4-H 573

Arcs & Sparks

Shielded Metal Arc Welding

Name _____

Date _____

Project Activity Guide

Table of Contents

Authors and other contributors are listed on page 74.

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Getting Started

This beginning-level project is designed for members 12 years of age and older. Younger members may take this project under the guidance of a knowledgeable adult. This project should take between three and six months to complete and may be repeated.

This is the first of four welding manuals we plan to publish as shown on the back cover. Ask your project leader for assistance when planning your project. Additional help may be available from your local welding distributor, area vocational school, and/or local section of the American Welding Society (AWS).

Be sure to check your county's project guidelines (if any) for additional requirements, especially if you wish to participate in county project judging or prepare an exhibit for the county and/or state fair.

Project Guidelines

1. **Complete the Planning Your Project section of this manual (Steps 1 through 4).**
2. **Explore the recommended Interest Areas for your year in the project.**
3. **Complete the recommended number of Building Skills and Developing Knowledge questions in each Interest Area.**
4. **Take part in at least two Learning Experiences.**
5. **Become involved in at least two Leadership/Citizenship Activities.**
6. **Build at least two weldments/items following the instructions in the back of this manual.**
7. **Write a one-page report telling what you did and learned through this project.**
8. **Members repeating this project should complete one additional activity in Interest Areas 1 through 3 and build two additional weldments/items.**

Planning Your Project

This planning section, Steps 1 through 4, is designed to be re-used if you repeat this project.

Step 1: Interest Areas

Explore the recommended chapters for your year in the project. As you begin to explore or re-explore a chapter, place the current date (month and year) next to it.

Year 1		Year 2		
Date Started	Date Completed	Date Started	Date Completed	Chapters
				Identifying Equipment, pages 8-15
				Staying Safe from Head to Toe, pages 16-20
				Examining Electrodes, pages 21-26
				Ready, Set, Weld!, pages 26-33
				Mastering the Trade, pages 33-41
				Showing Your Skills, pages 43-67

Step 2: Learning Activities

Plan to complete all the recommended Building Skills and Developing Knowledge questions for each chapter. Have your parent or project leader initial and date when you have learned a skill or answered a question correctly. Members who repeat this project are required to complete one additional Building Skills activity in Chapters 1 through 3.

Step 3: Learning Experiences

Select two of the Learning Experiences listed here and plan your involvement in the Report of Learning Experiences chart. Before starting your project, write your choices in the Plan to Do section. As soon as you have taken part in an activity, record what you did and when it was done (month and year). Learning Experiences may be added or changed at any time.

Sample Learning Experiences:

County Project Judging
Radio/TV Presentation
Demonstration
Speech
Field Trip
Welding Demonstration
Illustrated Talk
Trade Show
Exhibit Weldment
Welding Clinic
Project Meetings
Plant Tour

Report of Learning Experiences

Plan to Do	What I Did	Date
Example: Exhibit Weldment	I made a boot scraper and exhibited it at the fair.	July, 2002

Step 4: Leadership/Citizenship Activities

Place a check mark by the activities you wish to do, or plan your own activities in the space provided. Complete at least two activities. Keep track of your progress by marking the month and year when you complete each activity. Leadership/Citizenship activities may be added or changed at any time.

Plan to Do	Date Completed	Activity
____	_____	Encourage someone to take a 4-H welding project.
____	_____	Help someone with his or her 4-H welding project.
____	_____	Organize a welding demonstration for your club.
____	_____	Invite someone to talk to your club about welding safety and career opportunities in welding.
____	_____	Prepare and exhibit an educational display about welding safety.
____	_____	Promote the safe use of welding equipment in your community.

Plan to Do	Date Completed	Activity
____	_____	Teach someone something you learned in your 4-H welding project.
____	_____	Apply something you learned about welding to benefit your family or community.
____	_____	Help a member prepare his or her 4-H welding project for judging.
____	_____	Arrange for your club to tour a welding shop.
		Plan your own activities here: _____ _____ _____ _____

Reviewing Your Project

As soon as you complete what you plan to do, arrange for a local project review. This review can take place with a parent, your project advisor, or an interested adult. Your review may also be part of a more comprehensive member evaluation at a time agreed upon by club members.

