Miller®

ARC STUD WELDING FUNDAMENTALS

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WARNING:

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 the 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.

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PROCESS DESCRIPTION

As defined by the American Welding Society, stud welding is a process wherein coalescence is produced by heating with an arc drawn between a metal stud, or similar part, and the other part until the surfaces to be joined are properly heated when they are brought together under pressure. Partial shielding may be obtained by the use of a ceramic ferrule surrounding the stud. Shielding gas or flux may, or may not, be used.

The heat necessary for end welding of studs is developed by passage of current through an arc from the stud (electrode) to the plate (work), to which the stud is to be welded. The stud, held in a portable pistol-shaped tool called a stud-gun, is positioned by the operator, who then actuates the unit by pressing the trigger switch. The weld is completed quickly, usually in less than one second. The process obtains substantial shielding by use of a ceramic shield (ferrule) surrounding the stud, which also dams the molten metal to form a fillet weld.

EQUIPMENT

The necessary equipment for stud welding consists of:

1. POWER SOURCE
2. STUD WELDING GUN
3. CONTROL UNIT TO CONTROL THE WELD TIME

Figure 1 (on page 2) illustrates a typical setup for arc stud welding.

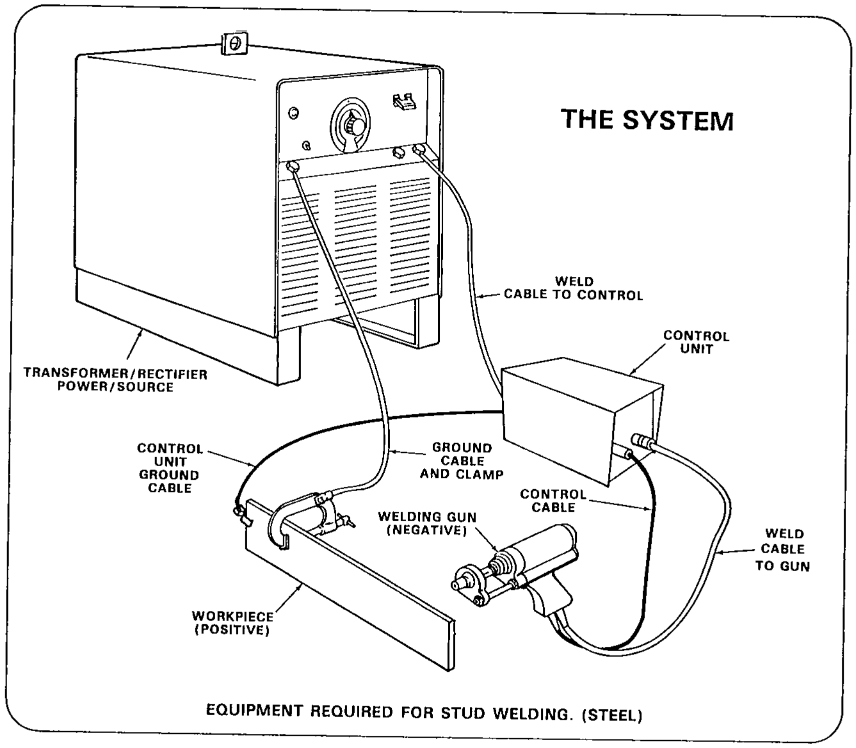


Figure 1

POWER SOURCE

The power source used for stud welding must be a direct current type. A generator, either motor or engine driven, or a transformer-rectifier may be used. The ampere rating of the machine depends upon the size of the stud and welding conditions. Some characteristics desired in a stud welding power source are:

1. Terminal voltage in the range of 70 to 100 volts, dc, open circuit. Many control units operate from machine open circuit voltage; therefore, the machine voltage is important to properly energize the control components. Some control units operate from 115 v. alternating current; therefore, machine open circuit voltage is irrelevant to the funtioning of the controls. Consult equipment manufacturers operation manuals for proper recommendations.
2. A drooping volt-amp characteristic or a constant potential machine may be used. The drooper type has been most popular because constant potential machines usually have an open circuit voltage below the required voltage to operate the control. However, constant potential power supplies with an open circuit voltage above 60 can be used. Some slope is desirable in a constant potential power supply to produce desirable arc characteristics.

3. Rapid current rise time is a necessity. This means the welding current should rise to a peak value within a few cycles. Since weld time for stud welding is usually one second or less, too slow a current rise would not allow the power source to reach peak value before the control unit times out and opens the contactor.
4. High current output is required for a relatively short time. The duty cycle is very low compared to the 60% to 100% rating for other welding processes. Because of this low duty cycle requirement, a machine rated at 400 amperes for welding may be used above the rated output safely.

