



SURFACE VEHICLE INFORMATION REPORT

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Automotive Metallurgical Joining

RATIONALE

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Foreword—This Document has also changed to comply with the new SAE Technical Standards Board format.

1. **Scope**—This report is an abbreviated summary of metallurgical joining by welding, brazing, and soldering. It is generally intended to reflect current usage in the automotive industry; however, it does include some of the more recently developed processes. More comprehensive coverage of materials, processing details, and equipment required may be found in the Welding Handbook, Soldering Manual, and other publications of the American Welding Society and the American Society for Testing and Materials. AWS Automotive Welding Committee publications on Recommended Practices are particularly recommended for the design or product engineer.

This report is not intended to cover mechanical joining such as rivets or screw fasteners, or chemical joining processes such as adhesive joining.

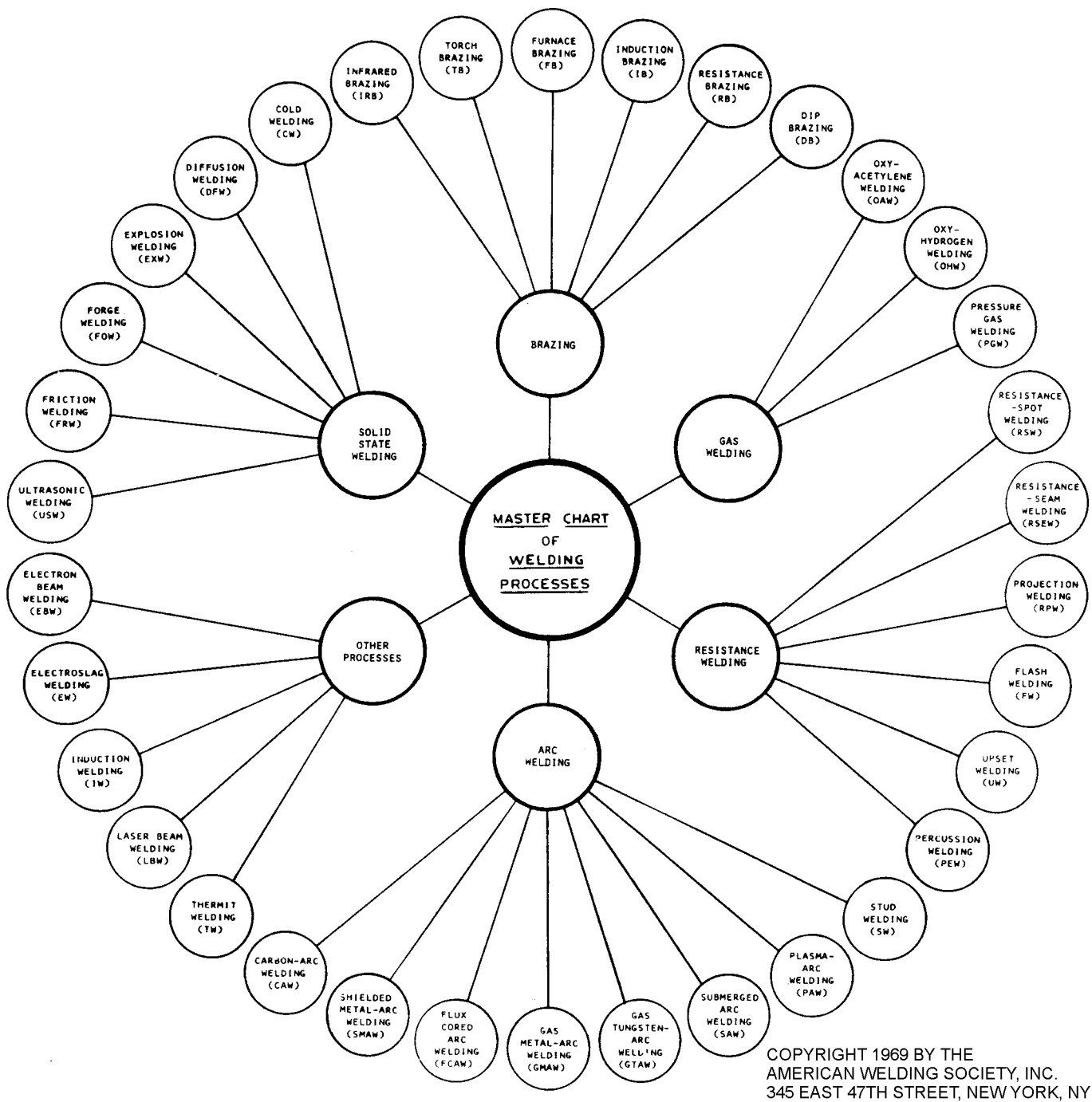
- 1.1 **Classification of Welding Processes**—Current welding practices utilize a great variety of other welding processes not covered in the scope of this report. The AWS has classified all these processes in their Master Chart of Welding Processes (Figure 1).