Evaluations help you reflect on what you have learned as well as on your growth as a 4-H member. Members who take part in this level of evaluation may receive special membership and project achievement awards, such as ribbons, pins, and certificates.

You also may want to take part in county project judging. However, this level of evaluation determines "how well" you did on your project by assigning you a "project grade." You will be compared against the achievements of others to determine "the best" in your project area, as well as to determine possible state fair participation.

Welcome to Welding

Life Skill: Exploring something new

Project Skill: Exploring the world of shielded metal arc welding. See how welding is part of your everyday life. Learn a new language — welding terms and phrases and concepts.

Welcome to the family of **welding**. To bring you into the family, we need to introduce you to the world of welding. To do this, we have broken the subject into four project manual books and an advisor's guide book to help you.

In welding we have two basic ways of joining parts, pieces, or members together. They are known as "solid-state" and "**fusion**" welding. To make these understandable let's see how we can relate them to our everyday experiences. We all need food and drink, so let's compare welding to cooking, especially making desserts.

Solid-state welding is like fixing an ice cream cone with real (i.e., hard) ice cream. After the first scoop of ice cream is in the cone, we build up the cone by placing each additional scoop of ice cream on the previous scoop(s). If the ice cream is too soft, (slightly liquid on the surface), the additional scoop(s) slips off. If the ice cream is too hard, the pushing required to join the new scoop onto the previous scoop(s) may crush or crack the cone. The ice cream has to be at the right temperature, soft enough but not liquid, so that the scoops can be joined without damaging the cone.

Fusion welding is like making chocolate candies. First, you melt a base of baker's chocolate, making sure the temperature is not too hot nor too cold, but just right. You may use this melt/liquid to make solid shapes or as a coating. In fusion welding this is called autogenous welding, where only the **base metal** is melted and then resolidified making a **weld (coalescence)**.

Or you can add milk (or cream) and sugar to the melted chocolate to make milk chocolate, which can then be used to make solid shapes or as a coating. The milk/cream and sugar are the equivalent of the **filler material**, which is used with most fusion welding. The filler metal changes the properties of the melted base metal. The result is a weld in which the weld metal is similar to the base metal. However, the weld metal may be softer or harder, weaker or stronger, depending on what kind and how much filler metal is added, as can the milk chocolate vary from bitter to sweet, from hard to soft depending on how much milk/cream and sugar are added.

In welding, the information needed to make a particular weld is contained in the welding procedure specification (WPS). The WPS is usually one to two pages in length and contains all the information, such as process, weld type, filler materials, process settings, sequence of welding, etc., to make the required weld. In cooking, this is the recipe: the list of ingredients and equipment and directions for making an item/dessert.

The four project manual books cover the five principal fusion welding processes that you may encounter in welding at home and on the farm. These books are written for you to learn the basics of these processes. With practice and guidance you will come to enjoy using these processes to make weldments/items, and help others to solve problems.

Glossary Terms: The first time a word in the glossary (Welding Terms, page 68-73) appears you will see it highlighted in **orange**.

Bon appétit and Welcome to the Welding Family!

SMAW

Electric **arc welding** was developed more than 200 years ago, but was not used successfully in industry until about 1910. For example, Henry Ford's Model T cars in the early 1900's were bolted together, not welded.

In 1782, Professor G. Charles Lichtenberg (in Germany) made the first known electric arc weld. In 1801, Sir Humphrey Davy (in England) made the first sustained arc weld. Arc welding has come a long way. There are more than 20 arc welding processes used in industry today. This project manual, "Arcs and Sparks" is about the first truly successful arc welding process: **shielded metal arc welding (SMAW)**.

