

Supplement
to
AWS D8.5-66
RECOMMENDED PRACTICES
for
AUTOMOTIVE PORTABLE-GUN
RESISTANCE-SPOT WELDING
on
**Electrode and Force
Recommendations**
for
**Two and Three
Loose Metal
Thicknesses**

AMERICAN WELDING SOCIETY

Supp. to
AWS D8.5-66

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Recommended Practices for
Automotive Portable-Gun
Resistance-Spot Welding
on
Electrode and Force
Recommendations
for
Two and Three
Loose Metal Thicknesses

Prepared by
AWS Automotive Welding Committee

Under the direction of
AWS Technical Activities Committee

Edward A. Fenton
Technical Director

Price \$1.00

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Table of Contents

FOREWORD

SECTION 1. GENERAL RECOMMENDATIONS FOR SELECTING ELECTRODE TIP SIZES AND ELECTRODE FORCE

(A) *Explanation of Selection Chart* 1

(B) *Use of Selection Chart* 1

SECTION 2. GENERAL RULES 4



FOREWORD

This document was developed to provide for the application of "Weldability Lobes" in *Recommended Practices for Resistance-Spot Welding*, AWS D8.5-66, to two and three unequal metal thickness combinations. Combinations of two and three unequal metal thicknesses constitute the majority of applications of the resistance-spot welding process. Resistance-spot welding two equal metal thicknesses of cold rolled sheet metal is the exception rather than the rule in today's industry.

Results of investigations are summarized in chart form, labeled "Selection of the Governing Metal Thicknesses to be used for Determining Electrode Force and Diameter Requirements for Welding Two and Three Metal Thickness Combinations." This chart is to serve as an aid in selecting the one metal thickness (from a given combination of metal thicknesses) that can be used as the governing reference to welding force and electrode geometry.

In those instances where a larger flat electrode is specified to benefit heat balance and/or surface marring, it will influence the governing metal thickness as evidenced by the chart data. Conditions other than those presented in the chart should not be read into the data. The 5/8 diameter flat electrode referenced is not and should not be considered the same as a flat copper backup or button type electrode.

The report is based on experimental data. New data will be considered when available. To this end, comments and reports of experience will be most welcome. Inquiries on the recommendations contained herein are also welcome. Address all communications to Secretary, AWS Automotive Welding Committee, American Welding Society, 345 East 47th Street, New York, New York 10017.

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SECTION 1. General Recommendations for Selecting Electrode Tip Sizes and Electrode Force

The recommendations from this investigation are summarized in the chart "Selection of the Governing Metal Thickness to be Used for Determining Electrode Force and Diameter Requirements for Welding Two and Three Metal Thickness Combinations". This chart and how to use it are explained below. The five general rules referred to on the chart are also listed.

(A) Explanation of Governing Metal Thickness Selection Chart

Shown in the left-hand column are all ten possible combinations and arrangements of two and three metal thicknesses. For example: (0.035 - 0.059) is a two unequal metal thickness combination shown in illustration No. 2 on the chart. Also (0.047 - 0.059 - 0.067) is a three unequal metal thickness combination with a medium gage in the center shown in illustration No. 6 on the chart. Any combination and arrangement of two or three metal thicknesses can be classified in terms of one of the ten illustrations shown in the left-hand column of the chart.

Across the top of the Governing Metal Thickness Selection Chart are illustrated the three possible arrangements of electrodes; (A) both tips pointed, (B) one tip pointed and the opposite tip flat, and (C) opposite arrangement from (B). The flat tip shown under (B) and (C) *must* be considered as only a 5/8-inch diameter flat tip or a 5/8-inch diameter flat backup button, and does *not* include any other size or form of flat backups, coppers or the like. The values listed in the Governing Metal Thickness Selection Chart opposite the variants (1) through (10) in the left hand column and under the (A) (B) (C) illustrated electrode arrangements across the top of the Governing Metal Thickness Selection Chart are given in terms of the governing metal thickness of the particular metal combination selected.

(B) Use of Governing Metal Thickness Selection Chart

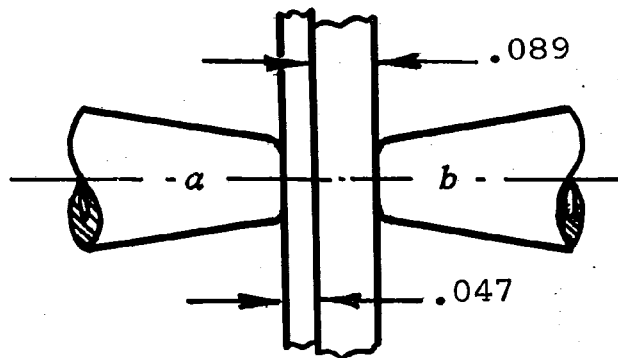
- (1) Select the applicable metal combination and arrangement from the left-hand column, (1) through (10).
- (2) Select the applicable electrode arrangement from across the top of the Governing Metal Thickness Selection Chart; (A), (B), (C).
- (3) In the box of the selected metal and electrode arrangement are listed the governing metal thicknesses for selection of sizes of tip (a), tip (b), electrode force, and the maximum thickness ratio.

2 | Supplement to AWS D8.5-66

- (4) These governing metal thicknesses are then used to refer back to standard weld schedules (see AWS D8.5-66 – *Recommended Practices for Automotive Portable-Gun Resistance-Spot Welding*) to determine the actual tip sizes and electrode forces required to weld the metal combination in question.

