

Making Resistance Spot Welding Safer



Fig. 1 — Metal expulsion typically caused by low electrode force.

The potential dangers involved with operating punch presses or press brakes are quite obvious. But most people do not realize that an unprotected or improperly installed spot welding machine can potentially cause serious injury to the operator. According to the Bureau of Labor Statistics, 3,974,700 accidents involving industrial welding were reported in 2005. Of these, 2,148,800 resulted in lost days of work. Spot welding safety should be as important to the manufacturer as are safety concerns for presses and other industrial machinery.

Metal Expulsion Injury

It is not unusual to see a shower of sparks (expulsion) coming from the electrodes on a spot welding machine — Fig. 1. Many

companies assume that this is a normal condition. Some believe that the expulsion is actually hot oil or grease. The truth is that these sparks are droplets of molten metal coming from under the electrode or from between the parts being welded.

Because metal expulsion can cause permanent eye damage, it is imperative that operators wear approved safety glasses that have side shields — Fig. 2. It is equally important to understand that a properly set spot welding machine should not create any major expulsion under any circumstances. This surprises many long-time users and gets to the heart of the resistance welding process.

Cause of Expulsion

When a spot weld is being made, the metal heats up to molten temperatures. At the same time, the metal molecules are all po-

Areas of potential injury on spot welding machines are detailed, and practical solutions are presented

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larized in the same way at any one instant of time. This causes an extremely strong magnetic repulsion between these molten droplets to literally launch them away from the part. You see this as expulsion. In extreme cases, metal expulsion can travel 10 ft or more to potentially injure other personnel in the area. It can also set fire to gloves, clothing, and other flammable material in the area.

Elimination of Expulsion

The solution is to use a proper welding schedule for the material being welded. Selection of the proper electrode force will create a mechanical barrier around the molten metal to keep the material within the nugget area and eliminate expulsion. It will also reduce the electrical resistance between the face of the electrode where it touches the outer sheet to lower surface heating under the electrode and keep it from reaching the molten state.

However, if the electrode force is too high, the amount of heat created in the nugget zone will be reduced to compromise the weld strength or, in extreme cases, totally eliminate fusion. The *RWMA Resistance Welding Manual*, Edition 4 (available at www.rwma.org), includes a collection of welding schedules for most metal alloys to provide high-strength welds while eliminating major metal expulsion¹.

Welding at Metal Edge

Placing a spot weld too close to the edge of a part can also cause metal expulsion. In this case, even use of proper electrode force will not keep the molten metal from flying out of the metal edge. The RWMA handbook recommends minimum edge distances to minimize expulsion. However, where the part design forces a weld location too close to an edge, use of pulsation in the welding schedule can be applied to minimize metal expulsion while maintaining weld strength. For most metals being joined, divide the weld time shown on the welding chart by three (round up), and install three impulses of this time with two cycles of cool time between impulses. This will minimize expulsion and form a nugget with acceptable penetration.

Pinch Point Injury

OSHA 1910.255(b)(4) states, "Guarding. All press welding machine operations,



Fig. 2 — Wearing of approved safety glasses with side shields is mandatory for eye protection.