Consulting the volt-amp curve chart and duty cycle chart (Figure 2 and 3) of a particular power source will reveal the maximum safe operating level.

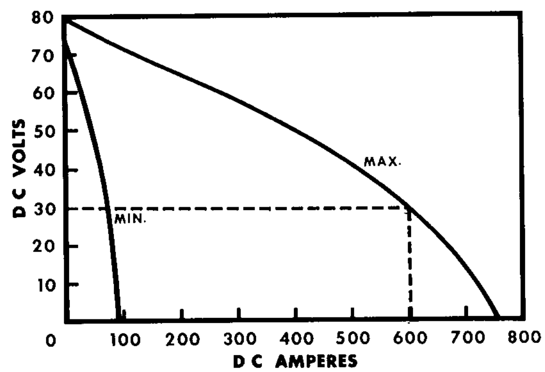


Figure 2

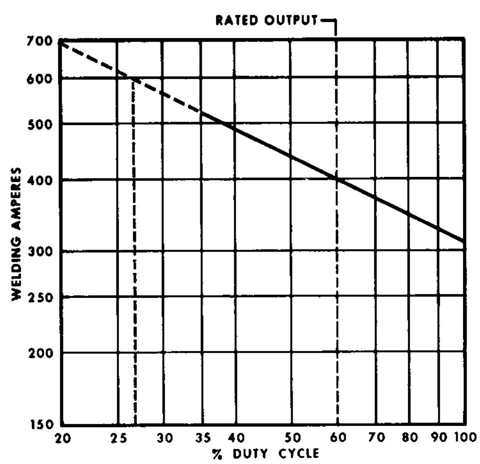


Figure 3

For example, the volt-amp curve shown here (Figure 2) is for a power source rated at 400 amperes @ 36 volts, complying with NEMA ratings.

The duty cycle chart (Figure 3) shows this machine is rated at 60% duty cycle. To determine the machine's maximum capability for stud welding, the volt-amp curve chart should be consulted. AWS information on stud welding lists the arc voltage range for stud welding from 25 to 35 volts. Selecting the middle of this range (30 volts), a line is drawn to the right until it intersects the maximum output curve. Constructing a vertical line from the point of intersection down to the amperage scale will show the amperage available at 30 volts. In this example, it is approximately 600 amps. Consulting the duty cycle chart for this same machine, the duty cycle at 600 amps can be determined. Starting at the rated output (400 amps at 60%), follow the duty cycle line to the left, and upward (extend the line as necessary) until the 600 ampere point is reached. Again, dropping a vertical line from this point to the duty cycle scale on the bottom, it can be noted that the duty cycle will be slightly over 25%. This would be the safe level of operation for this unit. Therefore, a power supply rated at 400 amps for arc welding could be used up to 600 amps for stud welding because of the lower duty cycle.

It must also be noted that other considerations are necessary. The example above would be accurate only as long as:

a. power source is in good condition.
b. input power is at rated input.
c. cables are of adequate size and reasonable lengths.
d. all connections are very sound.

If a power supply is not properly maintained, it will not be able to produce the required sudden surge of current in the short time required. Engine driven equipment in particular must be in good working order. The engine must be in good condition and operating at the rated rpm. For power supplies that operate from alternating current, primary power must be supplied with the required primary amperage at the correct voltage. Remember, of course, that a power supply used at maximum rating for stud welding will require considerably more input current than is necessary for its rated output for other welding processes. Fuses and primary wiring may need to be adjusted accordingly.

The welding cable length and cable size are very important. Oftentimes, a power source is penalized by the use of too small a cable or too long a cable system. The chart shown (Figure 4) will serve as a guide to selecting cable size and lengths in relation to the stud shank size and approximate amperage.

It should be realized that a voltage drop will occur between the machine terminals and the stud gun, due to cable resistance. Cables must be of sufficient size to allow the necessary voltage to be available at the stud gun. It is normally desirable not to have more than 5 volts drop in the cables.

Cable connections and splices are another area to consider. Make the best possible electrical and mechanical connections. Use commercially available welding cable connectors, making certain the right size is used for cable size being used. Since the time cycle is so short, any "arcing" in a poor connection will prevent satisfactory stud welding.

