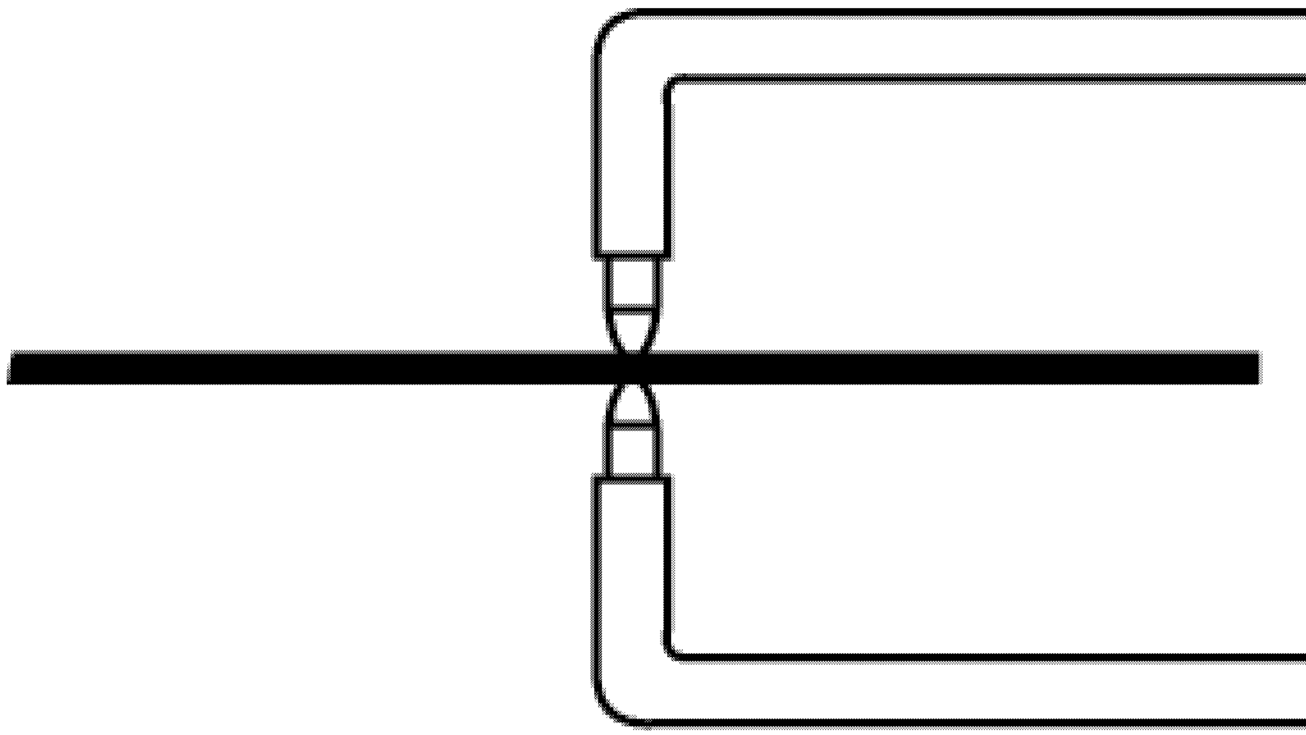
HANDBOOK FOR

Resistance Spot Welding



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LIST OF ILLUSTRATIONS

⚠ WARNING **ARC WELDING can be hazardous.**

This document contains general information about the topics discussed herein. This document is not an application manual and does not contain a complete statement of all factors pertaining to those topics.

The installation, operation, and maintenance of arc welding equipment and employment of procedures described in this document should be conducted only by qualified persons in accordance with applicable codes, safe practices, and manufacturer's instructions.

Always be certain that work areas are clean and safe and that proper ventilation is used. Misuse of equipment and failure to observe applicable codes and safe practices can result in serious personal injury and property damage.

SAFETY

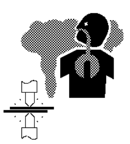
⚠ WARNING — **SPOT WELDING can be hazardous.**

PROTECT YOURSELF AND OTHERS FROM POSSIBLE SERIOUS INJURY OR DEATH. KEEP CHILDREN AWAY PACKEMAKER WEARERS KEEP AWAY UNTIL CONSULTING YOUR DOCTOR.

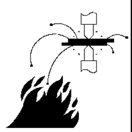
In resistance spot welding, as in most jobs, exposure to certain hazards occurs. Spot welding is safe when precautions are taken. The safety information given below is only a summary of the more complete safety information that will be found in the Safety Standards listed in the Owner's Manual. Read and follow all Safety Standards.

HAVE ALL INSTALLATION, OPERATION, MAINTENANCE, AND REPAIR WORK PERFORMED ONLY BY QUALIFIED PEOPLE.

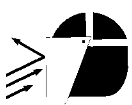
ELECTRIC SHOCK can kill.
- Always wear dry insulating gloves.
- Insulate yourself from work and ground.
- Do not touch live electrical parts.
- Keep all panels and covers securely in place.



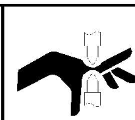
FUMES AND GASES can be hazardous to your health.
- Keep your head out of the fumes.
- Ventilate area, or use suction device at weld area.
- Read Material Safety Data Sheets (MSDSs) and manufacturer's instructions for metals, coatings, and cleaners.



WELDING can cause fire or explosion.
- Do not weld near flammable material.
- Watch for fire; keep extinguisher nearby.
- Allow work and equipment to cool before handling.
- Do not locate unit over combustible surfaces.
- Protect area and persons from flying sparks.

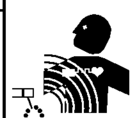


SPARKS AND HOT METAL can inure.
- Wear face shield or safety goggles.
- Wear body protection.
- Allow tips and work to cool before handling.

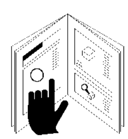


MOVING PARTS can injure.
- Do not put hands between tips.
- Keep away from pinch points.
- Keep guards in place.

HOT PARTS can cause injury.
- Allow cooling period before touching welded metal.
- Wear protective gloves and clothing.



MAGNETIC FIELDS FROM HIGH CURRENTS can affect pacemaker operation.
- Pacemaker wearers keep away.
- Wearers should consult their doctor before going near resistance spot welding operations.



Read and follow Safety Precautions at beginning of Owner's Manual for basic spot welding safety information.

INTRODUCTION

Resistance welding is one of the oldest of the electric welding processes in use by industry today. The weld is made by a combination of heat, pressure, and time. As the name resistance welding implies, it is the resistance of the material to be welded to current flow that causes a localized heating in the part. The pressure exerted by the tongs and electrode tips, through which the current flows, holds the parts to be welded in intimate contact before, during, and after the welding current time cycle. The required amount of time current flows in the joint is determined by material thickness and type, the amount of current flowing, and the cross-sectional area of the welding tip contact surfaces.

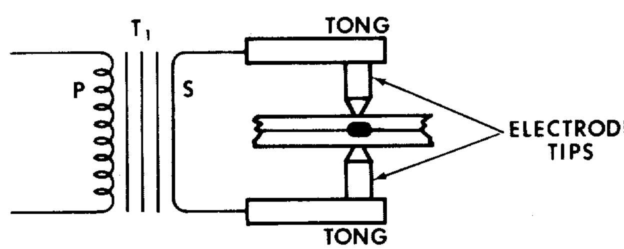


Figure 1 - Resistance Spot Welding Machine With Work

In Figure 1, a complete secondary resistance spot welding circuit is illustrated. For clarity, the various parts of the resistance spot welding machine are identified.

Resistance spot welding is accomplished when current is caused to flow through electrode tips and the separate pieces of metal to be joined. The resistance of the base metal to electrical current flow causes localized heating in the joint, and the weld is made.

The resistance spot weld is unique because the actual weld nugget is formed internally with relation to the surface of the base metal. Figure 2 shows a resistance spot weld nugget compared to a gas tungsten-arc (Tig) spot weld.

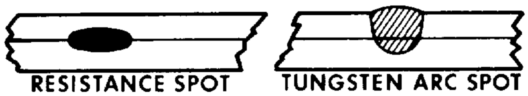


Figure 2 - Resistance And Tig Spot Weld Comparison

The gas tungsten-arc spot is made from one side only. The resistance spot weld is normally made with electrodes on each side of the workpiece. Resistance spot welds may be made with the workpiece in any position.

The resistance spot weld nugget is formed when the interface of the weld joint is heated due to the resistance of the joint surfaces to electrical current flow. In all cases, of course, the current must flow or the weld cannot be made. The pressure of the electrode tips on the workpiece holds the part in close and intimate contact during the making of the weld. Remember, however, that resistance spot welding machines are NOT designed as force clamps to pull the workpieces together for welding.

HEAT GENERATION

A modification of Ohm's Law may be made when watts and heat are considered synonymous. When current is passed through a conductor the electrical resistance of the conductor to current flow will cause heat to be generated. The basic formula for heat generation may be stated:

$H = I^2R$ where H = Heat
I^2 = Welding Current Squared
R = Resistance

The secondary portion of a resistance spot welding circuit, including the parts to be welded, is actually a series of resistances. The total additive value of this electrical resistance affects the current output of the resistance spot welding machine and the heat generation of the circuit.

The key fact is, although current value is the same in all parts of the electrical circuit, the resistance values may vary considerably at different points in the circuit. The heat generated is directly proportional to the resistance at any point in the circuit.

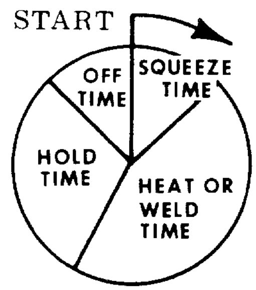


Figure 3 - Spot Welding Time Cycle

SQUEEZE TIME - Time between pressure application and weld.
HEAT OR WELD TIME - Weld time in cycles.
HOLD TIME - Time that pressure is maintained after weld is made.
OFF TIME - Electrodes separated to permit moving of material for next spot.