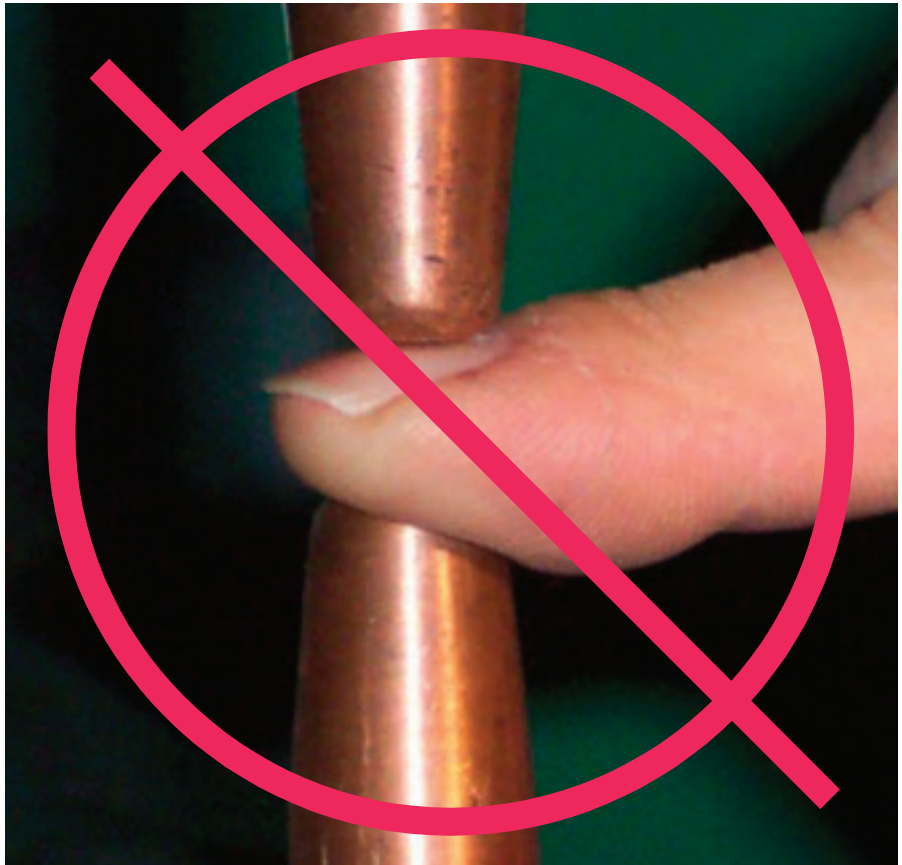


Fig. 3 — Pinch point injury at electrodes can be severe.

1. An extensive article on electrode force and expulsion was published in the *Welding Journal* and is now accessible at www.unitrol-electronics.com/pdf/awspape2color.pdf.



Fig. 4 — Two-hand antitiedown switch welding machine initiation.

where there is a possibility of the operator's fingers being under the point of operation, shall be effectively guarded by the use of a device such as an electronic eye safety circuit, two hand controls, or protection similar to that prescribed for punch press operation...." Unfortunately, most spot welding machines are operated

without safeguards to protect the operator from serious finger injury — Fig. 3.

Magnitude of Force

It is important to appreciate the magnitude of force between electrodes. For example, a welding machine with a ¼-in.

electrode face set with 600 lb of electrode force will develop 12,230 lb/in². This can cause major crushing damage to the operator's finger if caught at this pinch point.

Two-Hand Antitiedown Initiation

Where the part and fixture design allows for welding without the operator holding the part, use of two-hand antitiedown initiation will keep the operator's fingers out of the electrode pinch zone during welding — Fig. 4. The initiation buttons should be located at least 18 in. apart and far enough away from the electrodes so that no part of the hand can be in the weld zone while pushing the initiation buttons. Operation of the welding machine should only happen if both switches are pushed within less than one second of time. If the switch on either side is permanently closed, closing of the other switch will not cause the welding machine to operate (antitiedown function). If the space between the electrodes exceeds ¼ in., the control should be set so that releasing either of the initiation switches before the electrodes close will cause the electrodes to immediately retract.

Light Curtains

Light curtains are rarely practical with hand-fed welding operations since the operator's hands will normally be in the welding electrode zone. Also, light curtains cannot usually handle parts that have flanges that are in the same area as the operator's hands. However, light curtains can be used effectively for automatic and semiautomatic welding systems when installed so that no mechanical movement can take place if the light curtain beam is broken — Fig. 5. In this case, once the welding sequence has started, breaking of the light curtain beam should automatically cause any moving components to retract to a safe position, and then require reinitiating of the welding machine after the beam has been cleared.