1.2 Standard Welding Symbols

- 1.2.1 With the advancement of welding technology, more welding variables and controls are being continuously added to the manufacturing requirements of weldments. These may include:

- 1.2.1.1 Dimensional requirements of welds (size, length, pitch, number of welds, etc.).

- 1.2.1.2 Integrity requirements, such as shear strength for resistance welds, depth of penetration, etc.



AWS A1.1-69

FIGURE 1—AMERICAN WELDING SOCIETY MASTER CHART OF WELDING PROCESSES
(REPRINTED BY PERMISSION OF AMERICAN WELDING SOCIETY)

1.2.1.3 Performance requirements of welds and welded joints. These may include:

1.2.1.3.1 Dimensional requirements (joint preparation, root opening, etc.).

1.2.1.3.2 Process requirements (series, direct, indirect, over and under welding, and process designations).

1.2.1.3.3 Other requirements such as weld all around, field weld, etc.

1.2.2 Symbols provide a universal means of communicating the above referenced information from the product designer to the process man without the risk of misinterpretation. Internationally accepted process and weldment symbols are shown in Figure 2.

1.3 Automotive Welding Applications—Certain welding processes have made further inroads in the area of automotive welding than others. This fact is caused not only by their greater adaptability to perform automotive welds, but also by keeping up with high production requirements at lower costs. At the present time the following processes are being used extensively:

- a. Resistance welding processes.
- b. Arc welding processes.
- c. Brazing and soldering.
- d. Special process.

2. References

2.1 Applicable Publications—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated the latest revision of SAE publications shall apply.

2.1.1 AMERICAN WELDING SOCIETY PUBLICATIONS—Available from??

American Welding Society Welding Handbook, Fifth Edition, Section 2, Chapter 30, p. 30.1.
American Welding Society Welding Handbook, Fifth Edition, Section 5, Chapter 90, p. 90.18.
Resistance Welder Manufacturers Association Manual.
American Welding Society Welding Handbook, Fifth Edition, Section 2, Chapters 30 and 32.
Resistance Welding Manual (RWMA), Third Edition, Chapter 4, p. 52.
American Welding Society Welding Handbook, Fifth Edition, Section 2, Chapter 30.
Recommended Practices for Automotive Welding Design D8.4-61.
American Welding Society Welding Handbook, Fifth Edition, Section 2, Chapter 31.
Resistance Welding Manual (RWMA), Third Edition, Chapter 5, p. 67.
American Welding Society Welding Handbook, Fifth Edition, Section 2, Chapter 31.
Resistance Welding Manual (RWMA), Third Edition, Chapter 5, p. 67.
American Welding Society Welding Handbook, Fifth Edition, Chapter 31.
Resistance Welding Manual (RWMA), Chapter 9, p. 111.
American Welding Society Welding Handbook, Fifth Edition, Section 2, Chapter 35 (1964).
W. C. Rudd, "High Frequency Resistance Welding." Welding Journal, Vol. 36, July 1957, pp. 703–707.
"Modern Joining Processes," Chapter 5, p. 51. American Welding Society (1966).
American Welding Society Welding Handbook, Fifth Edition, Section 2, Chapter 25.
American Welding Society Welding Handbook, Fifth Edition, Section 2, Chapter 28.
American Welding Society Welding Handbook, Fifth Edition, Section 2, Chapter 27.
American Welding Society Recommended Practices for Automotive Welding Design D8.4-61.
American Welding Society Welding Handbook, Fifth Edition, Section 2, Chapter 29.
American Welding Society Welding Handbook, Fifth Edition, Section 3, Chapter 54.
American Welding Society Welding Handbook, Fifth Edition, Section 3, Chapter 52.
American Welding Society Welding Handbook, Fifth Edition, Section 3, Chapter 56.
American Welding Society Welding Handbook, Fifth Edition, Section 3, Chapter 49.
American Welding Society Soldering Manual, First Edition, 1959.