The resistance spot welding machines are constructed so minimum resistance will be apparent in the transformer, flexible cables, tongs, and electrode tips. The resistance spot welding machines are designed to bring the welding current to the weldment in the most efficient manner. It is at the weldment that the greatest relative resistance is required. The term "relative" means with relation to the rest of the actual welding circuit.

There are six major points of resistance in the work area. They are the following:

1. The contact point between the electrode and top workpiece.
2. The top workpiece.
3. The interface of the top and bottom workpieces.
4. The bottom workpiece.
5. The contact point between the bottom workpiece and the electrode.
6. Resistance of electrode tips.

The resistances are in series, and each point of resistance will retard current flow. The amount of resistance at point 3, the interface of the workpieces, will depend on the heat transfer capabilities of the material, its electrical resistance, and the combined thickness of the materials at the weld joint. It is at this part of the circuit that the nugget of the weld is formed.

THE TIME FACTOR

Resistance spot welding depends on the resistance of the base metal and the amount of current flowing to produce the heat necessary to make the spot weld. Another important factor is time. In most cases several thousands of amperes are used in making the spot weld. Such amperage values, flowing through a relatively high resistance, will create a lot of heat in a short time. To make good resistance spot welds, it is necessary to have close control of the time the current is flowing. Actually, time is the only controllable variable in most single impulse resistance spot welding applications. Current is very often economically impractical to control. It is also unpredictable in many cases.

Most resistance spot welds are made in very short time periods. Since alternating current is normally used for the welding process, procedures may be based on a 60 cycle time (sixty cycles = 1 second). Figure 3 shows the resistance spot welding time cycle.

Previously, the formula for heat generation was used. With the addition of the time element, the formula is completed as follows:

$H = I^2RTK$ where
H = Heat
I^2 = Current Squared
R = Resistance
T = Time
K = Heat Losses

Control of time is important. If the time element is too long, the base metal in the joint may exceed the melting (and possibly the boiling) point of the material. This could cause faulty welds due to gas porosity. There is also the possibility of expulsion of molten metal from the weld joint, which could decrease the cross section of the joint weakening the weld. Shorter weld times also decrease the possibility of excessive heat transfer in the base metal. Distortion of the welded parts is minimized, and the heat affected zone around the weld nugget is substantially smaller.

PRESSURE

The effect of pressure on the resistance spot weld should be carefully considered. The primary purpose of pressure is to hold the parts to be welded in intimate contact at the joint interface. This action assures consistent electrical resistance and conductivity at the point of weld. The tongs and electrode tips should NOT be used to pull the workpieces together. The resistance spot welding machine is not designed as an electrical "C" clamp! The parts to be welded should be in intimate contact BEFORE pressure is applied.

Investigations have shown that high pressures exerted on the weld joint decrease the resistance at the point of contact between the electrode tip and the workpiece surface. The greater the pressure the lower the resistance factor.

Proper pressures, with intimate contact of the electrode tip and the base metal, will tend to conduct heat away from the weld. Higher currents are necessary with greater pressures and, conversely, lower pressures require less amperage from the resistance spot welding machine. This fact should be carefully noted particularly when using a heat control with the various resistance spot welding machines.

ELECTRODE TIPS

Copper is the base metal normally used for resistance spot welding tongs and tips. The purpose of the electrode tips is to conduct the welding current to the workpiece, to be the focal point of the pressure applied to the weld joint, to conduct heat from the work surface, and to maintain their integrity of shape and characteristics of thermal and electrical conductivity under working conditions.

Electrode tips are made of copper alloys and other materials. The Resistance Welders Manufacturing Association (RWMA) has classified electrode tips into two groups:

Group A - Copper based alloys
Group B - Refractory metal tips

The groups are further classified by number. Group A, Class I, II, III, IV, and V are made of copper alloys. Group B, Class 10, 11, 12, 13, and 14 are the refractory alloys.

Group A, Call I electrode tips are the closest in composition to pure copper. As the Class Number goes higher, the hardness and annealing temperature values increase, while the thermal and electrical conductivity decrease.

Group B compositions are sintered mixtures of copper and tungsten, etc., designed for wear resistance and compressive strength at high temperatures. Group B, Class 10 alloys have about 40 percent the conductivity of copper with conductivity decreasing as the number value increases. Group B electrode tips are not normally used for applications in which resistance spot welding machines would be employed.

PRACTICAL USES OF RESISTANCE SPOT WELDING

⚠ WARNING SPOT WELDING can be hazardous. Read and follow Safety Section at front of this book as well as the Owner's Manual and all labels on the equipment.

Resistance spot welding techniques do not require extensive or elaborate safety precautions. There are some common sense actions that can, however, prevent injury to the operator.

Anytime work is being done in a shop, it is a wise rule to wear safety glasses. Resistance spot welding is no exception to the rule! Very often metal or oxides are expelled from the joint area. Protection of the face and especially of the eyes is necessary to escape serious injury.

Another area of concern is ventilation. This can be a serious problem when resistance spot welding galvanized metals (zinc coated) or metals with other coatings such as lead. The fumes from the welding operation have a certain toxicity which will cause illness to the operator. Proper ventilation can reduce the fume concentration in the welding area.

As explained in the preceding discussion on the fundamentals of resistance spot welding, there is a definite relationship between time, current, and pressure. Current and pressure help create the heat in the weld. Time helps determine the size and shape of the weld nugget.

If the weld current is too low for the application, current density is too weak to make the weld. This condition will also overheat the electrode tips which can cause them to anneal, mushroom, and possibly be contaminated. Even though time is increased, the amount of heat generated is less than the losses due to radiation and conduction in the workpiece and thermal conduction of the electrodes. The result is the possibility, with long weld times at low currents, of overheating the entire base metal area between the electrodes. This could cause burning of the top and bottom surfaces of the workpiece as well as possibly imbedding the electrode tips in the workpiece surfaces.

As current density is increased, the weld time is decreased proportionately. If, however, the current density becomes too high, there is the possibility of expelling molten metal from the interface of the joint thereby weakening the weld. The ideal time and current density condition is somewhere just below the level of causing metal to be expelled.

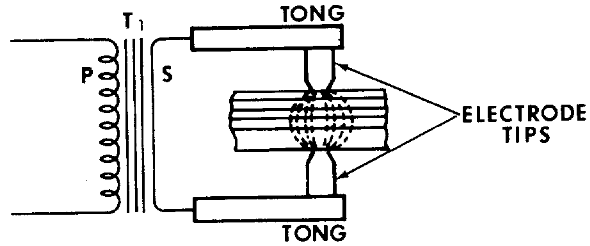


Figure 4 - Resistance Spot Weld Heat Zones

It is apparent that the heat input cannot be greater than the total dissipation rate of the workpiece and the electrode without having metal expelled from the joint.

An interesting discovery has been developed recently concerning the flow of current through the workpiece. Until recently, current was considered to flow in a straight line through the weld joint. This is not necessarily true when multiple thicknesses of material are being welded. The characteristic is for the current to "fan out" thereby decreasing the current density at the point of weld the greatest distance from the electrode tips. The illustration (Figure 4) shows the resistance spot weld heat zones for several thicknesses of metal. We note that the uncontrollable variables (such as interface resistance, thermal conductivity, and interface contamination) are multiplied when resistance spot welding several thicknesses of material. Quality levels will be much lower for "stack" resistance spot welding, which explains why such welding practices are avoided whenever possible.

Disregarding the quality factor, it becomes apparent that the number of thicknesses of a material which may be successfully resistance spot welded at one time will depend on the material type and thickness as well as the KVA capacity of the resistance spot welding machine.

KVA rating, duty cycle, and other pertinent information is shown on all resistance spot welding machine nameplates. The catalog literature and the operating manuals provide data on the maximum combined thicknesses of material that each unit can weld. A table showing the various models of resistance spot welding machines is located in the back of this book.

ELECTRODE TIP SIZE

When you consider that it is through the electrode that the welding current is permitted to flow into the workpiece, it is logical that the size of the electrode tip point controls the size of the resistance spot weld. Actually, the weld nugget diameter should be slightly less than the diameter of the electrode tip point.

If the electrode tip diameter is too small for the application, the weld nugget will be small and weak. If, however, the electrode tip diameter is too large, there is danger of overheating the base metal and developing voids and gas pockets. In either instance, the appearance and quality of the finished weld would not be acceptable.

To determine electrode tip diameter will require some decisions on the part of the weldment designer. The resistance factors involved for different materials will certainly have some bearing on electrode tip diameter determination. A general formula has been developed for low carbon steel. It will provide electrode tip diameter values that are usable for most applications.

NOTE: The TIP DIAMETER discussed in this text refers to the electrode tip diameter at the point of contact with the workpiece. It does not refer to the major diameter of the total electrode tip.

The formula generally used for low carbon steel is the following:

Electrode tip diameter = 0.100" + 2t

where "t" is the thickness in inches of one thickness of the metal to be welded. This formula is applicable to the welding of metals of dissimilar thicknesses. The formula is applied to each thickness individually, and the proper electrode tip diameter selected for each size of the joint.

