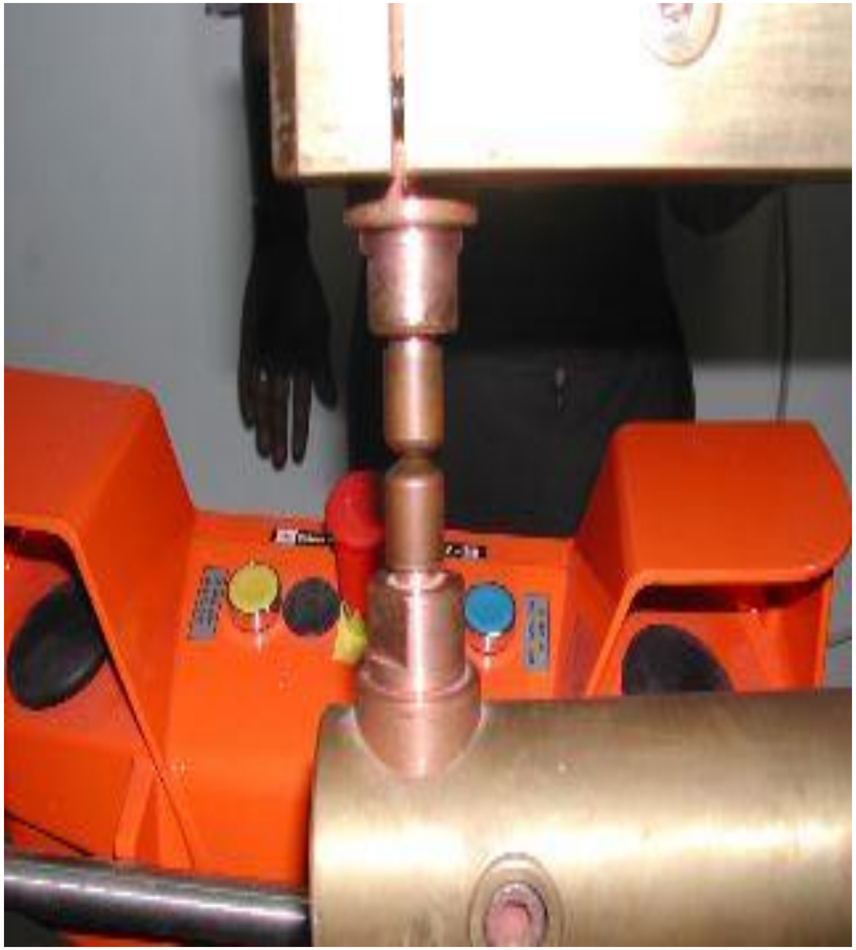
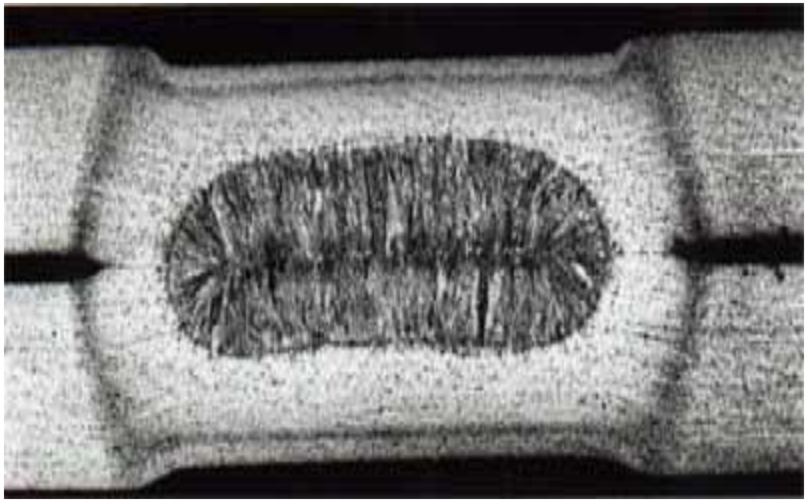
SPOT, SEAM, AND PROJECTION WELDING

Spot-welding equipment of the type frequently used in the automobile industry. The electrodes.

