Certified Welding Engineer

** Program Description, Body of Knowledge, Activities and Examination Requirements

Who is the AWS Certified Welding Engineer?

A person with the demonstrated education, experience, and knowledge as defined by this information and who successfully passes the required examinations is considered qualified as an AWS Certified Welding Engineer (CWEng).

The CWEng is capable of directing those operations associated with weldments and other types of joints that are completed in accordance with the appropriate contract documents, codes, and other standards to produce a satisfactory product. The welding engineer's activities begins before production or construction welding and continues through the production process then ending when the production process is complete.

Each employer is responsible for defining the specific duties of the CWEng in their place of employment.

PRECAUTION: While the AWS CWEng has established excellent credentials, qualification to this specification alone may not legally qualify the engineer to provide technical services to the public. Contract documents, building or jurisdiction laws may require technical services to be performed under the direction and responsibility of others such as a registered Professional Engineer. The AWS CWEng designation **DOES NOT** imply the status of a registered Professional Engineer (P.E.) under the laws of any state or other governmental entity.

Education and Experience Requirements for Access to the Examinations

Each individual for qualification as an AWS CWEng shall possess one of the following combinations of education and relevant experience to be eligible for the AWS CWEng examination. **You must meet one of the conditions below in order to gain entrance to the examination.**

1. Individuals with a Baccalaureate of Science (B.Sc.) degree in engineering and a minimum of one (1) year of related experience.

2. Individuals with a Baccalaureate of Science (B.Sc.) degree in engineering technology and a minimum of two (2) years of related experience.

3. Individuals with other related Baccalaureate of Science (B.Sc.) degrees and a minimum of five (5) years of related experience.

4. Individuals with an Associate in Applied Science (A.A.S.) degree and a minimum of ten (10) years of related experience.

5. Individuals who have successfully competed high school or an equivalent program and a minimum fifteen (15) years of related experience.

IMPORTANT:

As an alternate to the qualification requirements of this program, individuals possessing a State Professional Engineering License in *Welding Engineering* in the United States are qualified without further evaluation of education, experience, or examination.

For the Basic and Applied Science portion of the examination (Parts 1 and 2) requirements may be satisfied if you have already taken and passed the Engineering Fundamentals Examination (formerly the E.I.T. examination). The State Board of Engineering or other governmental entity administers this examination. Supply written documentation, which must show the State where the test was administered. You must still meet the education and experience requirements listed above. Plus must still complete the application and successfully pass Parts 3 and 4.

Individuals possessing a diploma indicating successful completion of the requirements for either the International Welding Engineer, IIW, European Welding Engineer, EWF, and have a minimum of one (1) year of experience (minimum may be obtained before or after the diploma) are eligible to take all parts of the AWS CWEng examination.

International applicants: Please indicate clearly the welding engineering subjects covered in your academic training at the university level. If an engineering degree was issued with a specialty in welding engineering, please include a copy of this diploma. For applicants possessing national engineering licenses in welding engineering (i.e. Professional or Chartered Engineer in Welding Engineering) please submit a copy of that license, you will be notified if your special situation is applicable to the AWS CWEng certification.

Activities

The AWS CWEng is able to demonstrate that he/she can perform these activities:

Safety. The AWS CWEng is knowledgeable of safety practices as they pertain to welding, cutting, and joining processes.

Design. The AWS CWEng is capable of applying sound engineering principles to the design of welded structures or structures manufactured using other related processes. This includes consideration for specific service requirements as well as compliance to applicable codes or specifications.

Materials and Welding/Joining Metallurgy. The AWS CWEng shall possess a practical knowledge of ferrous and nonferrous materials including: carbon steel, various types of alloy steels, stainless steels, nickel and nickel alloys, aluminum and aluminum alloys, copper and copper alloys, titanium and titanium alloys, ceramics, and plastics.

The AWS CWEng possesses knowledge of the welding metallurgy for ferrous and nonferrous materials. This includes an understanding of melting, solidification, solid-state transformations, thermal strains, and residual stress phenomena. The AWS CWEng is able to demonstrate a practical knowledge of how the different welding processes and pre- and post-welding heat-treating processes affect the metallurgy of ferrous and nonferrous materials. This knowledge shall also include an understanding of oxidation-reduction reactions.

Welding, Cutting, and Joining Processes. The AWS CWEng shall demonstrate a working knowledge of arc welding, resistance welding, brazing, and soldering. The AWS CWEng shall demonstrate working knowledge of oxyfuel gas cutting, arc cutting, and high-energy beam cutting. The AWS CWEng shall demonstrate a working knowledge of solid state welding, high-energy beam welding, and processes appropriate for non-metallic materials.

Quality Assurance, Quality Control, and Welding/Joining Economics. The AWS CWEng shall understand quality assurance systems and be able to participate in the implementation of quality assurance programs.

* The AWS CWEng is knowledgeable in all aspects of quality control.
* The AWS CWEng shall understand procedure and welder performance qualification, including destructive and nondestructive testing.
* The AWS CWEng is capable of performing visual inspection of welds and

specifying the appropriate nondestructive examination, NDE, methods for a particular weldment.
* The AWS CWEng shall understand the advantages and limitations of NDE.
* The AWS CWEng is familiar with the qualification requirements of NDE personnel.
* The AWS CWEng has a practical knowledge of manufacturing systems, including material control, production scheduling, and quality assurance.
* The AWS CWEng is able to evaluate the relative cost effectiveness of competitive welding/joining processes.

Mathematics. The AWS CWEng has a working knowledge of algebra, trigonometry, solid and plane geometry, calculus and statistical methods.

Physics. The AWS CWEng has a working knowledge of mechanics, heat, electricity, electronic systems, and magnetism. The engineer shall demonstrate competence in understanding the mechanics of arc plasmas, the dynamics of heat transfer, and fluid mechanics.

Chemistry. The AWS CWEng has a working knowledge of general and inorganic chemistry.

Definition of Experience—activities in one or more of the following areas:

Manufacturing. Experience shall consist of the design, application, or operation of welding lines or cells for the manufacture of welded products such as automobiles, appliances, welded pipe, or other welded standard products.

Fabrication. Experience shall consist of the design, application, or operation of welding facilities that fabricate welded products. Fabricated products may be covered by national, customer, or internal standards or specifications.

Construction. Experience shall consist of design on welding construction of projects such as buildings, pipelines, ships, plants and power generation facilities.

Research and Development. Experience shall consist of research and development to enhance welded products or processes, welding materials, manufacturing, fabrication, field erection of welded products or the design of welding manufacturing systems.

Training. Experience shall consist of instructing courses in various welding topics or related technologies.

Body of Knowledge

Basic Sciences

Mathematics. Simple calculations (multiple choice); special functions (exp, log); trigonometric functions (sin, cos, tan, cot, sec, csc, degrees, radians); algebraic equations (linear, quadratic, polynomial); graphs and equations (slope, intercept, roots, derivatives, minimum, maximum, interpolation, and extrapolation); geometry (common geometric shapes); hyperbola, parabola; complex numbers; statistics

(population and samples: normal distribution, mean, standard deviation, variance; simple correlation: linear regression via least squares method, r^2 correlation).

Physics. Unit conversion (dimension, mass, temperature, time, energy, power); mass, weight, volume, density; force, energy, work done, power; stress, strain, Hooke's Law (elasticity); moment and momentum; temperature, heat, temperature measurement, thermocouples, pyrometers; thermal properties of materials (thermal conductivity, thermal expansion, thermal stress and strain).

Chemistry. Symbols (elements and inorganic compounds - gases, fluxes, etc.); molecular weight and stoichiometry; acids and bases; balance chemical equations; gas combustion reactions (chemical heat generation) and oxidation-reduction reactions; ideal gas law (pressure, volume, temperature); mass balance (as in 7018 coating decomposition to gas, slag and metal); bulk and chemical analysis methodologies); reactivity, toxicity, environmental effect, disposal.