For example, if two pieces of 0.062" sheet steel are to be joined, the electrode tip diameter would be the same for both sides of the joint. The calculation would be as follows:

Electrode tip dia. = 0.100 + 2t
= 0.100 + 2 x -.062"
= 0.100 + 0.124"
Electrode tip dia. = 0.224"

If the two pieces were unequal in thickness, such as one piece 0.062" and the other 0.094", two calculations would have to be made. Each thickness would be treated as the basis for one electrode tip diameter determination, as follows:

Electrode tip dia. = 0.100 + 2t
= 0.100 + 2 x 0.062"
= 0.100 + 0.124"
Electrode tip dia. = 0.224" (one side only)

For the other side, the calculation is as follows:

Electrode tip dia. = 0.100 + 2t
= 0.100 + 2 x 0.9094"
= 0.100 + 0.188"
Electrode tip dia. = 0.288" (one side only)

Remember that the formula is applicable to low carbon steels and may not be correct for other materials.

PRESSURE OR WELDING FORCE

The pressure exerted by the tongs and the electrode tips on the workpiece have a great effect on the amount of weld current that flows through the joint. The greater the pressure, the higher the welding current value will be, within the capacity of the resistance spot welding machine.

Setting pressure is relatively easy. Normally, samples of the materials to be welded are placed between the electrode tips and checked for adequate pressure to make the weld. If more or less pressure is required, the operating manual for the resistance spot welding machine will give explicit directions for making the correct setting. As part of the setting up operation, the tong and electrode tip travel should be adjusted to the minimum required amount to prevent "hammering" the electrode tips and tip holders.

Tables are provided in the appendix of this book to serve as guidelines in making the necessary settings to obtain good resistance spot welding conditions. They should be used as guides only, since some slight variation in the settings may be necessary for a specific application.

MISCELLANEOUS DATA

This section of the text is designed to provide information regarding several of the variables that occur in some resistance spot welding applications.

HEAT BALANCE

There is no particular problem of heat balance when the materials to be welded are of equal type and thickness. The heat balance, in such cases, is automatically correct if the electrode tips are of equal diameter, type, etc. Heat balance may be defined as the conditions of welding in which the fusion zones of the pieces to be joined are subjected to equal heat and pressure.

When the weldment has parts of unequal thermal characteristics, such as copper and steel, a poor weld may result for several reasons. The metals may not alloy properly at the interface of the joint. There may be a greater amount of localized heating in the steel than in the copper. The reason would be because copper has low electrical resistance and high thermal transfer characteristics, while steel has high electrical resistance and low thermal transfer characteristics.

Correct heat balance may be obtained in a weldment of this type by one of several methods. Figure 5 illustrates three possible solutions to the problem. Figure 5 (a) shows the use of a smaller electrode tip area for the copper side of the joint to equalize the fusion characteristics by varying the current density in the dissimilar materials.

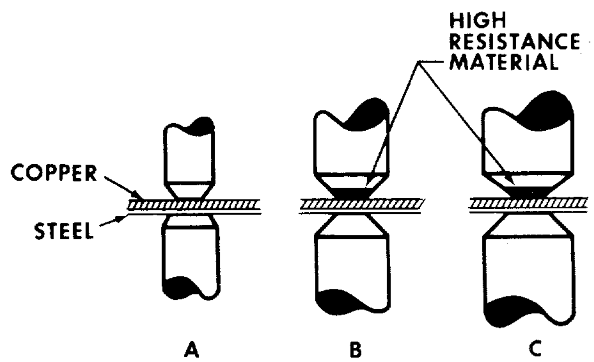


Figure 5 - Techniques For Obtaining Heat Balance

Figure 5 (b) shows the use of an electrode tip with high electrical resistance material, such as tungsten or molybdenum, at the contact point. The result is to create approximately the same fusion zone in the copper as in the steel. A combination of the two methods is shown in Figure 5 (c).

SURFACE CONDITIONS

All metals develop oxides which can be detrimental to resistance spot welding. Some oxides, particularly those of a refractory nature, are more troublesome than others. In addition, the mill scale found on hot-rolled steels will act as an insulator and prevent good quality resistance spot welding. Surfaces to be joined by this process should be clean, free of oxides, chemical compounds, and have a smooth surface.

MATERIALS DATA FOR RESISTANCE SPOT WELDING

This section of the text will consider methods used for resistance spot welding some of the common metals that are used in fabrication work. It is not intended that all the possible problems that could arise will be answered. The purpose of this part of the text is to provide general operational data for use with resistance welding machines. Where applicable, the data provided will be related to specific models and size (KVA) of units.

MILD STEEL

Mild or low carbon steel comprises the largest percentage of material welded with the resistance spot welding process. All low-carbon steels are readily weldable with the process if proper equipment and procedures are used.

The carbon steels have a tendency to develop hard, brittle welds as the carbon content increases if proper post-heating procedures are not used. Quick quenching of the weld, where the weld nugget cools rapidly, increases the probability of hard, brittle micro-structure in the weld.

Hot rolled steel will normally have mill scale on the surface of the metal. This type of material is usually not resistance spot welded with resistance welding machines of the KVA ratings of specific built units.

Cold rolled steel (CRS) and hot rolled steel, pickled and oiled (HRSP & O), may be resistance spot welded with very little trouble. If the oil concentration is excessive on the sheet metal, it could cause the formation of carbon at the electrode tips thereby decreasing their useful life. Degreasing or wiping is recommended for heavily oiled sheet stock.

The resistance spot weld should have shear strength equal to the base metal shear strength and should exceed the strength of a rivet or a fusion plug weld of the same cross sectional area. Shear strength is normally accepted as the criteria for resistance spot weld specifications, although other methods may be used.

A common practice is to "peel" two welded sample strips apart to see if a clean "rivet" is pulled from one piece. If it is, the resistance spot welding condition is considered correct.

With magnetic materials such as mild steel, the current through the weld can vary substantially depending on how much of the magnetic material is within the tong loop. The tong loop is sometimes called the "throat" of the resistance spot welding machine.

For example, the part to be welded may have the largest amount of the base metal within the throat of the unit for any one resistance spot weld and almost none of the base metal in the throat for the second spot weld. The current at the weld joint will be less for the first spot weld. The reason is the reactance caused by the ferrous material within the arc welding circuit.

In any material being resistance spot welded, there is the possibility of shunt currents flowing through the previously made spot welds. This can rob the second spot weld of the welding current necessary for making the joint.

Resistance spot welding machines are applicable to low carbon steel welding. They must be used within their rated capacity of total thickness of material for best results. They should not be used over the duty cycle since damage to the contactor and transformer may result. The 50 percent duty cycle provided for this type of equipment should be adequate for all applications within their rating. The 50 percent duty cycle is a RWMA standard rating for general duty resistance welding machines. The 50 percent duty cycle is based on a 10 second time period and means the unit can weld for 5 seconds out of each 10 second time period.

Table 1 provides the rating information for all models of resistance spot welding machines. The open -circuit voltage and short-circuit current for different tong lengths, etc., are given. The short-circuit currents values are according to RWMA test procedures for copper-to-copper contact. The values considered do not have weld metal in between the tips. The combined metal thickness that each model can accommodate is also shown.

LOW ALLOY AND MEDIUM CARBON STEELS

There are some pertinent differences in resistance spot welding low alloy and medium carbon steels as compared to mild or low carbon steels. The resistance factor for the low alloy and medium carbon steels is higher; therefore, the current requirements are slightly lower. Time and temperature are more critical since metallurgical changes will be greater with these alloys. There is certainly more possibility of weld embrittlement than there is with mild steel.

Resistance spot welding pressures are normally higher with these materials because of the additional compressive strength inherent in the low alloy and medium carbon steels. It is always a good idea to use longer welding times when welding these alloys to retard the cooling rate and permit more ductile welds.

STAINLESS STEELS

The chrome-nickel steel alloys (austenitic) have very high electrical resistance and are readily joined by resistance spot welding. The consideration of great importance with these materials is rapid cooling through the critical range, 800° - 1400° F. The rapid quench associated with resistance spot welding is ideal for reducing the possibility of chromium carbide precipitation at the grain boundaries. Of course, the longer the weldment is held at the critical temperatures, the greater the possibility of carbide precipitation.

STEELS, DIP COATED OR PLATED

The overwhelming majority of material in this category is galvanized, or zinc coated steel. Although some galvanized steel is electro-plated, the dip-coated costs less and is in predominant use. The zinc coating is uneven in thickness on dip coated steel. The resistance factor will vary from weld to weld, and it is very difficult to set conditions in chart form for the material.

It is impossible to maintain the integrity of the galvanized coating when resistance spot welding. The low melting point of the zinc coating, compared to the fusion temperature of the steel sheet, causes the zinc to vaporize. Of course, there must be adequate pressure to force the zinc aside at the weld interface to permit steel-to-steel fusion. Otherwise, the strength of the resistance spot weld is open to question.

Materials are available to repair the external damage to the coating that may be incurred because of the welding heat. There is no remedy for the loss of coating material at the interfaces of the weld, unfortunately. In fact, the vaporization of the zinc can cause porosity in the weld and a general weakening of the expected shear strength.

> **⚠ WARNING** The VAPORIZED ZINC, upon condensation to solid material, forms particles shaped like fishhooks. These particles CAN IMBED THEMSELVES IN THE TISSUES OF THE BODY and cause irritation. Use forced ventilation or exhaust at the weld area and wear long sleeve shirts, long pants, and protective face shields when working with this process and coated materials.

Other coated material, such as terne plate (lead coated) may have varying degrees of toxicity. Adequate ventilation is mandatory when working with these materials.

The vaporization of the coating material has a tendency to foul the electrode tips. The tips should be cleaned frequently to prevent the alloying of the lower melting materials with the copper tips. The tips may require cleaning and dressing every fourth or fifth weld to maintain quality in the product, although for some galvanized applications the best welds are made after several spots blacken the tips. The use of short weld times will increase the possibility of good welds with the least amount of tip fouling.

ALUMINUM AND ALUMINUM ALLOYS

Resistance spot welding machines with KVA ratings much greater than 20 KVA are necessary to make sound welds on most aluminum materials and any other high conductivity type of base metal. The electrical conductivity of aluminum is high, and welding machines must provide high currents and exact pressures in order to provide the heat necessary to melt the aluminum and produce a sound weld.