For the purpose of illustrating these steps the following two examples are presented:

EXAMPLE 1



Column A, opposite illustration 2, shows the following:

d_a	d_b	Electrode Force	Maximum Thickness Ratio
X	Y	X	$\frac{X}{Y} = \frac{1}{4}$

From figure (2), $X = 0.047$ inch, $Y = 0.089$ inch, and referring to the above and AWS D8.5-66 (*Recommended Practices for Automotive Portable-Gun Resistance-Spot Welding*) it is found that:

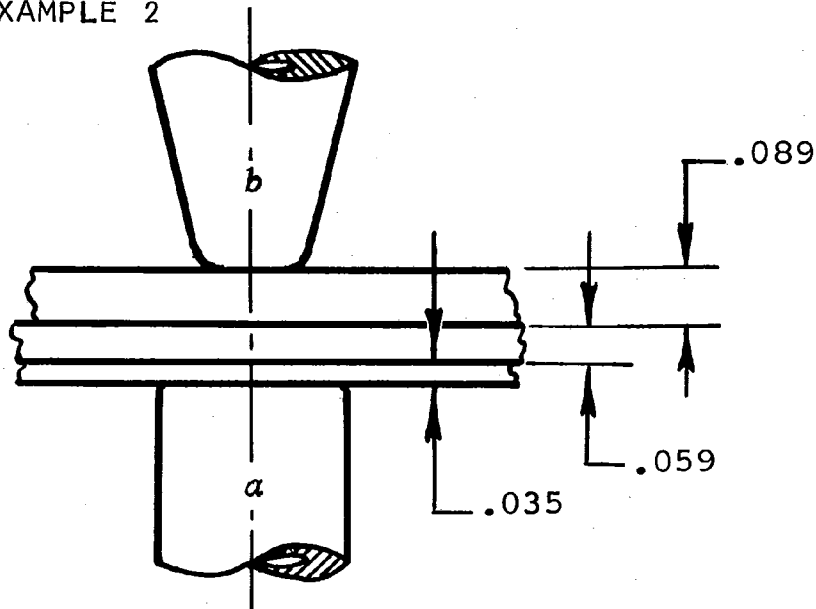
Diameter of tip (a) for metal thickness 0.047 inch = $1/4$ inch

Diameter of tip (B) for metal thickness 0.089 inch = $3/8$ inch

Electrode force for metal thickness 0.047 inch = 750 pounds

Maximum thickness ratio = $\frac{0.047}{0.089}$ (within 1:4)

EXAMPLE 2



Column C, opposite illustration 6, shows the following:

d_a	d_b	Electrode Force	Maximum Thickness Ratio
5/8 Flat	Z	Z	$\frac{X}{Z} = \frac{1}{4}$

From figure (6) $X = 0.035$ inch, $Y = 0.059$ inch, $Z = 0.089$ inch. Thus referring back to AWS D8.5-66

Tip (a) = 5/8 inch diameter flat

Tip (b) = 3/8 inch diameter flat (for thickness $Z = 0.089$ inch)

Electrode force = 1500 pounds

Maximum thickness ratio = $\frac{0.035}{0.089}$ (within 1:4)

4 | Supplement to AWS D8.5-66**SECTION 2. General Rules****(1) Force recommendations for portable guns**

Minimum force to be used for any three metal thickness weld is 800 lbs. In those cases where an option of force selection exists choose the higher force.

(2) Force recommendations for press welding guns

In those press electrode setups where few guns are being used and where adverse metal fit up and highly restrained joints are expected, forces in excess of the recommended minimum are suggested.

(3) Metal thickness ratio limitation

The welding of a three metal thickness combination with pointed electrodes is limited to those combinations in which the outer metal thickness ratio does not exceed 1 to 2-1/2. For welding metal combinations with higher ratio, the electrode size must be altered to suit these conditions.

(4) Minimum spacing between two spots for three metal thickness welds

Minimum recommended spacing for a three metal thickness weld is 30% greater than that spacing required for the heaviest outer metal.

(5) Effects of flat electrode

The use of flat electrodes results in size and shape variations of the weld nugget depending upon the thick to thin stacking arrangement of the metal in the pile-up. As the thickness ratio increases and the flat electrode contacts the heavier metal, the greater unbalance results in less desirable welding conditions. On the contrary, better welding conditions exist when the flat electrode contacts the thinner metal, although, increased currents and electrode forces are necessary.

SELECTION OF THE GOVERNING METAL THICKNESS TO BE USED FOR DETERMINING
ELECTRODE FORCE AND DIAMETER REQUIREMENTS FOR WELDING TWO AND THREE
METAL THICKNESS COMBINATIONS

ELECTRODE ARRANGEMENT (each electrode is placed to the side of its governing thickness below)											
METAL COMBINATIONS AND ARRANGEMENT	A		B		C						
				d_a	d_b	ELECTRODE FORCE	MAXIMUM THICKNESS RATIO	d_a	d_b	ELECTRODE FORCE	MAXIMUM THICKNESS RATIO
1 	X	Y	X	Y	X	Y	5/8 Flat	Y	Y	Y	-
	Least critical of all welding conditions shown.				See general rule No. 5 for effects of flat electrode.				See general rule No. 5 for effects of flat electrode.		
2 	X	Y	X	Y	X	Y	5/8 Flat	Y	Y	Y	$\frac{X}{Y} = \frac{1}{4}$
	Welding condition becomes more critical as the metal thickness ratio increases.				Welding condition is more critical than when both tips are pointed.				Above recommendations give maximum structural quality, providing optimum weld schedule parameters are used.		
3 	X	Z	X	Y	X	Y	5/8 Flat	Z	Z	Z	-
	One of the least critical of the three metal thickness conditions.				See general rule No. 5 for effects of flat electrode.				See general rule No. 5 for effects of flat electrode.		
4 	X	Z	X	Y	X	Y	5/8 Flat	Z	Z	Z	$\frac{X}{Z} = \frac{1}{4}$
	Welding condition becomes more critical as outer metal thickness ratio increases.				Welding condition is more critical than when both tips are pointed.				Above recommendations give maximum structural quality, providing optimum weld schedule parameters are used.		