2.1.2 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

Solders—SAE J473, Table 1.

2.1.3 ASTM PUBLICATION—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM solder classifications are given in Tables 44.3 and 44.4 of the Welding Handbook, American Welding Society, Fifth Edition, Section 3.

3. **Resistance Welding Processes**—Resistance welding is a group of welding processes wherein coalescence is produced by the heat obtained from resistance of the work to the flow of electric current in a circuit of which the work is a part and by the application of pressure. It differs somewhat from other forms of welding in that no extraneous materials, such as filler rods, fluxes, etc., are utilized; thus the metallography of the weld is not complicated by the addition of materials and the cost of consumable material is nonexistent.

The Master Chart of Welding Processes classifies six basic resistance welding processes; however, the great majority of metal joining is accomplished by the first three of the listed processes. These processes are:

1. Resistance-spot welding.
2. Resistance-seam and roll spot welding.
3. Projection welding.
4. Flash welding.
5. Upset welding.
6. Percussion welding.



Each of the processes described develops the heat of fusion by the resistance offered to short time flow of low-voltage, high-density electric current. Force is always applied before, during, and after the application of current to assure a continuous electrical circuit and to forge the heated parts together.



3.1 Resistance-Spot Welding—Resistance-spot welding is a process wherein coalescence at the faying surfaces is produced in one spot by the heat obtained from the resistance to the flow of electric current through the work parts held together under pressure by electrodes. The size and shape of the individually formed welds are limited primarily by the size and contour of the electrodes (see Figure 3).

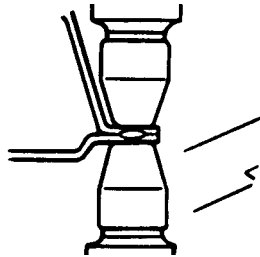


FIGURE 3—RESISTANCE-SPOT WELD

In the majority of the commercial resistance-spot welding applications, the alternating current single-phase system is used. It is the least expensive and simplest form of resistance welding equipment comprised of:

1. Welding transformer.
2. Force applying system - air, hydraulic, or spring type.
3. Timer and contactor.
4. Associated cables and hoses.

Figure 4 shows the resistance-spot weld setup.

