WELDING COMPLETE

2ND EDITION

TECHNIQUES, PROJECT PLANS & INSTRUCTIONS

MICHAEL A. REESER

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COOL SPRINGS PRESS

First published in 2009 by Creative Publishing international, an imprint of The Quarto Group, 401 Second Avenue North, Suite 310, Minneapolis, MN 55401 USA. This edition published 2017 by Cool Springs Press. Telephone: (612) 344-8100 Fax: (612) 344-8692

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10 9 8 7 6 5 4 3 2 1

ISBN: 978-1-59186-691-6
Digital edition: 978-0-76035-774-3
Softcover edition: 978-1-59186-691-6

Library of Congress Cataloging-in-Publication Data

Names: Cool Springs Press, author. | Creative Publishing International, author.
Title: Welding complete.
Description: 2nd edition. | Minneapolis : Cool Springs Press, 2017. | "First published in 2009 by Creative Publishing international, an imprint of Quarto Publishing Group USA Inc."--Verso title page. | Includes bibliographical references and index.
Identifiers: LCCN 2016059357 | ISBN 9781591866916 (plc)
Subjects: LCSH: Welding.
Classification: LCC TS227 .W357 2017 | DDC 739/.14--dc23
LC record available at https://lccn.loc.gov/2016059357

Acquiring Editor: Todd Berger
Project Manager: Alyssa Bluhm
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Book Designer: Simon Larkin
Layout: Rebecca Pagel
Photography: rau+barber
Edition Editor: Mark Schwendeman

Printed in China

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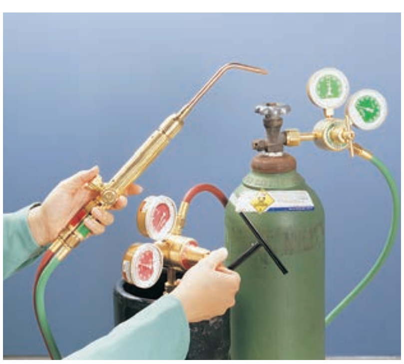


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POWER
PRESSURE
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OUTPUT

INTRODUCTION

Welding is a practical skill that is challenging, rewarding, and also great fun. We encounter welded items throughout our daily lives and activities—they are practically infinite. The appliances in our homes, the railing on our porches or stairs, our automobiles, the bridges and infrastructure we drive on, the structure of the buildings we work in, and even our computers. Welding makes everyday tasks more manageable. Welding can also bring joy to a craftsman making items for use in the shop, home décor, and outdoor living and décor.

In this book, we will thoroughly discuss the basics of welding and fabrication: safety, equipment, material selection, tools, and the various welding and cutting processes. With a firm understanding of the basics, applying safety and common sense, we will then move on and apply your newfound knowledge to specific projects in the book, complete with how-to instructions, tool lists, material lists, blueprints and illustrated pictorial plans, and photos. Developing your new welding and fabrication skills will provide hours of satisfaction as you create items and furnishings for your home, shop, and outdoor living space.

The shop section includes plans and instructions for making practical and useful items specific for your working space that will provide years of useful service. These tools include a rolling welding curtain, welding and cutting table, welding cart with cylinder rack, and an expandable welding table.

The home décor section includes plans and instructions for commonly used items, such as coat hooks, tables, and shelves, as well as decorative items, table candelabrum, and decorative wall fixtures.

The outdoor section includes plans and instructions for projects suitable for all hardworking DIYers, including a yard trailer and truck rack. Also included are plans and instructions for outdoor living space items, such as railings, a garden/yard gate, arbor, and firepit.

It is important as a welder to understand and use the correct terminology when discussing welding and the related processes. This will be useful in ordering equipment, and in selecting the proper filler metal and materials. The *weldment* (the parts to be joined) is referred to as the base metal. Additional metal, called the *filler metal*, is then added to the molten base metal to form a molten puddle that will solidify into a new metal—this is now known as the heat affected zone (HAZ). This is the area of focus for the welder. To maintain the proper fusion and strength of the newly formed weld, it is very important for the base metal and filler metal to have the same composition. The processes for joining metal without fusion are soldering, brazing, and braze welding. These processes can be used to join either similar or dissimilar metals.

The strength and quality of any weld is dependent on many factors. To achieve the proper amount of penetration, or weld fusion, it is critical that the heat input is controlled through an understanding of how to set, adjust, and maintain the following variables:

- Base metal selection
- Filler metal selection
- Proper heat input for a selected material thickness
- Work angle
- Travel angle
- Arc length
- Travel speed
- Aim
- Electrode manipulation
- Joint design

Welding is about managing heat input—whether it is from a fuel source such as oxyacetylene welding (OAW), or from electricity in an arc welding system, such as shielded metal arc welding (SMAW), gas metal arc welding (GMAW), flux core arc welding (FCAW), or gas tungsten arc welding (GTAW). Each process has its own

SAFETY

Welding can be a dangerous activity. Failure to follow safety procedures may result in serious injury or death. This book will provide useful instruction, but we cannot anticipate all working conditions presented while performing welding and cutting or the characteristics of your material and tools. Safety is applying good judgment and common sense—you should use caution and care when following the procedures described in the book. ALWAYS consider your own skill level and the Safety Notices associated with each tool, and use them properly; STOP and consult the owner's manual or manufacturer for any questions. The publisher, author, and technical director cannot assume responsibility for any damage to property or injury to persons as a result of misuse of the information provided.