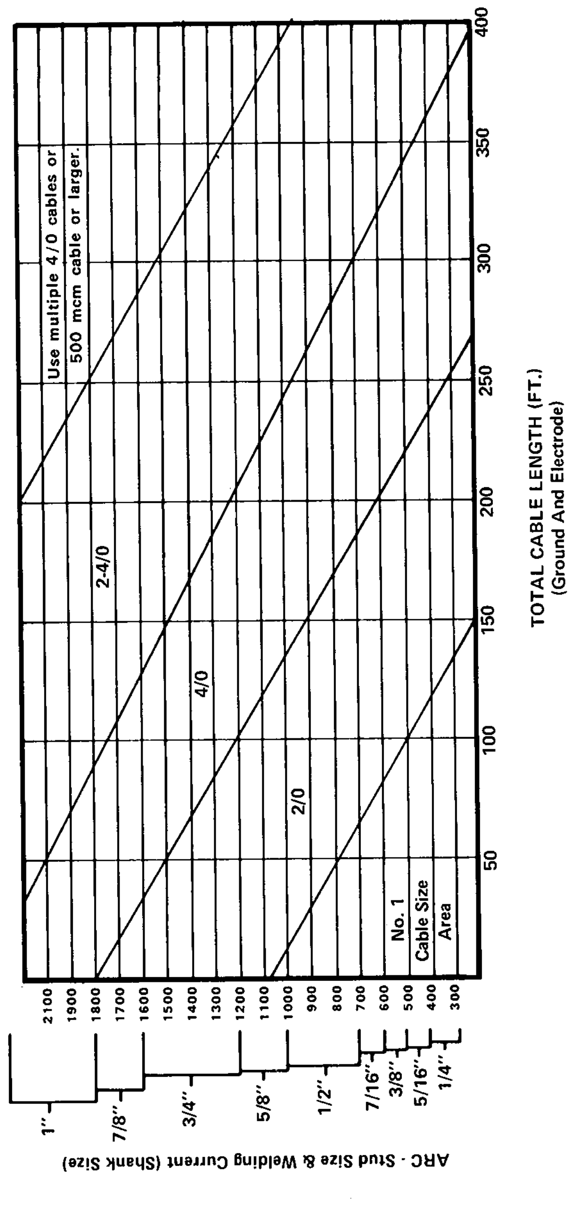


Figure 4

ARC STUD WELDING GUNS

There are two basic designs of arc stud welding guns available:

1. The portable, or pistol grip configuration, which is used for hand-held or manual operation.
2. The fixed, or production gun is usually mounted on a positioning device, and is usually incorporated with an automatic stud loading system.

The portable, or pistol grip design is usually available in two capacities:

a. Standard duty unit tooled to handle stud diameters from ⅛" (3.2 mm) to ½" (12.7 mm).
b. Heavy duty unit tooled to handle stud diameters from ⅛" (3.2 mm) to 1¼" (31.8 mm).

Portable stud guns normally weigh between 4½ (2 kg) to 9 (4 kg) lbs. with the body being constructed of high impact plastic.

The gun consists basically of a body, lift mechanism, chuck or stud holder, an adjustable support for ferrule holder and cables. Chucks and ferrule holders are easily changed to permit various diameters of studs and ferrules to be used. An adjustment for the lift of the stud is provided on the stud gun. Some manufacturers use a permanent ferrule, rather than individual ferrules. (Reference should be made to manuals of stud welding equipment manufacturers for detailed information and instructions).

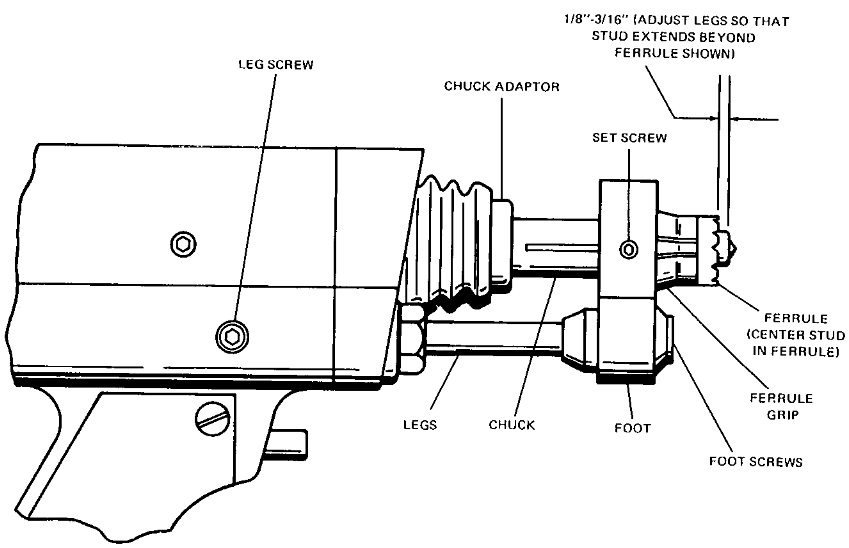


Figure 5

STUD WELDING CONTROLS

The control unit of an arc stud welding system is located in the welding circuit to regulate arc duration through the welding cycle and provides adjustable controls for various stud diameters.

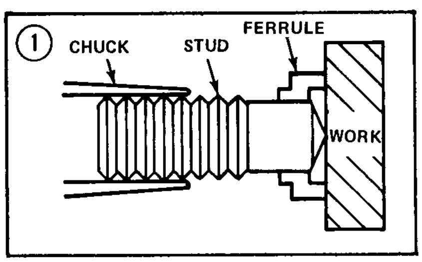
The control unit consists, fundamentally, of a contactor suitable for interruption of the weld current and a timing device. The weld timer is usually graduated in cycles (60 cycles = 1 second), and may have an adjustable range from 3 to 120 cycles (1/20 to 2 seconds). The time in cycles is determined by the stud diameter. Most equipment manufacturers' literature will provide adjustment information.

Control units are usually separate from the welding power supply. However, equipment designed specifically for stud welding only may incorporate the control unit into the power supply.

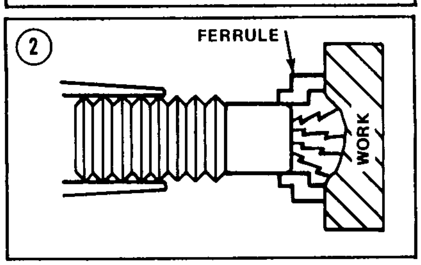
Like the arc stud gun, the control units are usually available in two capacity ratings:

a. Standard duty for a maximum stud diameter of ½" (12.7 mm).
b. Heavy duty unit suitable for a maximum diameter of 1¼" (31.8 mm).

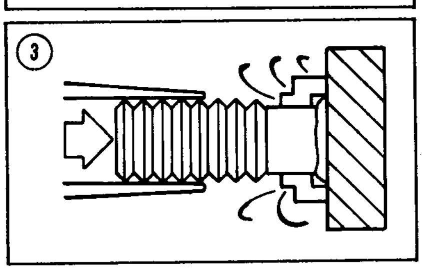
The operational sequence of the control unit and the process may be broken down into these four steps:



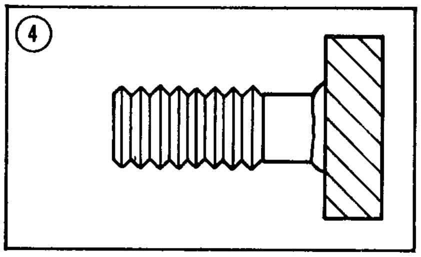
1. The stud, inserted in the welding end (chuck) of the stud gun, is placed against the work plate. The operator then presses the gun to the work plate until the ferrule, which is around the stud, is flat against the plate.



2. The trigger switch is pressed, starting the automatic welding cycle. The stud is automatically lifted or pulled away from the work piece creating an electric arc between the stud and plate. The stud remains in this position until the arcing period, as pre-set and controlled by the timer control unit, is completed. A portion of the end of the stud and the plate are melted by the arc.



3. After completion of the arcing period, the main spring in the gun is released, plunging the stud into the molten pool on the plate to complete the weld.



4. The gun is pulled away from the stud and ferrule is knocked off.

THE WELDING STUD

Welding grade studs are made of most commercially used metals, and normally range in diameters from ⅛" (3.2 mm) to 1¼" (31.8 mm), with lengths as required. In addition to straight threaded or unthreaded studs, it is possible to obtain a wide variety of shapes and sizes. The illustration (Figue 6) shows some of the various configurations.

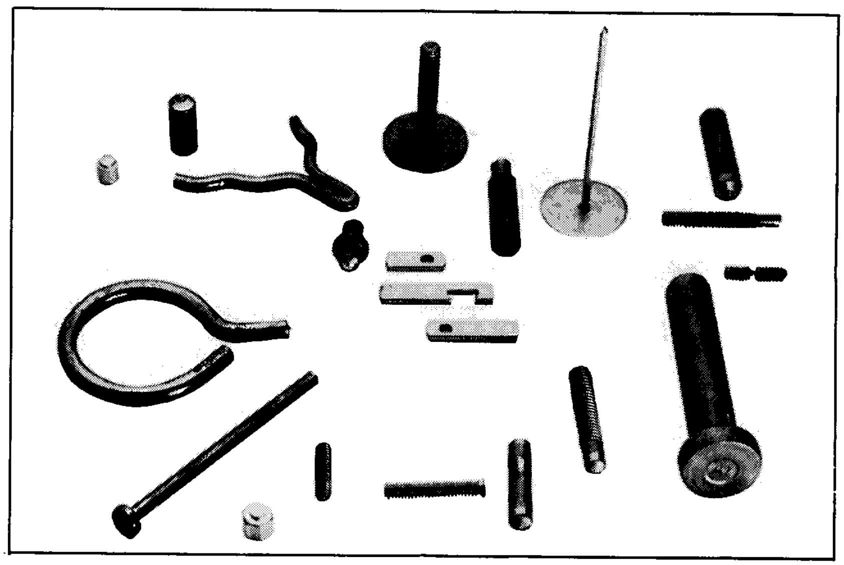
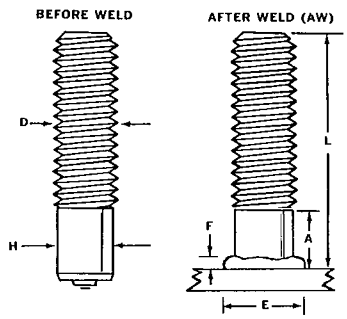