Continuity Monitoring

This type of system measures electrical continuity between the electrodes to verify they are actually touching the part to be welded — Fig. 6A. If anything, such as the operator's finger, blocks the movement of the electrode, this system will not detect continuity. The continuity signal is picked up from points on the welding transformer secondary pads. This eliminates the need for wire connections at the electrodes — 6B.

In operation, the electrodes are closed under low force that is accomplished by a modified pneumatic valve system. A group of precision pressure regulators in a pad-



Fig. 5 — Light curtain guarding on all sides protects the operator on this hand-loaded semi-automatic dial table welding machine.

locked box provides pressure needed to counterbalance heavy welding rams to less than 50 lb of force at the electrodes. The same components, arranged differently, can be used to furnish low pressure for operating welding machines with lightweight rams, or for operation of rocker arm or transgun welding machines — 6C. If continuity is detected before a maximum time has been reached, the electrodes are brought to full welding force. However, if continuity is not detected before that time, the electrodes are retracted and will not come forward until the initiation switch has been released and closed again.

This type of safety system does not have any operator-set components and does not require any adjustment when new setups are made. If designed properly, the continuity system cannot be overridden and is in place at all times that the welding machine is under power. Because this is a fully passive process, it can be used as the primary pinch point safety system for a spot welding machine.

Ring Guards

These devices typically utilize a rod with a horizontal ring installed at one end that encircles the moving electrode. A limit switch in this system is adjusted every time a new setup is made on the welding machine so that it closes if the rod travels to a position less than ¼ in. from the part being welded. When the welding machine is initiated, the rod lowers before the electrode starts movement. If the limit switch closes within a timer setting, the rod retracts while allowing the electrode to travel forward for the weld.

This type of system is not usable where the parts being welded are not flat in the area of the weld. More importantly, the fact that the level of safety is determined by how the limit switch is adjusted during each setup makes this process nonpassive and, therefore, ring guards should not be used as the primary safety system for a spot welding machine.

Ram Limit Switches

With this system, a limit switch is installed on the frame, and a cam moves with the ram. The limit switch cam is adjusted to close when the electrode is at a position less than ¼ in. from the metal surface. The welding machine's pneumatic system is designed to lower the electrodes under less than welding force until the limit switch has been closed, and retract the electrodes if this switch is not closed within a timer setting. Like the ring guards, this type of guarding requires adjustment every time a new setup is made and is, therefore, not passive. All safety of the welding machine is controlled by



Fig. 6 — A — This system from Unitrol Electronics provides passive electrode pinch-point protection at Ada Metal Products, Inc., Lincolnwood, Ill. B — continuity measuring wires connected to welding transformer secondary pads; C — padlocked NEMA-4 enclosure with precision regulators supply pressure to new solenoid and quick exhaust valves. This arrangement counterbalances an 160-lb ram to less than 40 lb.

the actions of the last person who adjusted the limit switch cam. Therefore, this type of system cannot be considered as the primary guarding method.

Barrier Guards

On automatic or semiautomatic welding machines, systems can be installed that will automatically close a mechanical barrier at the start of each sequence. The moving barrier contains an interlocking limit switch to prevent electrode move-

ment if the barrier is not fully closed. The mechanical barrier should be designed to preclude any ability for the operator to reach into the electrode area when it is in place. Closing force for the barrier should be selected to prevent injury to the operator from the moving barrier.

Interlocked Cage Doors

Systems, such as robotic welding cells, should have a cage installed to prevent movement within the cell when an entry



Fig. 7 — A separate, properly sized incoming ground wire is required to protect from electrical shock.

door is open. If an entry door is opened during a welding sequence, all movement must stop. Once the door is again closed, movement can only be started when an initiation switch on the outside of the cage is activated. Under no circumstances should an initiation button station be installed on the interior of the cage.