Oxyacetylene welding.

Shielded metal arc welding (SMAW).

Gas metal arc welding (GMAW).

advantages and disadvantages. Once a welding process is selected, the goal is to join the selected parts to form a useful tool or item in a permanent manner. Learning to manage the heat input allows the welder to control the molten metal *puddle* or the HAZ, thus allowing the base metal, original parts, and filler metal to flow and fuse into a new coalesced area, joining the parts into a weldment.

OAW and Oxyacetylene cutting (OAC) use acetylene for the fuel source to produce flames to generate heat to melt the base and filler metal for welding or for cutting of ferrous metals. Acetylene is the fuel of choice for welding, because it is the only fuel source that will generate a truly "neutral" flame. When alternative fuel sources such as propane or natural gas are used, the process is then referred to as Oxy-fuel welding (OFW) and Oxy-fuel cutting (OFC). These fuels are often selected for cutting purposes because of their lower cost and ease of access.

While performing OAW, the formation of the puddle is easier to see, as it is a slower process. The welder is watching for a color change of the base metal as it approaches the melting temperature. As the temperature increases, the color reaches a reddish color and appears glossy as it starts to melt (*wet out*). This wetting action allows the melting base metal to flow or join with the filler metal that is added to the joint to form the new metal in the HAZ. This forms a seamless molten area that will solidify into new metal.

The arc welding (AW) processes—SMAW, GMAW, FCAW, GTAW, and PAC—all use electrical current to produce an arc to generate the heat necessary to melt the base and filler metal to form the weld. With the AW process, the arc forms the puddle quickly and may be difficult to see without the proper lens shade, due to the intense light created by the arc. This is why wearing the proper shade of filter lens is important.

Penetration of the weld is also a critical heat-dependent factor. A strong weld penetrates all the way through the base metal. To ensure a successful, completely fused weld, the filler metal size, heat input (welding current), and base metal thickness must be matched to travel speed, travel angle, and arc length. It is easy to achieve an appropriately shaped weld profile that has not penetrated the base metal at all and merely sits on the surface. This is known as a "cold" weld and is associated with insufficient current. An opposite problem is "burn through"—where the current is set too high or the arc length is too long and overheats the base metal, making the puddle difficult to maintain and eventually burning through the base metal, leaving a hole that can be difficult to correct or repair.

Distortion caused by heat applied during all welding and cutting operations, whether by flame or electrical arc, is an unwanted by-product the welder must learn to identify. Pre-welding setup, welding sequence, and post-weld heat management are key to accurate dimensions. The welding or cutting process selected can produce flame or arc with a temperature of up to 10,000 degrees Fahrenheit. As we apply the arc (heat or current) to melt the base metal and filler metal to form the new material in the HAZ, the metal expands; as the metal cools, it contracts, causing potential stresses to form in the metal and the weld joint. If the expansion and contraction of the metal are not considered during the fit-up, the welding process can cause parts to move out of alignment or ultimately fail. Although the welder can clamp and/or tack weld parts together, he or she still needs to consider the stress in the HAZ and/or surrounding area. Clamping or improperly located tacks can alter where the stress concentrates, potentially causing premature failure of the weldment.

It is also imperative that the welding process is properly matched for each type and thickness of base metal. For example, SMAW is typically best suited for welding on material $\frac{3}{16}$ inch or thicker, due to the heat input of the arc and difficulty in maintaining the arc on thinner material. GMAW, on the other hand, is well suited for thinner material or sheet metal.

As the arc is developing the HAZ or welding puddle, it is critical that atmospheric air—mainly oxygen and nitrogen—is kept away from the puddle while it is molten and as it cools or solidifies. Oxygen and nitrogen that contaminate the puddle as it cools will produce a very weak and brittle material. The welding process selected provides a protective area around the puddle to shield it as it cools or solidifies. In OFW, the properly adjusted neutral flame burns off ambient oxygen in a small zone around the weld puddle. GMAW and GTAW processes utilize an externally applied inert shielding gas to protect the puddle from atmospheric air as it solidifies; this is accomplished by attaching an external high-pressure cylinder. The most common shielding gas utilized is argon, chosen because it is denser than air and settles around the weld puddle, and because it is inert and does not react with the atmospheric air or the weld puddle. SMAW and FCAW processes use fluxes (chemical compounds) added in or on the filler metal. When these fluxes burn or melt, they produce shielding gases and form a protective coating (slag), both of which protect the weld area until it has solidified.

Welding can be difficult and takes years to master, but with basic knowledge and lots of practice, it is possible to make many useful and decorative items. If you wish to move beyond the projects outlined in this book, talk with a more experienced welder and have him or her evaluate some of your practice welds. Remember the safety of others is involved when you choose to make a utility trailer or spiral staircase. Take the time and make the effort to ensure that any project you make is safe.

