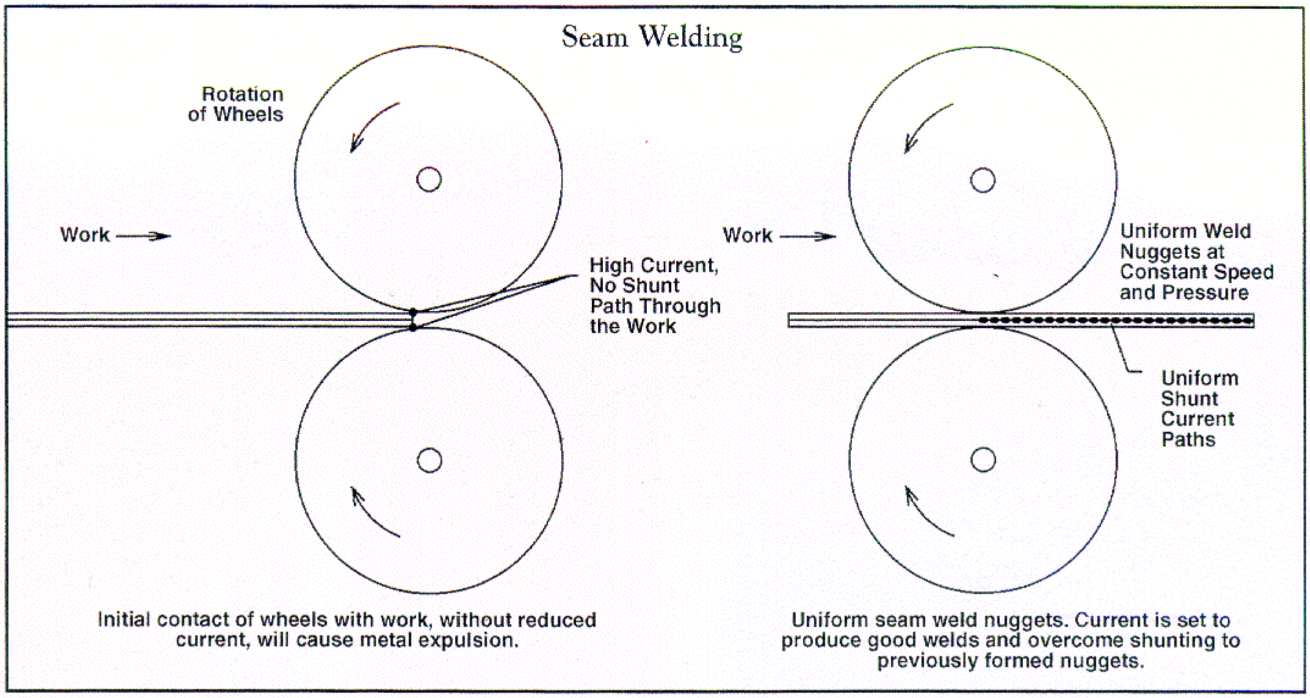


Figure 6

Usually, reduction in the first three or four weld impulses is enough to prevent damage to the parts or wheels caused by metal expulsion.