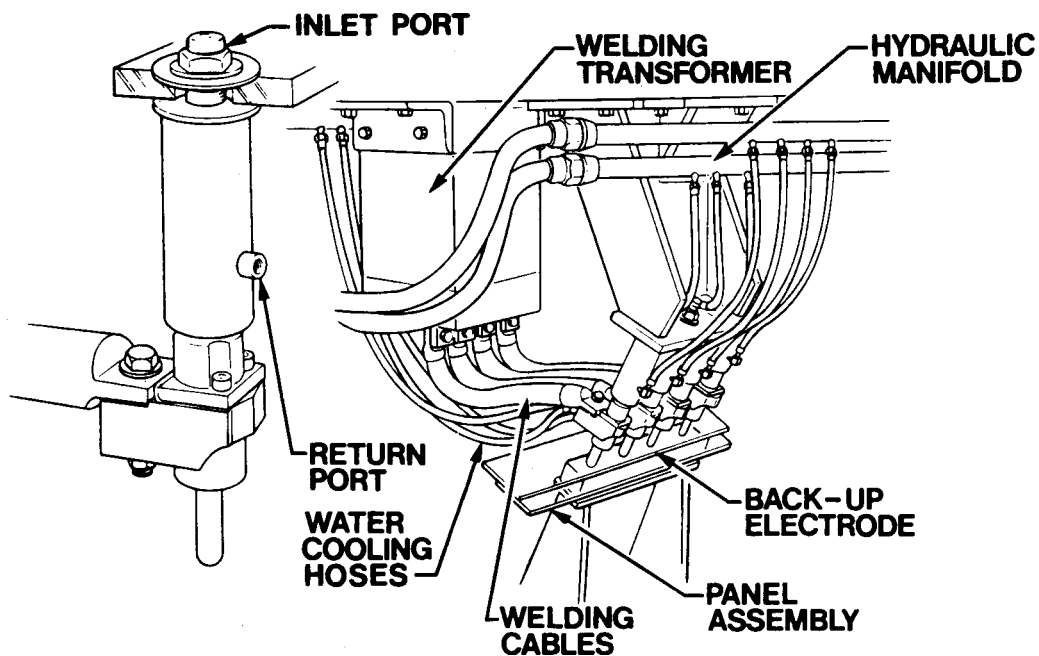


FIGURE 4—RESISTANCE-SPOT WELD SETUP

Resistance welding equipment varies in form from a portable resistance-spot welding gun, which makes a single spot at a time and is taken to the work, to a multiple spot welding machine which will make as many as 50 or more spot welds simultaneously on assemblies shuttled in and out of the machine at rates as high as 600/h. See Figure 5–Figure 7 for the respective types of equipment.