The American Welding Society (AWS) defines SMAW as: "An arc welding process wherein coalescence is produced by heating with an **arc** between a covered metal **electrode** and the work. Shielding is obtained from decomposition of the electrode covering. Pressure is not used and filler material is obtained from the electrode."

To understand this definition, you need to become familiar with various welding terms and phrases. The list of welding terms and definitions presented at the end of this book will help you understand and learn more from this project.

Identifying Equipment

Before you arc weld, you should become familiar with the machines you will need to operate. Although you may not see all of the equipment discussed here on your farm or at work, you will still need a general knowledge of this equipment if you are to become a good **welder**.

In shielded metal arc welding, electrical energy is conducted from one point to another and converted into a large quantity of heat at the arc. The heat produced at the arc melts the filler metal and the base metal. To create this heat, you need an arc welding power source such as the one pictured.

Life Skill: Planning and organizing

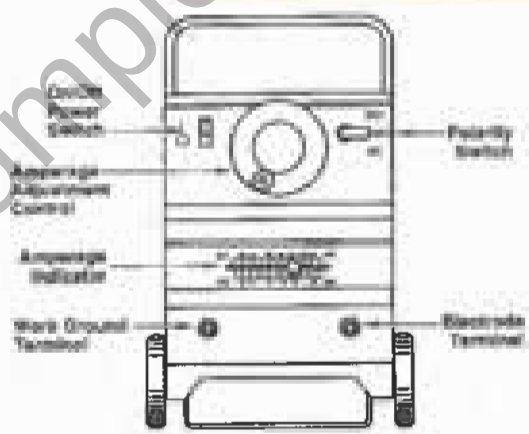
Project Skill: Learning about the different power sources available and their correct configurations, and identifying optional equipment used in welding.

Power Sources

The welding industry, farms and small shops use numerous types of **power sources**. Power sources use either static converters (transformers) or rotating converters (generators/alternators) to produce the electric power needed for SMAW — high **amperage** at low **voltage** (e.g., 25-400 amps at 15 to 35 volts). Regardless of how the power is produced, the unit can be classified as:

- **Alternating current (AC)** power source
- **Direct current (DC)** power source

or • Combination power source, both AC and DC in one.



A Typical SMAW AC/DC Power Source

Alternating Current Power Sources

SMAW alternating current (AC) power sources are mostly found on the farm and at home. Of these, the transformer based power source is the most common.

A transformer based power source consists of a housing and frame in which a "step-down" transformer and current control circuit are mounted. This means that the incoming single phase supply voltage (power line service), which is usually in the range of 220-480 volts, is stepped down by the power source transformer to between 50-80 volts open circuit.

The current control is designed to produce a constant (steady) current at the **arc voltage** being used. That is, the control keeps the current constant/steady (only a slight variation) as you attempt to maintain a uniform arc length. Ideally, the current remains at the value selected no matter how the arc length (arc voltage) varies during welding. The layout of the current control adjustment helps the welder select the correct current (amps) to fit the type and size of electrode chosen.

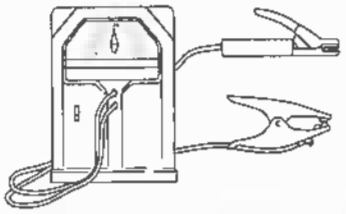
Direct Current Power Sources

Direct current (DC) welding power sources, like AC power sources, can be either a static or a rotating type. The static types are the transformer with **rectifier bridge** and the inverter with rectifier bridge(s), and the rotating type is the engine drive generator and the engine drive alternator with rectifier bridge. A rectifier bridge changes AC input, from the "step-down" transformer, inverter or alternator, into DC output to the welding cables/leads.

A generator/alternator is a machine that makes (or generates) electricity, i.e., DC from a generator and AC from an alternator. Before this can take place, some form of power is required to run (turn) the device. An engine drive is the usual power source. A three-phase AC motor was the choice before the high power diode rectifier bridge became reliable. Since then the motor/generator (M/G) power source has effectively become obsolete. M/G sets are much more expensive to make than alternators with rectifier bridges or static type power sources, and they require much more maintenance.