Spot-welding equipment of the type frequently used in the automobile industry





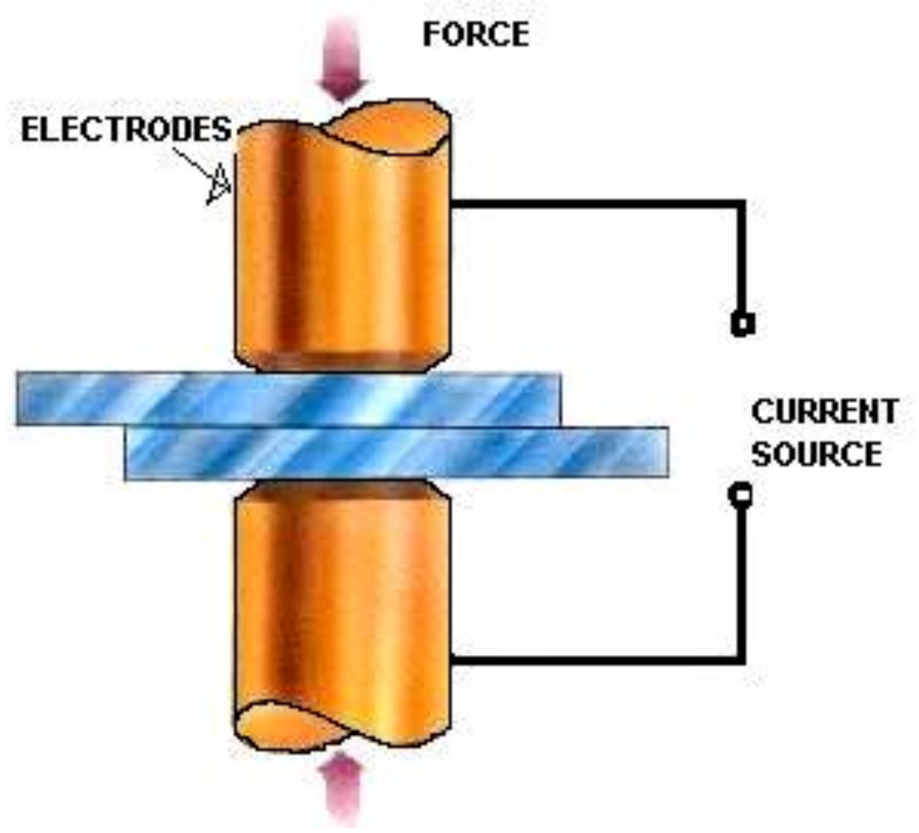
Spot-welding equipment of the type frequently used in the automobile industry. The electrodes

DEFINITION AND GENERAL DESCRIPTION

- SPOT, SEAM, and PROJECTION welding are three resistance welding processes in which coalescence of metals is produced at the faying surfaces by the heat generated by the resistance of the work to the passage of electric current.
- Force is always applied before, during, and after the application of current to confine the weld contact area at the faying surfaces and, in some applications, to forge the weld metal during post-heating.

Spot welding

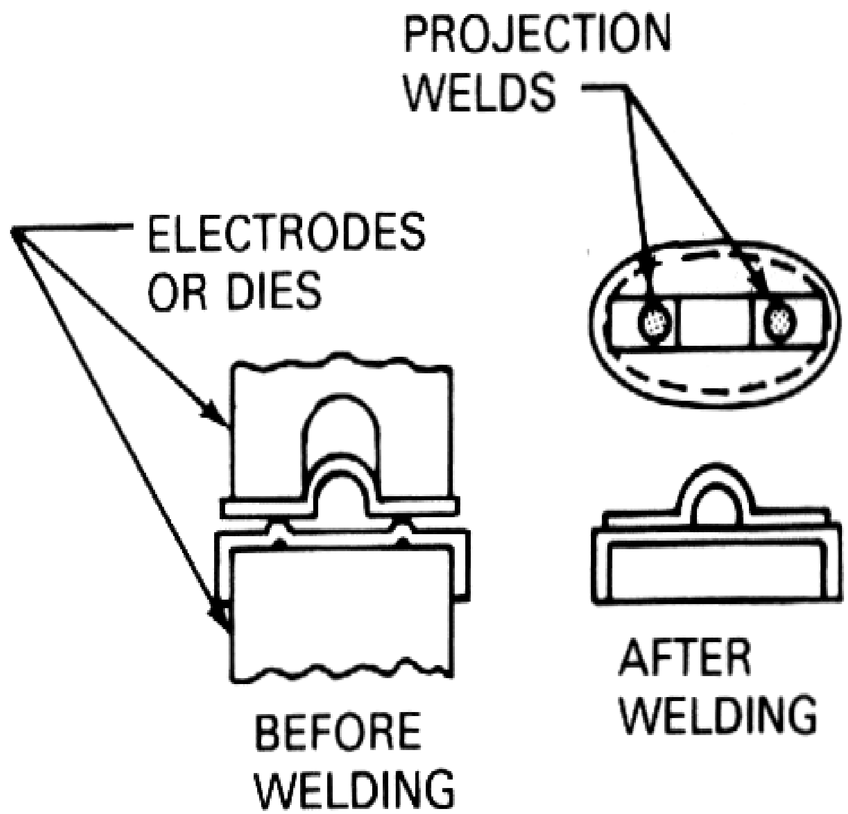
In spot welding, a nugget of weld metal is produced at the electrode site, but two or more nuggets may be made simultaneously using multiple sets of electrodes.



Projection welding

Projection welding is similar except that nugget location is determined by a projection or embossment on one faying surface, or by the intersection of parts in the case of wires or rods (cross-wire welding).