Applied Sciences

Strength of Materials. Load, deformation (elastic and plastic, buckling), stress-strain, Young's Modulus, shear modulus, stress-strain curve (yield stress, ultimate tensile stress, elongation), tensile stress and shear stress computation; welded member cross-section effect; mechanical testing (tensile, bend, fracture toughness, hardness, creep, and fatigue) and data interpretation; Law of Conservation of Energy/Momentum; stress analysis; typical engineering material properties.

Heat Transfer and Fluid Mechanics. Heat conduction, convection, and radiation, thermal conductivity and diffusivity, heat transfer coefficients of engineering materials, Fourier's Law; heating rate and cooling rate; industrial heating methods and power consumption, gas flow rates; laminar and turbulent flow (Reynold's Number), dew point and relative humidity, pressure and regulators; venturi effect and gas velocity calculation; atmospheric pressure and hyperbaric conditions; vacuum equipment and measurements.

Electricity. Current, voltage, resistance, impedance, and circuits; Ohm's Law; Kirchoff's Law; resistance loss and current rectification; power generation; AC/DC, polarity; power factor; electromagnetic properties, right-hand rule; current and voltage measurements (devices and principles).

Welding Related Disciplines

NDE/Weld Discontinuities. NDE processes (radiographic, ultrasonic, magnetic particle, liquid penetrant, eddy current, etc. - characteristics, advantages and limitations). NDE symbols.

Welding Heat Sources and Arc Physics. Power source static and dynamic characteristics (open circuit voltage and short circuiting current, slope); differences between CC and CV designs (principle of self-adjusting); welding arc characteristics (current and voltage relationship, arc length effect); electron emission (ionization potential, work function, electrode material, shielding gas, arc stability); arc temperature and degree of ionization (shielding gas influence); magnetic arc blow (ground location and condition); Lorentz Force (effect on droplet detachment and on

adjacent power cables); shielding gas drag force (effect on droplet detachment and metal transfer mode) weld penetration and width for different shielding gases.

Welding Processes and Controls. Arc welding processes (SMAW, GMAW, FCAW, GTAW, SAW, PAW); resistance welding processes (RW, high frequency RW), high energy density welding processes (LBW, EBW); cutting processes (OFC, CAC, and PAC); surfacing processing (SW, THSP); solid-state welding processes (FRW, FW).

Welding and Joining Metallurgy. Crystal structure of metals (FCC, BCC, HCP, unit cells, lattice parameter, c/a ratio, atom positions, interstitial positions); melting, and solidification, phase transformations and phase diagrams (eutectic, eutectoid, peritectic and monotectic, lever rule calculation) metallurgy and weldability of typical engineering materials (low carbon structural steels, cast irons, stainless steels, nickel alloys, aluminum alloys, titanium alloys, etc.) microstructure (e.g. ferrous alloys - grain boundary ferrite, acicular ferrite, bainite, martensite, austenite, delta ferrite, etc.) and mechanical properties; carbon equivalent (CE_{IIW}, P_{cm}, expressions, alloying content and carbon content effect); hydrogen assisted cracking (heat affected zone cracking, cold cracking) base metal matching (e.g. electrodes with high strength steels); solidification cracking (segregation of impurity atoms, shrinkage cracking, lamellar tearing); delta ferrite in stainless consumables, specifications for consumables (categories; all position, rutile, basic); flux-metal reactions (oxygen and sulfur control in weld pool); typical temperature range of a heat source; temperature distribution in a weldment; HAZ formation; multipass thermal experience, reheated weld metal properties; weld macro and micro-graph interpretation; solidification profile and preferred grain orientation (epitaxial growth); origin of weld ripples; special attributes of base metal (as-cast structure, deformation texture, oxide on flame-cut surfaces); thermal treatments (preheat, postheat, interpass influence on weld cooling rate and residual stress distribution); solid-state transformations in welds (different forms of ferrite, bainite, and martensite, sigma phase in stainless steels, Guinier-Preston type precipitates zones and aging in aluminum alloys); corrosion (sensitization in stainless steel welds, stress corrosion cracking in welds).

Weld Design. Structural fabrication requirements, sectional properties, stress gradient; stress triaxiality, weld symbols, hardness and microhardness (e.g. across a weld cross-section); tensile properties, ductility, toughness, fillet break test (influence of second phase and porosity), ductile fracture, brittle fracture, fatigue (initiation, propagation, failure, high-cycle, low-cycle), temperature and strain rate effect.

Brazing and Soldering. Characteristics of brazing and soldering, fluxes and substrates, capillary action, wetting and spreading, contact angle, joint clearance, viscosity, liquidus and solidus, flow of molten filler in horizontal and vertical joints (maximum penetration and rate), filler metal systems (Sn-Pb solders, Ni and Cu based alloys, Ag-Cu based brazing alloys), and intermetallic compound formation.

Safety. Recognize health hazards relating to welding, (fumes, toxic gases, noise, radiation). Recognize safety hazards, (electric shock, compressed gases, fire, welding in a confined space, welding on containers that have held toxic or flammable materials, moving equipment). Recognize precautions to avoid injury, and possess a working knowledge of safety and fire codes.

Examination Requirements

Individuals seeking qualification as an AWS CWEng shall successfully complete the following examinations drawn from the Body of Knowledge. Parts 1 and 2 are taken first, after successful completion, Parts 3 and 4 are scheduled at a later date. Each of the four examinations must have an individual score of not less than sixty percent (60%). Each individual examination is weighted and the resulting composite score from sections is not than seventy percent (70%).

Parts 1 and 2 are each, 2 hour written multiple-choice exams. They are given together and must be passed together. If the candidate fails only one part, both parts must be repeated. Both must be passed before a candidate can qualify to take Parts 3 and 4. Part 1 and 2 may be taken at any location where the SCWI/CWI/CWE examinations are also given.

Part 1 Basic Science Fundamental Examination. Closed Book. The individual shall pass an examination without references consisting of questions from each of the three Basic Science topics:

Topic	Percent of Examination Questions
Mathematics	25%
Physics	50%
Chemistry	25%
Total	100%

Part 2 Applied Science Fundamental Examination. Closed Book. The individual shall pass an examination without references consisting of questions from each of the three Applied Science topics:

Topic	Percent of Examination Questions
Strength of Materials	40%
Heat Transfer and Fluid Mechanics	30%
Electricity	30%
Total	100%

Parts 3 and 4 are each, 3 hour essay and calculation exams. Candidates who have successfully passed Parts 1 and 2 will be invited to sit for these exams. Specific arrangements will be made for these exams and they will be available 4 times during a calendar year.

These are open book examinations. Candidates are invited to bring any textbooks, articles, or codes in their library. Programmable calculators are allowed that do not have audible sounds that would disturb others. Laptops are also allowed, but no modem or wireless connections will be permitted. Sharing of resources between candidates will not be permitted.

Part 3 Welding Related Disciplines Examination. Open Book. The individual shall pass an examination with references on the application of engineering concepts in the areas of:

Topic	Percent of Examination Questions
NDE/Weld Discontinuities	10%
Welding Heat Sources and Arc Physics	20%
Welding Processes and Controls	20%
Welding and Joining Metallurgy	20%
Weld Design	20%
Brazing and Soldering	5%
Safety	5%
Total	100%

Part 4 Practical Welding and Related Applications Examination. Open Book. The individual shall pass an examination with references on the application of welding engineering concepts in the areas of welding safety, weldment design, welding metallurgy, materials, welding process selection, NDE including visual weld inspection, quality assurance, quality control in accordance with codes, specifications, other standards, and/or drawings.

The following references have been identified as useful study guides for the Body of Knowledge. This does not preclude the use of other potentially beneficial references.