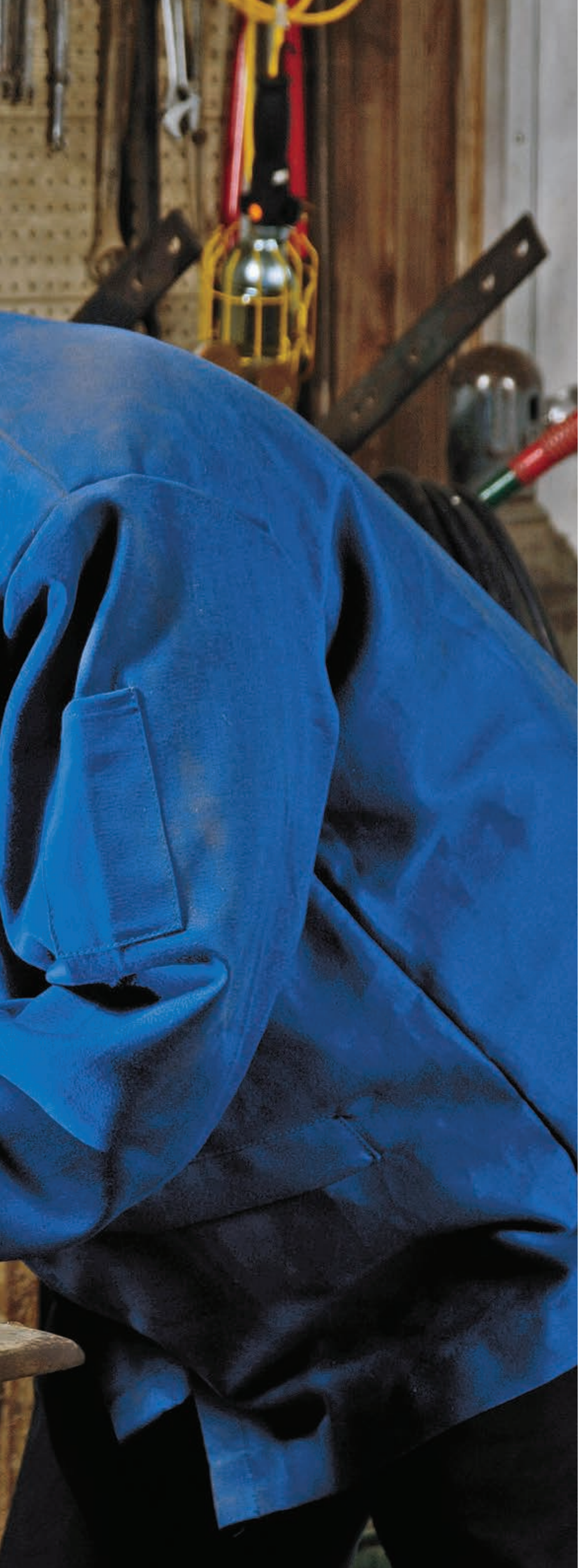
This book is intended as a reference for people who have had some exposure to welding and who can follow the steps and safety precautions outlined in each project. It is not intended to teach welding to someone who has never handled welding equipment. If you wish to further your welding experience and improve your skill set, many community colleges, technical colleges, and art centers offer welding classes. Such classes are an ideal way to learn the basics of welding, the proper techniques associated with each process, and specific welding safety.

Gas tungsten arc welding (GTAW).
Chris Alleaume/ Alamy Stock Photo

Plasma arc cutting (PAC).

Oxyacetylene cutting (OAC).


Miller.



BASICS

The costs involved in setting up a well-equipped home welding shop are comparable to setting up a well-equipped woodworking shop. A knowledgeable welder with the proper equipment has a great advantage, because the projects and repairs he or she can accomplish are too numerous to count. The availability of numerous inexpensive materials is also key to being creative. From basic repairs, to building your own shop tools and work stations, to creating items you can sell—the possibilities with welding are only limited by your imagination and experience. Always striving to learn and improve your craft lets you experience the "wow" factor when others see and admire your work.

IN THIS CHAPTER:

SAFETY

Safety is very important when welding. The potential dangers inherent to welding and cutting processes are numerous. Failure to follow or overlook manufacturer's Material Data Safety Sheets (MSDS), recommended practices, and guidelines can result in injury or death. Welders may encounter such hazards as electrical shock, exposure to fumes and gases, fire, explosion, arc radiation burns, and cuts and abrasions. Proper preparation for all welding and cutting operations is critical for your personal safety and the safety of those around you. Always familiarize yourself with ALL safety information pertaining to a piece of welding or cutting equipment, and apply the information outlined in American National Standards Institute (ANSI) publication Z49.1, Safety in Welding, Cutting, and Allied Processes. A free copy of this standard can be downloaded from the American Welding Society website, www.aws.org. Important: when in doubt or when you have a question, consult the operator's manual or manufacturer's website, and remember safety is your first responsibility. Follow all safety rules and never take shortcuts.

FUMES. Welding produces potentially hazardous fumes and gases. Always keep your face out of the weld plume, and avoid breathing concentrations of those fumes. Welding indoors requires special precautions. When and what type of ventilation to select is the first and most important question to ask when welding indoors. Typically, any area with a ceiling lower than 16 feet or a width a total area of less than 10,000 square feet will require forced ventilation. A fan, exhaust hood, or fume extractor may be used. If adequate ventilation cannot be provided, an OSHA-approved respirator or particle mask may be needed. Always follow the fitting guidelines when purchasing a respirator. If you may be pregnant or plan to become pregnant, consult your physician. Never cut or weld on a container or material if you are unsure about its prior use or the type of coatings that it may have applied to the surface. Cutting or welding on containers or materials that contain toxic chemicals can be potentially deadly.