⑤		Y	Z	Z	$\frac{X}{Z} = \frac{1}{2.5}$	Y	$\frac{5}{8}$ Flat	Y	$\frac{X}{Z} = \frac{1}{2.5}$	$\frac{5}{8}$ Flat	Z	Z	$\frac{X}{Z} = \frac{1}{4}$
⑥		Y	Z	Y	$\frac{X}{Z} = \frac{1}{2.5}$	Y	$\frac{5}{8}$ Flat	Y	$\frac{X}{Z} = \frac{1}{2.5}$	$\frac{5}{8}$ Flat	Z	Z	$\frac{X}{Z} = \frac{1}{4}$
⑦		X	Z	X	-	X	$\frac{5}{8}$ Flat	X	-	$\frac{5}{8}$ Flat	Z	Z	-
⑧		Y	Z	Y	$\frac{X}{Z} = \frac{1}{2.5}$	Y	$\frac{5}{8}$ Flat	Y	$\frac{X}{Z} = \frac{1}{2.5}$	$\frac{5}{8}$ Flat	Z	Z	$\frac{X}{Z} = \frac{1}{4}$
⑨		X	Z	X	-	X	$\frac{5}{8}$ Flat	X	-	$\frac{5}{8}$ Flat	Z	Z	-
⑩		X	Z	X	$\frac{X}{Z} = \frac{1}{2.5}$	X	$\frac{5}{8}$ Flat	X	$\frac{X}{Z} = \frac{1}{2.5}$	$\frac{5}{8}$ Flat	Z	Z	$\frac{X}{Z} = \frac{1}{4}$
Preferred electrode arrangement for maximum structural quality, providing optimum weld schedule parameters are used.													

**Recommended
Practices
for
Automotive Portable Gun
Resistance-Spot Welding**

AMERICAN WELDING SOCIETY

AWS D8.5-66

**Recommended
Practices
for**

**Automotive Portable Gun
Resistance-Spot Welding**

Prepared by
AWS Automotive Welding Committee

Under the direction of
AWS Technical Activities Committee

Edward A. Fenton
Technical Director

Price \$1.50

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FOREWORD

The object of this document is to present recommended practices for portable gun resistance-spot welding of low-carbon steel in the automotive industry. The actual material used to prepare the lobes was SAE 1008 with a pickled and oiled surface condition (hot rolled) and also scale-free and oiled (cold rolled).

The weld schedules being used in the automotive industry on portable resistance welding equipment tend toward higher currents and shorter times. Although the present AWS Recommended Practices For Resistance Welding (C1.1-66) fall within the lobes presented in this document, it is possible to produce satisfactory welds in other areas of the lobes which are not in accordance with the present standard (C1.1-66). The welding rate for portable equipment is specified in spots/minute while rates for stationary equipment are in terms of spots/hour. Due to this higher rate, weld times for portable equipment applications are minimized and current magnitudes increased to meet the necessary heat requirements to establish structural quality weldments.

The report is based on experimental data. New data will be considered when available. To this end, comments and reports of experience will be most welcome. Inquiries on the recommendations contained herein are also welcome. Address all communications to Secretary, AWS Automotive Welding Committee, American Welding Society, 345 East 47th Street, New York, New York 10017.

Note: By publication of these recommended practices, the American Welding Society does not insure anyone utilizing the recommended practices against liability arising from the use of such recommended practices. A publication of a recommended practice by the American Welding Society does not carry with it the right to make, use or sell patented items. Each prospective user should make independent investigation.

**Recommended
Practices
for**

Automotive Portable Gun Resistance-Spot Welding

Because of the variety of fabrication by resistance-spot welding in the broad category of "Automotive Work", and the differences in operations within a given company in the industry, it was considered consistent to present these recommended practices in such a manner as to offer some latitude in schedule selection.

The recommendations are presented in a form referred to as "Weldability Lobes," and are attached in graph form. This data was developed in accordance with specified conditions established by a sub-committee responsible for developing the "Recommended Practices." There are nine graphic lobe presentations attached with the specified conditions previously referenced indicated on each for the respective metal thickness concerned. The diameter of the contact face of the electrode should conform to the dimension specified on each weldability lobe. These graphic illustrations of the inter-relationship of weld time and weld current were developed maintaining the electrode force, geometry, and cooling constant and varying the parameters of weld time and weld current. For several realistic values of weld time, that are associated with the metal thickness to be spot welded, two values of weld current for each weld time selected was determined:

1. That magnitude of current which produces the minimum acceptable weld nugget size determined by destructive peel testing (see C1.1-66) and
2. The maximum allowable current determined by flashing and evidence of excessive heat energy.