SUMMARY

Resistance spot welding is a welding technique that is used for almost all known metals. The actual weld is made at the interface of the parts to be joined. The electrical resistance of the material to be welded causes a localized heating at the interfaces of the metals to be joined. Welding procedures for each type of material must be developed for the most satisfactory results.

It is possible that shunt currents flowing through a previously made spot weld will take welding current away from the second spot weld to be made. This will occur if the two spot welds are too close together, and it will happen with all metals.

The following tables and charts are intended as guides for setting up resistance spot welding procedures. The exact time, pressure, and current setting will depend on the specific application and the KVA rating of the resistance spot welding machine employed. Some areas of the tables may not apply to resistance spot welders in the KVA ratings available from this company.

Table 1—Resistance Spot Welding Machine Specifications

Model	KVA Rating	Rated Output 6" Tongs	Rated Output 12" Tongs	Rated Output 18" Tongs	Open Circuit Voltage	Max. Capacity** Uncoated Mild Steel, Combined Thickness Using 6" Tongs
MSW-41	1.5	5,550	4,500	3,600	1.6	1/8"
MSW-41T*	1.5	5,550	4,500	3,600	1.6	1/8"
MSW-42	1.5	5,550	4,500	3,600	1.6	1/8"
MSW-42T*	1.5	5,550	4,500	3,600	1.6	1/8"
LMSW-52	2.5	6,750	5,800	4,850	2.5	3/16"
LMSW-52T*	2.5	6,750	5,800	4,850	2.5	3/16"
PSW-1020	10.0	9,500	7,500	6,500	2.5	3/16"
PSW-2020	20.0	12,500	10,500	9,000	3.55	1/4"
SSW-1020	10	9,500	7,500	6,500	2.5	3/16"
SSW-1040	10	9,500	7,500	6,500	2.5	3/16"
SSW-2020	20	12,500	10,500	9,000	3.55	1/4"
SSW-2040	20	12,500	10,500	9,000	3.55	1/4"

*"T" Series feature an automatic timer.

**Ratings are for uncoated mild and low carbon steel with 6" tongs. For other metals, the combined thickness will have to be determined.

The following general data is provided to assist the operator in setting up welding procedures when using any of the resistance spot welding machines listed above.

Tong pressure settings should be made ONLY when the primary power cord is disconnected from the primary power input supply.

1. Close tongs and measure space between electrode tip contact surfaces.
2. Measure the thickness of the total weldment.
3. Adjust tong gap to measurement of Step 2 less 1/2 the thickness of the thinnest weld number.
4. Insert the parts to be welded between the electrode tips and bring tips to welding pressure. There should be a slight deflection of the tongs. This may be measured with a straight edge set on the tong longitudinal axis.
5. Energize the spot welding machine and make a sample weld.
6. Test the weld by visual and mechanical means. Check the electrode tip for deformation and contamination (see test procedures).
7. Adjust tong pressure as required (see Operating Manual for tong adjustment procedures).

TEST PROCEDURES

The test procedures outlined are very simple and require a minimum of equipment to perform.

1. Visual Test

   Observe the deformation and shape of the surface contact points at both sides of the weld. Excessive "dishing" of the surface contact point indicates one or more of the following:

   a. Excessive tong pressure.
   b. Weld time too long.
   c. Misalignment of the electrode tips.

   If the resistance spot weld does not have an even, concentric surface appearance, the problem could be misalignment of the electrode tips. Align electrode tips with the power off and a typical weld joint between the tip surfaces.

2. Mechanical Test

   Place one end of the resistance spot weld sample in vice jaws. Use mechanical means to force the weld apart. One side of the weld should pull loose from parent metal with a metal extension from the weld. Check for proper weld diameter.

Table 2—Recommended practices for spot welding low-carbon steel

Thickness "T" of Thinnest Outside Piece (a), (b), (c), (d)	Electrode Diameter and Shape (e)		Net Electrode Force, Lb.	Weld Time (Single Impulse), Cycles (60 per Sec)	Welding Current (Approx.). Amps	Minimum Contacting Overlap, In.	Minimum Weld Spacing, (f) ℄ TO ℄ In.	Diameter of Fused Zone D_ω In. Approx.	Minimum Shear Strength, Lb. — Ultimate Tensile Strength of Metal	
Inches	D, In., Min.	D, In., Max.							Tensile Strength Below 70,000 psi	Tensile Strength 70,000 psi and Above
0.010	3/8	1/8	200	4	4000	3/8	1/4	0.10	130	180
0.021	3/8	3/16	300	6	6500	7/16	3/8	0.13	320	440
0.031	3/8	3/16	400	8	8000	7/16	1/2	0.16	570	800
0.040	1/2	1/4	500	10	9500	1/2	3/4	0.19	920	1200
0.050	1/2	1/4	650	12	10,500	9/16	7/8	0.22	1350	....
0.062	1/2	1/4	800	14	12,000	5/8	1	0.25	1850	....
0.078	5/8	5/16	1100	17	14,000	11/16	1-1/4	0.29	2700	....
0.094	5/8	5/16	1300	20	15,500	3/4	1-1/2	0.31	3450	....
0.109	5/8	3/8	1600	23	17,500	13/16	1-5/8	0.32	4150	....
0.125	7/8	3/8	1800	26	19,000	7/8	1-3/4	0.33	5000	....

(a) Type of Steel—SAE 1010.
(b) Material should be free from scale, oxides, paint, grease, and oil.
(c) Welding conditions determined by thickness of thinnest outside piece "T".
(d) Data for total thickness of pile-up not exceeding 4 "T". Maximum ratio between two thickness 3 to 1.
(e) Electrode Material: Class 2
    Minimum Conductivity – 75% of Copper
    Minimum Hardness – 75 Rockwell "B"
(f) Minimum weld spacing is that spacing for two pieces for which no special measures need be taken to compensate for shunted current effect of adjacent welds. For three pieces, increase spacing 30 percent.

Table 3—Recommended practices for spot welding stainless steels

Thickness "T" of Thinnest Outside Piece (a), (b), (c), (d)	Electrode Diameter and Shape (e)		Net Electrode Force, Lb.	Weld Time (Single Impulse) Cycles (60 per Sec)	Minimum Shear Strength, Lb. — Ultimate Tensile Strength of Metal			Welding Current (Approx.), Amps		Diameter of Fused Zone	Minimum Weld Spacing, (f) ℄ to ℄	Minimum Contacting Overlap,
Inches	D. In., Min.,	d. In., Max.			70,000 up to 90,000 psi	90,000 up to 150,000 psi	150,000 psi and Higher	Tensile Strength Below 150,000 psi	Tensile Strength 150,000 psi and Higher	In., Approx.	In.	In.
0.006	3/16	3/32	180	2	60	70	85	2000	2000	0.045	3/16	3/16
0.008	3/16	3/32	200	3	100	130	145	2000	2000	0.055	3/16	3/16
0.010	3/16	1/8	230	3	150	170	210	2000	2000	0.065	3/16	3/16
0.012	1/4	1/8	260	3	185	210	250	2100	2000	0.076	1/4	1/4
0.014	1/4	1/8	300	4	240	250	320	2500	2200	0.082	1/4	1/4
0.016	1/4	1/8	330	4	280	300	380	3000	2500	0.088	5/16	1/4
0.018	1/4	1/8	380	4	320	360	470	3500	2800	0.093	5/16	1/4
0.021	1/4	5/32	400	4	370	470	500	4000	3200	0.100	5/16	5/16
0.025	3/8	5/32	520	5	500	600	680	5000	4100	0.120	7/16	3/8
0.031	3/8	3/16	650	5	680	800	930	6000	4800	0.130	1/2	3/8
0.034	3/8	3/16	750	6	800	920	1100	7000	5500	0.150	9/16	7/16
0.040	3/8	3/16	900	6	1000	1270	1400	7800	6300	0.160	5/8	7/16
0.044	3/8	3/16	1000	8	1200	1450	1700	8700	7000	0.180	11/16	7/16
0.050	1/2	1/4	1200	8	1450	1700	2000	9500	7500	0.190	3/4	1/2
0.056	1/2	1/4	1350	10	1700	2000	2450	10,300	8300	0.210	7/8	9/16
0.062	1/2	1/4	1500	10	1950	2400	2900	11,000	9000	0.220	1	5/8
0.070	5/8	1/4	1700	12	2400	2800	3550	12,300	10,000	0.250	1-1/8	5/8
0.078	5/8	5/16	1900	14	2700	3400	4000	14,000	11,000	0.275	1-1/4	11/16
0.094	5/8	5/16	2400	16	3550	4200	5300	15,700	12,700	0.285	1-3/8	3/4
0.109	3/4	3/8	2800	18	4200	5000	6400	17,700	14,000	0.290	1-1/2	13/16
0.125	3/4	3/8	3300	20	5000	6000	7600	18,000	15,500	0.300	2	7/8

(a) Type of Steel—301, 302, 303, 304, 308, 309, 310, 316, 317, 321, 347, and 349.
(b) Material should be free from scale, oxides, paint, grease, and oil.
(c) Welding conditions determined by thickness of thinnest outside piece "T".
(d) Data for total thickness of pile-up not exceeding 4 "T". Maximum ratio between two thicknesses 3 to 1.
(e) Electrode Material:

	Class 2	Class 3	or Class 11
Minimum Conductivity –	75%	45%	30% of Copper
Minimum Hardness –	75	95	98 Rockwell "B"

(f) Minimum weld spacing is that spacing for two pieces for which no special measures need be taken to compensate for shunted current effect of adjacent welds. For three pieces, increase spacing 30 percent.