BURNS. Hot sparks, flying slag, and molten metal can cause severe burns in the welding shop. Always protect any exposed skin or body parts with the proper personal protective equipment (PPE). The most common materials to use are natural fibers—leather, wool, or cotton. **Never** wear synthetic materials, as they can melt to skin and cause more severe damage and burns. Wear leather boots with pants that fall over the top of the boots. Do not roll up or cuff pant legs or shirt sleeves, as they may trap sparks or slag. Make sure pants are free from frayed

Welding safety includes protecting yourself with safety gear, following manufacturer's instructions, and being aware of the surroundings in which you are welding.

edges and holes, as they are also a fire hazard. Wear a welding cap and keep hair tucked away.

ARC BURN. Welding arcs produce ultraviolet and infrared light. Both of these can damage your eyes permanently, burn your skin, and potentially lead to skin cancer. Always protect your face and eyes by wearing a welding helmet with a shaded lens of the appropriate number for the selected process. Wear a long-sleeve cotton shirt or welding jacket with long pants to protect skin. Remember to use welding curtains/screens and to have an extra welding helmet on hand for observers.

FIRE. Remove flammable items, such as lumber, rags, drop cloths, cigarette lighters, matches, and any other flammable items from the work area. Do not grind or weld in a sawdust-filled shop—sparks can ignite airborne dust and fumes or ignite flammable materials. Mount an ABC-rated fire extinguisher and first aid kit in your work area. Check your welding area for a full 30 minutes after welding to make sure no materials have been left to smolder or catch on fire.

EXPLOSION. *Never* cut, weld, or heat on a closed cylinder or container, because pressure could build and cause the container to rupture or explode. If this occurs, you may be responsible for the replacement cost of the cylinder if it was leased from a welding equipment supplier. Nonflammable and inert gases are stored in high-pressure cylinders with capacities of approximately 2,000 psi—**always** store these cylinders in a proper location with safety caps secured when not in use or during transport. If cylinders are in use with regulators attached, they must still be secured to a cart or structure. Never weld or strike an arc on a cylinder, because this could cause an explosion or rupture. Another explosion hazard is concrete. Always elevate material above a concrete floor when tacking or welding. The heat from the arc may cause the concrete to crack or explode.

ELECTRIC SHOCK. Electrical shock is an inherent risk when working with arc welding equipment. Always wear the proper PPE, making sure it is dry and free from holes. Never work in a wet environment, such as standing water, or while wearing wet gloves. Remember, electricity follows the path of least resistance, and water offers just that. Check equipment and welding leads daily to ensure insulation is not cracked or in disrepair; if such a defect is found, replace or repair the lead immediately to avoid serious electrical shock.

Other hazards include noise from grinding, cutting, sawing, and finishing metal; laceration from sharp metal edges; and asphyxiation from inert shielding gases such as carbon dioxide. **Always** read and follow the manufacturer's instructions before using any welding process.

MINIMUM LENS SHADE NUMBERS FOR WELDING

APPLICATION	SUGGESTED SHADE
Shielded Metal Arc Welding (SMAW)	
1/16 to 5/32" electrodes	10
3/16 to 1/4" electrodes	12
5/16 to 3/8" electrodes	14
Gas Metal Arc Welding (GMAW)	
1/16 to 5/32" non-ferrous	11
1/16 to 5/32" ferrous	12
Gas Tungsten Arc Welding (GTAW)	10 to 14
Plasma Cutting	8
Oxyacetylene Welding	5
Oxyacetylene Cutting	5
Brazing	3 to 5

Welding helmets are typically available with filter lenses in either 2" × 4 1/4" or 4 1/2" × 5 1/4" sizes. Helmets with auto-darkening lenses are also available. Clear, full-face protective shields are available for grinding or chipping and with a #5 filter for oxyacetylene operations.

Welding safety equipment includes: **(A) safety glasses, (B) particle mask, (C) low-profile respirator, (D) leather slip-on boots, (E) fire-retardant jacket, (F) fire-retardant jacket with leather sleeves, (G) welding cap, (H) leather cape with apron, (I) leather gloves with gauntlets, (J) heavy-duty welding gloves, (K) welding helmet with auto-darkening lens, (L) welding helmet with flip-up lens, (M) full-face #5 filter, (N) full-face clear protective shield.**

METAL BASICS

The suitability of a metal for welding is dependent upon what elements are used to create the metal. It is important to identify the type of metal and what alloying elements have been added to increase its strength, toughness, impact resistance, corrosion resistance, or ductility. We typically divide metals into two categories: ferrous and nonferrous. Ferrous metals contain iron as their major element and include cast iron, forged steel, mild steel, and stainless steels. These metals are typically magnetic. Nonferrous metals include the "pure" elements, such as aluminum. Because they do not contain iron, they are nonmagnetic and have a lower melting temperature. It is essential that base metal and filler metal are matched to ensure that like metals are welded. Because this process does involve the melting and fusion of the base and filler into one new metal, melting temperatures and metal characteristics must be similar. We can join dissimilar metals by brazing, braze welding, or soldering, because these processes do not actually melt the base metal.

