

THE REGISTERED APPRENTICESHIP OCCUPATIONS AND STANDARDS CENTER OF EXCELLENCE (AOSC)

Combination Welder National Occupational Framework

ONET Code: 51-4121.00

RAPIDS Code: 0622

Created: March 2023

This project has been funded, either wholly or in part, with federal funds from the Department of Labor, Employment and Training Administration under Cooperative Grant Number AP-36653-21-75-A-11. The contents of this publication do not necessarily reflect the views or policies of the Department of Labor, nor does mention of trade names, commercial products, or organizations imply endorsement of the same by the US Government.





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Acknowledgments

We would like to thank several people who have contributed to the development and vetting of this National Occupational Framework. We would especially like to thank Diane Jones for her research, support and contributions to the development of the framework. Additionally, we had terrific experts lend their time, review, and support to the framework. They include Eric Cochran of the Robert C. Byrd Institute for Advanced Flexible Manufacturing; Seth Harms of West Delaware High School; Danille Kesteloot of Des Moines Public Schools; Thomas Kostreba of the American Welding Society; Dawn Moore of the Virginia Manufacturer's Association; Robert Richard of Crystal Steel Fabricators, Inc.; Paul Reeves and Kevin Bouman of Pfizer; and Karter Krueger and Tony Barnard of Snead State Community College and Oceaneering International, Inc. We also want to thank Zach Boren, Shruti Nayak, and Erikah Garnett for their thoughtful creation and review of this framework. Finally, we want to thank our editor, Liza Hagerman.

Introduction to Using This Document

Under the Registered Apprenticeship Technical Assistance Centers of Excellence award, the Urban Institute leads the Occupations and Standards work. One of the main objectives of Urban's project is to create high-quality, well-researched, consensus-based work process schedules that are nonproprietary and widely available. This document is a product of that work and contains three sections: the occupational overview, the work process schedule, and the related technical instruction.

The **occupational overview** is a general introduction, including alternative job titles, any prerequisites, and, if applicable, the total number of hours needed to complete a time-based or hybrid program.

The **work process schedule** outlines the major job functions, competencies, and/or hours an apprentice completes in a registered apprenticeship program. It outlines what apprentices are expected to learn on the job with the support of a mentor or journeyworker (a worker mastering the competencies of an occupation in a particular industry), including both core competencies and those deemed optional by experts in the field. The work process schedule is the foundational document guiding a program.

Urban works with numerous experts to ensure the content is thoroughly researched and vetted to reflect the expectations of industry, educators, labor unions, employers, and others involved in apprenticeship for this occupation. Sponsors and employers can use the work process schedule as their program standards with assurances it has been approved by experts in the field.

The **related technical instruction** presents considerations for the coursework that apprentices will undertake to supplement on-the-job learning. It is intended to serve as a reference to sponsors exploring their options for the accompanying classroom, virtual, or hybrid training.

How to Use the Work Process Schedule

Sponsors can adapt the work process schedule to accommodate their needs for competency- or time-based or hybrid programs. In a **competency-based** apprenticeship, sponsors assess apprentices' progress across core and optional competencies listed in the work process schedule. In a **time-based** apprenticeship, apprentices complete a predetermined number of hours across major job functions and the program overall. In a **hybrid** apprenticeship, sponsors monitor apprentices' hours spent on major job functions and assess their proficiency across competencies.

Each program type has a different method of assessment:

- **For a competency-based program**, apprentices engage in activities and make progress toward proficiency in the identified competencies. Sponsors overseeing apprentices' work assess their mastery of the outlined competencies using the following rating scale:

- 4—Competent/proficient (able to perform all elements of the task successfully and independently)
- 3—Satisfactory performance (able to perform elements of the task with minimal assistance)
- 2—Completed the task with significant assistance
- 1—Unsuccessfully attempted the task
- 0—No exposure (note the reason—absence, skill isn't covered, etc.)

The competencies may be completed in any order. Apprentices must perform at a level 4 or 3 in all competencies listed as “core” to complete the apprenticeship program successfully.