Table 4—Recommended practices for spot welding low—alloy and medium—carbon steels

Material (a), (b), (c), (d)			Electrode Diameter and Shape			Net Electrode Weld And Temper Force,	Weld Time Cycles (60 per sec)	Quench Time Cycles (60 per sec)	Temper Time Cycles (60 per sec)	Welding Current (App.) Amps	Temper Current % of Welding Current	Minimum Contacting Overlap	Minimum Weld Spacing (e)	Die of Fused Zone,	Minimum Weld Strength		Ratio Tensile Shear Strength,
Type	Condition	"T" Thickness Inches	D In. Min.	d In.	R In.	Lb.						Inches	Inches	Inches (App.)	Shear Str. Lbs.	Tensile Str. Lbs.	Percent
1020	Hot Rolled	0.040	5/8	1/4	6	1475	6	17	6	16000	90	1/2	1	0.23	1360	920	68
1035	Hot Rolled	0.040	5/8	1/4	6	1475	6	20	6	14200	91	1/2	1	0.22	1560	520	33
1045	Hot Rolled	0.040	5/8	1/4	6	1475	6	24	6	13800	88	1/2	1	0.21	2000	680	33
4130	Hot Rolled	0.040	5/8	1/4	6	1475	6	18	6	13000	90	1/2	1	0.22	2120	640	30
4340	Normalized & Drawn	0.031	5/8	3/16	6	900	4	12	4	8250	84	7/16	3/4	0.16	1084	290	27
4340	Normalized & Drawn	0.062	3/4	5/16	6	2000	10	45	10	13900	77	5/8	1-1/2	0.27	3840	1440	37
4340	Normalized & Drawn	0.125	1	5/8	10	5500	45	240	90	21800	88	7/8	2-1/2	0.55	13680	4000	29
8630	Normalized & Drawn	0.031	1/2	3/16	6	800	4	12	4	8650	88	7/16	3/4	0.16	1220	524	43
8630	Normalized & Drawn	0.062	5/8	5/16	6	1800	10	36	10	12800	83	5/8	1-1/2	0.27	4240	2200	52
8630	Normalized & Drawn	0.125	1	5/8	10	4500	45	210	90	21800	84	7/8	2-1/2	0.55	13200	4500	34
8715	Normalized & Drawn	0.018	1/2	1/8	6	350	3	4	3	3900	85	7/16	5/8	0.10	400	200	50
8715	Normalized & Drawn	0.062	5/8	5/16	6	1600	10	28	10	12250	85	5/8	1-1/2	0.27	3300	1800	55
8715	Normalized & Drawn	0.125	1	5/8	10	4500	45	180	90	22700	85	7/8	2-1/2	0.55	12760	4500	35

(a) Material should be pickled or otherwise cleaned to obtain a surface contact resistance not exceeding 200 microhms.
(b) Data is for two pieces of equal thickness, each of thickness "T".
(c) Electrode material: RWMA Class 2 minimum electrical conductivity - 75% of copper, minimum hardness 75 Rockwell B.
(d) Electrode diameter and shape are the same for both upper and lower electrodes.
(e) Minimum spacing is that spacing for which no special measures need to be taken to compensate for shunted current effect of adjacent welds.

Table 5—Recommended practices for spot welding magnesium alloys

Material (a), (b), (c) Kind ASTM Alloy	Thickness In.	Electrode Diameter and Tip Radius (d), (e), (f) D In.	R In.	AC Machine Net Electrode Force, Lbs.	AC Machine Weld Time Cycles (60/Sec)	AC Machine Welding Current (Approx.) Amps.	Condenser Discharge Machine Net Electrode Force Lbs.	Condenser Discharge Machine Capacitance (g) mfd	Condenser Discharge Machine Condenser Voltage (g) Volts	Minimum Contacting Overlap In.	Minimum Weld Spacing In.	Diameter Of Fused Zone (Approx.) D_ω In.	Minimum Shear Strength Lbs.
M1	0.016	1/4	2	300	3	17,000	300	360	1800	5/16	1/4	0.08	72
AZ31	0.016	1/4	2	300	2	16,000	650	240	1400	5/16	1/4	0.10	140
M1	0.020	3/8	3	300	3	20,000	350	600	2000	5/16	1/4	0.12	96
AZ31	0.020	3/8	3	350	3	18,000	700	240	1600	5/16	1/4	0.14	176
M1	0.025	3/8	3	350	4	24,000	400	720	2000	5/16	1/4	0.14	128
AZ31	0.025	3/8	3	400	3	22,000	750	360	1800	5/16	1/4	0.16	216
M1	0.032	3/8	3	400	5	26,000	500	840	2000	3/8	5/16	0.16	176
AZ31	0.032	3/8	3	450	4	24,000	850	480	2000	3/8	5/16	0.18	272
M1	0.040	1/2	4	450	6	28,000	650	960	2000	7/16	3/8	0.18	224
AZ31	0.040	1/2	4	500	5	26,000	1000	720	2200	7/16	3/8	0.20	344
M1	0.051	1/2	4	500	7	30,000	850	1200	2000	1/2	7/16	0.21	296
AZ31	0.051	1/2	4	550	5	29,000	1300	840	2200	1/2	7/16	0.23	432
M1	0.064	1/2	4	550	8	32,000	1150	1440	2000	9/16	1/2	0.24	384
AZ31	0.064	1/2	4	600	6	31,000	1650	1080	2200	9/16	1/2	0.27	544
M1	0.072	5/8	5	600	9	33,000	1400	1680	2000	9/16	9/16	0.26	432
AZ31	0.072	5/8	5	650	7	32,000	1900	1320	2200	9/16	9/16	0.29	608
M1	0.081	5/8	5	650	10	35,000	1650	1800	2000	5/8	5/8	0.28	496
AZ31	0.081	5/8	5	700	8	33,000	2200	1440	2200	5/8	5/8	0.31	688
M1	0.091	5/8	5	700	11	36,000	1900	2040	2000	11/16	3/4	0.29	560
AZ31	0.091	5/8	5	750	9	34,000	2550	1560	2200	11/16	3/4	0.32	768
M1	0.102	3/4	6	750	12	38,000	2200	2160	2000	3/4	7/8	0.31	632
AZ31	0.102	3/4	6	800	10	36,000	2950	1800	2200	3/4	7/8	0.34	864
M1	0.110	3/4	6	800	13	41,000	2500	2400	2200	13/16	7/8	0.33	680
AZ31	0.110	3/4	6	850	11	39,000	3250	2040	2200	13/16	7/8	0.36	928
M1	0.128	3/4	6	950	14	45,000	3000	2640	2400	7/8	1	0.35	800
AZ31	0.128	3/4	6	1000	12	42,000	4000	2280	2200	7/8	1	0.38	1080

(a) Types of magnesium alloys:
(MG + 1.5 Mn) ASTM-M1, An-M-30, Ma, Mh, 3S-O, 3S-H.
(MG + 3A1 + 1 Zn) ASTM-AZ31, AN-M-29, FS-1a, FS-1h, C52S-O, C52S-H.

(b) Material should be chemically cleaned or otherwise mechanically cleaned to a surface contact resistance not to exceed 50 microhms. For all magnesium and magnesium Alloys, either oiled or plain, the following cleaning prior to welding is recommended:
A. Degrease in solvent, trichlorethylene, or emulsion-type cleaner.
B. Clean in hot alkaline cleaner by immersion for 5 to 15 minutes or by electrolytic means, followed by thorough rinsing, preferably spray-rinse.
C. Clean in chromic acid-sulfate solution* by immersing, until oxide layer is removed, usually not more than 3 minutes followed by cold water rinse and air dry.
*Solution: 18% CrO_3 + 0.05% H_2SO_4 or $NaSO_4$ (70-90°F); chromic acid - 1.5 lb. concentrated sulfuric acid 0.065 fl oz., water to make 1 gallon.

(c) Data for two pieces of equal thickness. For unequal thicknesses welding conditions determined by thickness of thinnest piece. Maximum ratio between two thicknesses 2-1/2 to 1.

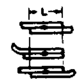
(d) Electrode material: Class 1
Minimum Conductivity – 80% of copper, Minimum Hardness - 65 Rockwell B.

(e) Electrodes water-cooled. Dome-shaped tips for both upper and lower electrodes. Flat tips with diameters from 3/8 to 1-1/4 inches can be used on one side of work where surfaces are to be essentially free from marks. Flat tips suitable for material thicknesses up to 0.064 inches without appreciable displacement of weld.

(f) Maximum number of sound welds obtainable between tip cleaning about 25 on M1 alloy and 100 to 200 on AZ31 alloy.

(g) Condenser discharge machine settings based on turns ration of 480:1.