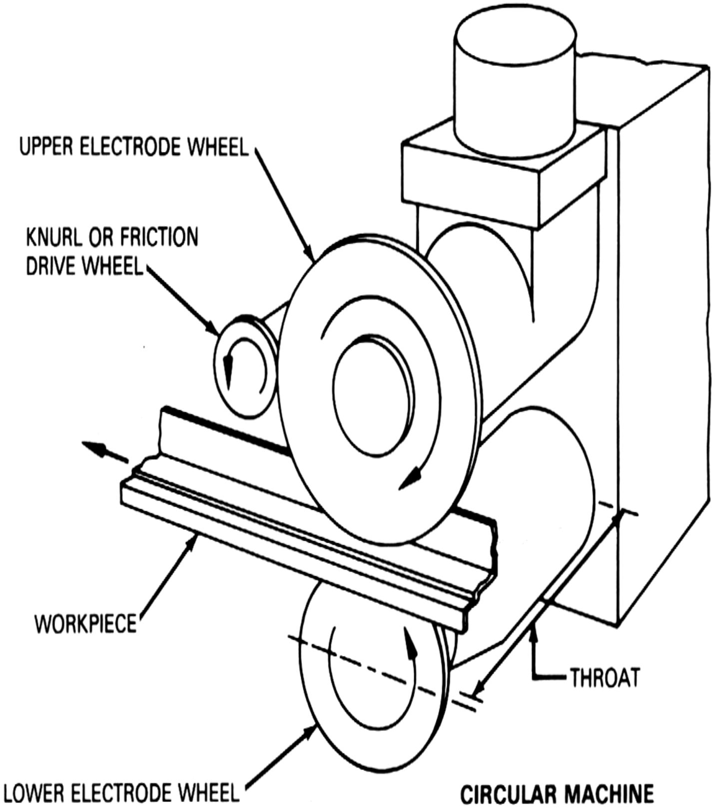
Two or more projection welds can be made simultaneously with one set of electrodes.



Seam welding

Seam welding is a variation of spot welding in which a series of overlapping nuggets is produced to obtain a continuous, leak tight seam.

One or both electrodes are generally wheels that rotate as the work passes between them. A series of separate spot welds may be made with a seam welding machine and wheel electrodes by suitably adjusting the travel speed and the time between welds.



PRINCIPLES OF OPERATION

- ‘Spot, Seam, and Projection welding operations involve a coordinated application of electric current and mechanical pressure of the proper magnitudes and durations.
- The welding current must pass from the electrodes through the work. Its continuity is assured by forces applied to the electrodes, or by projections which are shaped to provide necessary current density and pressure.
- The sequence of operation must first develop sufficient heat to raise a confined volume of metal to the molten state. This metal is allowed to cool while under pressure until it has adequate strength to hold the parts together.

Heat Generation

In an electrical conductor, the amount of heat generated depends upon three factors: (1) **the amperage**, (2) **the resistance of the conductor** (including interface resistance), and (3) **the duration of current**.

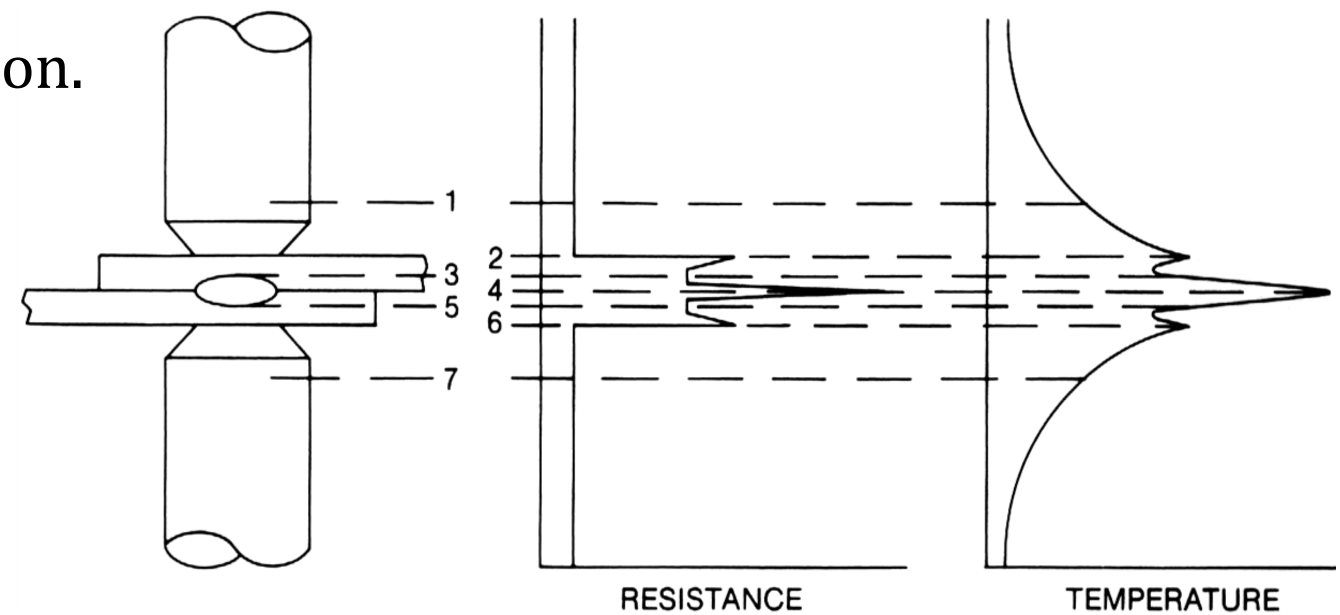
These three factors affect the heat generated as expressed in the formula:-

$$Q = I^2Rt$$

Q = heat generated, joules, I = current, amperes, R = resistance of the work, ohms, t = duration of current, seconds.

The heat generated is proportional to the square of the welding current and directly proportional to the resistance and the time. Part of the heat generated is used to make the and part is lost to the surrounding metal.

The welding current required to produce a given weld is approximately inversely proportional to the square root of the time. Thus, if the time is extremely short, the current required will be very high. A combination of high current and insufficiently short time may produce an undesirable distribution of heat in the weld zone, resulting in severe surface melting and rapid electrode deterioration.