Figure 6
Studs are available in hundreds of configurations and may be round, square or rectangular in cross section.

The stud manufacturers' catalogs will list the characteristics and dimensions of the various studs available. When setting up the welding parameters, the shank diameter (where contact is made to work) should be used as the determining factor for amperage and time setting. On threaded fasteners, the shank diameter may be less than the thread diameter. The specification chart shown (Figure 7) lists the various diameters for standard steel studs.

Figure 7



SPECIFICATIONS					
DIAMETER AND THREAD D	MIN. (AW) LENGTH A	H	MIN. (AW) LENGTH L	WELD BEAD DIMENSIONS E	F
1/4-20	1/4	.217	5/8	5/16	3/32
5/16 18	1/4	.275	5/8	13/32	7/64
3/8-16	1/4	.312	5/8	7/16	7/64
7/16-14	1/4	.375	3/4	1/2	1/8
1/2-13	5/16	.437	3/4	19/32	9/64
5/8-11	5/16	.500	7/8	11/16	5/32
3/4-10	1/2	.625	1-1/8	7/8	3/16
7/8-9	1/2	.750	1-3/8	1	3/16
1-8	13/16	.875	1-7/8	1-1/8	3/16

The stud gun should be set up in accordance with the manufacturer's recommendation. The timing device on the control unit and the power source should be adjusted to the approximate settings shown in the following table. (Figure 8)

* TYPICAL WELDING CONDITIONS FOR STUD WELDING OF STEEL

STUD-WELD BASE DIAMETER (INS.)	(MMS.)	WELD TIME (Cycles) + or — 10%	WELDING AMPERAGE[1] + or — 10%
3/16	4.8	7	300
1/4	6.4	10	400
5/16	7.9	15	500
3/8	9.5	20	600
7/16	11.1	25	700
1/2	12.7	30	900
5/8	15.9	38	1200
3/4	19.1	50	1600
7/8	22.2	60	1800
1	25.4	70	2000

* Settings should be adjusted to suit job conditions.

1. Amperages shown are actual welding amperages, and do NOT necessarily correspond to power source dial settings.

Figure 8

It should be emphasized that the amperage values shown are actual metered readings and not necessarily the dial settings on the machine. The amperage and time values shown are at approximately the mid-point of the operating range. Similar results can be obtained with a lower amperage setting and more time, or with a higher amperage setting and less time. The plus or minus tolerance listed should keep conditions within the range for satisfactory results. Once again, consideration should be given to cable sizes, lengths, condition of material, type of stud, etc., when comparing settings from charts to actual conditions.

ARC SHIELDS (Ferrules)

The ceramic ferrule performs several important functions and is required to do each weld. Some equipment is available with a permanent shield attached directly to the stud gun. The ferrule:

1. concentrates the arc heat to the immediate weld area.
2. protects the molten weld pool from atmospheric contamination.
3. confines the molten metal to the weld zone, to form a fillet.
4. prevents charring and disruption of surrounding base metal surfaces.
5. reduces the possibility of open arc flash; therefore, the operator and surrounding personnel need only wear suitable flash type safety glasses.

Upon completion of the weld, the protective ceramic shield can be easily removed by chipping it away or lifting it off with a suitable tool.