Table 6—Recommended practices for spot welding annealed nickel

Material Thickness (a) Inches	Electrode Diameter (b), (c),  d. In., Max.	D, In., Min.	Net Electrode Force, Lbs.	Weld Time Cycles (60 per Sec)	Welding Current (Approx.), Amps	Minimum Contacting Overlap  In.	Minimum Weld Spacing (d) In.	Diameter Fused Zone  In.	Minimum Shear Strength, Lbs.
0.005 to:									
0.005	5/32	5/32	100	3	7,100	1/4	3/8	0.10	30
0.010	5/32	5/32	100	3	7,400	1/4	7/16	0.10	35
0.015	5/32	5/32	110	3	7,500	1/4	7/16	0.10	40
0.021	5/32	5/32	110	3	7,800	1/4	1/2	0.10	45
0.031	5/32	3/16	110	3	8,000	1/4	1/2	0.10	50
0.063	5/32	3/16	115	3	8,100	1/4	5/8	0.10	50
0.093	5/32	3/16	115	3	8,150	1/4	5/8	0.10	50
0.125	5/32	3/16	115	3	8,200	1/4	5/8	0.10	55
0.010 to:									
0.010	3/16	3/16	130	3	11,800	1/4	3/8	0.12	135
0.015	5/32	3/16	130	3	11,900	1/4	3/8	0.12	145
0.021	5/32	3/16	130	3	12,000	1/4	7/16	0.12	150
0.031	5/32	3/16	130	3	12,200	1/4	7/16	0.12	160
0.063	5/32	3/16	140	3	12,300	1/4	1/2	0.12	185
0.094	5/32	3/16	140	3	12,300	1/4	5/8	0.12	190
0.125	5/32	3/16	150	3	12,500	1/4	5/8	0.12	210
0.015 to:									
0.015	3/16	3/16	250	3	12,300	1/4	7/16	0.12	180
0.021	3/16	3/16	250	3	12,500	1/4	1/2	0.13	250
0.031	3/16	3/16	250	3	12,600	1/4	1/2	0.13	280
0.063	3/16	1/4	260	3	12,800	1/4	9/16	0.13	300
0.094	3/16	5/8	260	3	13,000	1/4	5/8	0.13	305
0.125	3/16	5/8	260	3	13,100	1/4	5/8	0.13	310
0.021 to:									
0.021	5/32	5/32	370	4	7,800	5/16	9/16	0.12	350
0.031	5/32	5/32	370	4	8,200	5/16	5/8	0.12	370
0.063	5/32	5/32	370	4	8.600	5/8	5/8	0.12	395
0.094	5/32	5/8	380	4	8,800	5/16	11/16	0.12	430
0.125	5/32	5/8	380	4	9,000	5/16	3/4	0.13	450
0.031 to:									
0.031	3/16	3/16	900	4	15,400	3/8	7/8	0.18	760
0.063	3/16	3/16	900	4	15,200	3/8	7/8	0.17	770
0.094	3/16	3/16	900	6	13,500	3/8	1	0.18	840
0.125	3/16	5/8	980	6	14,200	3/8	1	0.18	930
0.063 to:									
0.063	1/4	1/4	1720	6	21,600	5/8	1-1/2	0.25	2400
0.094	1/4	1/4	1800	8	20,000	5/8	1-5/8	0.25	2550
0.125	1/4	1/4	1800	10	21,000	5/8	1-3/4	0.25	2650
0.094 to:									
0.094	5/16	5/16	2300	12	26,400	3/4	1-7/8	0.31	3600
0.125	5/16	5/16	2300	20	25,400	3/4	2	0.31	3780
0.125 to:									
0.125	3/8	3/8	3300	20	31,000	7/8	2-1/4	0.37	5600

(a) Material should be free from scale, oxides, paint, grease, and oil.

(b) Electrode shape may be flat rather than domed, in which case the shear strengths and nugget diameters will be higher and larger than shown in the table.

(c) Electrode Materials: Class 1 or Class 2
Minimum Conductivity – 80% Cu 75% Cu
Minimum Hardness – 68 Rb 75 Rb

(d) Minimum weld spacing is that spacing for two pieces for which no special measures need be taken to compensate for shunted current effect of adjacent welds. For three pieces, increase spacing 30 percent.

Table 7—Recommended practices for spot welding annealed Monel alloy

Material Thickness (a) Inches	Electrode Diameter (b), (c) d. In., Max.	D. In., Min.	Net Electrode Force, Lbs.	Weld Time Cycles (60 per Sec)	Welding Current (Approx.), Amps	Minimum Contacting Overlap In.	Minimum Weld Spacing (d) In.	Diameter Fused Zone In.	Minimum Shear Strength, Lbs.
0.005 to:									
0.005	5/32	5/32	220	2	5,000	1/4	1/4	0.10	55
0.010	5/32	5/32	220	2	6,100	1/4	1/4	0.10	60
0.015	5/32	5/32	220	2	7,000	1/4	5/16	0.10	75
0.021	5/32	1/4	220	3	7,200	1/4	3/8	0.11	85
0.031	5/32	1/4	250	4	7,400	1/4	3/8	0.11	95
0.063	5/32	5/8	250	4	8,000	1/4	7/16	0.11	90
0.094	5/32	5/8	250	4	8,600	1/4	1/2	0.11	90
0.125	5/32	5/8	250	4	8,700	1/4	1/2	0.11	85
0.010 to:									
0.010	5/32	5/32	270	2	7,200	1/4	1/4	0.12	145
0.015	5/32	5/32	280	2	8,600	1/4	5/16	0.12	155
0.021	5/32	5/32	280	3	8,200	1/4	5/16	0.13	170
0.031	5/32	5/32	300	4	8,800	1/4	3/8	0.13	190
0.063	5/32	5/16	300	4	9,200	1/4	7/16	0.13	190
0.094	5/32	5/8	325	4	9,900	1/4	1/2	0.14	210
0.125	5/32	5/8	325	4	9,900	1/4	1/2	0.14	220
0.015 to:									
0.015	3/16	3/16	300	2	8,600	1/4	5/16	0.13	250
0.021	3/16	3/16	300	6	8,200	1/4	3/8	0.13	295
0.031	3/16	3/16	325	6	9,300	1/4	3/8	0.13	300
0.063	3/16	5/8	325	6	9,400	1/4	7/16	0.14	350
0.093	3/16	5/8	325	8	9,500	1/4	1/2	0.14	360
0.125	3/16	5/8	325	8	9,500	1/4	1/2	0.14	365
0.021 to:									
0.021	3/16	3/16	300	12	6,200	5/16	7/16	0.13	450
0.031	3/16	3/16	325	12	6,800	5/16	7/16	0.13	460
0.063	3/16	3/16	325	12	7,200	5/16	1/2	0.14	500
0.093	3/16	5/8	325	12	7,700	3/8	9/16	0.14	530
0.125	3/16	5/8	325	12	8,200	3/8	9/16	0.14	550
0.031 to:									
0.031	3/16	3/16	700	12	10,500	3/8	5/8	0.17	845
0.063	3/16	1/4	750	12	11,200	1/2	11/16	0.18	910
0.094	3/16	5/8	775	12	11.400	1/2	3/4	0.19	1035
0.125	3/16	5/8	775	12	11.800	1/2	3/4	0.19	1075
0.063 to:									
0.063	5/16	5/16	2700	12	15,300	5/8	1-1/8	0.31	2060
0.093	5/16	5/8	2700	12	15,900	5/8	1-3/16	0.31	2180
0.125	5/16	5/8	2700	12	16,200	5/8	1-1/4	0.32	2360
0.093 to:									
0.093	3/8	3/8	2760	20	22,600	3/4	1-1/4	0.37	3880
0.125	3/8	3/8	2760	20	25,000	3/4	1-1/4	0.38	4390
0.125 to:									
0.125	1/2	1/2	5000	30	30,000	7/8	1-5/8	0.47	5850

(a) Material should be free from scale, oxides, paint, grease, and oil.

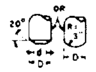
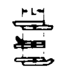
(b) Electrode shape may be flat rather than domed, in which case the shear strengths and nugget diameters will be higher and larger than shown in the table.

(c) Electrode Materials: Class 1 or Class 2

	Class 1	Class 2
Minimum Conductivity –	80% Cu	75% Cu
Minimum Hardness –	68 Rb	75 Rb

(d) Minimum weld spacing is that spacing for two pieces for which no special meausres need be taken to compensate for shunted current effect of adjacent welds. For three pieces, increase spacing 30 percent.

Table 8—Recommended practices for spot welding annealed Inconel alloy

Material Thickness (a) Inches	Electrode Diameter (b), (c)  d, In., Max.	D, In., Min.	Net Electrode Force, Lbs.	Weld Time Cycles (60 per Sec)	Welding Current (Approx.), Amps	Minimum Contacting Overlap  In.	Minimum Weld Spacing (d) In.	Diameter Fused Zone  In.	Minimum Shear Strength, Lbs.
0.005 to:									
0.005	5/32	5/32	300	2	7,000	1/4	1/4	0.11	70
0.010	5/32	3/16	300	4	5,300	1/4	1/4	0.12	100
0.015	5/32(e)	3/16	300	4	5,500	1/4	1/4	0.12	105
0.021	5/32(e)	3/16	300	6	4,800	1/4	5/16	0.13	110
0.031	5/32(e)	3/16	325	6	5,400	1/4	5/16	0.13	120
0.062	5/32(e)	5/8	325	6	5,600	1/4	3/8	0.15	135
0.094	5/32(e)	5/8	325	6	5,800	1/4	3/8	0.16	145
0.125	5/32(e)	5/8	325	6	5,600	1/4	3/8	0.15	130
0.010 to:									
0.010	3/16	3/16	320	4	7,500	1/4	1/4	0.12	175
0.015	5/32(e)	3/16	320	4	5,500	1/4	1/4	0.13	215
0.021	5/32(e)	3/16	320	6	5,100	1/4	9/32	0.13	215
0.031	5/32(e)	3/16	350	6	5,600	1/4	9/32	0.14	290
0.063	5/32(e)	3/16	400	6	5,500	1/4	5/16	0.14	315
0.094	5/32(e)	5/8	400	6	5,800	1/4	3/8	0.15	350
0.125	5/32(e)	5/8	400	6	4,600	1/4	3/8	0.14	370
0.015 to:									
0.015	3/16	3/16	360	6	7,600	1/4	1/4	0.12	295
0.021	3/16	3/16	360	6	5,400	1/4	1/4	0.12	290
0.031	5/32(e)	3/16	400	8	4,600	1/4	9/32	0.13	370
0.063	5/32(e)	5/16	400	8	4,700	1/4	5/16	0.13	440
0.094	3/16(e)	5/8	400	10	4,700	1/4	11/32	0.16	535
0.125	3/16	5/8	400	12	4,600	1/4	3/8	0.16	560
0.021 to:									
0.021	5/32	5/32	300	12	4,000	5/16	7/16	0.12	545
0.031	5/32	3/16	350	12	4,100	5/16	7/16	0.12	535
0.063	3/16(e)	5/16	400	12	5,300	5/16	15/32	0.12	580
0.094	3/16(e)	5/8	500	12	5,900	5/16	1/2	0.15	670
0.125	3/16(e)	5/8	550	12	6,300	5/16	1/2	0.15	690
0.031 to:									
0.031	3/16	3/16	700	12	6,700	3/8	9/16	0.18	920
0.063	3/16	5/16	700	12	7,100	3/8	5/8	0.18	965
0.094	1/4(e)	5/8	700	12	8,300	3/8	11/16	0.20	1250
0.125	1/4(e)	5/8	750	12	8,500	3/8	3/4	0.20	1210
0.063 to:									
0.063	5/16	5/16	2070	12	12,000	5/8	1-1/8	0.31	2750
0.093	5/16	5/8	2450	16	12,000	5/8	1-3/16	0.31	2750
0.125	5/16	5/8	2600	20	12,000	5/8	1-1/4	0.32	3820
0.093 to:									
0.093	3/8	3/8	3870	20	15,000	3/4	1-3/16	0.37	4400
0.125	7/16	7/16	5100	30	20,000	3/4	1-1/4	0.40	4700
0.125 to:									
0.125	7/16	7/16	5270	30	20,100	7/8	1-5/16	0.44	6400