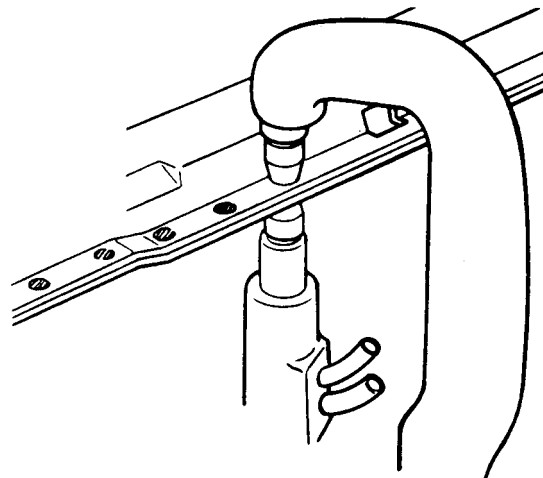


FIGURE 5—PORTABLE RESISTANCE WELD GUN

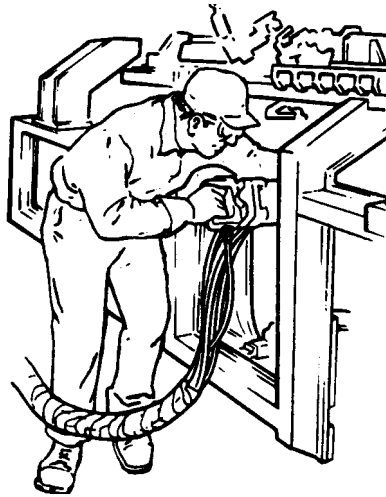


FIGURE 6—PORTABLE RESISTANCE-SPOT WELDING GUN APPLICATION

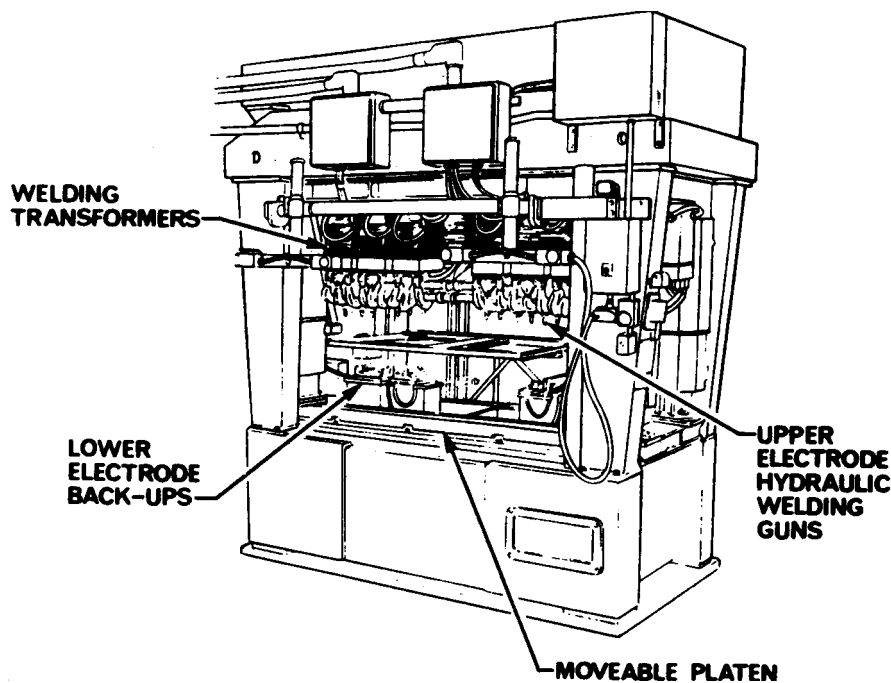


FIGURE 7—MULTIPLE ELECTRODE PRESS WELDING MACHINE

The complexity of the spot welding equipment is predicated by the volume of production to support the equipment investment. The initial equipment cost is high compared to manual arc and gas equipment; however, the rate of welding is faster and the consumable material cost is nonexistent.

High-quality fabrications can be produced consistently by use of proper designs and welding procedure. During the design of the product to be assembled by resistance-spot welding, consideration must be given to provide adequate flange widths and accessibility for welding equipment application. Difficulty in positioning and applying the welding equipment can materially affect production rate and quality.

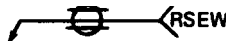
3.1.1 REFERENCES

- 3.1.1.1 American Welding Society Welding Handbook, Fifth Edition, Section 2, Chapter 30, p. 30.1.
- 3.1.1.2 American Welding Society Welding Handbook, Fifth Edition, Section 5, Chapter 90, p. 90.18.
- 3.1.1.3 Resistance Welder Manufacturers Association Manual.



3.2 Roll-Resistance Spot Welding—Roll-spot welding consists of making a series of separated spot welds in a row by means of one or two rotating, circular electrodes without retracting the electrodes or removing the welding force between spots. The principles described for conventional spot welding apply also to this process. The weld spacing is obtained and accurately maintained by proper adjustment of electrode speed and current off-time using conventional seam welding equipment. In the case of roll-resistance spot welding utilizing continuous motion, welding times are usually held to lower levels than that used for conventional spot welding, thus requiring higher magnitudes of current. Due to the continuous electrode travel the welds tend to be of an elongated nugget.

Roll-spot welding is usually accomplished on thicknesses up to 1/8 in with continuous motion of the wheel electrodes driven at a constant speed. For heavier thicknesses of 3/16 in and above, an intermittent motion is suggested. In this method, the work stops during the time required to make each individual weld and is automatically advanced the proper distance for the next weldment. This sequence is continued for the full length of the joint.



3.3 Resistance-Seam Welding—Seam welding is a resistance welding process wherein coalescence is produced by the heat obtained from resistance to the flow of electric current through the work parts held together under pressure by circular electrodes. The resultant weld is a series of overlapping spot welds made progressively along a joint by rotating the electrodes.

Seam welding is usually applied to two types of joint designs - lap and flanged-lap. Variations of the standard seam weld principle are mash seam weld, foil-butt seam weld, and butt seam weld. For the respective characteristics of each variety, see Section 3.3.1.

Roll-spot welding is used where precise spacing between welds is desired, as in welding the roof panel at the gutter area on an automobile body. Seam welding to produce a liquid and gas tight joint is used to fabricate automobile gas tanks, buckets, mufflers, water tanks, thin wall piping, etc. Mash seam welding and foil-butt seam welds are used where surface finishing is required after the joining process as there is a minimum of material required to be removed - applied to refrigerator and appliance cabinets and limited automotive outer panel fabrications. The butt seam weld is used for non-structural type joints, examples of which are found in toy and automobile horn fabrication.