Ferrous metals contain iron with varying amounts of carbon and other alloying elements, such as chromium, molybdenum, manganese, and nickel. Each alloy imparts a unique characteristic to the low carbon steel. Mild steel (low carbon steel) is the most commonly used type and the easiest with which to work. Mild steel can be cut and welded with all of the processes covered in this book. It makes up most of the metal items you commonly use, make, or repair, including automobile bodies, bicycles, railings, furniture, cabinets, and shelving. Adding more carbon to the steel makes it harder but also more brittle and more difficult to cut or weld. These high-carbon steels are used to make cutting tools, such as drill bits, machining bits, and knife blades. Adding other alloying elements, such as chromium and nickel, to the low carbon steel produces stainless steel. Because the stainless steel does not oxidize (rust) easily, it is cut best with a plasma cutter. As always when welding low carbon steel or alloyed steel, the filler metal must be matched to the elements to ensure a high-quality weld is produced.

Aluminum is the most widely used nonferrous metal, because it is lightweight and corrosion resistant. Like steel, it is available in many alloys and is often heat-treated to increase strength. Aluminum is used for engine parts, boats, bicycles, furniture, kitchenware, and now automobile frames. Various characteristics make aluminum difficult to weld successfully—it does not change color when it melts, it conducts heat rapidly, and it immediately develops an oxide layer that melts at a higher temperature than the base metal itself, causing overheating and extreme distortion and metal destruction.

METAL	WELDING PROCESS	CUTTING PROCESS
Mild steel	All welding processes	Oxyfuel, plasma
Aluminum	Gas tungsten arc, gas metal arc	Plasma
Stainless steel	Gas tungsten arc, gas metal arc, shielded metal arc	Plasma
Chrome moly steel	Gas tungsten arc, oxyfuel	Plasma
Titanium	Gas tungsten arc	Plasma
Cast iron	Shielded metal arc, brazing	Plasma
Brass	Braze welding	Plasma

METAL MELTING POINTS

METAL	MELTING POINT (F)
Aluminum	1217°
Brass	1652 - 1724°
Bronze	1566 - 1832°
Chromium	3034°
Copper	1981°
Gold	1946°
Iron	2786°
Lead	621°
Mild steel	2462 - 2786°
Titanium	3263°
Tungsten	5432°
Zinc	786°

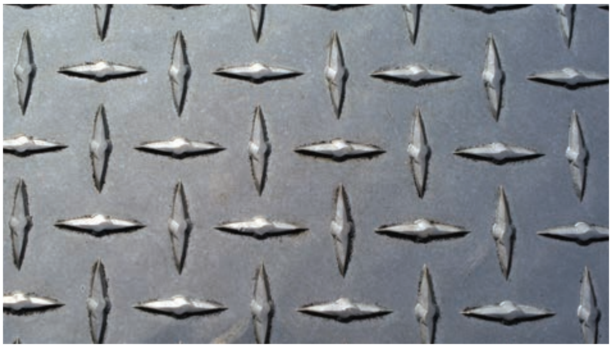
METAL SHAPES & SIZES

Mild steel and most other metals come in a variety of shapes, sizes, and thicknesses. Metal thickness may be given as a fraction of an inch, decimal, or gauge. Sheet metal is typically 3/16 inch or less in thickness and called out as a gauge number, and plate metal is 1/4 inch or thicker. Structural metal typically is identified by its length, width, and by its wall, leg, or web thickness. Some of the most common structure types and size call-outs are:

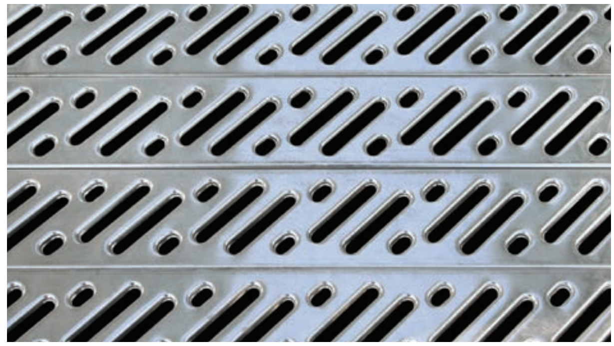
A. Rectangular tubing is used for structural framing, trailers, and furniture. Dimensions for rectangular tubing are specified by width × height × wall thickness × length.
B. Square tubing is used for structural framing, trailers, and furniture. Dimensions for square tubing are specified by width × height × wall thickness × length.
C. Rail cap is used for making handrails. Rail cap dimensions are the overall width and the widths of the channels on the underside.
D. Channel is often used for making handrails. Very large channel can be used in truck frames and structural items, such as bridges or industrial equipment. The legs, or flanges, make it stronger than flat bars. Dimensions for channel are specified by flange thickness × flange height × channel width (outside) × length.
E. Round tubing is not the same as pipe. Round tubing is used for structural items, while pipe is used to transport liquids or gases. Dimensions for round tubing are specified by outside diameter (OD) × wall thickness × length.
F. T-bar dimensions are given as width × height × thickness of flanges × height.
G. Angle or angle iron has many structural and decorative uses. Dimensions for angle are specified by flange thickness × flange width (leg) × flange height (leg) × length. Angle can be equal leg length or unequal leg length.
H. I. J. Square, round, or hexagonal bar (hex bar) dimensions are specified by width/outside diameter (flat to flat for hexagonal bar) × length.

