

(up to 10,000 amp) in resistance welding does not permit the use of plugs except for control circuits, usually 120 volts or less. Power lead terminals should be securely and permanently attached with screws or bolts for the duration of service.

The magnitude of the secondary welding current is such that the cables for a portable welding machine must be heavy. Even with sizes from 200,000 to 1,000,000 circular mils, power losses are high and in many instances water cooling is required, especially for high production portable, as well as multiple-spot station, welding machines. The length of these cables varies from 1 to 14 ft, the latter being the maximum considered reasonably economical. The covering for the cable used with a portable welding machine is thick, high tensile rubber, or now, more commonly, neoprene. These are now commonly concentric—two cables in one with water cooling.

Abuse of the cables for resistance welding is severe. The production requirements demand the utmost of the cable materials used, and even the best cables need frequent replacement during a production year. In use the cables are subjected to electrical pulsation, bending, and twisting. Electrical pulses at the rate of 3600 per minute cause a continuous whipping of the two cables which leads to fatigue and eventual breakdown. This condition is minimized by the use of concentric cables.

The secondary voltage presents little shock hazard, since the maximum voltage is about 30 volts, but the operator can be hurt by a cable blowout caused by steam pressure due to overheating from faulty water cooling circulation.

A periodic check for weak spots in the cable covering is good practice. The use of concentric welding cables is now common because they do not have the undesirable features of the pulsating cables. Portable welding machines, including the cables, should have proper weight balance to permit operation without undue strain to the operator.

Electrodes and holders

For resistance welding, copper or copper alloy electrodes are in general use. Made in various shapes for particular applications, they are, with few exceptions, water cooled. Re-

sistance-welding electrodes, unlike those used in arc welding, are not deposited on the work. However, the high current density and continuous application of mechanical force finally cause wear and necessitate redressing and replacement.

Electrodes are placed in holders connected to the secondary circuit. The welding pressure is also applied through the holders. Their designs cover a multitude of applications and vary considerably with the welding methods used. Electrode holders and electrodes should be water cooled to minimize softening of the metal from heat and to reduce the chance of heat burns to the operator.

Machine installation

Installation of resistance welding equipment should conform to the NFPA *National Electrical Code*, Standard No. 70. Some items worthy of special attention are listed below.

- 1 Control circuits should operate on low voltage, not exceeding 24/36 volts maximum for portable spot welders.
- 2 Stored energy equipment (capacitor discharge or resistance welding) having control panels involving high voltage (more than 550 volts) should be completely enclosed. Doors should have locks and contacts wired in the control circuit to short circuit the capacitors when door or panel is opened. A manually operated switch will serve as an additional safety measure, assuring complete discharge of the capacitors.
- 3 Back doors of machines and panels should be kept locked or interlocked to prevent tampering.
- 4 A fused safety switch or circuit breaker should be located conveniently near the welding machine so that power supply circuits may be opened before a man services the machine and its controls.
- 5 The point-of-operation hazard should be eliminated by suitable guards. Enclosure guards, gate guards, two-hand controls, and similar standard guards as designed for punch press operations are applicable.
- 6 A flash welding machine should have a