Figures 8 and 9 show equipment concepts of a standard seam welder and a schematic of a roll-spot welder, respectively.

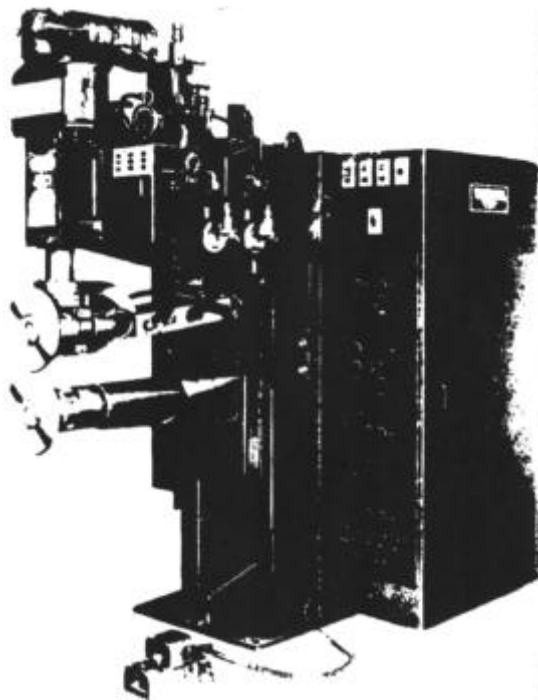


FIGURE 8—RESISTANCE SEAM WELDING MACHINE

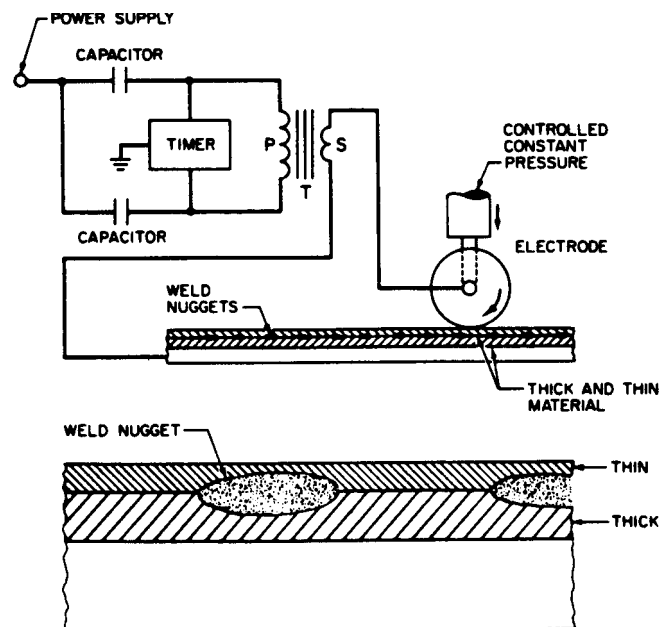


FIGURE 9—ROLL RESISTANCE-SPOT WELDING MACHINE

3.3.1 Additional information can be found on seam-resistance and roll-resistance spot welding and the variation of the process in the following references:

3.3.1.1 American Welding Society Welding Handbook, Fifth Edition, Section 2, Chapters 30 and 32.

3.3.1.2 Resistance Welding Manual (RWMA), Third Edition, Chapter 4, p. 52.



3.4 Projection Welding—Projection welding is a resistance welding process wherein coalescence is produced by the heat obtained from resistance to the flow of electric current through the work parts held together under pressure by electrodes. The resulting welds are localized at predetermined points by the design of the parts to be welded. The localization is usually accomplished by projections, embossments, or intersections.

Projection welding is a modification of the spot welding process. The concentration of the welding current and force is made by projections prepared in the workpiece rather than by the size and shape of the welding electrode. Normally, the projections are formed in the heavier of the two light metal pieces to be joined and in the case of dissimilar metal in the piece with higher electrical conductivity.

Projections can be produced by means of drawing with a punch and die, cold heading, coining, machining, shearing, and using natural projections as is the case with cross wire welding.