(a) Material should be free from scale, oxides, paint, grease, and oil.
(b) Electrode shape may be flat rather than domed, in which case the shear strengths and nugget diameters will be higher and larger than shown in the table.
(c) Electrode Materials:

	Class 1	or	Class 2	molybdenum faced
Minimum Conductivity –	80% Cu		75% Cu	Cu
Minimum Hardness –	68 Rb		75 Rb	83 Rb

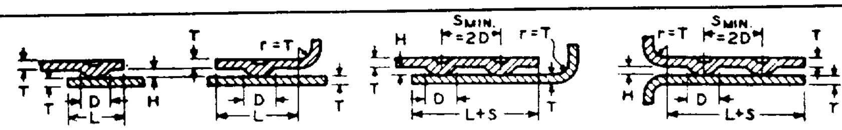
(d) Minimum weld spacing is that spacing for two pieces for which no special measures need be taken to compensate for shunted current effect of adjacent welds. For three pieces, increase spacing 30 percent.
(e) Indicates molybdenum tipped electrode.

Table 9—Recommended practices for seam welding stainless steels

Thickness "T" of Thinnest Outside Piece (a), (b), (c), (d)	Electrode Width and Shape (e) 	Net Electrode Force,	On Time, Cycles (60 per Sec)	Off Time for Maximum Speed (Pressure-Tight), Cycles		Maximum Weld Speed, In. per Minute		Welds per Inch		Welding Current (Approx.), Amps	Minimum Contacting Overlap (f) 
Inches	W. In., Min	Lb.		2 "T"	4"T"	2 "T"	4 "T"	2 "T"	4 "T"		In.
0.006	3/16	300	2	1	1	60	67	20	18	4000	1/4
0.008	3/16	350	2	1	2	67	56	18	16	4600	1/4
0.010	3/16	400	3	2	2	45	51	16	14	5000	1/4
0.012	1/4	450	3	2	2	48	55	15	13	5600	5/16
0.014	1/4	500	3	2	3	51	46	14	13	6200	5/16
0.016	1/4	600	3	2	3	51	50	14	12	6700	5/16
0.018	1/4	650	3	2	3	55	50	13	12	7300	5/16
0.021	1/4	700	3	2	3	55	55	13	11	7900	3/8
0.025	3/8	850	3	3	4	50	47	12	11	9200	7/16
0.031	3/8	1000	3	3	4	50	47	12	11	10,600	7/16
0.040	3/8	1300	3	4	5	47	45	11	10	13,000	1/2
0.050	1/2	1600	4	4	5	45	44	10	9	14,200	5/8
0.062	1/2	1850	4	5	7	40	41	10	8	15,100	5/8
0.070	5/8	2150	4	5	7	44	41	9	8	15,900	11/16
0.078	5/8	2300	4	6	7	40	41	9	8	16,500	11/16
0.094	5/8	2550	5	6	7	36	38	9	8	16,600	3/4
0.109	3/4	2950	5	7	9	38	37	8	7	16,800	13/16
0.125	3/4	3300	6	6	8	38	37	8	7	17,000	7/8

(a) Types of steel—301, 302, 303, 304, 308, 309, 310, 316, 317, 321, 347, and 349.
(b) Material should be free from scale, oxides, paint, grease, and oil.
(c) Welding conditions determined by thickness of thinnest outside piece "T".
(d) Data for total thickness of pile-up not exceeding 4 "T". Maximum ratio between thicknesses 3 to 1.
(e) Electrode Material: Class 3
Minimum Conductivity – 45% of copper
Minimum Hardness – 95 Rockwell B
(f) For large assemblies, minimum contacting overlap indicated should be increased 30 percent.

Table 10—Projection welding design data



Thickness "T" of Thinnest Outside Piece (Nominal) (a), (b), (c), (d) Inches	Diameter of Projection "D" (g), (h), (j) In.	Height of Projection "H" (g), (i), (j) In.	Minimum Shear Strength (Single Projections Only), Lb.			Diameter of Fused Zone Minimum (At Weld Interface), In.	Minimum Contacting Overlap "L" (e), (f) In.
			Tensile Strength Below 70,000 psi	Tensile Strength 70,000 up to 150,000 psi	Tensile Strength 150,000 psi and above		
0.010	0.055	0.015	130	180	250	0.112	1/8
0.012	0.055	0.015	170	220	330	0.112	1/8
0.014	0.055	0.015	200	280	380	0.112	1/8
0.016	0.067	0.017	240	330	450	0.112	5/32
0.021	0.067	0.017	320	440	600	0.140	5/32
0.025	0.081	0.020	450	600	820	0.140	3/16
0.031	0.094	0.022	635	850	1100	0.169	7/32
0.034	0.094	0.022	790	1000	1300	0.169	7/32
0.044	0.119	0.028	920	1300	2000	0.169	9/32
0.050	0.119	0.028	1350	1700	2400	0.225	9/32
0.062	0.156	0.035	1950	2250	3400	0.225	3/8
0.070	0.156	0.035	2300	2800	4200	0.281	3/8
0.078	0.187	0.041	2700	3200	4800	0.281	7/16
0.094	0.218	0.048	3450	4000	6100	0.281	1/2
0.109	0.250	0.054	4150	5000	7000	0.338	5/8
0.125	0.281	0.060	4800	5700	8000	0.338	11/16
0.140	0.312	0.066	6000	....	....	7/16	3/4
0.156	0.343	0.072	7500	....	....	1/2	13/16
0.171	0.375	0.078	8500	....	....	9/16	7/8
0.187	0.406	0.085	10,000	....	....	9/16	15/16
0.203	0.437	0.091	12,000	....	....	5/8	1
0.250	0.531	0.110	15,000	....	....	11/16	1-1/4

Notes:

(a) Types of steel:
Low-carbon—SAE 1010.
Stainless—Types 309, 310, 316, 317, 321, 347, and 349.
(Max. carbon content 0.15%)

(b) Material should be free from scale, oxides, paint, grease, and oil.

(c) Size of projection normally determined by thickness of thinner piece, and projection should be on thicker piece where possible.

(d) Data based on thickness of thinner sheet, and for two thicknesses only.

(e) Contacting overlap does not include any radii from forming, etc.

(f) Weld should be located in center of overlap.

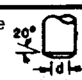
(g) Projection should be made on piece of higher conductivity when dissimilar metals are welded.

(h) For diameter of projection "D", a tolerance of ±0.003 inch in material up to and including 0.050 inch in thickness and ±0.007 inch in material over 0.050 inch in thickness may be allowed.

(i) For height of projection "H", a tolerance of ±0.002 inch in material up to and including 0.050 inch in thickness and ±0.005 inch in material over 0.050 inch in thickness may be allowed.

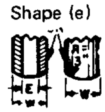
(j) See Table 30.13 for data on punch and die designs for making projections.