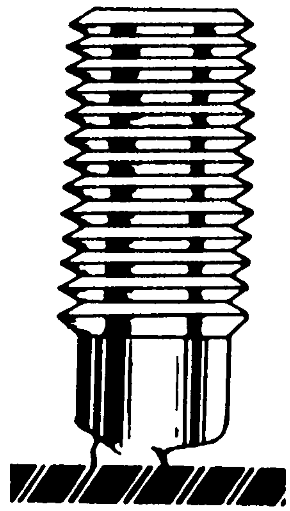
RECOMMENDED PROCEDURES AND TECHNIQUES

Once the part has been designed for stud welding and a particular type and size of stud has been selected, a few basic points may be followed in establishing a suitable procedure:

1. Have sufficient weld power available for the diameter of stud to be welded. Stainless steel studs require approximately 10% more power than an equivalent sized steel stud.
2. Have secondary cables of sufficient size, reasonable length, and assure all connections are tight.
3. Secondary hook-up should be dc straight polarity for steel and stainless steel, and reverse polarity for aluminum and magnesium.
4. A good ground is essential. Use a "C" clamp type ground, and clean contact area of paint and heavy surface scale.
5. Set up stud gun in accordance with manufacturer's recommendations. Adjust gun leg(s) so that stud extension beyond ferrule is as recommended.
6. Select positions of stud placement by layout or suitable templates.
7. Clean area where stud is to be placed. Grind or scrape area to remove any surface contaminants.
8. The stud gun should be positioned perpendicular to the work surface, and depressed until the ferrule is firmly seated against the work.
9. The trigger should be actuated once, and released. Do NOT move the gun during welding. Do NOT actuate the trigger a second time if the stud is attached to the plate. (Damage could result to the chuck (arcing).
10. At the completion of the weld cycle, the gun should be held in position momentarily to allow solidification of molten metal. Remove the gun and ferrule, and inspect weld.

WELD INSPECTION AND TROUBLESHOOTING

Welded studs may be inspected by visual examination or by mechanical testing. Visual inspection is probably most often used once the procedure is established, and persons involved are familiarized with the process. Visual examination may reveal some of the following conditions:



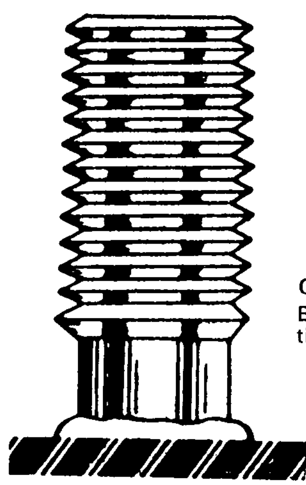
Poor Weld

CAUSE:

Plunge of stud too short or high amperage.

HOW TO AVOID THIS:

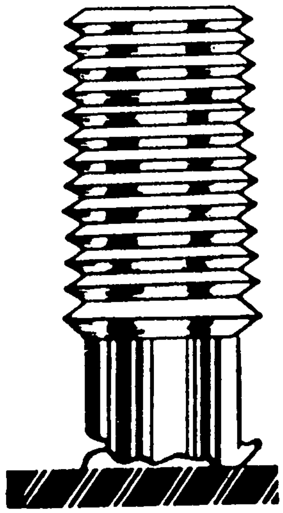
Make necessary adjustment so that the stud extends from 1/8 to 3/16 inch beyond the ferrule. Also, check to make sure that the gun action works smoothly and stud is centered inside of the ferrule. Foot and leg adaptors may need adjusting or gun needs cleaning. Power source may be set too high.



Good Weld

CORRECT WELD

By conforming with the above suggestions a satisfactory weld is attained.

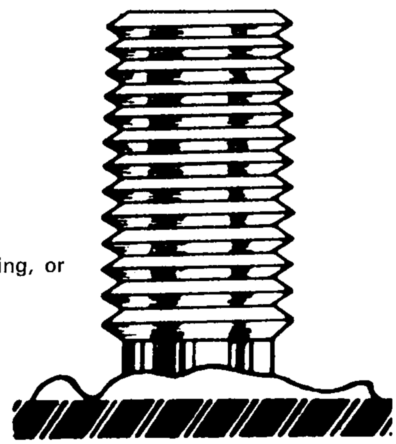


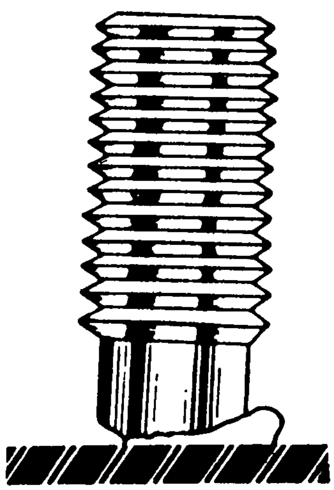
CAUSE:
Not enough amperage.

HOW TO AVOID THIS:
First, check all cable connections and the ground. If all are satisfactory, turn up the amperage slightly on the power source, or increase the weld time setting a little.

CAUSE:
Too much amperage.

HOW TO AVOID THIS:
Turn back the power source setting, or the timer setting.