DC polarity (**DCEN** and **DCEP**) is selected by either a polarity switch or changing cable/lead connection points. Usually, the electrode lead is changeable and the work lead is fixed.

Most DC power sources, except generators, are actually combination AC/DC units. That is, they are basically AC units with rectifier bridges added to the welding circuit. To compare the units, AC vs. DC, see the table.



A Typical SMAW AC Power Source

Comparing AC & DC SMAW

Choice AC vs. DC		Welding Characteristic/Aspect
✓		Lowest Voltage Drop in Welding Cables
	✓	Welding at Low Current with Small Dia. Electrodes
	✓	Weld with all Classes of Covered Electrodes
	✓	Arc Starting, Especially Small Dia. Electrodes
	✓	Maintaining a Short Arc when Needed
✓		Least Affected by Arc Blow
	✓	Out of Position Welding Hor., Vert. & Overhead
	✓	Welding of Sheet Metal & Thin-walled Tubing
✓		Welding of Thick Sections
	✓	Least Amount of Weld Spatter
✓		Lowest Cost per Output Ampere
✓		Lowest Maintenance Cost for Given Power Source Type

Combination Units — AC/DC

The advantages of AC and DC power sources are combined when purchased in one unit. These units can be switched from AC to DC by throwing the right switch(es) or by using the proper cable connection point(s). Different electrodes operate better using different types of current. An AC/DC power source can be very versatile in use because it allows you to use whatever electrode you choose.

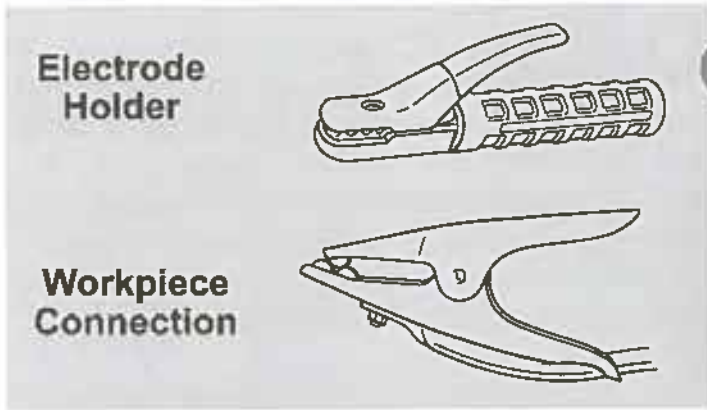
An engine drive alternator with rectifier bridge power source provides for AC/DC welding almost anywhere. They are lower in initial and operating costs compared to an engine drive generator. Also, most units provide auxiliary power (110-120 volts) for portable power tools.

Duty Cycle

Every welding power source is rated according to amperage output at a rated voltage and **duty cycle**. This rating is specified by the manufacturer of the power source, who has determined the duty cycle by following the requirements of the National Electrical Manufacturers Association (NEMA) for duty cycle determination and specification.

The normal output rating is amperage capacity at specified duty cycle: this ranges from 150-600 amps for duty cycles from 20-60 percent. A 20-30 percent duty cycle is typical of power sources designed for home shop and/or farm use with 40-60 percent units for industrial use. For most farm welding, a 200-300 amp at 20-30 duty cycle power source is more than adequate. Before purchasing a welding power source, determine the type of incoming electrical power to your farm or home shop. With this knowledge, you can choose a power source suited to your needs and applications.