2 | Automotive Portable Gun Resistance-Spot Welding

This upper limit is represented as a range noted on the lobes as the "transition area" as specific interpretation of the maximum current as a discreet point is difficult. These minimum and maximum points of current for several weld times when connected describe a "Weldability Lobe" as shown.

Any weld made, under conditions specified for electrode geometry, force and cooling, with a weld time and current combination which lies within the confines of the weldability lobe, results in a weld of satisfactory quality. Those combinations of weld time and weld current that lie at a point to the left of the weldability lobe result in weldments which fail in shear or produce nugget diameters less than the minimum specified. Combinations of weld time and weld current placing a point to the right of the lobe result in weldments made with excessive heat energy evidenced by heavy flash, electrode indentation, electrode sticking and poor electrode life.

From these lobes it is possible to select short time—high current or long time—low current combinations with a certainty that the resultant heat energy level will produce weldments of a satisfactory structural quality.

For the weld time selected, and using the weldability lobe for the metal thickness involved, a current magnitude can be associated with this time to yield quality weldments. To obtain the longest production operation between electrode dressings or phase shift adjustments, the current selection should be made at the higher level, just below the flash point.

TIMER SETTING AT MAXIMUM SPEEDS
FOR VARIOUS METAL THICKNESSES

Maximum Gun Speed Spots/Min	TIMER SETTING (Time/Spot) Cycles (60 Per Sec.)					Metal Thickness
	Squeeze	Weld	Hold	Off	Total	
60	16	24	6	14	60	0.105 & above
80	12	20	3	10	45	0.089
100	9	14	3	10	36	0.075
120	7	12	2	9	30	0.067
133	7	10	1	9	27	0.059
150	7	8	1	8	24	0.047
164	7	7	1	7	22	0.041
180	7	5	1	7	20	0.035
200	6	4	1	7	18	

Supporting Information

The information presented in the preceding table suggests *maximum* portable resistance welding gun speeds for respective governing metal thicknesses to be welded. Speeds in excess of those listed for the respective metal gauge should not be considered. No limitations or restrictions are intended for gun speeds lower than those listed. It is acknowledged that welding equipment variations and its condition along with many other factors specific to a particular application might make it prohibitive to operate at the suggested maximum rates. Dependent on the operational rate, spots per minute of the gun welding machine dictates the total time allotted to make an individual weld. The total time per spot weld for the various operational rates are shown prorated into suggested squeeze, weld, hold, and off times. The suggested values for these intervals can require modification for the following reasons:

Squeeze Time—this time interval must be of a magnitude to allow a minimum of 90% full force development of the force applying system. Due to the variation in the inertia of the force systems, this time requirement must be adjusted to suit the condition.

Weld Time—times indicated are to be considered *minimum* times.

Hold Time—characteristics of force decay and joint restraint will influence this time interval.

Off Time—time to be selected to allow the welder to move and properly position gun between welds.

These factors can change the suggested operational rate for the respective metal thickness; however, the previous mentioned requirements for the time intervals should be met in any spot welding schedule developed. The requirements of the squeeze, weld, hold, and off times as described should be met in preference to the suggested maximum speeds listed.

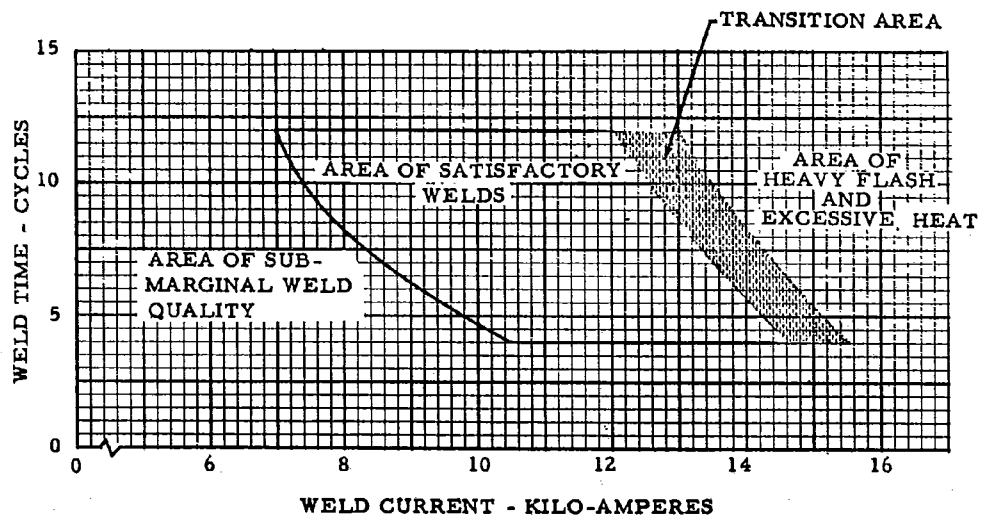
4 | Automotive Portable Gun Resistance-Spot Welding

WELDABILITY LOBE * FOR

Metal thickness	0.035 - 0.035 in.
Material	Low carbon steel

WELD SCHEDULE

Electrode force	600 lb.
Hold time	1 cycle
Electrode	¼ in. dia flat truncated cone
Nugget diameter (min)	0.18 in.



*Note: Lobe developed for second weld at ½ in. pitch.

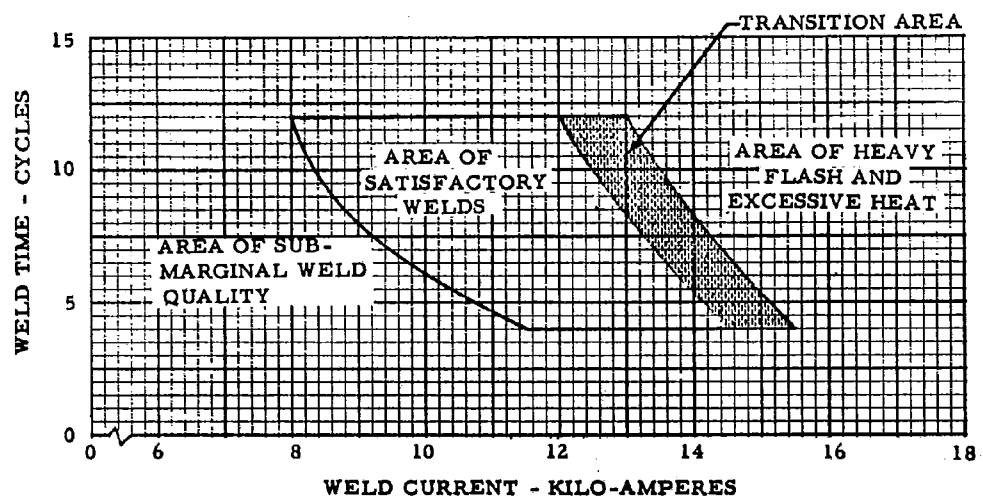
Automotive Portable Gun Resistance-Spot Welding | 5

WELDABILITY LOBE * FOR

Metal thickness	0.041 - 0.041 in.
Material	Low carbon steel

WELD SCHEDULE

Electrode force	650 lb.
Hold time	1 cycle
Electrode	¼ in. dia flat truncated cone
Nugget diameter (min)	0.19 in.



*Note: Lobe developed for second weld at ¾ in. pitch.

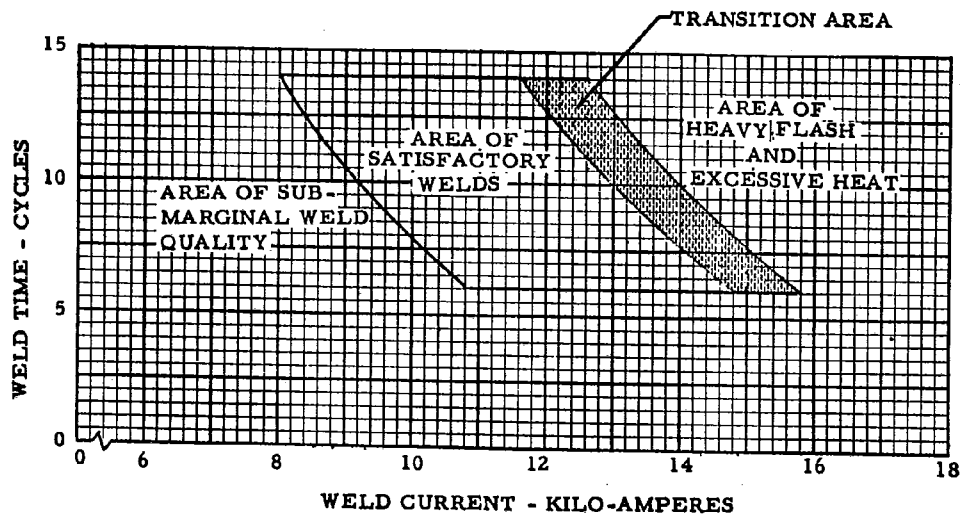
6 | Automotive Portable Gun Resistance-Spot Welding

WELDABILITY LOBE * FOR

Metal thickness	0.047 - 0.047 in.
Material	Low carbon steel

WELD SCHEDULE

Electrode force	750 lb.
Hold time	1 cycle
Electrode	¼ in. dia flat truncated cone
Nugget diameter (min)	0.20 in.



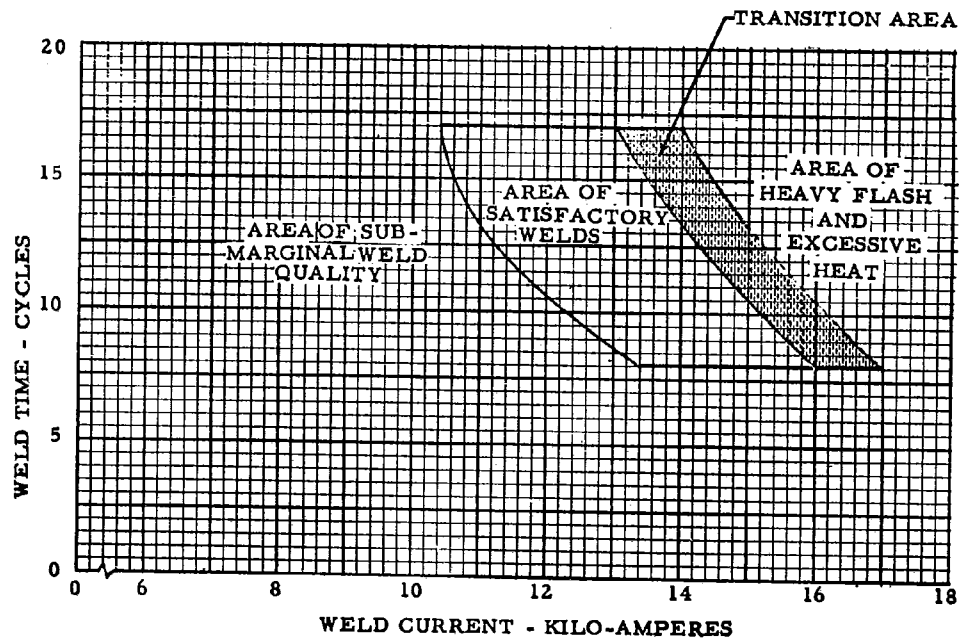
*Note: Lobe developed for second weld at ¾ in. pitch.

Automotive Portable Gun Resistance-Spot Welding | 7**WELDABILITY LOBE * FOR**

Metal thickness 0.059 - 0.059 in.
Material Low carbon steel

WELD SCHEDULE

Electrode force 900 lb.
Hold time 1 cycle
Electrode 5/16 in. dia flat
truncated cone
Nugget diameter (min) 0.23 in.



*Note: Lobe developed for second weld at $\frac{7}{8}$ in. pitch.

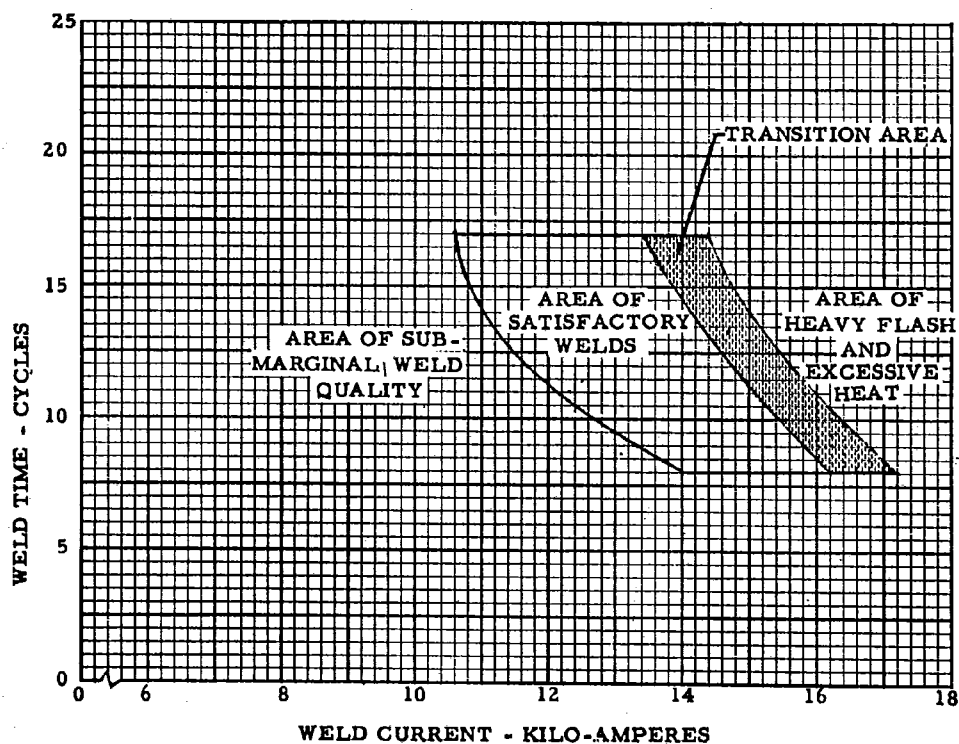
8 Automotive Portable Gun Resistance-Spot Welding

WELDABILITY LOBE * FOR

Metal thickness 0.067 - 0.067 in.
Material Low carbon steel

WELD SCHEDULE

Electrode force 1000 lb.
Hold time 2 cycles
Electrode 5/16 in. dia flat truncated cone
Nugget diameter (min) 0.26 in.



*Note: Lobe developed for second weld at $\frac{7}{8}$ in. pitch.

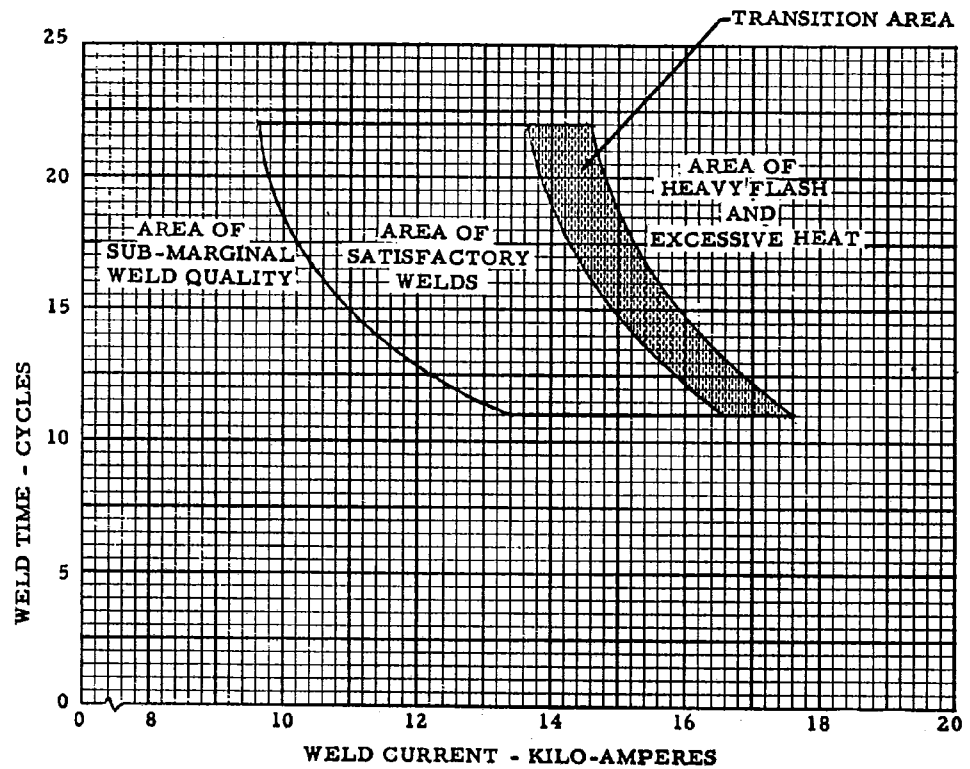
Automotive Portable Gun Resistance-Spot Welding | 9

WELDABILITY LOBE * FOR

Metal thickness 0.075 - 0.075 in.
Material Low carbon steel

WELD SCHEDULE

Electrode force 1200 lb.
Hold time 3 cycles
Electrode 5/16 in. dia flat truncated cone
Nugget diameter (min) 0.28 in.



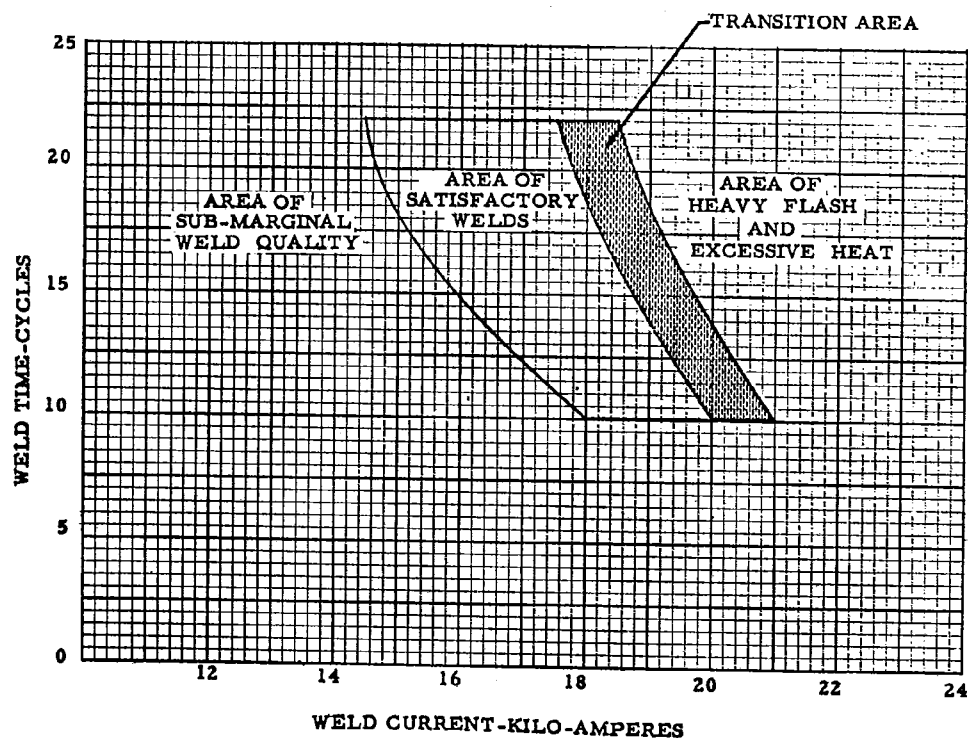
*Note: Lobe developed for second weld at 1 1/4 in. pitch.

10 | Automotive Portable Gun Resistance-Spot Welding**WELDABILITY LOBE * FOR**

Metal thickness	0.089 - 0.089 in.
Material	Low carbon steel

WELD SCHEDULE

Electrode force	1500 lb.
Hold time	3 cycles
Electrode	3/8 in. dia flat truncated cone
Nugget diameter (min)	0.29 in.



*Note: Lobe developed for second weld at 1 3/8 in. pitch.

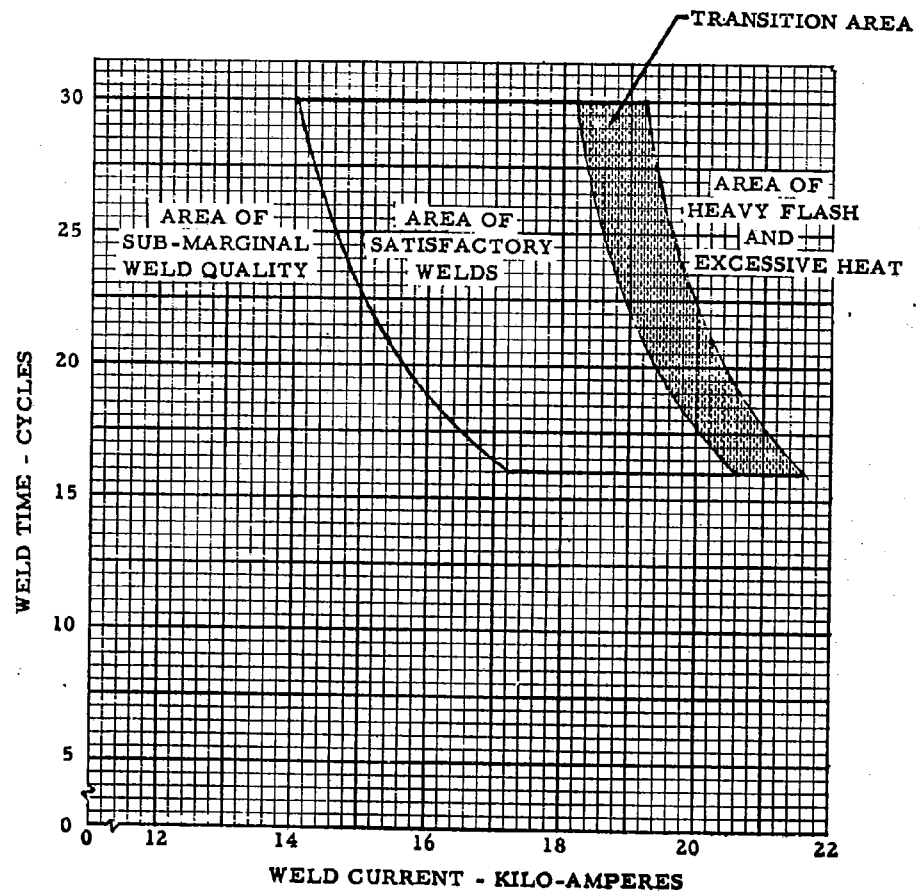
Automotive Portable Gun Resistance-Spot Welding | 11