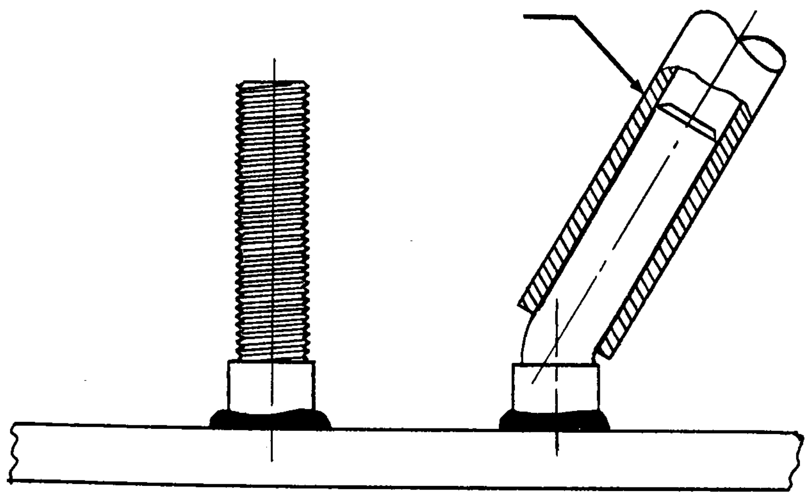




CAUSE:
Poor alignment.

HOW TO AVOID THIS:
The stud and ferrule must be held square or perpendicular to the work. Otherwise you will get an uneven fillet and a poorly aligned stud.

Mechanical testing can be done to determine the strength of the welded area. A frequently used test is the bend test shown in Figure 9. This should be done when setting up parameters to assure a sound weld is being made.



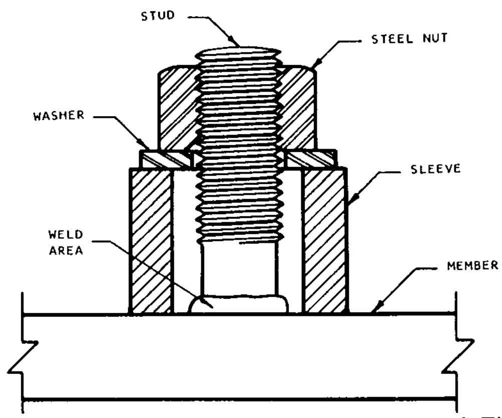
STANDARD A.W.S. BEND TEST

Figure 9

The AWS Structural Welding Code D1.1-72 states: "Each welding unit before use in production shall be used to weld two stud or shear connectors to separate material in the same general position (flat, vertical, overhead, sloping) and of similar thickness. After being allowed to cool each stud shall be bent to an angle of 30° from its original position by striking with a hammer. If failure occurs in the weld zone of either stud the procedure shall be corrected and two successive studs welded and tested."

Threaded studs may be torque tested with a calibrated torque wrench.

The values shown in the table below meet the requirements of the AWS Structural Welding Code D1.1-72.