Flat bar/strap (not pictured) is available in many sizes and is typically not wider than 12" for flat bar are specified by thickness × width × length.

Sheet metal (not pictured) is 3/16" or less in thickness, and is often referred to by its gauge number. Plate is 1/4" or greater in thickness, and is specified by its thickness in fractions of an inch.



Diamond plate is used as a heavy-duty siding for toolboxes and carts because of its durability and strength. It is also used for decorative applications. It is sold as length × width × thickness.



Perforated sheet metal is used for industrial shelving, fences, stair treads, grates for floor drains, and a host of decorative sidings and top treatments. There are numerous shapes and styles available. They are sometimes referred to as perforated metal screens. Perforated sheets are sold as length × width × thickness. Lighter-weight sheets are sold by the yard in a roll.

METAL IDENTIFICATION CHART

Test	Appearance	Fracture	Magnetic	Torch	Chip	Spark	Volume of stream
Manganese steel	Dull cast finish	Rough grained	Nonmagnetic	Turns bright red, melts quickly	Hard to chip	Bright white bursts, heavy pattern	Moderately large
Stainless steel	Bright, smooth surface lines	Bright appearance	Depends on exact composition	Turns bright red, melts quickly	Smooth chip, smooth bright color	Very few short full red sparks with few forks	Moderate
Low carbon steel (mild steel < 30% carbon)	Gray, fine	Gray, bright crystalline	Highly magnetic	Gives off sparks when melted, pool solidifies rapidly	Chips easily, smooth and long chip	Long white sparks, some forks near end of stream	Moderately large
Medium carbon steel (.30 to .45% carbon)	Gray finish	Light gray	Highly magnetic	Melts quickly, gives off some sparks	Chips easily, smooth and long chip	Long white sparks with secondary bursts along stream	Moderately large
High carbon steel (> 45% carbon)	Dark gray, smooth finish	Light gray-white, finer grained than low carbon steel	Highly magnetic	Melts quickly, molten metal is brighter than low carbon steel	Difficult to chip, brittle	Large volume of brilliant white sparks	Moderate
Wrought iron	Gray, fine surface lines	Fibrous structure, split in same direction of fibers	Highly magnetic	Melts quickly, slight tendency to spark	Chips easily, continuous chip	Straw-colored sparks near wheel, few white forks near stream end	Large
Cast iron	Rough, very dull gray	Brittle gray	Highly magnetic	Turns dull red, first puddle is very fluid, no sparks	Very small and brittle chips	Dull red sparks formed close to wheel	Small
High sulfur steel	Dark gray	Gray, very fine grain	Highly magnetic	Melts quickly, turns bright red before melting	Chips easily, smooth and long chips	Bright carrier lines with cigar-shaped swells	Large

PURCHASING METALS

Finding a metal supplier can be a challenging task. The materials that are readily available at home centers and hardware stores may not be the size and shapes needed for a project and can be very expensive; and if ordered online or through a catalog, product weight can create significant shipping charges. With some searching, though, most products can be found at reasonable prices. Once a metal supplier has been found, materials can typically be purchased by weight or per linear foot. The price for small pieces of mild steel at a home center or hardware store might be as much as $3 to $5 per pound, but the price at a larger steel supplier may be as little as $1 per pound, depending on the type of material ordered. Many steel suppliers have an odds and ends bin or rack where material is discounted even more than retail or wholesale prices. Stainless steel and aluminum are higher cost relative to mild steel. When purchasing at a home center or hardware store, material can be purchased in three-, four-, or even six-foot lengths that are much easier to handle. When purchasing from a steel supplier, the common lengths are 10, 12, and even 20 feet, so plan accordingly—as always convenience will cost more. Steel suppliers have most common types and lengths in stock and can order other sizes. Some steel suppliers are distributors for decorative metal products, but many specialty items, such as wrought-iron railing materials, decorative accessories, and weldable hardware, are only available by catalog. A number of catalog supply companies sell to the public and have varied selections and reasonable prices (see Resources).

INCH EQUIVALENT FOR GAUGE THICKNESS

GAUGE	INCHES
24	0.020
22	0.026
20	0.032
18	0.043
16	0.054
14	0.069
12	0.098
11	0.113
10	0.128

Metal less than ⅛" thick is often referred to by gauge. For reference, the decimal equivalent of ⅛" is 0.125.

Wall plates, hooks, rings, balls, bushings, candle cups, drip plates, and stamped or cast items are available in a wide variety of shapes, sizes, and sheets.

METAL CLEANING & PREPARATION

A successful weld begins with a well-prepared welding joint. More attention paid while cleaning and preparing the welding joint ensures a higher quality weld with an acceptable appearance. When working with hot rolled steel (HRS), the mill scale—a thin layer of oxide formed when the material is processed while it is hot—needs to be removed. Clean all project parts to remove any oil, dirt, rust, and mill scale. This can be time consuming but will ensure a long-lasting project that will need little maintenance or repair. For any project that will be painted or powder coated, it is important to clean the entire project. If parts will be allowed to rust or become aged, thoroughly clean all areas to be welded.