- **For a time-based program**, sponsors monitor apprentices' completion of hours in training across major job functions. The total number of hours recommended for this occupation is listed in the occupational overview and is based on guidance from the US Department of Labor. Generally, apprentices must have at least 2,000 hours overall for on-the-job learning, but occupations of greater complexity may require more hours. Sponsors will provide apprentices with supervised work experience and allocate the total number of hours across the major job functions to adequately train their apprentices.
- **The hybrid approach** blends both competency- and time-based strategies. Sponsors measure apprentices' skills acquisition through a combination of completing the minimum number of hours of on-the-job learning successfully demonstrating identified competencies. Sponsors will assess apprentices' proficiencies as described for competency-based programs with a rating scale of 0–4 for every core competency. Generally, apprentices have at least 2,000 hours overall for on-the-job learning, but occupations of greater complexity may require more hours. Sponsors will document apprentices' completion within a minimum and maximum range of hours assigned for each major job function.

Combination Welder Occupational Overview

Occupational Purpose and Context

Welding is the chemical process of melting and heating sculptures and forming a new shape or figure by fusing the melted parts together. A combination welder uses specialized welding equipment to construct, maintain, and repair metal parts, such as pipes. Welding requires extremely high temperatures that melt the base materials. Welders often work on a construction or job site where they weld rebar, beams, or other metal structural components. The job duties of a combination welder also include preparing materials, reading technical schematics, making precise measurements, and welding components in a variety of space constraints.

Welding applies to various materials, including metal, wood, and plastic. Several types of welding are available, with various uses for them. One specialty and niche in welding is combination welding, which is the process of preparing materials to be welded, welding metal parts, and performing maintenance work on welding torches and other equipment.

A combination welder is responsible for making, repairing, and maintaining metal parts using specialized equipment. Combination welders are often preferred on construction sites, where they assist with the welding of the beams and other structural components.

Potential Job Titles

Welder, combination welder, assembly line brazer, brazer, fabrication welder, maintenance welder, solderer, welder fitter, wirer, gas metal arc welder (GMAW/MIG), gas tungsten arc welder (GTAW/TIG), shielded metal arc welder (SMAW), flux cored arc welder (FCAW), plasma arc welder (PAW), and oxyfuel welder

Apprenticeship Prerequisites

Candidates may typically hold a high school diploma or GED, though it is not required in all cases. Formal education beyond high school is not required, though some candidates may pursue community college or vocational school courses in metalworking and mechanics. Apprenticeship candidates should also have attention to detail, manual dexterity, and adequate physical aptitude to perform required tasks.

Recommended Length of Apprenticeship (Time/Hybrid Programs Only)

The recommended length of time for on-the-job training in a combination welding apprenticeship is 3,000 to 6,000 hours.

Work Process Schedule

Combination Welder

ONET Code: 51-4121.00

RAPIDS Code: 0622

Instructions for Use:

Competency-based programs: In the “performance level achieved” column of the work process schedule (see examples starting on the next page), assess apprentices’ performances on each competency with the scale below. No monitoring of hours is required for this approach. See “Guidelines for Competency-Based, Hybrid and Time-Based Apprenticeship Training Approaches,” US Department of Labor, Employment and Training Administration, Office of Apprenticeship, October 20, 2015, <https://www.apprenticeship.gov/sites/default/files/bulletins/Cir2016-01.pdf>.

- 4—Competent/proficient (able to perform all elements of the task successfully and independently)
- 3—Satisfactory performance (able to perform elements of the task with minimal assistance)
- 2—Completed the task with significant assistance
- 1—Unsuccessfully attempted the task
- 0—No exposure (note the reason—absence, skill isn’t covered, etc.)

Time-based programs: In the “hours” row, specify the number of hours apprentices will fulfill for each job function. No assessment of competencies is required for this approach.

Hybrid programs: In the “performance level achieved” column, assess apprentices’ performances on each competency using the 0–4 scale above. In the “hours” row, identify a range of hours apprentices should spend working on each major job function.