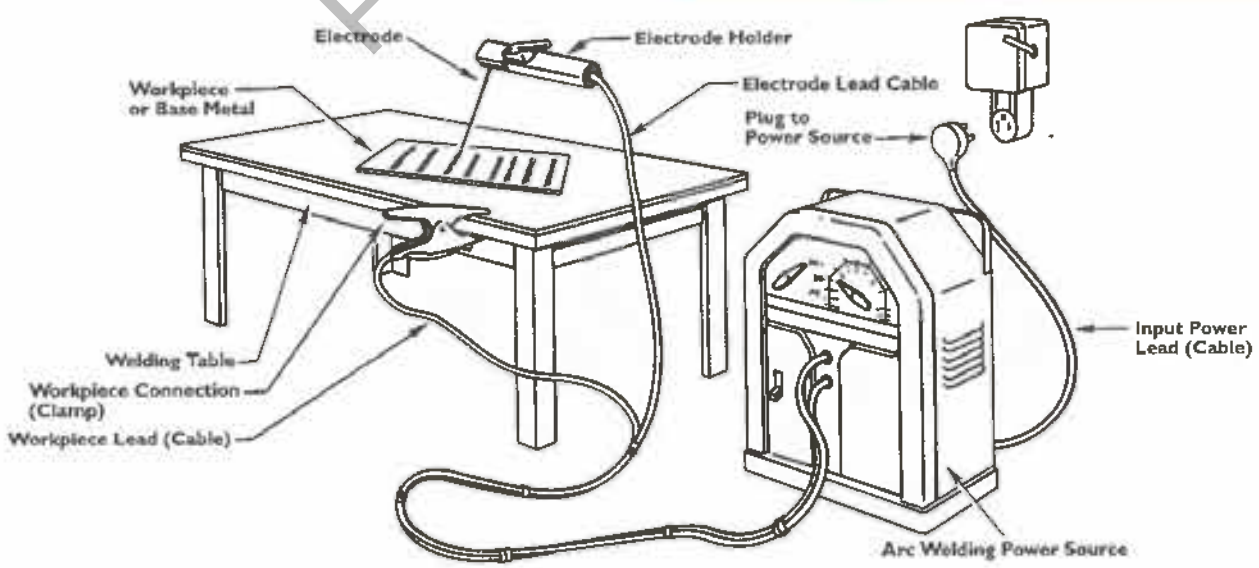
Cables & Clamps



The first items you will need to attach to the welding power source are the cables/leads. If you are using a static power source, connect the input power cable to the circuit breaker for incoming power. This cable is often called a "pig tail." The "pig tail" for a single-phase hookup contains three heavy wires, two of which carry the current; the third is a ground. This cable is similar to a household dryer or stove appliance cord.

Two single **conductor** cables/leads carry the current to and from the item being welded. One of these is attached to the **workpiece lead** connection (clamp). The workpiece lead connection (clamp) is either fastened to the part to be welded or to the

SMAW Circuit Layout



metal table on which the part is lying. This workpiece lead connection (clamp) and workpiece lead (cable) provide a path through which the current flows. If the workpiece lead connection (clamp) does not make good contact, you will encounter difficulty striking an arc. If this occurs, check the **workpiece connections**. Paint, rust, or dirty surfaces will cause poor connections. Always clean the work surfaces before attempting to weld.

The second single conductor (electrode cable/lead) is attached to the electrode holder. The **electrode holder** is an insulated clamp used to hold the electrode; sometimes, the holder is called a stinger. Most holders have at least three different grooves in the jaws. These grooves allow the electrode to be held at different angles. Most electrode holders also have an insulating cover. This allows you to lay the clamp — **with no electrode clamped in it** — on the welding table without causing an arc to occur. If this cover is damaged, replace the cover before using the holder.

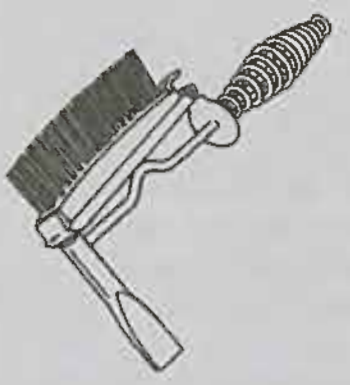
Both the workpiece lead (cable) and the **electrode lead** (cable) should be large enough to carry the necessary current without getting hot. Leads (cables) come in different sizes, such as a No. 8, No. 4, or No. 0. The larger leads (cables) have a smaller number and carry more current without overheating. Most small shops or farm welders have a No. 4 or larger lead (cable). Lead/cable size is determined by considering current setting, duty cycle, and total length of leads (electrode and **workpiece**). (See table below).

Take care to keep your leads (cables) in good condition. Never allow hot metal to touch the leads (cables) or a short may occur. Most leads (cables) are made of stranded copper wire insulated with rubber. Keep leads (cables) clean and free of oil or grease. Over time, oil and grease will deteriorate the rubber insulation. The leads (cables) will last much longer if you keep them coiled when not in use. This will also prevent people from tripping over them.

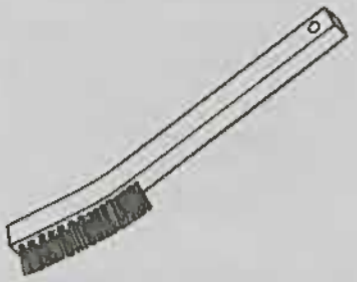
Recommended Cable/Lead Sizes for SMAW

Machine Size in Amperes	Duty Cycle (%)	Copper Cable Sizes for Combined Length of Electrode Plus Workpiece Cables				
		Up to 50 Feet	50–100 Feet	100–150 Feet	150–200 Feet	200-250 Feet
100	20	#8	#4	#3	#2	#1
180	20	#5	#4	#3	#2	#1
180	30	#4	#4	#3	#2	#1
200	50	#3	#3	#2	#1	#1/0
200	60	#2	#2	#2	#1	#1/0
225	20	#4	#3	#2	#1	#1/0
250	30	#3	#3	#2	#1	#1/0
300	60	#1/0	#1/0	#1/0	#2/0	#3/0
400	60	#2/0	#2/0	#2/0	#3/0	#4/0

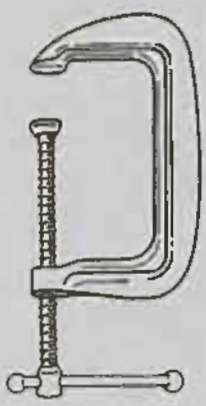
Auxiliary Equipment



Spring Handle Chipping Hammer with Wire Brush on top



Wire Brush



C-Clamp

Other pieces of equipment that are useful when working with shielded metal arc welding are chipping hammers, wire brushes, C-clamps, slip-joint pliers, and locking (e.g., VISE-GRIP™) pliers.

Chipping hammers are used to remove **slag** and **spatter** and usually have a point at one end and a chisel at the other. If used properly, the chipping hammer can remove most of the slag from a deposited weld without marking the weld. Always wear personal eye protection when chipping slag from the weld because pieces of slag will fly in all directions.

Wire brushes are used to whisk away small debris left from chipping the slag. Often, a wire brush is conveniently attached to the back of the chipping hammer. These brushes generally are made of fine, stiff steel wire.

C-clamps are useful when welding two objects together that are difficult to keep in contact. The C-clamp allows you to position the objects and clamp them in place.

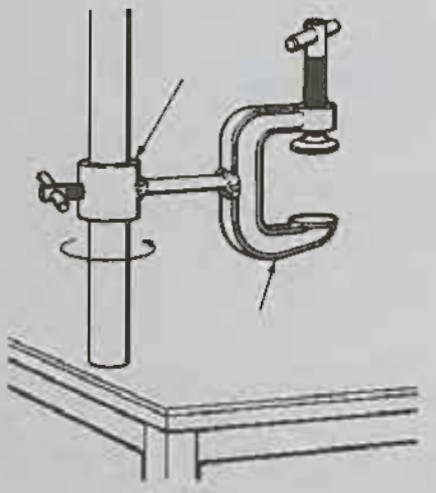
Slip-joint pliers are used to pick up and move hot pieces without being burned. Pliers can be used to position hot **weldments**, as when inspecting a just-made weld.

Locking pliers perform a similar function to C-clamps or slip-joint pliers. They can be used to pick up and inspect hot pieces without you being burned. These pliers can be used to hold onto parts while preparing them for welding and for positioning hot pieces for welding. Also, there are locking clamps made just for welding.

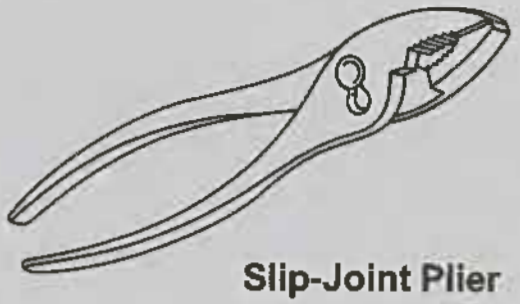
You also should have a welding table or stand to set small parts on to secure them when welding. To be of any value, the table must conduct electricity and the workpiece lead (cable) must be securely attached at a location out of the way of the welder and work surface.

The metal table provides the final part of the welding circuit. A 1/4 to 3/8 inch thick steel plate generally works well for a table top. Other types of metal, such as copper or cast iron, can be advantageous because spatter does not tend to stick to them. Many welders attach vertical pipes to the table, which allows them to attach special fixturing clamps for out-of-position welding. No matter what type of table you use, keep it reasonably clean to ensure accurate welding setups.

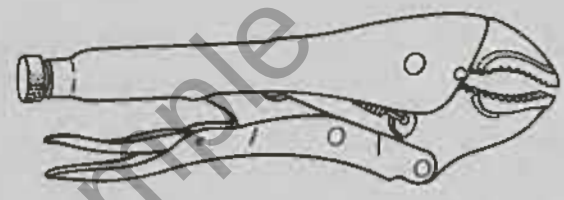
Auxiliary Equipment (continued)



Special Fixturing Clamp



Slip-Joint Plier



Locking (e.g., VISE-GRIP™) Plier

Welding Wonders

Circular boxes of gold were made by forge/hammer welding lap joints together more than 4,000 years ago.

Sir Humphry Davy produced an arc between two carbon electrodes in 1801.

In 1885, Bernardos and Olszewski secured a British patent for arc welding.

Building Skills

Complete three of the activities listed here. Check those you plan to do and mark the date (month and year) you complete them.

Plan to Do	Date Completed	Activity
_____	_____	Visit a welding shop. Ask the owner about and observe the types of power source(s) he or she uses. Also ask why he or she has chosen this type of power source.
_____	_____	Visit a farm supply or welding supply store. Find the costs of AC only, DC only, and AC/DC power sources with 220–250 amp capacity. How do the prices compare?
_____	_____	Make a display board or poster of the various auxiliary equipment used with welding power sources.
_____	_____	Demonstrate to your parent(s), advisor, or your club the proper procedure for setting up SMAW welding equipment.
_____	_____	Keep a record of the amount of time you spent doing one of the weldments in this manual. Divide the time into: time preparing to weld, actual weld time, and time to finish (i.e., clean, deburr, paint, etc.) the weldment after welding is done. Which time was the longest? Which time was the shortest?
_____	_____	Visit a welding shop. Ask the owner how much welding equipment and auxiliary equipment he or she has. Does he or she have more welding or more auxiliary equipment? Why?

Developing Knowledge

Who decides how welding power sources are rated? Why is an industry standard for rating welding power sources necessary?

What are some important characteristics of an arc welding table? Why are these characteristics essential for welding?

#3 What would be the best power source for a beginning welder to use? Justify your answer.

#4 How can line power (up to 200 amps at 220-480 volts) be changed to welding power (25-400 amps at 15-35 volts)? How can AC power be changed to DC power?

Going Beyond

Why do you need to have all your equipment assembled and hooked up before beginning to weld?

Fueling Your Interest

Why is it important to be organized in your life?