BODY OF KNOWLEDGE
Certified Welding Engineer

The AWS Certified Welding Engineer (CWEng) examination is four parts. Parts 1 and 2 must be successfully completed in order to take Parts 3 and 4. The first two parts of the exam are closed book and cover basic science fundamentals and applied science fundamentals. Parts 1 and 2 are each two hour written multiple-choice exams (total time of four hours). Part 1 is a 35 question multiple choice exam and Part 2 is a 25 question multiple choice exam. They are given together and must be passed together. If the candidate fails only one part, only that part must be repeated.

Parts 3 and 4 of the exam are open book examinations on welding related disciplines and practical welding and related applications. They are each three hours in length. Part 3 is a 45 question essay exam. Part 4 is a 39 question multiple choice exam. Candidates that successfully pass Parts 1 and 2 will be invited to sit for these exams and a separate application must be submitted to AWS.

The exams may be taken at any location where the CWI examinations are given. Candidates may bring any textbooks, articles or codes in their library that are published and publicly available. All reference materials must be bound and remain bound during the exam. Bound refers to (1) materials permanently bound, as by stitching or glue, and (2) materials securely fastened in their covers by fasteners that penetrate all papers. Ring binders, spiral binders, plastic snap binders, brads, and screw posts are acceptable fasteners. Staples are not acceptable fasteners. Writing tablets and legal pads are not allowed. Examinees may tab reference books before the exam with Post-it type notes and flags, but pads of Post-it notes and flags are not permitted in the exam room.

To protect the integrity of its exams, AWS limits the types of calculators you may bring to exam sites for this exam. The only calculator models acceptable for use during the CWEng exams are as follows.

- **Casio:** All fx-115 and fx-991 models (Any Casio calculator must have “fx-115” or “fx-991” in its model name.)
- **Hewlett Packard:** The HP 33s and HP 35s models, but no others
- **Texas Instruments:** All TI-30X and TI-36X models (Any Texas Instruments calculator must have “TI-30X” or “TI-36X” in its model name.)

Candidates must pass each of the four examinations with an individual score no less than 60% and attain a minimum weighted percentage of 70% for all 4 parts. Note: The D1.1 2010 edition is applicable to the current CWEng Part 4 exam only (subject to change). All applicants shall successfully meet the CWEng requirements as contained in clauses 6 and 7 of AWS B5.16, Specification for the Qualification of Welding Engineers.

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**Approximate subject weights for the four examination parts are as follows:**

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<tr>
<th>Part 1 – Basic Science Fundamentals</th>
<th>Part 2 – Applied Science Fundamentals</th>
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<tbody>
<tr>
<td>Mathematics</td>
<td>Strength of Materials</td>
</tr>
<tr>
<td>Mathematics</td>
<td>Heat Transfer and Fluid Mechanics</td>
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<tr>
<td>Physics</td>
<td>Electricity</td>
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<tr>
<td>Chemistry</td>
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<tr>
<td>Part 3 – Welding Related Disciplines (Essay Exam)</td>
<td>Part 4 – Practical Welding and Related Applications</td>
</tr>
<tr>
<td>NDE/Weld Discontinuities</td>
<td>Exam using references on the application of welding</td>
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<tr>
<td>Welding Heat Sources and Arc Physics</td>
<td>engineering concepts in the areas of:</td>
</tr>
<tr>
<td>Welding Processes and Controls</td>
<td>Welding safety, weldment design, welding</td>
</tr>
<tr>
<td>Welding and Joining Metallurgy</td>
<td>metallurgy, materials, welding process</td>
</tr>
<tr>
<td>Weld Design</td>
<td>selection, NDE including visual weld</td>
</tr>
<tr>
<td>Brazing and Soldering</td>
<td>inspection, quality assurance, quality</td>
</tr>
<tr>
<td>Safety</td>
<td>control in accordance with codes,</td>
</tr>
<tr>
<td>Safety</td>
<td>specifications, other standards, and/or</td>
</tr>
<tr>
<td>Safety</td>
<td>drawings.</td>
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</table>

CWEng BOK_2253

May 11, 2017
8.1 Basic Sciences Fundamentals

8.1.1 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
- calculus (fundamentals of differential equations)
- statistics (population and samples: normal distribution, mean, standard deviation, variance)
- simple correlation: linear regression via least squares method, $r^2$ correlation

8.1.2 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)

8.1.3 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 E7018 coating decomposition to gas, slag and metal)
- bulk and chemical analysis methodologies
- reactivity, toxicity, environmental effect, disposal.

8.2 Applied Sciences

8.2.1 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

8.2.2 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

8.2.3 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)
8.3 Welding Related Disciplines

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

8.3.2 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 (work lead 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

8.3.3 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 (OFW, CAC, and PAC)
- surfacing processing (SW, THSP)
- solid-state welding processes (FRW, FW)

8.3.4 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 (CEIIW, Pcm, 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)
- fluxmetal 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 flamecut surfaces)

8.3.5 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

8.3.6 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)
- intermetallic compound formation

8.3.7 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 and piping, moving equipment)
- recognize precautions to avoid injury
- possess a working knowledge of safety and fire codes
<table>
<thead>
<tr>
<th>Reference Title</th>
<th>Author</th>
<th>Publisher</th>
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<tbody>
<tr>
<td>ANSI Z49.1 Safety in Welding, Cutting and Allied Processes</td>
<td></td>
<td>AWS</td>
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<tr>
<td>Applied Fluid Mechanics, 4th Ed.</td>
<td>Mott</td>
<td>Merrill Publishing Company</td>
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<tr>
<td>ASM Handbook Vol. 17, NDE</td>
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<tr>
<td>ASM Handbook Vol. 6 Welding/ Brazing 10th Ed.</td>
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<td>AWS D1.1 Structural Welding Code—Steel</td>
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<tr>
<td>Design of Weldments</td>
<td>Omer W. Blodgett</td>
<td>The James F. Lincoln Arc Welding Foundation</td>
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<td>Engineer in Training Manual</td>
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<tr>
<td>Fundamentals of Welding Technology, Modules 1 - 9</td>
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<td>CWB Group – cwbstore.org</td>
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<td>Handbook of Arc Welding</td>
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<tr>
<td>HB for Mechanical Engineers</td>
<td>Mark Standard</td>
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<td>Introduction to the Practice of Statistics</td>
<td>Moore &amp; McCabe</td>
<td>Freeman</td>
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<td>Introductory Physical Metallurgy of Welding</td>
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<td>Introductory Welding Metallurgy</td>
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<tr>
<td>Manufacturing, Engineering &amp; Technology ISBN 0 201 538460</td>
<td>Serope and Kalpakjian</td>
<td>Addison Wesley</td>
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<td>Mechanical Metallurgy</td>
<td>Dieter</td>
<td>McGraw Hill</td>
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<td>Modern Welding Technology</td>
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<td>Prentice Hall</td>
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<tr>
<td>Physics of Arc Welding</td>
<td>J. Lancaster</td>
<td>Pergamon</td>
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<tr>
<td>Product Design for Manufacture and Assembly ISBN 0 8247 9176 2</td>
<td>Boothroyd, Dewhurst &amp; Knight</td>
<td>Marcel Dekker</td>
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<td>Quality Control, 5th Ed.</td>
<td>Besterfield</td>
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<td>Robots &amp; Manufacturing Automation</td>
<td>Asfahl</td>
<td>John Wiley</td>
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<td>Stainless Steel</td>
<td>R.A. Lula</td>
<td>ASM International, 1986</td>
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<tr>
<td>Statics &amp; Strength of Materials: A Parallel Approach to Understanding Structures</td>
<td>Lawrence J. Wolf</td>
<td>Merrill Publishing Company</td>
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<tr>
<td>Weldability of Steels</td>
<td>Stout &amp; Doty</td>
<td>Welding Research Council</td>
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<td>Welding Design, Modules 30-39</td>
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