The first step in cleaning is to remove all grease, oil, or dirt by wiping the part down with denatured alcohol, acetone, or a commercial degreaser. Alcohol works the best, as it has minimal odor and does not dissolve or damage plastics like acetone does. Both acetone and degreasers tend to leave a residue that may diminish the quality of the final weld or finish.

Once the grease, oil, and dirt have been removed from the surface, the mill scale must be removed. You can do this by wire brushing, grinding, sanding, or sand blasting the part. A bench-mounted grinder with a wire bush works well for cleaning small parts or the ends of smaller parts, but it cannot be used on larger surfaces. For larger surfaces, you will need an angle grinder outfitted with a grinding wheel, wire brush, or flap wheel. A hand-held, battery-powered drill with a wire brush or wire brush cup will also work. Remember, when working with any power tools, you must wear the appropriate PPE, including safety glasses, face shield, and long sleeves to protect your eyes and body from wire fragments that can be thrown from the brush. Also, never force or apply too much pressure to an angle grinder or drill, as the tool can kick back and cause severe injuries.

Once all parts have been cleaned and you have removed all of the mill scale, it is important to complete the project in a timely manner before the metal rusts.

Apply denatured alcohol with a clean rag to clean dirt and oil from project parts. Wear rubber gloves to protect your hands.

Cleaning the mill scale off mild steel is an important step. A bench-mounted power wire brush works well on small pieces. Wire brushing the entire project prior to finishing is critical for good paint adhesion.

SETTING UP THE WELDING SHOP

If you plan to weld on a regular basis, it makes sense to set up a welding shop or area in an existing shop. The primary concern, especially if you are going to share space with other interests, such as woodworking, will be to contain the hot sparks, slag, and other flammable elements that are naturally associated with welding. It is also imperative that all welding fumes be properly exhausted and that proper ventilation is provided to allow for a safe working environment. Although it is possible to weld outside, not all processes work well in an outdoor area. Wire feed welding (GMAW) and tig welding (GTAW) require a shielding gas, and wind can be a challenge, resulting in poor welds with unacceptable profiles or appearance. All of the arc welding processes must be performed in a dry environment to prevent electrical shock. In certain areas, a cold climate can negatively impact the welding process, as cold metals do not respond well to an electric arc. A heated garage or outbuilding is well suited for welding, while a basement is a poor choice due to the chance of fire and explosion, not to mention poor ventilation in or near a living space. Be sure to check with your homeowner's insurance policy or landlord, as welding in an attached garage may void your policy or lease.

Remember that very small sparks and pieces of slag can scatter or be projected from a grinder or welder up to 40 feet from the source. If they land on a flammable or combustible material they may smolder, and under the right conditions they can ignite. Always prepare for cutting, welding, and grinding operations with the proper protective welding curtains and remove all combustible material from the immediate area. Perform a safety walk before and after welding to make sure the area is clear and that no material is smoldering. Never weld on wooden structures or wooden structures covered with metal, as the heat may transfer from the metal through the wood, which can smolder for a long period of time before igniting.

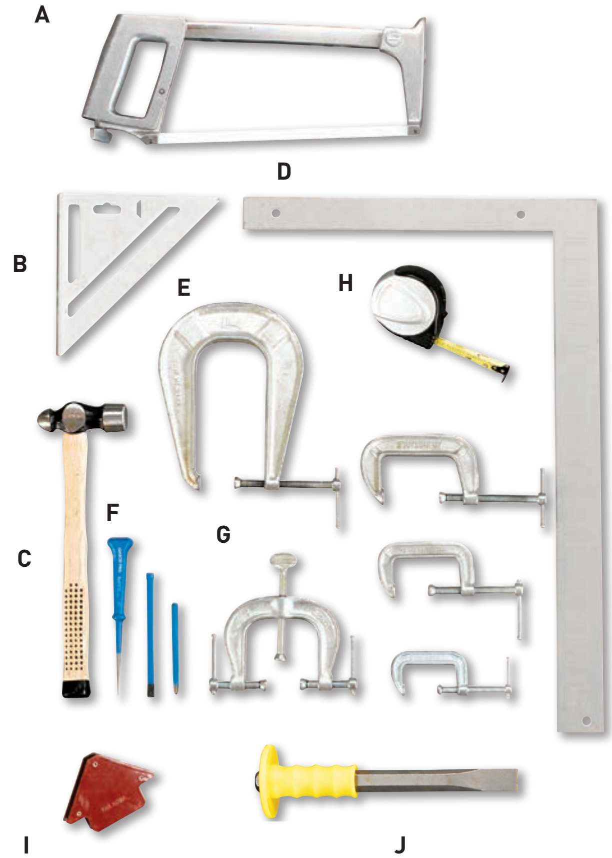
Shop space with a concrete floor and cement block walls is ideal for welding. Good ventilation is also important.

SHOP TOOLS

Selecting tools for the welding shop can be a daunting task. The wish to buy cheap while expecting quality sometimes frustrates new welders. Invest as much as you can comfortably spend, and buy industrial grade equipment from a welding supplier. If this means spreading your purchases out over a long period of time, that is okay—you will be more successful and less frustrated in the end. Beware of buying used welding equipment online. Some older machines may work great, and the price is usually right. But as newer models come out, finding consumable items such as electrode holders, GMAW liners, and repair parts can be challenging. Do your homework and research the availability of parts, consumables, and accessories for the machine before buying. Remember this is one of the largest investments you will make in your welding career.