Graphs of Resistance and Temperature as a Function of Location in the Diagrammed Circuit

Factors that affect the amount of heat generated

(1) The electrical resistances within the metal being welded and the electrodes,

(2) The contact resistances between the work pieces and between the electrodes and the work pieces, and

(3) The heat lost to the work pieces and the electrodes.

Effect of Welding Current

In the formula, $\mathbf{Q = I^2Rt}$, current has a greater effect on the generation of heat than either resistance or time. Therefore, it is an important variable to be controlled. Two factors that cause variation in welding current are

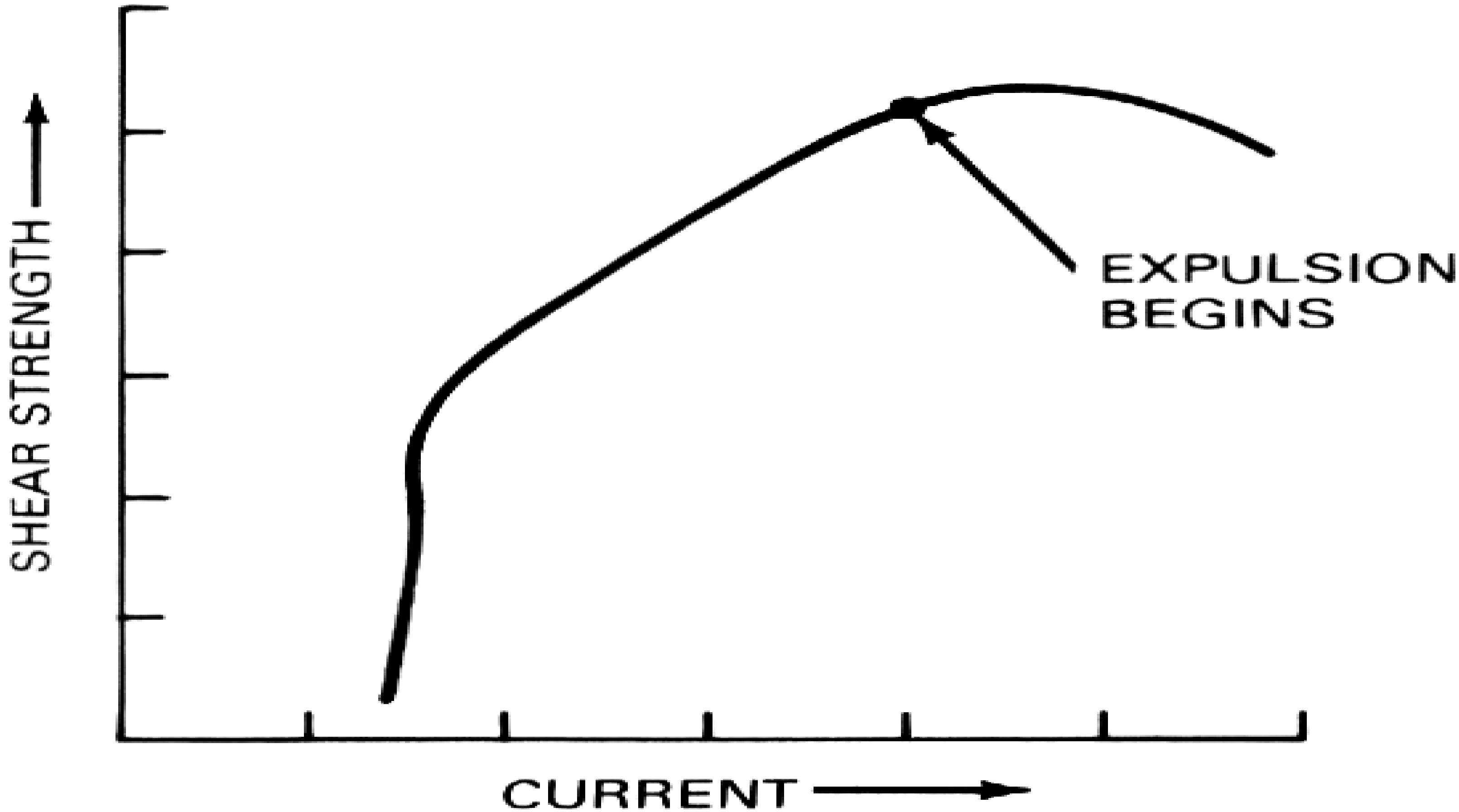
1. fluctuations in power line voltage and
2. variations in the impedance of the secondary circuit with AC machines.

An increase in electrode face area, or projection size in the case of projection welding, will decrease current density and welding heat. This may cause a significant decrease in weld strength.

A minimum current density for a finite time is required to produce fusion at the interface. Sufficient heat must be generated to overcome the losses to the adjacent base metal and the electrodes.

Weld nugget size and strength increase rapidly with increasing current density. Excessive current density will cause molten metal expulsion (resulting in internal voids), weld cracking, and lower mechanical strength properties.

In the case of spot and seam welding, excessive current will overheat the base metal and result in deep indentations in the parts and, it will cause overheating and rapid deterioration of the electrodes.