Table 11—Manufacturing process data for projection welding stainless steels

Thickness "T" of Thinnest Outside Piece (Nominal) (a), (b), (c) Inches	Electrode Face Diameter "d"  (d = 2 x Proj. Dia)(d) In.	Net Electrode Force, Lb.	Weld Time, Cycles (60 per sec)	Hold Time, Cycles (60 per sec)	Welding Current (at Electrodes) 60 Cycles a.c. (Approx.). Amps
0.014	1/8	300	7	15	4500
0.021	3/32	500	10	15	4750
0.031	3/16	700	15	15	5750
0.044	1/4	700	20	15	6000
0.062	5/16	1200	25	15	7500
0.078	3/8	1900	30	30	10000
0.094	7/16	1900	30	30	10000
0.109	1/2	2800	30	45	13000
0.125	9/16	2800	30	45	14000

(a) Types of Steel—309, 310, 316, 317, 321, 347, and 349 (nonhardenable; max. carbon content - 0.15%).
(b) Material should be free from scale, oxides, paint, grease, and oil.
(c) Data based on thickness of thinner sheet, and for two thicknesses only. Maximum ratio between two thicknesses 3 to 1.
(d) See Table 10 for standard projections.
(e) Electrode Material: Class 2 or Class 12
Minimum Conductivity – 75 29% of Copper
Minimum Hardness – 75 100 Rockwell B

Table 12—Recommended practices for seam welding low-carbon steel

Thickness "T" of Thinnest Outside Piece (a), (b), (c), (d) Inches	Electrode Width and Shape (e)  W, In., Min.	E, In., Max.	Net Electrode Force, Lb.	On Time Cycles (60 per Sec)	Off Time (Pressure-Tight) Cycles	Weld Speed, In. per Min.	Welds per Inch	Welding Current (Approx.). Amps	Minimum Contacting Overlap (f)  In.
0.010	3/8	3/16	400	2	1	80	15	8,000	3/8
0.021	3/8	3/16	550	2	2	75	12	11,000	7/16
0.031	1/2	1/4	700	3	2	72	10	13,000	1/2
0.040	1/2	1/4	900	3	3	67	9	15,000	1/2
0.050	1/2	5/16	1050	4	3	65	8	16,500	9/16
0.062	1/2	5/16	1200	4	4	63	7	17,500	5/8
0.078	5/8	3/8	1500	6	5	55	6	19,000	11/16
0.094	5/8	7/16	1700	7	6	50	5.5	20,000	3/4
0.109	3/4	1/2	1950	9	6	48	5	21,000	13/16
0.125	3/4	1/2	2200	11	7	45	4.5	22,000	7/8

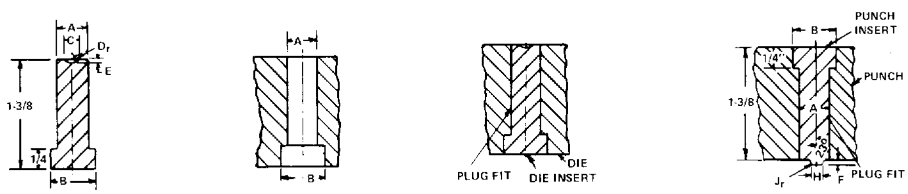
(a) Type of Steel—SAE 1010.
(b) Material should be free from scale, oxides, paint, grease, and oil.
(c) Welding conditions determined by thickness of thinnest outside piece "T".
(d) Data for total thickness of pile-up not exceeding 4 "T". Maximum ratio between thicknesses 3 to 1.
(e) Electrode Material: Class 2
Minimum Conductivity – 75% of Copper
Minimum Hardness – 75 Rockwell B
(f) For large assemblies, minimum contacting overlap indicated should be increased 30 percent.

Table 13—Manufacturing process data for projection welding mild steel

Thickness "T" of Thinnest Outside Piece (Nominal) (a), (b), (c) Inches	Electrode Face Diameter "d" (d = 2 x Proj. Dia)(d) In.	Net Electrode Force, Lb.	Weld Time, Cycles (60 per sec)	Hold Time, Cycles (60 per sec)	Welding Current (at Electrodes) 60 Cycles a.c. (Approx.). Amps
0.014	1/8	175	7	15	5000
0.021	3/32	300	10	15	6000
0.031	3/16	400	15	15	7000
0.044	1/4	400	20	15	7000
0.062	5/16	700	25	15	9500
0.078	3/8	1200	30	30	13000
0.094	7/16	1200	30	30	14500
0.109	1/2	1700	30	45	16000
0.125	9/16	1700	30	45	17000

(a) Types of Steel—SAE 1010 (Max. carbon content 0.15%).
(b) Material should be free from scale, oxides, paint, grease, and oil.
(c) Data based on thickness of thinner sheet, and for two thicknesses only. Maximum ratio between two thicknesses 3 to 1.
(d) Electrode Material: Class 2
Minimum Conductivity – 75% of Copper
Minimum Hardness – 75 Rockwell B

Table 14—Projection welding punch and die design data



Material Thickness	Pt. No.	A	B	±0.002 C	Dr	±0.001 E	±0.001 F	±0.001 H	Jr.
0.012 to 0.016	1	3/8	9/16	0.055	0.033	0.015	0.015	0.035	0.005
0.016 to 0.020	2	3/8	9/16	0.067	0.042	0.017	0.020	0.039	0.005
0.025	3	3/8	9/16	0.081	0.050	0.020	0.025	0.044	0.005
0.031	4	3/8	9/16	0.094	0.062	0.022	0.030	0.050	0.005
0.035	5	3/8	9/16	0.094	0.062	0.022	0.030	0.050	0.005
0.044	6	3/8	9/16	0.119	0.078	0.028	0.035	0.062	0.005
0.050	7	3/8	9/16	0.119	0.078	0.028	0.035	0.062	0.005
0.062	8	3/8	9/16	0.156	0.105	0.035	0.043	0.081	0.005
0.071	9	3/8	9/16	0.156	0.105	0.035	0.043	0.081	0.005
0.078	10	3/8	9/16	0.187	0.128	0.041	0.055	0.104	0.010
0.094	11	1/2	11/16	0.218	0.148	0.048	0.065	0.115	0.010
0.109	12	1/2	11/16	0.250	0.172	0.054	0.075	0.137	1/64
0.125	13	1/2	11/16	0.281	0.193	0.060	0.085	0.154	1/64
0.140	14	1/2	11/16	0.312	0.217	0.066	0.096	0.172	1/64
0.156	15	5/8	13/16	0.343	0.243	0.072	0.107	0.191	1/64
0.171	16	5/8	13/16	0.375	0.265	0.078	0.118	0.210	1/64
0.187	17	5/8	13/16	0.406	0.285	0.085	0.130	0.229	1/64
0.203	18	11/16	7/8	0.437	0.308	0.091	0.143	0.240	0.020
0.250	19	13/16	1	0.531	0.375	0.110	0.175	0.285	0.025

Material:
Make die and punch inserts from air-hardening chrome-vanadium steel.
Finish all over and harden to 65-68 Rockwell C scale.

Note:
Each part number represents one complete die unit which is made up of punch and die insert.
All working surfaces of die unit must be polished.

Table 15—Recommended practices for pulsation welding low-carbon steel

Combination of Thicknesses to Be Welded (a), (b) T-1	T-2	Electrode Diameter and Shape (c), Min. d = 1/4 in. D. In., Min.	d. In., Max.	Net Electrode Force, Lb.	Weld Time On 20 Cycles, Off 5 Cycles (60 Per Sec), No. of Pulsations: Single Welds	Adjacent Welds 1 In. to 2 In. Centers	Adjacent Welds 2 In. to 4 In. Centers	Welding Current (Approx.), Amps	Minimum Contacting Overlap In.	Minimum Diameter of Fused Zone, In. Approx.	Minimum Shear Strength (For Steel of Tensile Strength Less Than 70,000 psi)., Lb.
1/8	1/8	1	7/16	1800	3	5	4	18,000	7/8	3/8	5,000
1/8	3/16	1	7/16	1800	3	5	4	18,000	7/8	3/8	5,000
1/8	1/4	1	7/16	1800	3	5	4	18,000	7/8	3/8	5,000
3/16	3/16	1-1/4	1/2	1950	6	20	14	19,500	1-1/8	9/16	10,000
3/16	1/4	1-1/4	1/2	1950	6	20	14	19,500	1-1/8	9/16	10,000
3/16	5/16	1-1/4	1/2	1950	6	20	14	19,500	1-1/8	9/16	10,000
1/4	1/4	1-1/4	9/16	2150	12	24	18	21,500	1-3/8	3/4	15,000
1/4	5/16	1-1/4	9/16	2150	12	24	18	21,500	1-3/8	3/4	15,000
5/16	5/16	1-1/2	5/8	2400	15	30	23	24,000	1-1/2	7/8	20,000

(a) Type of Steel—SAE 1010.
(b) Material should be free from scale, oxides, paint, grease, and oil.
(c) Electrode Material: Class 2
Minimum Conductivity – 75% of Copper
Minimum Hardness – 75 Rockwell B

Table 16—Recommended practices for pulsation welding stainless steels

Thickness "T" of Thinnest Outside - Piece (a), (b), (c), (d) Inches	Electrode Dia. and Shape (e) D. In., Min.	d. In., Max.	Net Electrode Force, Lb.	Weld Time On 15 Cycles, Off 6 Cycles (60 per Sec), No. of Pulsations	Welding Current (Approx.) Amps, Base Metal Tensile Strength: Below 150,000 psi	150,000 psi and higher	Minimum Contacting Overlap In.	Minimum Weld Spacing (f) ℄ TO ℄ In.	Minimum Diameter Of Fused Zone In.	Minimum Shear Strength, Lb., Ultimate Tensile Strength of Metal: 90,000 Up To 150,000 psi	150,000 psi and higher
0.156	1	1/2	4000	4	20,700	17,500	1-1/4	1-7/8	0.440	7,600	10,000
0.187	1	1/2	5000	5	21,500	18,500	1-1/2	2	0.500	9,750	12,300
0.203	1	5/8	5500	6	22,000	19,000	1-5/8	2-1/8	0.530	10,600	13,000
0.250	1	5/8	7000	7	22,500	20,000	1-3/4	2-3/8	0.600	13,500	17,000

(a) Types of Steel—301, 302, 303, 304, 308, 309, 310, 316, 317, 321, 347, and 349.
(b) Material should be free from scale, oxides, paint, grease, and oil.
(c) Welding conditions determined by thickness of thinnest outside piece "T".
(d) Data for total thickness of pile-up not exceeding 4 "T". Maximum ratio between two thicknesses 3 to 1.
(e) Electrode Material: Class 3 or Class II
Minimum Conductivity – 45% 30% of Copper
Minimum Hardness – 95 98 Rockwell B
(f) Minimum weld spacing is that spacing for two pieces for which no special measures need be taken to compensate for shunted current effect of adjacent welds. For three pieces, increase spacing 30 percent.

All Tables Courtesy of the American Welding Society

LITHO IN U.S.A.

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