Reference Title	Author	Publisher
ANSI Z49.1 Safety in Welding, Cutting and Allied Processes		AWS
Applied Fluid Mechanics, 4th Ed.	Mott	Merrill Publishing Company
ASM Handbook Vol. 17, NDE		ASM
ASM Handbook Vol. 6 Welding/Brazing 10th Ed.		ASM
AWS D1.1 Structural Welding Code—Steel		AWS
Design of Weldments	Omer W. Blodgett	The James F. Lincoln Arc Welding Foundation
Engineer in Training Manual		
Essentials of Engineering Economics, 2nd ed.	Riggs & West	McGraw Hill
Fracture & Fatigue Control in Structures, Application of Fracture Mechanics	John M. Barson & Stanley T. Rolfe	Prentice Hall Second Edition, 1987
Fundamentals of Engineering: The Most Effective FE/EIT Review	Merle C. Potter	Great Lakes Press
Fundamentals of Welding Technology, Modules 1-19		Gooderham Centre for Industrial Learning
Handbook of Arc Welding		James F. Lincoln Arc Welding Foundation

HB for Mechanical Engineers	Mark Standard	Avallone or Baumeister
Introduction to the Practice of Statistics ISBN 0 7167 2250 X	Moore & McCabe	Freeman
Introductory Physical Metallurgy of Welding	Easterling	Butterworths
Introductory Welding Metallurgy		AWS
Manufacturing, Engineering & Technology ISBN 0 201 538460	Serope and Kalpakjian	Addison Wesley
Mechanical Metallurgy	G. Dieter	McGraw Hill
Metals and How to Weld Them		James F. Lincoln Arc Welding Foundation, Second Edition, 1990
Modern Welding Technology	H. Cary	Prentice Hall
Physics of Arc Welding	J. Lancaster	Pergamon
Product Design for Manufacture and Assembly ISBN 0 8247 9176 2	Boothroyd, Dewhust & Knight	Marcel Dekker
Quality Control, 5th Ed.	Besterfield	Prentice Hall
Robots & Manufacturing Automation	Asfahl	John Wiley
Stainless Steel	R.A. Lula	ASM International, 1986
Statics & Strength of Materials, 3rd Edition, ISBN 0-13-453201-5	Morrow	Prentice Hall
Statics & Strength of Materials: A Parallel Approach to Understanding Structures	Lawrence J. Wolf	Merrill Publishing Company
Weld IT CD, Computer Influence for Welding Personnel		Gooderham Centre for Industrial Learning
Weldability of Steels	Stout & Doty	Welding Research Council
Welding Aluminum: Theory and Practice		The Aluminum Association, Second Edition, June 1991
Welding Design, Modules 30-39		Gooderham Centre for Industrial Learning
Welding Encyclopedia	Jefferson	AWS
Welding Handbook Vol. 1, 2, 3, 8th Ed.		AWS
Welding Metallurgy	Sindo Kou	John Wiley & Sons
Welding Metallurgy	Linnert	AWS
Welding Metallurgy	J. Lancaster	Pergamon
Welding Metallurgy, Modules 8, 9, 12, 20-23		Gooderham Centre for Industrial Learning

Other Information…

Prices

Exam cost for Parts 1 and 2 $270 $200 member discount price

Exam cost for Parts 3 and 4 $420 $350 member discount price

CWEng without testing $200 $125 member discount price
(Must meet all qualifications and requirements as specified)

NOTE: Processing your application will be DELAYED if you:

1. Omit any required information or documentation regarding your work experience and education.
2. Neglect to have your signature notarized.
3. Neglect to have your employment verified.
4. Provide more documentation than necessary.
5. Please do not enclose payment, company purchase order, or authorize AWS to charge your credit card.

Applications must be received not later than 6 weeks prior to the exam date requested.

Parts 1 & 2 Exam Locations and Dates
These exams are administered during the regular CWI/CWE/SCW Examination Schedule.

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