Job Function 1: Demonstrates preparation to weld and executes welding procedures		
Hours (time-based and hybrid programs only):		
Competencies	Core or optional	Performance level achieved (0–4) (competency-based and hybrid programs only)
A. Analyzes engineering drawings, blueprints, specifications, sketches, work orders, and material safety data sheets to plan layout, assembly, and operations	Core	
B. Prepares all material surfaces to be welded, ensuring there is no loose or thick scale, slag, rust, moisture, grease, or other foreign matter	Core	
C. Determines required equipment and welding methods, applying proper knowledge of material grade, geometry, and welding techniques	Core	
D. Accurately estimates load of weights and center of gravity	Core	
E. Welds components in flat, vertical, horizontal, or overhead positions	Core	
F. Grinds, cuts, buffs, or bends edges of workpieces to be joined per technical drawing	Core	
G. Uses electric, gas, and other welding processes such as electron beam welding, and the skill to apply these processes in manufacturing, repairing, modifying, rebuilding, and constructing	Core	
H. Assembles various types of metal and alloy parts, equipment, systems, and structures	Core	
I. Conducts fabrication welding as necessary using a combination of welding processes, cutting, assembling, and binding	Core	
J. Monitors the welding process to prevent overheating, distortion, or shrinking during the process	Core	
K. Welds metal parts and structures that may vary in size, shape, and thickness from very thin (e.g., .025 inches or less) to very thick (e.g., armor plating), requiring multiple welding passes	Core	
L. Welds dissimilar metals	Optional	
M. Assists other welders in installation, preparation, and fabrication while not actively welding	Core	

N. Follows Weld Procedure Specification (WPS) as applicable	Core	
O. Demonstrates understanding of PQR's (Procedure Qualification Record) and WPQR's (Welder Performance Qualification Record)	Optional	
P. Demonstrates ability to recognize welding symbols	Core	

Job Function 2: Demonstrates proper use of tools and welding technique

Hours (time-based and hybrid programs only):

Competencies	Core or optional	Performance level achieved (0-4) (competency-based and hybrid programs only)
A. Selects and installs torches, torch tips, filler rods, and flux, according to welding chart specifications or types and thicknesses of metals	Core	
B. Recognizes, sets up, and operates hand and power tools common to the welding trade, such as shielded metal arc and gas metal arc welding equipment	Core	
C. Ignites torches or start power supplies and strike arcs by touching electrodes to metals being welded, completing electrical circuits	Core	
D. Melts and applies solder along adjoining edges of workpieces to solder joints, using soldering irons, gas torches, or electric-ultrasonic equipment	Optional	
E. Secures pipes to structure with bracket, clamps, and hangers, using hand tools and power tools	Core	
F. Uses straps, cables, and chains correctly	Core	
G. Performs rigging, lifting, and moving of product using cranes, forklifts, metal carts, etc.	Core	
H. Guides and directs flames or electrodes on or across workpieces to straighten, bend, melt, or build up metal	Core	
I. Performs visual inspection of completed work (and reworks as needed)	Core	

Job Function 3: Follows safety precautions in the workspace		
Hours (time-based and hybrid programs only):		
Competencies	Core or optional	Performance level achieved (0–4) (competency-based and hybrid programs only)
A. Develops and practices safe working habits and works in such a manner as to ensure personal safety and that of fellow workers	Core	
B. Inspects equipment for defects and ensures proper working order	Core	
C. Maintains work area and equipment in a safe, clean, and orderly condition	Core	
D. Detects faulty operation of equipment or defective materials and notifies supervisors	Core	
E. Properly determines rigging and hoisting capacity of cranes, lifts, and other tools based on weight of objects to be picked up	Core	
F. Completes assigned tasks while wearing personal protective equipment (PPE) including but not limited to hard hat, safety glasses/goggles, ear plugs/muffs, masks/respirators, safety vests, gloves, and leather work boots	Core	

Job Function 4: Engages in professional and ethical communication		
Hours (time-based and hybrid programs only):		
Competencies	Core or optional	Performance level achieved (0–4) (competency-based and hybrid programs only)
A. Adheres to employer communication policies, rules, regulations, and process instructions	Core	
B. Accepts constructive feedback and criticism to improve performance	Core	
C. Cooperates with and assists coworkers on projects when necessary	Core	

D. Demonstrates effective one-on-one communication skills with supervisor and coworkers to discuss workplace challenges, personal limitations, and questions	Core	
E. Completes assigned tasks on time	Core	