Now that you have a welder you can purchase power tools. An angle grinder, portable bandsaw, and a chop saw are very useful for cutting and preparing parts for welding. A drill press and bandsaw can also be useful.

As your welding skills and fabrication knowledge improve, you can add specific metalworking equipment, including metal brakes and benders, tubing benders, and scroll benders for ornamental work. These pieces of equipment can range in price depending upon the name brand, size, and whether they are manually or hydraulically operated.



K

L

Standard tools for a welding shop include:
(A) hacksaw, (B) combination square,
(C) ball peen hammer, (D) framing square,
(E) various sizes of C-clamps, (F) center punches, (G) alternative C-clamp, (H) measuring tape,
(I) magnetic clamp, (J) cold chisel, (K) circular saw, (L) portable band saw, (M) air compressor, (N) angle grinder, (O) angle pointer/calculator, (P) level, (Q) metal file, (R) oxyacetylene and oxygen (including regulators, hoses, torch with tip), (S) plasma cutter, (T) TIG stick welder, (U) multiple-purpose cut-off saw, (V) MIG welder.

M


Coleman Powermate
DIRECT DRIVE AIR COMPRESSOR

N


BOSCH

O

P

Q

R

S


THERMAL DYNAMICS

T


ESAB

U


RAGE

V


LINCOLN ELECTRIC
SP-175 PLUS

METAL REPAIR

Once you begin welding, you will encounter numerous opportunities to repair items. When your friends and neighbors discover you can do repairs, even more challenges will come your way.

Performing weld repairs can be very tricky, even dangerous, if you are not sure of the type of material and what the part was used for. When in doubt, bow out, especially on a vessel or drum where you are unsure of its previous contents. It is important to assess your welding skills, the difficulty of the repair, and the intended use of the repaired item. Any structural or vehicle repairs, such as stairways, ladders, trailers, or chassis, need to meet the same safety standards as they did in the original condition.

The first step when considering a repair is determining why the item broke or failed. If the failure was due to a poorly executed weld, the repair might be as simple as grinding out the welded area, tacking the area back together, and performing a satisfactory weld. But if a piece has broken due to metal fatigue, simply welding over the cracked area may only cause more cracks in different areas. Investigate and ask questions, and reach out to mentors with suggestions of how to properly repair the failed item.

The second step in a repair is determining the base metal. A magnet will be attracted to metals with a fairly high concentration of iron, but stainless steel (which is sometimes nonmagnetic), mild steel, and cast iron each require very different welding techniques. Aluminum is nonmagnetic and is discernable from stainless steel by its light weight—but which alloy is included with the aluminum? Some aluminum alloys are not weldable. Unfortunately, many manufactured metal items are alloyed and may have been heat-treated. Without access to the manufacturer's specifications, it is sometimes impossible to determine the composition of the base metal. It is important to understand the effects of welding on these materials before attempting a repair.

The third step after determining the feasibility of a repair is to properly clean and prepare the area to be welded, removing all dirt, oil, and paint or finishes. If one of the arc welding processes is selected, you must also clean an area down to bare metal so the work clamp may be properly secured. If the break is at a welded joint, you must also remove areas of the old weld bead to ensure complete penetration into the base metal.

All parts need to be carefully prepared before attempting a repair. Paint needs to be ground or sanded off and grease and oil need to be cleaned away. This cast iron part is being beveled to allow greater weld penetration.

Mild steel is the easiest material to repair. Simply prepare the metal as we discussed in the metal cleaning and preparation section and the weld may then be completed with any of the arc welding processes.

Cast iron and cast aluminum both need to be preheated before welding to help prevent cracking due to temperature fluctuations. If the piece is small enough, it can be placed in an oven at 400 to 500 degrees Fahrenheit. Otherwise, use an oxyacetylene or oxy-propane rosebud or heating tip. Temperature crayons that melt at specific temperatures are available for marking metals for preheating. Post-weld heating and penning may also be required to dissipate stress while the part returns to ambient temperature at a controlled rate—this will further reduce the chance of cracking.

Some aluminum is not weldable, but if an aluminum part has been welded before, it is typically safe to perform a repair weld. If the composition of the base metal can be determined, match the filler metal makeup to the base metal. Some filler metals are multipurpose and can be used on more than one alloy. Consult the manufacturer's recommendations or ask a professional at a welding supplier.

Stainless steel also comes in numerous alloys, and it is important to match the filler metal with the base metal. Do not clean stainless steel with a wire brush, as the mild steel wires may contaminate the base metal. Instead, use a flap wheel, emery cloth, or an abrasive pad.

Remove the paint and finish from the weld area. If you are arc welding, also remove the paint from an area close to the weld for attaching the work clamp.

Cast iron can be braze welded as shown here, or shielded metal arc welded with cast iron electrodes. Either way, the metal needs to be preheated to 450°F before being welded.

TECHNIQUES

In this chapter we will discuss the basic cutting and welding processes. These techniques are the foundation of your skill set as a welder—skills you will use again and again, regardless of the type of welding you pursue. This chapter also provides basic directions and step-by-step photos that illustrate major welding and cutting processes. You will find quick reference charts that describe electrode selection and filler wire choices, metal types and weldability, and joint design and weld types.

IN THIS CHAPTER: