Audel™ Welding Pocket Reference

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Acknowledgments

No book of this nature can be written without the aid of many people. It takes a great number of individuals to put together the information available about any particular technical field into a book. The field of welding is no exception. Many firms have also contributed information, illustrations, and analysis of the book.

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Welder's Guide

Preface

Audel's *Welding Pocket Reference* is written for everyone who wants or needs to know about welding. Whether you are trying to construct a building, repair a railroad problem, or solder a tin can for a project, the rewards from a job well done are many.

This book can be used by students in vocational courses, technical colleges, apprenticeship programs, and welding classes in industrial technology programs. The home do-it-yourselfer will find answers to questions that pop up in the course of getting a job done, whether over a weekend or a longer period of time. The professional welder will find this to be a handy reference while working on a project in the field, and everyday welding problems can be handled easily with the aid of this book.

The purpose of this book is to aid you in your everyday tasks and keep you updated with the latest facts, figures, and devices in this important trade.

Many illustrations are included that show a variety of parts and techniques found in present-day practice in the field. Obviously, not all related problems can be presented here, and a worker needs a great deal of ingenuity on the job. For standard procedure, however, the *Welding Pocket Reference* does give a guide to which electrode numbers to use for particular metals, what welding tips to use, and other important facts and figures. This handbook should be kept in your pocket or toolbox for easy access.

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Welding Pocket Reference

1. WELDING AND CUTTING SAFETY

The *American Welding Society* and the *American Standards Association*, as well as various governmental and private organizations, have compiled safety standards for the operation of gas and arc welding and cutting equipment. You are encouraged to read these publications and become familiar with their recommendations. The various manufacturers of welding equipment and supplies also publish safety information.

OXYACETYLENE WELDING AND CUTTING SAFETY

The safety recommendations for oxyacetylene welding and cutting covered in this chapter also apply to the other oxyfuel processes, such as oxyhydrogen welding and cutting, oxy-natural gas cutting, and air-acetylene welding.

General Safety Recommendations for Oxyacetylene Welding and Cutting

- Never weld in the vicinity of flammable or combustible materials.
- Never weld on containers that have held combustible or flammable materials without first exercising the proper precautions.
- Never weld in confined spaces without adequate ventilation or individual respiratory equipment.
- Never pick up hot objects.
- Never do any chipping or grinding without suitable goggles.

General Recommendations for Safe Handling of Cylinders and Regulators

- Make certain that the connections between the regulators, adapters, and cylinder valves are gas-tight.

Escaping acetylene can generally be detected by the odor. Test with soapy water—never with an open flame.

- Never move individual cylinders unless the valve protection cap, where provided, is in place, hand-tight.
- Never drop or roughly handle cylinders in any way.
- Make certain that cylinders are well fastened in their station so that they will not fall.
- Never use a hammer or wrench to open any valve on a cylinder.
- Never force connections that do not fit.
- Never tamper with cylinder safety devices.
- Never use oil to clean a regulator gauge. As a combustible substance, oil has a very low flash point.

Protecting Oxygen and Acetylene Hoses

- Always protect hoses from being stepped on or run over. Avoid tangles and kinks. Never leave hoses where they can be tripped over.
- Protect hoses and cylinders from flying sparks, hot slag, hot objects, and open flame.
- Never allow a hose to come into contact with oil or grease; these substances deteriorate the rubber and constitute a hazard with oxygen.

Oxygen Gas and Cylinder Safety Recommendations

- Always refer to oxygen by its full name—oxygen—and not by the word air. This will avoid the possibility of confusing oxygen with compressed air.
- Never use oxygen near flammable materials, especially grease, oil, or any substance likely to cause or accelerate fire. Oxygen itself is not flammable, but it does *strongly* support combustion.
- Do not store oxygen and acetylene cylinders together. They should be separately grouped.

- Never permit oil or grease to come in contact with oxygen cylinders, valves, regulators, hoses, or fittings. Do not handle oxygen cylinders with oily hands or oily gloves.
- Never use oxygen pressure-reducing regulators, hoses, or other pieces of apparatus with any other gases.
- Always open the oxygen cylinder valve slowly.
- Never attempt to store any other gases in an oxygen cylinder.
- Oxygen must never be used for ventilation or as a substitute for compressed air.
- Never use oxygen from cylinders without first connecting a suitable pressure-reducing regulator to the cylinder valve.
- Never tamper with nor attempt to repair oxygen cylinder valves, unless qualified to do so.

Acetylene Fuel Gas and Cylinder Safety Recommendations

- Call acetylene by its full name—acetylene—and not by the word gas.
- Acetylene cylinders should be used and stored valve end up.
- Never use acetylene from cylinders without a suitable pressure valve.
- Turn the acetylene cylinder so that the valve outlet will point away from the oxygen cylinder.
- When opening an acetylene cylinder valve, do not turn the key or spindle more than one and one-half turns.
- The acetylene cylinder key for opening the valve must be kept on the valve stem while the cylinder is in use, so that the acetylene cylinder may be quickly turned off in an emergency.

- Never use acetylene pressure-reducing regulators, hoses, or other pieces of apparatus with any other gases.
- Never attempt to transfer acetylene from one cylinder to another, refill an acetylene cylinder, or store any other gases in an acetylene cylinder.
- Should a leak occur in an acetylene cylinder, take the cylinder out into the open air, keeping it well away from fires or open lights. Notify the manufacturer immediately if any leaks occur.
- Never use acetylene at pressures in excess of 15 psi. The use of higher pressures is prohibited by all insurance authorities, and by law in many localities.

General Welding and Cutting Safety Tips

- Never use matches for lighting torches (hand burns may result). Use spark lighters, stationary pilot flames, or some other suitable source of ignition.
- Do not light torches from hot work while in a pocket or small confined space.
- Never attempt to relight a torch that has blown out without first closing both valves and relighting in the proper manner.
- Never hang a torch and its hose on regulators or cylinder valves.
- Never cut material in a position that will permit sparks, hot metal, or the severed section to fall on the cylinder, hose, or your legs or feet.
- When welding or cutting is to be stopped temporarily, release the pressure-adjusting screws of the regulators by turning them to the left.
- When the welding or cutting is to be stopped for a long time (during lunch hour or overnight) or taken down, close the cylinder valves and then release all gas

pressures from the regulators and hose by opening the torch valves momentarily. Close the torch valves and release the pressure-adjusting screws. If the equipment is to be taken down, make certain that all gas pressures are released from the regulators and hoses and that the pressure-adjusting screws are turned to the left until free.

ARC WELDING AND CUTTING SAFETY

Important safety recommendations for the arc welding and cutting processes include the following:

- Keep the work area and floor clean and clear of electrode stubs, scraps of metal, and carelessly placed tools.
- Always work in a well-ventilated area. This is the best protection against toxic fumes and dust. If the ventilation is poor, adequate respiratory equipment is necessary.
- Make sure cable connections are tight and that cables do not become hot.
- Never look at an electric arc with the naked eye. An electric arc gives off harmful radiation. Goggles with suitable lenses and protective clothing are recommended as protection against these rays, as well as against flying sparks, splattering metal, and hot metal.
- Electric shock can be avoided by proper handling of the arc welding equipment. The arc welding machine must be properly grounded at all times. The work area should be dry. All insulation (wiring, electrodes, and so forth) should be checked, and replaced if damaged.
- Never weld while wearing wet gloves or wet shoes.
- Never use electrode holders with defective jaws.
- Never leave the electrode holder on the table or in contact with a grounded metallic surface. Place it on the support provided for that purpose.

- Never weld on closed containers or on containers that have held combustible materials.
- Never allow an arc welding machine to rest on a dirt floor.
- Operate arc welding machines and equipment only in clean, dry locations.
- Insofar as possible, protect arc welding machines in the field from weather conditions.
- Always install an arc welding machine in compliance with the requirements of the *National Electrical Code* and local ordinances, and make certain it is properly grounded.
- Use the proper terminals on the arc welding machine for the power line voltage connection.
- Never work on the wiring of an arc welding machine unless qualified to do so.

WELDING AND CUTTING SAFETY EQUIPMENT

Eye Protection

The welder and others associated with welding operations should be provided with glasses designed to provide maximum protection while affording adequate vision for proper welding technique. Until recently it was customary to assume that if the visible rays were cut down to a comfortable intensity, the ultraviolet and infrared rays were also reduced proportionately. The usual practice was to use alternate layers of red and blue glass to reduce the light intensity to a value consistent with the work being done. Such a procedure may or may not offer complete protection, because some glasses strongly absorb the visible rays while transmitting the harmful infrared or ultraviolet rays quite freely.

Scientific methods for testing protective lenses have been developed. These tests have resulted in the establishment of standards for lenses of various grades and have led to the

development of glass formulas that have materially increased the protective qualities of lenses. Complete and positive protection for the eyes is now available. Suggested shades for various types of welding and joining operations are given in Table 1-1.

Table 1-1 Recommended Lens Shades for Various Welding and Cutting Operations

Operation	*Shade Number*
Torch Brazing	3 or 4
Oxyacetylene Cutting	
>1″ thick metal	3 or 4
1 to 6″ thick metal	4 or 5
6″ thick metal and thicker	5 or 6
Oxyfuel Gas Welding	
>1/8″	4 or 5
1/8 to 1/2″	5 or 6
1/2″ and up	6 or 8
Oxyacetylene Flame Spraying	5
Shielded Metal-Arc Welding (SMAW)	
up to 5/32″ electrodes	10
3/16- to 1/4″ electrodes	12
5/16″ electrodes and up	14
Gas Metal-Arc Welding (GMAW) – MIG Welding	
>60 amps	8 to 10
60–160 amp range	11
160–250 amp range	12
250 amps and above	14
Flux Cored-Arc welding (FCAW)	
>60 amps	8 to 10
60–160 amp range	11
160–250 amp range	12
250 amps and above	14

(*continued*)

Table 1-1 (*continued*)

Operation	*Shade Number*
Gas Tungsten-Arc Welding (GTAW) – TIG Welding	
>20 amps	5 to 9
20–100 amp range	10 to 11
100–400 amp range	12
400 amps and above	14
Plasma-Arc Welding	
>20 amps	8
20–100 amp range	10
100–400 amp range	12
400 amps and above	14
Soldering	2

Eye Protection Tips:

- Seeing white spots in your vision after you've stopped welding and removed your goggles is an indication that you need darker lenses.
- Failure to distinguish between a neutral and a carburizing oxyacetylene flame while wearing your goggles is an indication that the colored lenses you are wearing are too dark.
- If you cannot see the weld puddle while wearing your goggles, you need a lighter-colored lens.

NOTE

Federal specifications for welding lenses specify not only the percentage of rays transmitted by the various shade numbers, but also the thickness of the glass and its optical properties.

Proper lens selection is important. There is a vast difference in welding lenses, both as to their value and their effect on welding production. It is impossible to distinguish one lens

from another by casual inspection. Scientific tests are required to determine their qualities. It is vitally important when selecting a welding lens to take into account the reputation of the manufacturer and their experience in the welding field.

NOTE

Install screens or barriers to protect nearby workers from flash and glare created by the welding or cutting process.

Nonspatter cover glass is a chemically treated glass that protects the lens from spatter yet allows maximum visibility. Spatter does not adhere to this special type of glass, prolonging its life to five or ten times that of ordinary glass and maintaining clear visibility. A soft cloth should be used for cleaning.

Goggles are available in a great number of different designs and types. Either glass or plastic lenses may be purchased, and the lenses themselves can be either clear or tinted. Most goggles have either round or rectangular lenses.

Face shields are also useful for protecting the face of the operator against flying sparks and other dangerous matter. They find widespread use in arc welding and cutting. Face shields are available in clear plastic or in different shades of green and can be purchased in several thicknesses. (ANSI requires a minimum thickness of 0.041 inch or more.) Note: Face shields provide limited impact and splash protection.

Helmets, safety caps, and other headgear have been designed for operators of welding and cutting equipment to protect the head against serious blows. These are available in many different designs and a great number of sizes. The helmets are made from either molded fiberglass or metal plate.

Respirators

It is absolutely necessary that proper ventilation be provided for each welding and cutting operation. The fumes produced during welding and cutting can be injurious to the welder's health (see Table 1-2). Some fumes, such as those produced

Table 1-2 Some Common Sources of Potentially Hazardous Fumes

Type	*Comments*
Beryllium	Beryllium is found in beryllium base metal, beryllium alloys, and some filler metals. Breathing even small amounts of dust containing beryllium or beryllium fumes can cause lung inflammation, serious lung disease, and cancer.
Bismuth	
Cadmium	Cadmium is found in cadmium-coated base metals, filler metals, and fluxes. The fumes are extremely toxic.
Cleaning compounds and solvents	Cleaning compounds and solvents are potentially hazardous to the health. Gasoline and benzene, for example, produce toxic fumes and are also flammable. The vapors of some solvents, such as trichloroethylene, create toxic halogens and phosgene when in contact with a hot object or a welding arc.
Columbium (Niobium)	Columbium (niobium) contains many highly toxic compounds. Metallic columbium dust is an eye and skin irritant and also can be a fire hazard.
Lead	Lead, lead alloys, and lead coatings or paints containing lead can be dangerous. Breathing lead fumes can cause a wide variety of serious health problems, ranging from simple eye irritation to damage to the kidneys, heart, liver, and brain.
Manganese	Manganese is found in many welding products, such as electrodes and welding rods. Manganese is toxic to the brain and central nervous system when the levels in the body exceed normal limits. Breathing welding fumes containing manganese over a long period of time can lead to *manganism*, a condition similar to Parkinson's disease.

(*continued*)

Table 1-2 (*continued*)

Type	*Comments*
Mercury	Mercury is found in some paints and coatings used on metals. Breathing mercury vapors can result in serious pulmonary and neurological disorders. Symptoms include coughing, chest pains, nausea, vomiting, diarrhea, fever, and a metallic taste in the mouth.
Zinc	Zinc oxide fumes are released when the zinc layer on zinc-coated metals is melted. These fumes result in a condition known as *metal fume fever* or *zinc chills*, with symptoms resembling a viral flu.
Zirconium	Zirconium is found in beryllium base metal and alloys. Breathing zirconium fumes can cause irritation to the respiratory tract. Symptoms may include coughing, shortness of breath, sore throat, and runny nose.

when working with zinc, lead, or cadmium, can be toxic. These conditions also hold true for braze welding, brazing, and soldering.

Other sources of hazardous fumes produced during the various welding, joining, and cutting processes include antimony, bismuth, chromium, cobalt, copper, magnesium, molybdenum, nickel, thorium, and vanadium.

In the case of permanent welding stations, the size of the working area is an important consideration. Overcrowding will reduce the effectiveness of any ventilating system. The ventilating system itself (exhaust fans, etc.) should be designed to keep the level of toxic fumes and other contaminants at or below the maximum permitted level. Individual respiratory equipment is sometimes necessary when room ventilation is inadequate.

Protective Clothing

The manufacturers of welding equipment and supplies offer a broad range of protective clothing for welders, such as leather jackets; cape sleeves with detachable bib; waist, bib, or split-leg aprons; and shirt sleeves with snap fasteners at the wrist and adjustable leather straps at the top of the arm.

- Pants, shirts, and other clothing should be made of a flame-resistant material. The pants should be without cuffs, because cuffs can trap sparks and bits of molten metal.
- The clothing must be thick enough to minimize or prevent penetration by the dangerous radiation given off by an arc. The arc rays produce very strong visible and invisible rays (both ultraviolet and infrared) that can burn the eyes and skin. This radiation cannot be seen, but it is present. Any exposed skin can be burned quickly by these rays, which cause skin burns similar to sunburn.
- Sleeve cuffs should be tight against the wrist to prevent trapping flying sparks or molten particles. For this purpose, elastic bands or gauntlet cuffs are recommended.
- Black, flame-resistant cotton twill is often recommended for use with inert gas arc welding. Protective clothing made from this type of cloth is cheaper and lighter than leather.
- Wear high-top leather shoes, work shoes, or boots. Tennis shoes are not acceptable footwear.

2. OXYACETYLENE WELDING

Oxyacetylene welding (OAW) is a welding process in which the heat for welding is produced by burning a mixture of oxygen and acetylene. It is commonly referred to as *gas welding*.

NOTE

Oxyfuel welding (OFW) is the American Welding Society's name for any welding process in which coalescence is produced by a gas flame obtained by combining oxygen and an appropriate fuel gas. Oxyacetylene welding is the most widely used gas welding process in the oxyfuel group, and it is the one that will be covered in this section of the *Welding Pocket Reference*.

OXYACETYLENE WELDING APPLICATIONS

Oxyacetylene was the first welding process used commercially and industrially, especially for welding cast iron, wrought iron, low-alloy steels, copper, and bronze. Except for repair and maintenance work, oxyacetylene welding has been replaced by various arc welding processes, such as shielded metal arc welding (or stick welding), gas metal arc welding (or MIG welding), and tungsten metal arc welding (or TIG welding). Although relegated to a minor role in welding, oxyacetylene is still widely used for a wide variety of nonwelding uses such as cutting, preheating and post-heating, flame hardening, case hardening, braze welding, brazing, soldering, and descaling.

Oxyacetylene Welding (OAW) Advantages and Disadvantages

OAW Advantages:

- Self-contained and easily portable equipment
- Widely available equipment
- Relatively inexpensive equipment
- Easy to learn

OAW Disadvantages:

- Slower welding process than others.
- Uses volatile and potentially dangerous gases.
- Fuel gas and oxygen cylinders require special handling to avoid damage. Damaged cylinders can cause fire or explosions.

OXYACETYLENE WELDING EQUIPMENT

A typical oxyacetylene welding station will include the following components: (1) welding torch and nozzle; (2) oxygen cylinder, oxygen regulator, and oxygen hose; (3) acetylene cylinder, acetylene supply, acetylene regulator, and acetylene hose; (4) flashback arrestors and check valves; and torch lighter/sparklighter (see Figure 2-1).

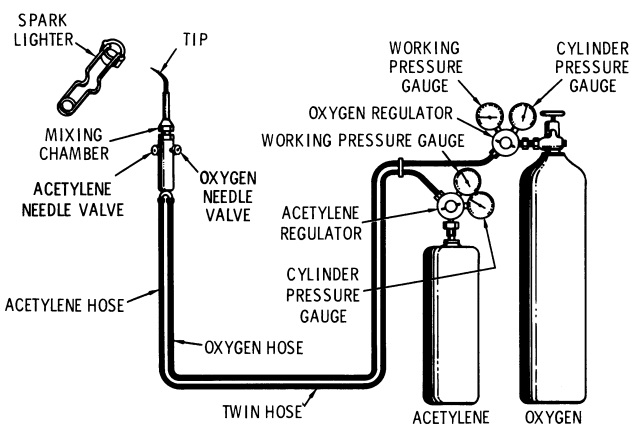

Fig. 2-1 Principal components of a typical oxyacetylene welding station.

Welding Torch

The welding torch is designed to mix oxygen and acetylene in nearly equal amounts, and then ignite and burn the gas mixture at the torch tip. The welding torch has two tubes (one for oxygen and the other for acetylene), a mixing chamber, and oxygen and acetylene valves to control and adjust the flame (see Figure 2-2).

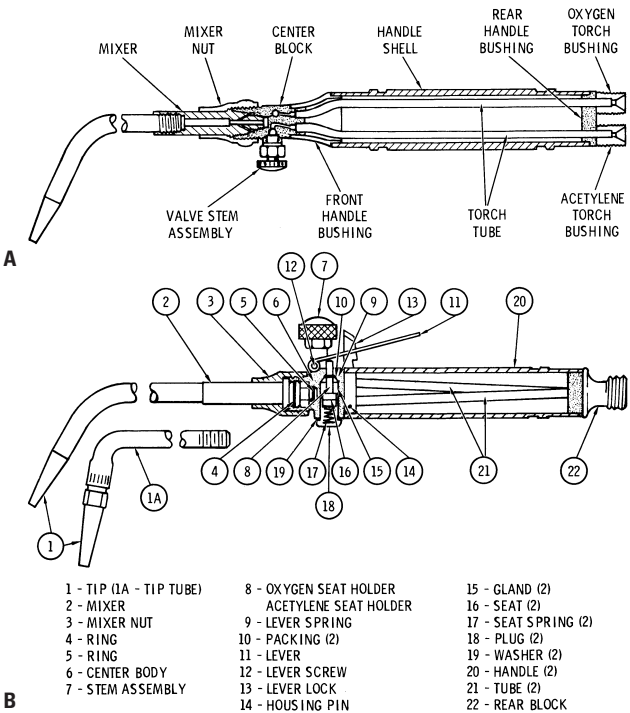

Fig. 2-2 Typical oxyacetylene torch.

Torch Tips

Welding tips may be purchased in a wide variety of sizes and shapes. The suitability of a particular welding tip design depends on a number of factors, including the accessibility of the area being welded, the rate of welding speed desired, and the size of the welding flame required for the job.

Manufacturers have their own numbering systems for indicating the different welding tip sizes. There is no industry standard, although there are comparison charts available. Tip size identifications have no bearing on minimum or maximum gas consumption or flame characteristics.

Drill size alone also fails to give an adequate comparison between the various makes of welding tips with identical tip drill sizes, because internal torch and tip construction may cause gas exit velocities and gas pressure adjustments to vary.

The welding torch nozzle is replaceable and is available in a wide variety of sizes. The size selected will depend on the thickness of the metal being welded. Table 2-1 contains data for the selection of welding tips. These are recommended sizes, and all variables should be taken into consideration before making the final selection.

NOTE

Because tips are subject to wear, they must be replaced from time to time. Use an appropriate wrench for this purpose (never pliers). Malfunctions such as *backfire*, *blowback*, and *popping out* will be greatly (if not completely) reduced by using the appropriate tip at the recommended pressure.

Oxygen Cylinders

Oxygen cylinders are seamless steel containers holding about 244 cubic feet of oxygen at a pressure of 2200 psi at 70°F. Smaller cylinders holding about 122 cubic feet is also available. A typical oxygen cylinder (see Figure 2-3) has an outside diameter of approximately 9 inches, is 54 inches high, and weighs (empty) between 104 and 139 pounds. The difference