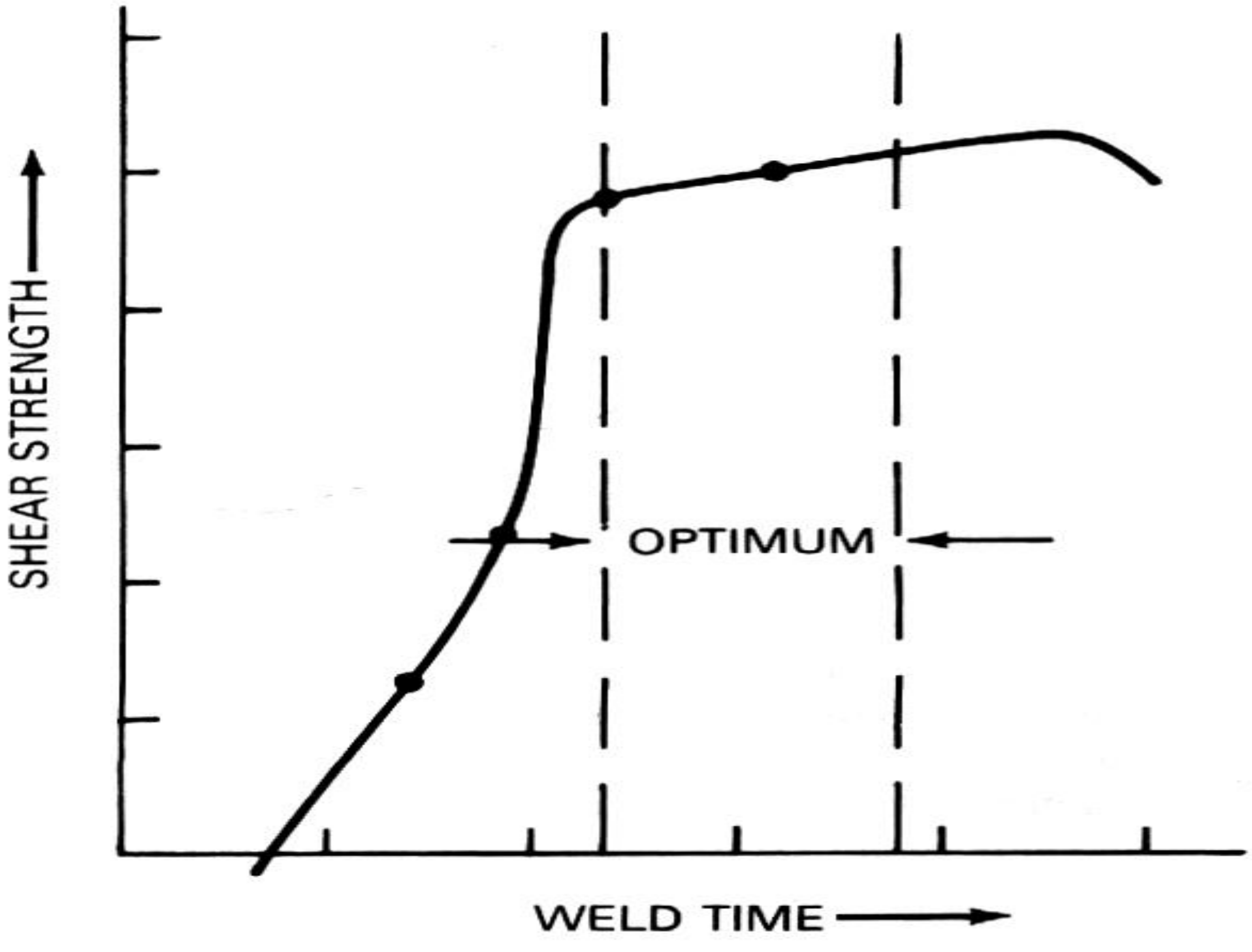


Effect of Welding Current on Spot Weld Shear Strength

Effect of Weld Time

- The rate of heat generation must be such that welds with adequate strength will be produced without excessive electrode heating and rapid deterioration.
- The total heat developed is proportional to weld time. Essentially, heat is lost by conduction into the surrounding base metal and the electrodes; a very small amount is lost by radiation. These losses increase with increases in weld time and in metal temperature, but they are essentially uncontrollable.

- Excessively long weld time will have the same effect as excessive amperage on the base metal and electrodes. Furthermore, the weld heat-affected zone will extend farther into the base metal.



Tensile-Shear Strength as a Function of Weld Time

Effect of Welding Pressure

- The resistance R in the heat formula is influenced by welding pressure through its effect on contact resistance at the interface between work pieces.
- Welding pressure is produced by the force on the joint by the electrodes. Electrode force is considered to be the net dynamic force of the electrodes upon the work, and it is the resultant pressure produced by force that affects the contact resistance.

Influence of Electrodes

- Electrodes play a vital role in the generation of heat because they conduct the welding current to the work. In the case of spot and seam welding, the electrode contact area largely controls the welding current density and the resulting weld size.
- Electrodes must have good electrical conductivity, but they must also have adequate strength and hardness to resist deformation caused by repeated applications of high electrode force.

- Deformation or “mushrooming” of the electrode face increases the contact area and decreases both current density and welding pressure. Weld quality will deteriorate as tip deformation proceeds; consequently, the electrodes must be reshaped or replaced at intervals to maintain adequate heat generation for acceptable weld properties.

- **Influence of Surface Condition:-** The surface condition of the parts influences heat generation because contact resistance is affected by oxides, dirt, oil, and other foreign matter on the surfaces. The most uniform weld properties are obtained when the surfaces are clean.
- **Influence of Metal Composition:-** The electrical receptivity of a metal directly influences resistance heating during welding. In high-conductivity metals such as silver and copper, little heat is developed even under high-current densities; The small amount of heat generated is rapidly transmitted into the surrounding work and the electrodes.