Job Function 5: Possesses physical aptitude for welding		
Hours (time-based and hybrid programs only):		
Competencies	Core or optional	Performance level achieved (0–4) (competency-based and hybrid programs only)
A. Endures large amounts of standing, walking, bending, squatting, sitting, and lifting	Core	
B. Utilizes arms and hands to signal, grab, hold, turn, push, and pull objects, materials, controls and tools	Core	
C. Lifts, carries and moves heavy objects, possibly anywhere between 25 and 50 lbs. (with reasonable accommodations for workers with disabilities or injuries)	Core	
D. Works at heights, climbs ladders and stairways, and works from platforms using the appropriate fall protection requirements	Optional	
E. Able to work in different weather conditions including heat conditions while wearing appropriate PPE	Core	

Job Function 6: Applies math skills to conduct tasks with precision and accuracy		
Hours (time-based and hybrid programs only):		
Competencies	Core or optional	Performance level achieved (0–4) (competency-based and hybrid programs only)
A. Arranges, adds, subtracts, multiplies and divides whole numbers	Core	
B. Solves practical problems using addition, subtraction, multiplication, and division of whole numbers	Core	
C. Solves practical problems involving fractions	Core	
D. Solves problems using operations with decimal fractions	Core	

E. Solves more complex percentage problems in which two of the three parts are not directly given	Optional	
F. Solves practical applied problems involving tolerances and limits (customary and metric)	Core	
G. Computes areas of more complex figures that consist of two or more common polygons	Optional	
H. Reads and interprets graph data	Core	

Related Technical Instruction

Combination Welder

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RAPIDS Code: 0622

Instructions for Use:

Registered apprenticeships must include at least 144 hours of related technical instruction (RTI). Courses offered by accredited colleges and universities may be assigned a credit hour determination rather than a contact hour determination. In general, an academic credit unit is the equivalent of 15 clock hours of instruction.

Development and Use of This RTI Outline: Employers and academic institutions may approach RTI in markedly different ways. Our goal was not to identify the single best way to provide RTI or to identify a single provider whose content we deemed to be superior. Instead, our goal was to survey numerous education providers, including employers, institutions of higher education, high schools, private continuing education providers, labor organizations, professional associations and, in some cases, municipalities that provide worker training, to identify topics or courses common among those providers that align with the job functions included in this work process schedule. Those common topics or courses are reflected in the RTI outline provided below, which may be useful in developing your RTI program or communicating your needs to an educational partner.

Licensure or certification requirements: While licensure may not be required by all employers, some give hiring preference or may limit employment or promotion opportunities to individuals who have obtained the appropriate skills certifications. Examples of welding certifications include the following:

AWS D1.1 SMAW, GMAW, FCAW and GTAW

AWS D17.1 GTAW

ASME SEC. IX GTAW and SMAW

Degree requirements for licensure or certification, if applicable: not applicable

Accreditation requirements of instructional provider for licensure or certification, if applicable: The American Welding Society offers certification for welding educators; however, there are not specific accreditation requirements associated with licensure or certifications.

Anticipated changes in licensure or certification requirements, if known: none

Examples of state licensure or certification requirements: none known

Examples of RTI providers for this occupation

Professional associations and labor organizations: The American Welding Society provides an industry-developed Fundamentals of Welding Curriculum that includes student activities, videos, laboratory manuals, teacher resources, and electronic grade book access to those teaching welding and cutting skills.

Military: The US military provides training for enlisted personnel to become welders.

Colleges and universities: Many community colleges offer certificate programs in welding technology.

Continuing education or specialty education providers: A number of equipment manufacturers and suppliers provide welding instruction.

Prerequisite knowledge, skills or experience typically required by RTI providers for this occupation

Apprenticeship sponsors may require individuals to be able to lift up to 50 pounds, stand on their feet for long periods of time, position themselves in tight spaces, and work in challenging climates or environmental conditions. Employers with lifting requirements should include opportunities for reasonable accommodations for such requirements.

Fundamentals of Mathematics

Hours: 30

Sample learning objectives

- Manipulate integers, natural numbers, and negative numbers
- Accurately, and without the use of a calculator or other electronic device, add, subtract, multiply, and divide whole numbers, decimals, and fractions
- Convert decimals to fractions and fractions to decimals
- Define, measure, and calculate area, volume, diameter, length, and circumference
- Convert metric lengths and volumes to English lengths and volumes and vice versa
- Convert units within the metric and English systems
- Follow the appropriate order of operations
- Solve single and double variable linear equations
- Calculate ratios and percentages
- Measure angles using a protractor, define the different types of angles in a triangle, and demonstrate the ability to determine the angles in triangles, quadrilaterals, and polygons
- Calculate the sine, cosine, and tangent of a triangle and demonstrate the ability to use the Pythagorean Theorem to determine the measurements of a right triangle (legs and hypotenuse)

Maintaining Occupational Health and Safety in Welding

Hours: 20

Sample learning objectives

- Discuss the hazards associated with welding and cutting operations and select the appropriate protective gear, including the protective shade number recommended by OSHA, ANSI, and AWS for a variety of welding and cutting operations
- Explain the potential sources of harm to the work environment or work materials during the welding process as well as strategies for eliminating or mitigating those risks
- Define physical hazards in the workplace that can lead to death or injury and discuss safety practices to reduce this risk
- Discuss the hazards of fumes and gasses produced during welding and the safety strategies employed to mitigate these risks
- Define the elements of a fire-safe area and demonstrate the ability to survey and prepare the work area for cutting and welding operations
- Demonstrate the ability to select and use appropriate fire control and extinguishing devices
- Demonstrate the ability to provide emergency first aid in the event of worker lacerations, burns, electric shock, eye injury, and accidental exposure to hazardous substances or fumes
- Explain the significance of material safety data sheets and develop storage, clean-up, and/or emergency response plans for items commonly used in the welding environment
- Complete “Fire Watch” training and be capable of assuming the responsibilities of a Fire Watch for hot work operations

Introduction to Welding and Cutting

Hours: 30–40

Sample learning objectives

- Define and provide examples of the appropriate uses for welding, brazing, and soldering
- Differentiate between mechanical, chemical, and metallurgical joining, describing the advantages, disadvantages, and indicated uses of each
- Differentiate between stick welding (also known as Shielded Metal Arc Welding, or SMAW), Manual Metal Arc Welding (MMAW), and flux-shielded arc welding; Gas Metal Arc Welding (GMAW) or Metal Inert Gas (MIG) welding; Active and Inert Gas welding is compiled in GMAW; Flux Cored Arc Welding (FCAW); and Gas Tungsten Arc (GTAW) Welding; describe the appropriate uses, advantages, and disadvantages of each
- Define and identify different types of electrodes used in welding as well as various types of metals used in construction, manufacturing, and metal work

- Describe the metallurgy of common alloys and correctly identify types of metals included in sample materials
- Define flux, slag, spatter, weld bead, and other key welding terms
- Identify different types of welds, such as groove welds, fillet welds, plug welds, and slot welds
- Differentiate between butt joints, cross joints, T-joints, corner joints, strapped joints, lap joints, and edge joints
- Discuss the importance of cleaning materials before cutting and welding, and demonstrate the ability to perform the appropriate cleaning processes
- Explain the characteristics of a properly performed welding operation and identify examples of quality welding versus defective welding (i.e., pits, undercut, overlap, insufficient reinforcement, surface crack, arc strike, bead meandering [consistency], blow holes [porosity], impurities, slag inclusion, incomplete penetration, incomplete fusion, internal cracking, etc.)
- Correctly read engineering diagrams and construction or manufacturing blueprints to identify instances when welding is required and what type of welding is required
- Describe the purpose of a welding code, identify sources of information about relevant welding codes, and explain how to comply with various welding codes relevant to the work performed
- Describe the various techniques, tools, and processes used to inspect weld quality

Shielded Metal Arc Welding

Hours: 30–40

Sample learning objectives

- Demonstrate the appropriate use of arc welding shields and other safety equipment
- Inspect welding equipment and accessories and set-up equipment and materials needed to perform welding
- Explain the principles of metal arc welding, including the use of consumable electrodes, AC or DC power, and flux materials to combine metals
- Describe the process by which the flux coating of the welding electrode forms shielding gas and slag to protect the weld area
- Select the appropriate power source based on the materials to be combined and the type of weld desired, and adjust the power source to desired polarity and amperage setting
- Select the appropriate electrode based on the materials being joined and demonstrate the ability to change electrodes during the welding process
- Describe the main types of welding joints, the applications for each, and the criteria used to evaluate the quality and durability of such joints
- Demonstrate the ability to perform welding of fillet and groove welds on carbon steel
- Identify the types of metals that can be joined by shielded metal arc welding