Laser Measurement Systems

In this type of guard, a laser beam is aimed alongside the electrode at the part being welded. When the welding machine is initiated, the laser measurement system checks to verify that the distance being measured is no less than ¼ in. from the top of the metal being welded before allowing any movement of the electrode. Like the ring guards, this type of guarding requires adjustment every time a new setup is made. Laser beam measurement systems are not passive and therefore should not be used as the primary safety system.

Electrical Shock Injury

By design, a resistance welding machine uses low voltage at the electrodes to produce an intrinsically safe process. However, an incorrectly grounded welding machine can pose a serious shock danger to the operator. A potentially fatal shock can occur if the primary winding of the welding transformer shorts to the transformer frame, or if a line voltage connection comes loose and shorts to the body. If a proper ground is in place on the welding machine, the line voltage will have a good path to ground and clear the control's circuit breaker, line fuses, or main power circuit breaker.

Incoming Ground Wire

Proper grounding of all types of welding machines depends on the quality of the incoming ground wire to the machine.

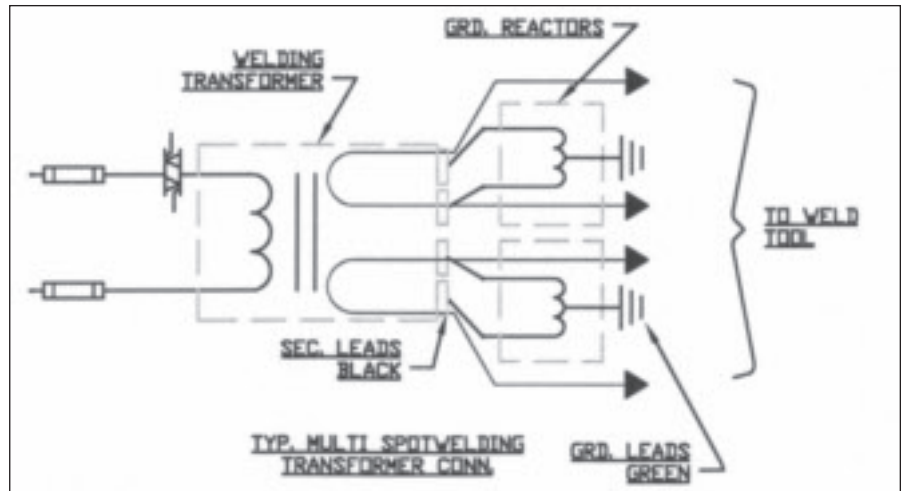


Fig. 8 — On a dual secondary welding transformer, one grounding reactor is required for each secondary. The center tap from both devices is connected to the building ground.

Grounding a welding machine using the conduit or BX cable is not an acceptable method. The separate ground wire should enter the welding control enclosure and be connected to a properly bonded ground stud — Fig. 7. Wire size should be in line with NEC250.122 standards.

Transformer Secondary Grounding

OSHA Standard 1910.255(b)(9) covers grounding as follows: “Where technically practical, the secondary of all welding transformers used in multispot, projection and seam welding machines shall be grounded. This may be done by permanently grounding one side of the welding secondary current circuit. Where not technically practical, a center tapped grounding reactor connected across the secondary....”

Press and Rocker Arm Welding Machines

Floor- or bench-mounted welding machines are normally manufactured with the stationary arm bolted to the transformer secondary pad and also connected to the frame. The frame is grounded to complete the path from secondary to ground. The movable arm of the welding machine is not grounded.

Portable Gun Welding Machines

Welding machines that use a permanently mounted transformer that connects to a portable welding gun by a long kickless cable require a ground strap to connect either side of the transformer secondary to the transformer frame. With the transformer frame properly connected to a ground wire, the path from the portable welding gun to ground is fully established.

Portable Transguns

This type of welding machine includes in one package a welding transformer and arms typically suspended by a counterbalanced mount and positioned by an operator. A flexible cable enters into the transformer carrying line voltage from the control. Because this portable device cannot be hard-connected to a suitable ground, the ground wire comes into the welding machine in the same flexible cable that contains the line voltage wires.

While many older transguns were supplied simply with a double-pole contactor between the control and the transgun, this form of protection is not adequate for personnel protection and can expose the operator to potentially fatal electrical shock even when the welding machine is under power but not being operated.

The RWMA bulletin 5, section 5-015.68.04, covers the special requirements for portable transgun grounding. Because the transgun is not hard-grounded, safety of the operator depends on the presence of a reliable ground path. However, since the ground path comes from a long flexible wire, there are additional requirements for this type of welding machine that monitor ground wire integrity and ground fault leakage current.

Grounding Integrity

The RWMA standard requires that “the welding gun transformer case and secondary shell be grounded and protected by fail safe circuitry designed to immediately disconnect line voltage from the transgun via a circuit breaker with under-voltage trip. The combined clearing time shall not exceed 60 ms. A sensed value of grounding conductor resistance in excess of 1Ω by the ground integrity

monitor would be considered an inadequate ground.”

Ground Fault Current Relay

If the transformer primary shorts to the secondary, line voltage will be present on the case of the transgun. With the operator maneuvering the transgun while holding parts of the welding machine case, this voltage can find a path through the operator and to ground. This leakage through the operator reduces current returning to the control and can be measured by a ground fault relay. The RWMA standard continues: “A sensitive, fail safe, ground fault relay with a maximum trip point of 15 mA must be used to provide protection against ground fault leakage currents. The ground fault relay must immediately disconnect line voltage from the Portable Transgun via a circuit breaker with shunt trip or a circuit breaker with undervoltage trip. The combined clearing time shall not exceed 60 ms.”

If purchasing a new transgun for hand-held application, verify that the welding control contains systems to match the above requirements. If operating an existing hand-held transgun, check to be sure that the welding control includes this full protection.

Robotic Transguns

Since the frame-grounding path to a robotically moved transgun is through hinge points, grounding must be done using a separate ground wire similar to that for the portable transgun above. Because it is possible for an operator to touch the frame of a transgun, the same type of grounding integrity and ground fault current relay applied to portable transguns should be used for robotic transguns.

Fixture Transformers

Welding machines that utilize multiple transformers on the same structure require special grounding. Connection of one side of the welding machine’s secondary on multiple transformers to the common ground causes ground paths through the metal being welded and through the fixture. These ground paths can easily weld or tack the metal parts to the fixture. There can also be electrical paths back through the metal being welded to other grounded electrodes to cause arcing throughout the system. For this application, a grounding reactor must be installed on the welding transformer secondary in place of a hard-wire ground.

This grounding reactor, containing an internal saturable coil, is connected across the weld transformer secondary with a center tap on the saturable coil connected

to ground (Fig. 8). The coil has high impedance when voltage applied across it is less than the device’s rating (24–34 V). However, if the transformer secondary becomes connected to line voltage, the coil saturates and becomes a very low-impedance device. This drains the high voltage from the transformer secondary through the ground wire to produce high current that should trip the control’s circuit breaker or blow the line fuses. If the transformer has two secondary circuits, one grounding reactor must be installed on each circuit.

Permanently Mounted Transguns

These welding machines are structurally like the portable transguns discussed earlier, but are permanently mounted to a properly grounded steel pedestal. Either side of the machine’s transformer should be connected to the transformer frame to complete the ground path. Where multiple transguns are used in a system, or where arcing to the fixture is a potential problem, a grounding reactor, as presented above, should be used in place of a hard-wire ground connection.

Conclusion

Resistance welding can be one of the safest processes in the factory when proper personnel protection, correct equipment design, and appropriate electrical grounding are utilized. ♦

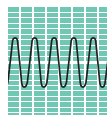
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