Heat Balance

Heat balance occurs when the depths of fusion (penetration) in the two work pieces are approximately the same. The majority of spot and seam welding applications are confined to the welding of equal thicknesses of the same metal, with electrodes of the same alloy, shape, and size, Heat balance in these eases is automatic; however, in many applications, the heat generated in the parts is unbalanced.

Heat balance may be affected by the following:

- Relative electrical and thermal conductivities of the metals to be joined
- Relative geometry of the parts at the joint
- Thermal and electrical conductivities of the electrodes
- Geometry of the electrodes

Heat Dissipation

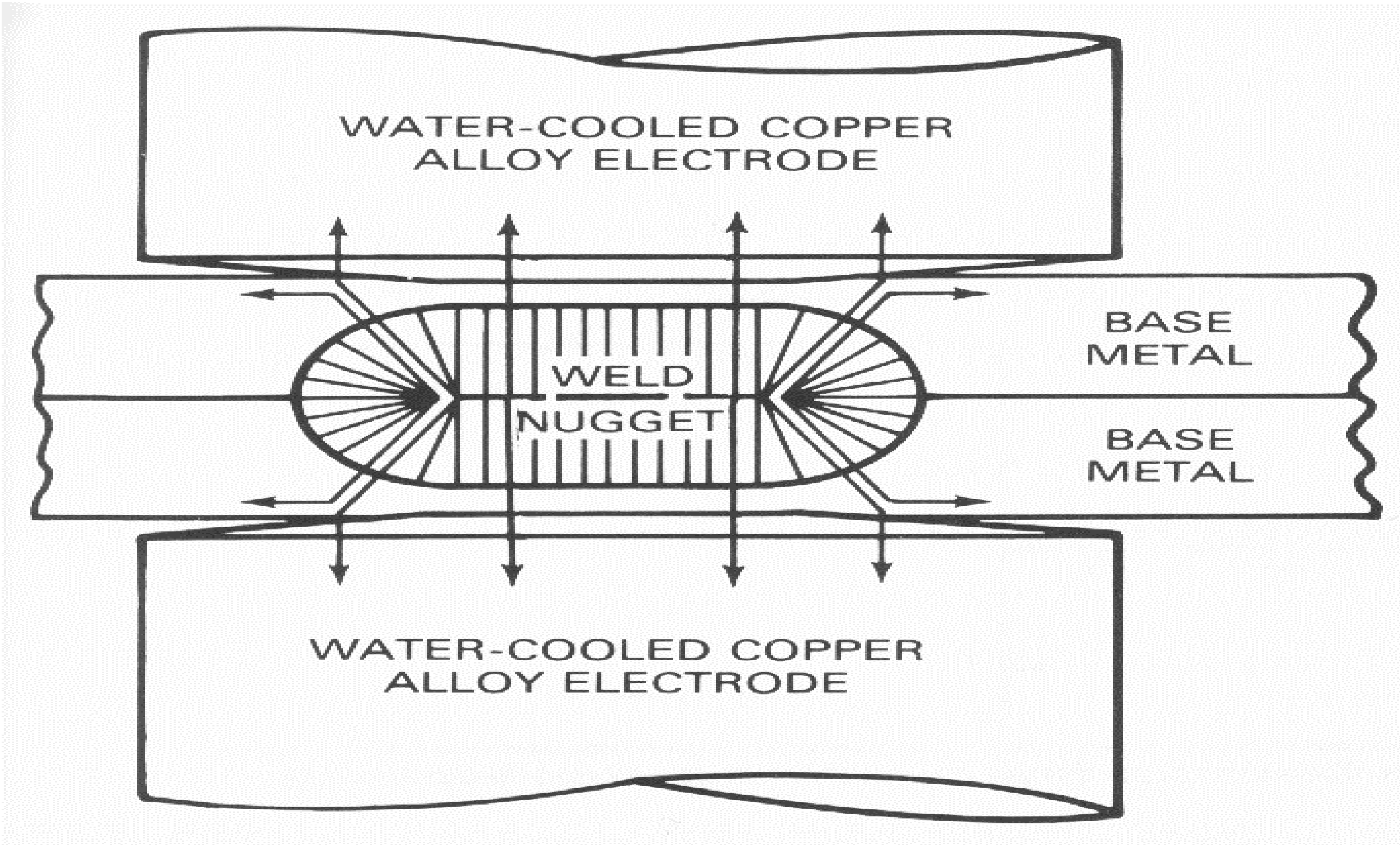
During welding, heat is lost by conduction into the adjacent base metal and the electrodes, as shown in following figure. This heat dissipation continues at varying rates during current application and afterward, until the weld has cooled to room temperature.

It may be divided into two phases:

(1) during the time of current application, and

(2) after the cessation of current. The extent of the first phase depends upon the composition and mass of the work pieces, the welding time, and the external cooling means. The composition and mass of the work pieces ate determined by the design.

External cooling depends upon the welding setup and the welding



Heat dissipation during Resistance Welding into the surrounding base metal and electrodes

WELDING CYCLE

THE WELDING CYCLE for spot, seam, and projection welding

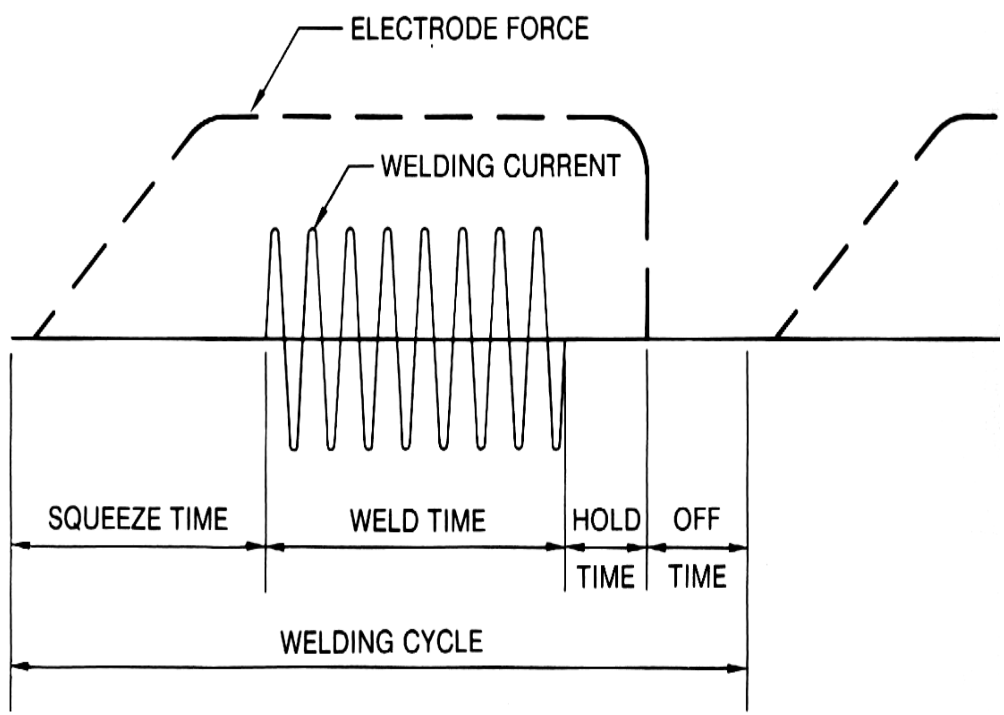
Consists basically of four phases:

(**1) Squeeze time** - the time interval between timer initiation and the first application of current; the time interval is to assure that the electrodes contact the work and establish the full electrode force before welding current is applied.

(2) Weld time - the time that welding current is applied to the work in making a weld in single-impulse welding.

(3) Hold time - the time during which force is maintained to the work after the last impulse of current ends; during this time, the weld nugget solidifies and is cooled until it has adequate strength.

(4) Off time - the time during which the electrodes are off the work and the work is moved to the next weld location; the term is generally applied where the welding cycle is repetitive. figure in next slide shows a basic welding cycle.



Welding Cycle for Spot and Projection Welding

One or more of the following features may be added to this basic cycle to improve the physical and mechanical properties of the weld zone:

(1) Precompression force to seat the electrodes and work pieces together

(2) Preheat to reduce the thermal gradient in the metal at the start of weld time

(3) Forging force to consolidate the weld nugget

(4) Quench and temper times to produce the desired weld strength properties in hardenable alloy steels

(5) Postheat to refine the weld grain size in steels

(6) Current decay to retard cooling on aluminum

ELECTRODES

RESISTANCE WELDING ELECTRODES perform four functions:

1) Conduct the welding current to the work, and for spot and seam welding, fix the current density in the weld In projection welding, the current density is determined by the size, shape, and number of projections.

2) Transmit a force to the work pieces.

3) Dissipate part of the heat from the weld zone.

4) Maintain relative alignment and position of the work pieces in projection welding.

SURFACE PREPARATION

For all types of resistance welding, the condition of the surfaces of the parts to be welded largely controls how consistent the weld quality will be.

The contact resistance of the faying surfaces has a significant influence on the amount of welding heat generated; hence,

- the electrical resistance of these surfaces must be highly uniform for consistent results.
- They must be free of high-resistance materials such as paint, scale, thick oxides, and heavy oil and grease.
- If it is necessary to use a primer paint on the faying surfaces prior to welding, as is sometimes the ease, the welding operation must be performed immediately after applying the primer, or special conducting primers must be used.
- For best results, the primer should be as thin as possible so that the electrode force will displace it and give metal-to-metal contact.
- The methods used for preparing surfaces for resistance welding differ for various metals and alloys.

APPLICATIONS

- Resistance spot welding (RSW) is used to fabricate sheet metal assemblies up to about 3.2 mm thickness, when the design permits the use of lap joints and leak tight seams will not be required. Occasionally the process is used to join steel plates 6.35 mm thick or thicker; however, loading of such joints is limited and the joint overlap adds weight and cost to the assembly when compared to the cost of an arc welded butt joint.
- The process is used in preference to mechanical fastening, such as riveting or screwing, when disassembly for maintenance is not required. It is much faster and more economical because separate fasteners are not needed for assembly.
- Spot welding is used extensively for joining low carbon steel sheet metal components for automobiles, cabinets, furniture, and similar products. Stainless steel, aluminum, and copper alloys are commonly spot welded commercially.