- Demonstrate the ability to select the appropriate voltage, and strike an arc sufficient to combine various types of metals
- Demonstrate the ability to produce clean, effective welds across a range of joints and under various environmental conditions
- Critique a variety of welds to determine their quality and sufficiency; troubleshoot technique to improve weld quality, strength, appearance, and durability

Gas Tungsten Arc Welding

Hours: 30–40

Sample learning objectives

- Describe the types of metals and processes for which GTAW provides the best welding option
- Select the appropriate power source, tungsten electrode, sacrificial or filler rod (consumable), and shielding gas
- Select the appropriate filler material, if needed, based on the job specifications
- Inspect equipment for safety, assemble it properly, and start an arc
- Demonstrate proper use of safety equipment and proper preparation of the workspace
- Prepare materials for welding
- Perform flat, horizontal, and vertical fillet welds and flat groove welds in carbon steel, stainless steel, and aluminum
- Identify tungsten inclusion defects in sample welds and describe how to eliminate them from welds

Gas Metal Arc Welding

Hours: 30–40

Sample learning objectives

- Demonstrate proper use of safety equipment and proper set-up of workspace
- Explain the use of different types of feed (filler) wire and shielding gasses (inert and noninert gasses such as carbon dioxide) in GMAW and the advantages and disadvantages of each
- Assemble power source, wire feed unit, gun assembly, ground unit and gas source; set up and adjust machine to correct polarity, wire speed, and voltage based on type and position of joint desired
- Demonstrate safe use and storage of gas bottles, cylinder valves, and protective valve covers
- Make fillet welds in all positions on carbon steel material
- Make groove welds in all positions on carbon steel material
- Perform vertical and overhead welds

- Explain the importance of maintaining a consistent CTWB (Contact to Work Distance), weld speed, and voltage to produce an optimal weld
- Explain the importance of maintaining a consistent arc gap, weld speed, angles, and voltage to produce an optimal weld
- Compare and contrast between the use and techniques of short circuit transfer, globular transfer, and spray transfer
- Set up equipment, select wire size, select contact tip, and install new roll of wire
- Describe how variations in voltage and wire speed can change the type of joint produced
- Demonstrate weld puddle pushing, pulling and side-to-side motions to create appropriate weld type and dimensions
- Demonstrate the ability to use welding charts to determine the minimum voltage and wire speed needed for metal depth of materials being joined
- Demonstrate proper techniques for preparing metal for joining

Thermal Cutting Processes

Hours: 10

Sample learning objectives

- Differentiate between flame, plasma, oxyfuel, and laser cutting processes
- Demonstrate the ability to use oxyfuel cutting to cut through materials
- Explain how changes in gas purity will impact cutting speed and gas consumption
- List the five most common fuel gasses used for high-energy cutting and discuss the advantages and disadvantages of each
- Demonstrate the ability to use grinders to complete cutting and prepare edges and grooves for welding
- Demonstrate the process of gouging, joint edge preparation, and removal of defective weld metal
- Set up a plasma arc cutting circuit, and select the appropriate cutting gas based on the type of metal being cut
- Demonstrate appropriate use of measuring devices to cut metal to appropriate specifications and dimensions

Relevant military experience

The military trains allied trade specialists, including military welders (MOS 91E). Other military occupations that involve welding include Navy damage controlmen, hull technicians, steelworkers, US Army Welders, and Air Force Aircraft Metalworkers.

Diversity, equity, and inclusion

According to Zippia, 6.1 percent of welders are women while 93.9 percent are male. Of all welders, 68.1 percent are white, 15.8 percent are Hispanic, 9.7 percent are Black, and 3 percent are Asian. The average age of working welders is 40. White workers and males, on average, earn higher annual wages than workers of color and women. The American Welding Society sponsors a diversity, equity, and inclusion board.

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