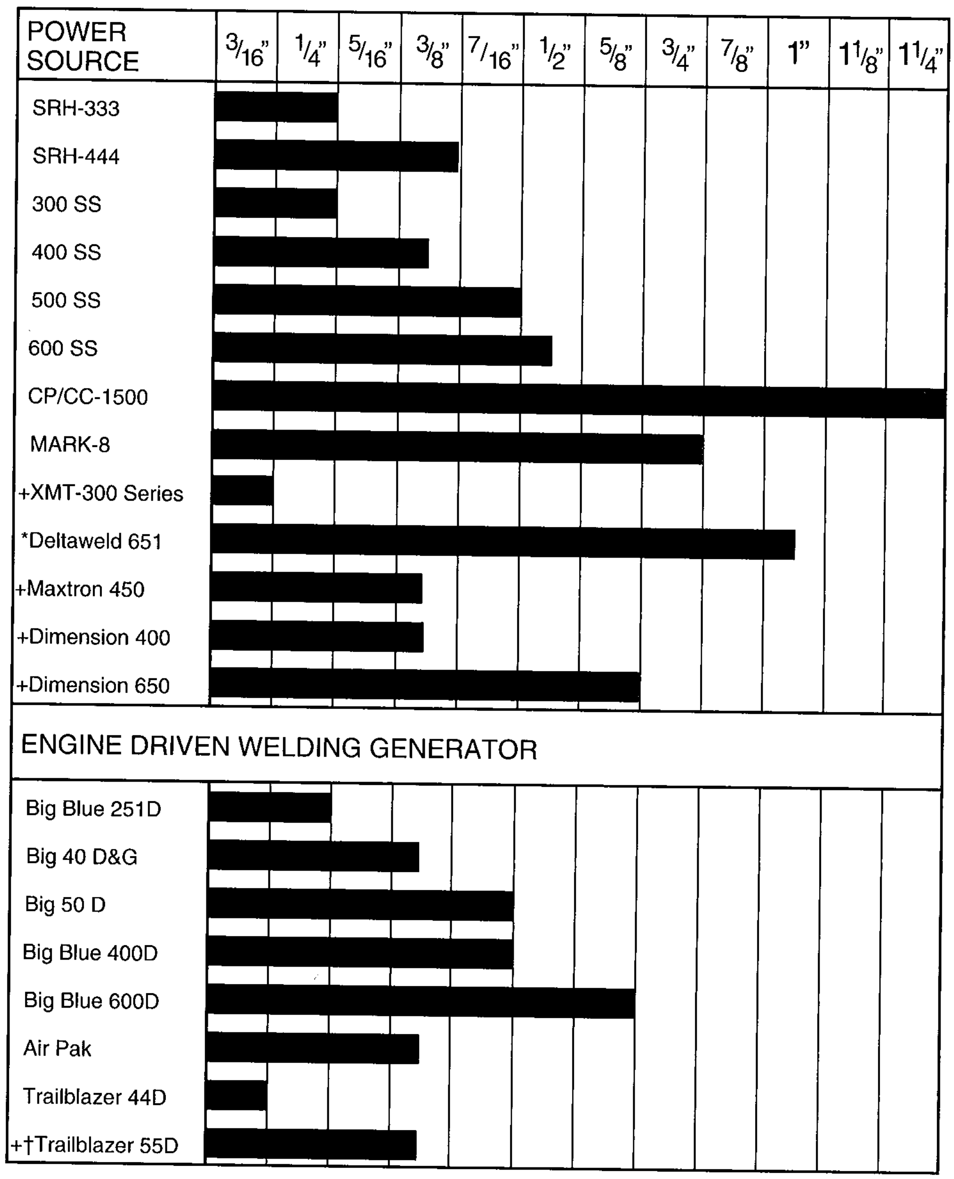


Dimensions are appropriate to the size of the stud. Threads of the stud shall be clean and free of lubricant other than for the residue of cutting oil.

STANDARD A.W.S. TORQUE TEST

REQUIRED TORQUE FOR TESTING THREADED STUDS		
NOMINAL DIAMETER OF STUDS, INCHES	THREADS PER INCH AND SERIES DESIGNATED	TESTING TORQUE FOOT - POUNDS
1/4	28 UNF	5.0
1/4	20 UNC	4.2
5/16	24 UNF	9.5
5/16	18 UNC	8.6
3/8	24 UNF	17.
3/8	16 UNC	15.
7/16	20 UNF	27.
7/16	14 UNC	24.
1/2	20 UNF	42.
1/2	13 UNC	37.
9/16	18 UNF	60.
9/16	12 UNC	54.
5/8	18 UNF	84.
5/8	11 UNC	74.
3/4	16 UNF	147.
3/4	10 UNC	132.
7/8	14 UNF	234.
7/8	9 UNC	212.
1	12 UNF	348.
1	8 UNC	318.

SUGGESTED MILLER POWER SOURCES



+ In C.C. Mode

* Open circuit voltage may be marginal from controls which operate from power source open circuit voltage. Controls that operate from 115 v.a.c. or controls with a low voltage coil are recommended.

† Range may be extended 15% (on amperage) to include 3/8" studs by using CP mode and suitable gun control as mentioned above.

Paralleling two or more of the power supplies listed will expand the stud diameter range that may be welded. Consult equipment manufacturer's manual for proper paralleling procedures.

TYPICAL USES OF THE ARC STUD WELDING PROCESS

The arc stud welding process lends itself to a wide range of applications such as: automotive, appliance, aero dynamics, boilers, light or heavy construction, preassembled fabrication designs, fit-up parts design and others too numerous to mention.

The process may be utilized on a range of material thickness from about .060" to several inches.

The process is advantageous for the following reasons:

1. Major design specifications may be readily adapted to the process, such as: material types, metallurgical aspects, special thread designs, fit-up tolerances, etc.
2. The process is capable of producing a fully sealed weldment with a minimum of base metal distortion or surface disruption.
3. The process extends its usability into locations which do not permit use of other fastening methods.
4. The process lends itself to the automated concept of high production shops.
5. The process is capable of producing welds which are less costly per unit than other methods.
6. The process may be effectively utilized with a minimum of time spent in personnel training.
7. The process can be effectively used in maintaining weld quality with a minimum of time for inspection.

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