ADVANTAGES AND LIMITATIONS

The major advantages of resistance spot welding are its high speed and adaptability for automation in high-rate production of sheet metal assemblies. Spot welding is also economical in many job shop operations, because it is faster than arc welding or brazing and requires less skill to perform.

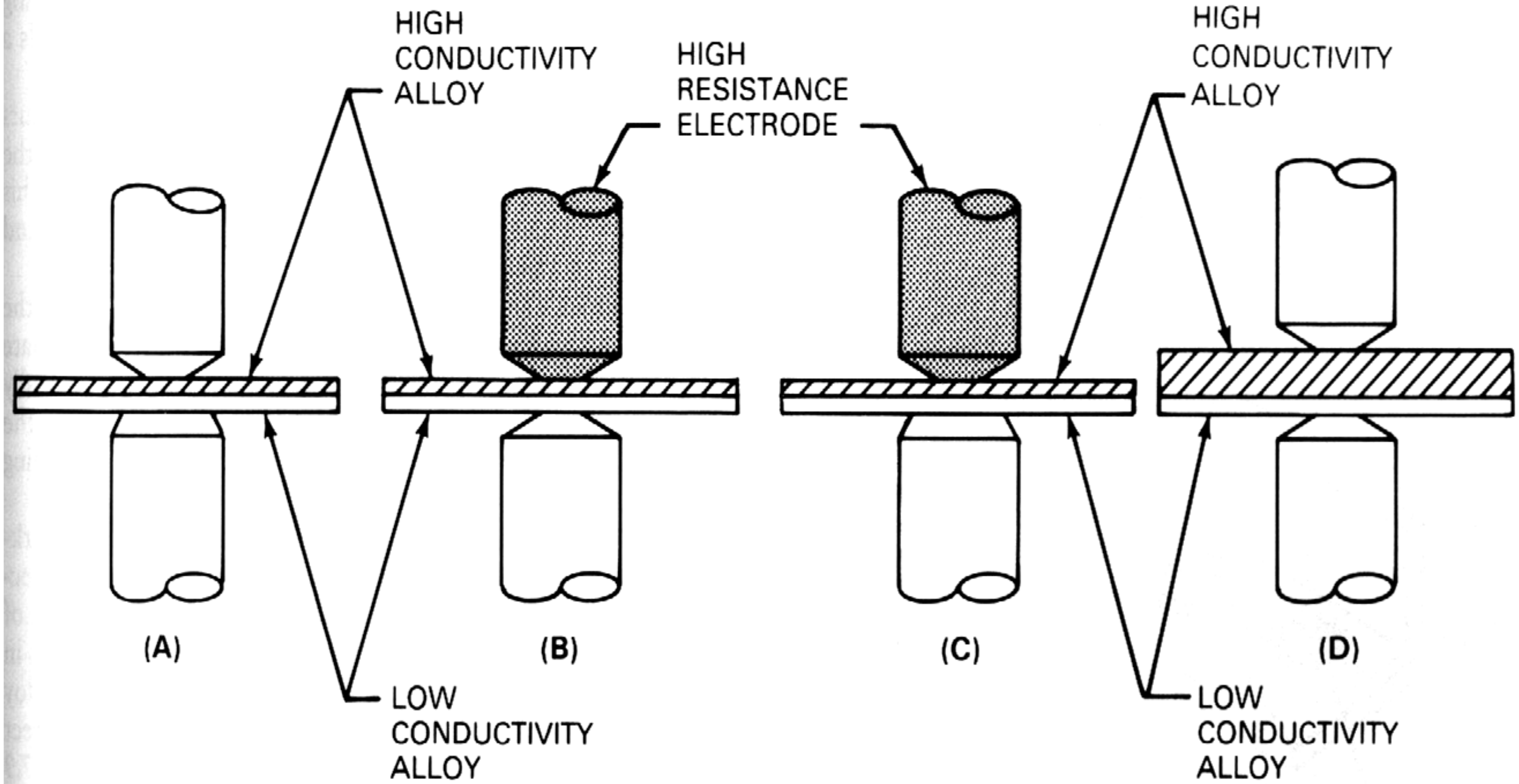
The process also has some limitations:

- Disassembly for maintenance or repair is very difficult.
- A lap joint adds weight and material cost to the product, when compared to a butt joint.
- The equipment costs are generally higher than the costs of most arc welding equipment.
- The short time, high-current power requirement produces unfavorable line power demands, particularly with single phase machines.
- Spot welds have low tensile and fatigue strengths, because of the notch around the periphery of the nugget between the sheets.
- The full strength of the sheet cannot prevail across a spot welded joint, because fusion is intermittent and loading is eccentric due to the overlap.

Joint design

Factors that should be considered when designing for spot welding include:

1. Edge distance
2. Joint overlap
3. Fit-up
4. Weld spacing
5. Joint accessibility
6. Surface making
7. Weld strength



(A) ELECTRODE WITH SMALLER FACE AREA AGAINST HIGH-CONDUCTIVITY ALLOY
(B) HIGH-ELECTRICAL RESISTANCE ELECTRODE AGAINST HIGH-CONDUCTIVITY ALLOY
(C) SAME AS B. WITH ADDITION OF LARGER ELECTRODE FACE AGAINST LOW-CONDUCTIVITY MATERIAL
(D) INCREASE THICKNESS OF HIGH-CONDUCTIVITY WORKPIECE

Typical techniques for improving joint heat balance when spot welding metals with different electrical conductivities