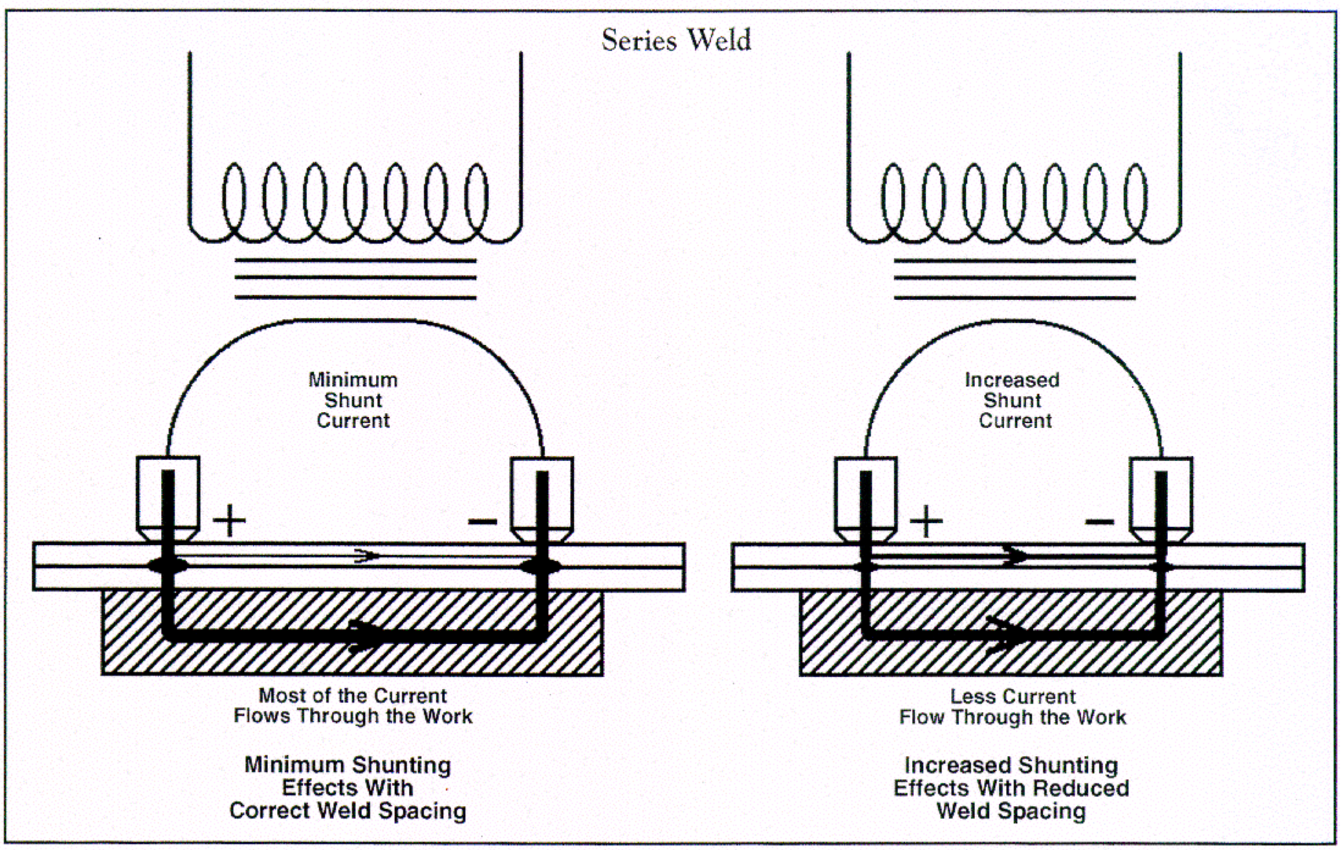


Figure 7

Spot weld spacing should conform to the recommended practices for the material thicknesses being welded.

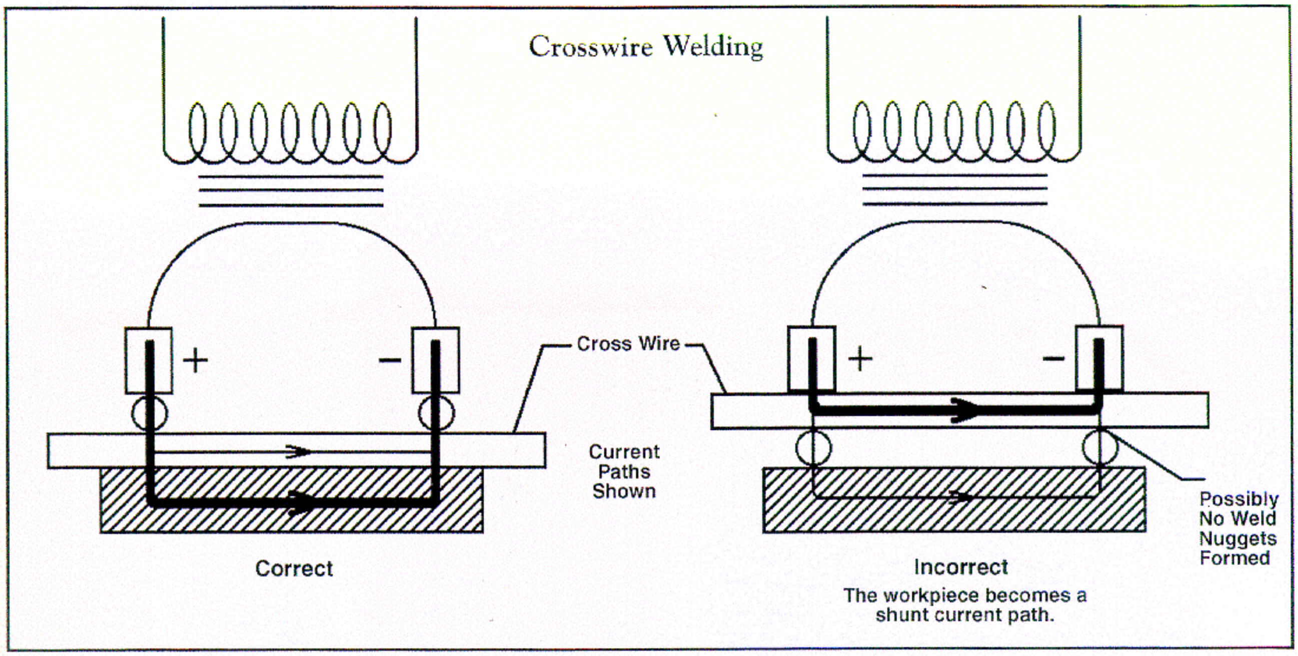


Figure 8
Crosswire welding is a form of series welding that can be accomplished when welding a number of cross wires in parallel.

The cross wires always must be set up against the backup conductor so that the electrodes contact only the parallel wires. If the cross wire is placed above the parallel wires, it becomes a shunt path for the welding current, making it nearly impossible to form a proper weld nugget wire-to-wire.

Conclusion

If shunt current paths are present in the secondary circuit of a resistance weld setup, some current will flow through these shunt paths, as well as through the welding electrodes and through the workpieces. Kirchoff's Law applies to this situation. The sum of the currents will, of course, be equal to the output at the secondary circuit to the welding transformer, but the current through the workpieces will be reduced by the shunt currents. Poor welds or no weld at all may be the result.

A constant current control cannot overcome shunt losses. The control can maintain a constant current in the secondary circuit, but it cannot redistribute the current in the secondary circuit to maintain the correct value of current to form a properly sized weld nugget. Instead, correct welding equipment setup, fixture design, and overall maintenance of the secondary circuit of the machine are required. ■

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