WELDABILITY LOBE * FOR

Metal thickness 0.105 - 0.105 in.
 Material Low carbon steel

WELD SCHEDULE

Electrode force 1800 lb.
 Hold time 6 cycles
 Electrode $\frac{3}{8}$ in. dia flat truncated cone
 Nugget diameter (min) 0.31 in.



*Note: Lobe developed for second weld at 1½ in. pitch.

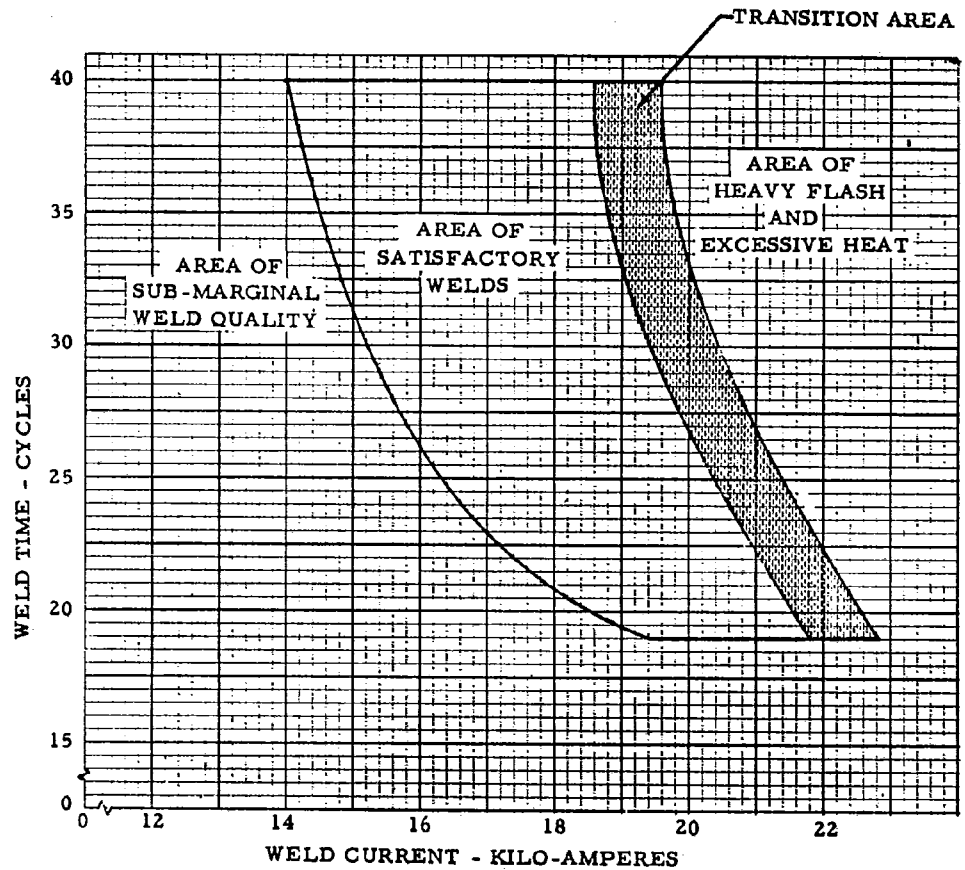
12 | Automotive Portable Gun Resistance-Spot Welding

WELDABILITY LOBE * FOR

Metal thickness	0.120 - 0.120 in.
Material	Low carbon steel

WELD SCHEDULE

Electrode force	2000 lb.
Hold time	6 cycles
Electrode	3/8 in. dia flat truncated cone
Nugget diameter (min)	0.31 in.



*Note: Lobe developed for second weld at 1½ in. pitch.

AWS

Technical Publications

GROUP A—FUNDAMENTALS OF WELDING

Definitions, Symbols, Testing

Standard Welding Symbols A2.0-58	\$3.00
Welding Symbols Chart A2.1-58	
Wall Size (22" x 28")	\$1.50
Desk Size (8½" x 11")	50c
Nondestructive Testing Symbols A2.2-58	\$1.00
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Standard Methods for Mechanical Testing of Welds (with 1945 Supplement) A4.0-42	50c

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