Advantages of projection welding which determine where the process can be best applied are:

1. More welds per unit area.
2. Improved surface marring condition.
3. Join difficult metal thickness combinations.
4. Increase output.
5. Less flange width requirement.
6. Consistent location of weld spots.
7. Longer electrode life.
8. Surface conditions less critical.
9. Allows joining components of irregular shapes (weld bolts, nuts, and tapping plates).

There are also factors which can be considered disadvantages:

1. Projections must be provided, which may mean an extra operation.
2. Projection dimensions must be maintained, so die maintenance is required.
3. Electrodes must be maintained although electrode life is longer.
4. Nugget size is limited by projection size.
5. High-capacity equipment required when making multiple simultaneous welds.
6. Limited generally to single-plane welding.
7. Poor condition and unfavorable characteristics of welding machine relative to impact and inertia will adversely affect the weld structural quality.

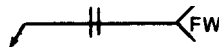
Commercially available hardware items of nuts, bolts, tapping plates, and pads are widely used throughout the industry. Application of other projection welding techniques on sheet metal and wire to sheet metal is limited primarily by the ingenuity of the product designer.

Figures 10–14 illustrate the process and typical applications.

3.4.1 Additional detailed technical information related to the process and product design requirements can be found in the following references:

3.4.1.1 American Welding Society Welding Handbook, Fifth Edition, Section 2, Chapter 30.

3.4.1.2 Recommended Practices for Automotive Welding Design D8.4–61.



3.5 Flash Butt Welding—Flash butt welding is a resistance welding process whereby the weld is made over the entire area of the abutting surfaces, and the upset force is applied only after heating is substantially completed.

The majority of the production machines is completely automatic (Figure 15). Movable platens, which carry the movable workpiece, are cam operated to control travel rate and acceleration. Unlike other resistance welding processes in flash butt welding, the heat is generated by the arc flashing action and only slightly by the actual resistance of the workpieces. Flashing is maintained for a sufficient length of time to develop that heat in the work parts to allow the upsetting force to forge the work together and displace all the slag and oxidized material from the joint's faying surface. This displaced metal is referred to as flash and usually is required to be removed by a grinding or cutting procedure.

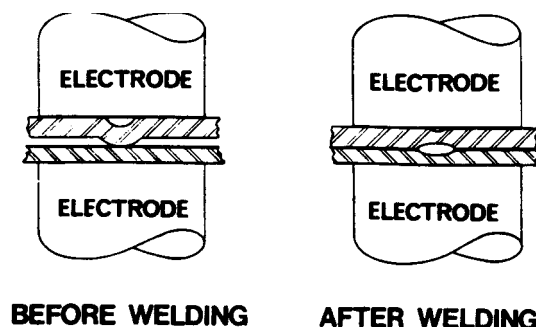
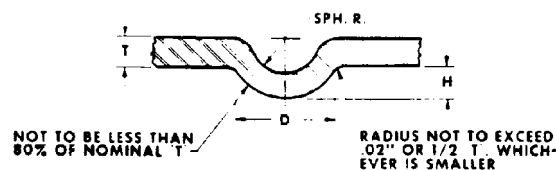


FIGURE 10A—DEFINITION OF PROJECTION WELDING. PROJECTION WELDING IS A METHOD OF RESISTANCE WELDING BY WHICH THE CURRENT FLOW AND HEATING DURING WELDING ARE LOCALIZED AT A PREDETERMINED POINT BY THE DESIGN OF THE PARTS BEING WELDED.



"D" REPRESENTS THE DIAMETER OF THE HOLE IN THE DIE AND THE RADIUS REFERRED TO IS THE ROUNDED EDGE OF THE HOLE

EMBOSSED SHEET THICKNESS	PROJECTION DIAMETER "D"	THINNER SHEET THICKNESS	PROJECTION HEIGHT "H"
.030	.105	.030	.030
.035	.120	.035	.035
.041		.041	
.047	.135	.047	.040
.054		.054	
.059	.150	.059	.045
.067		.067	
.075	.170	.075	.050
.089		.089	
.105	.190	.105	.055
.120		.120	
.125		.125	
.194	.250	.194	.070
.209		.209	

FIGURE 10B—PROJECTION WELDING EMBOSSEMENTS