2nd Class Power (Operating) Engineer Certification and Examination Guide

Effective: March 2017

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This document replaces all previous versions
Revisions/updates to this document are reflected by a change in the above date

Syllabus

The following SOPEEC syllabus has been adopted by TSSA and provides the subject matter upon which a candidate will be examined, and all related topics of study.

2A-1

A. A.S.M.E. CODE, SECTIONS 1 & 8, CALCULATIONS:

Design values to be computed for the following boiler and pressure vessel parts:

a. Cylindrical components; dished heads; unstayed flat heads, formed heads, shells and covers.
b. Openings and compensation: openings in shells, headers and heads; compensation required; strength of compensation, pressure vessel openings and reinforcements.
c. Stayed surfaces: dimensions and locations of staybolts, ligaments and braced surfaces.
d. Safety valves and safety relief valves: size and capacity.
e. Firetube Boilers:
    i. Combustion chambers and furnaces: plain circular furnaces; circular flues; Adamson ring reinforced and corrugated furnaces.
    ii. Stayed surfaces: maximum spacing of stays; areas of heads to be stayed; stresses in diagonal stays.

B. INDUSTRIAL ADMINISTRATION:

a. Legislation: a thorough knowledge of the jurisdictional Act and the Regulations under the Act.
b. Installations: factors and codes governing plant designs and layouts; contract specifications; working knowledge of the engineering and administration involved in plant erection; practical modifications of existing plant.
c. Management:
    i. Functions and objectives of management.
    ii. Personnel management: selection of staff; personnel training; motivating personnel; disciplining employees.
    iii. Planning; decision-making; report writing.
    iv. Plant maintenance; inspection; budgeting.
    v. Safety programs.

C. APPLIED MECHANICS:

a. Velocity and acceleration: speed; linear velocity and acceleration; angular velocity and acceleration; relative and absolute velocity.
b. Mass, motion and inertia: force of gravity; weight; mass inertia; accelerating force; momentum.
c. Work, power and energy: work, graphical representation; indicated and brake horsepower; potential and kinetic energy; conservation of energy; flywheel.
d. Torque and angular motion: moment of inertia; radius of gyration; work done by torque.
e. Motion in a circular path: centripetal acceleration; centripetal and centrifugal force; balancing of rotating masses; governors.
f. Friction: coefficient of friction; frictional force; motion on horizontal and inclined planes; the screw thread; transmission of power by belt drives.
g. Moments: moments of forces; couple; centroids and second moments of area.
h. Stress and strain: modulus of elasticity; restricted expansion.
i. Shearing forces and bending moments: sign conventions; conditions of equilibrium; simply supported beams and cantilevers; concentrated and distributed loading; mathematical and graphical

solutions for shearing force and bending moment diagrams.

j. Torsion: fundamental torsion equation; relationship between torque, stress and horsepower; maximum and mean torque; coupling bolts.
k. Pressure of liquids: density; specific gravity; pressure at any depth; centre of pressure; displacement.
l. Flow of liquids: pressure head; Bernoulli's law; Venturi meter; flow through orifices.

2A2

D. THERMODYNAMICS:

a. Heat and measurement of heat: temperature scales; absolute temperature; units of heat and their relationship; specific heat; water equivalent; sensible and latent heat; heat mixtures.
b. Expansion of solids and heat transfer: linear, surface and volumetric expansion; conduction, convection and radiation.
c. Work and heat: mechanical equivalent of heat; laws of thermo-dynamics; Boyle's and Charles' Laws; general gas law; characteristic constant of a gas; specific heats of gases; thermal efficiency.
d. Expansion and compression of gases: Dalton's Law of partial pressures, adiabatic, isothermal and polytropic; ratios of expansion and compression; work done during expansion and compression.
e. Thermodynamics of steam: steam tables; saturated and superheated steam; dryness fraction; specific volume; specific heat of superheated steam; heat mixtures; throttling and separating calorimeters; internal energy of steam, enthalpy.
f. Entropy: entropy of water, evaporation and superheated steam; temperature-entropy diagrams and charts; computations of entropy values.
g. Practical Cycles:
    i. Practical cycles: Rankine; Otto; Diesel; Brayton, thermal efficiencies; pressure-volume and temperature-entropy diagrams.
    ii. Energy flow calculations; efficiency limits of heat engines, boiler and plant efficiencies, heat balance testing.

E. METALLURGY:

a. Non-ferrous metals: properties, composition and uses; copper; brasses; bronzes; aluminum; white metal.
b. The structure of metals: atoms; elements; crystalline structure of metals; grains and grain boundaries, metallographic examination.
c. Alloying elements in iron; iron-carbon equilibrium diagram; alloy steels; stainless steels and high-chromium alloys; cladding steels.
d. Heat treatment of metals: normalizing; annealing; spheroidizing; hardening; tempering; quenching.
e. Welding symbols
f. Metallurgical applications/specifications to power plant piping and tubing
g. Electrochemistry principles applied to corrosion, corrosion forms, control method, testing, monitoring, prevention and failure analysis (effective July 1, 2011).

F. TESTING OF MATERIALS:

a. Procedures and interpretations affecting tensile, hardness and impact tests; forms of specimens tested.
b. Mechanical, physical and thermal properties of ferrous metals: creep resistance, corrosion resistance and fatigue tests.
c. Weldment defects: dimensional defects; structural discontinuities; defective properties.
d. Nondestructive testing: visual inspection; magnetic particle inspection; liquid penetrant testing; proof tests; leak tests, ultrasonic, radiography, acoustic emission.

2A3

G. BOILERS:

a. Steam generator design considerations.
b. Methods of heat transfer; circulation; steam generator ratings.
c. Specialized boiler designs and applications
d. Types and applications of firetube and watertube boilers/steam generators.
e. Boiler fittings, including safety devices, drum internals, soot blowers.
f. Boiler details: waterwalls; superheaters; desuperheaters; attemperators; economizers; air heaters; blow-down systems; flash tanks; steam separators.
g. Methods of installation and support: foundations; settings; methods of tubing; top drum erection; shop and field assembly.
h. Insulation: duct and baffle arrangements; boiler casings.
i. Operation: start up and shut down; boiling out; drying out refractory; lay-up procedure; safety precautions.
j. Maintenance; mechanical and chemical cleaning; inspection; upkeep and repairs; hydrostatic test; safety precautions.
k. Boiler Inspections: ***detailed procedure for complete inspection of a large boiler, including water side, fire side, and auxiliary equipment; thermal radiation techniques; inspection records and reporting procedures; liaison procedure with boiler inspector; involvement of other personnel in inspection (engineering staff, operators); inspection equipment; inspection safety.***

H. PUMPS:

a. Practical Applications of pumping theory for power plants;
b. Installation; maintenance; operation/control.
c. Constructional details including impeller types; seal selection; shaft alignment; thrust balancers; tachometers.
d. Boiler feed pump re-circulation control.

I. WATER TREATMENT:

a. Water and its impurities.
b. Methods of feedwater treatment: subsidence; coagulation; filtration; oil removal; lime-soda softening; hot process phosphate softening; sodium and hydrogen zeolite softening; silica removal; demineralization; deaeration; evaporation; electro-dialysis and electro-deionization (ED / EDI); reverse osmosis (RO); microfiltration
c. Internal treatment of boiler water: control of scale, foam, embrittlement, return line corrosion; chelating agents; sludge conditioning; pH control; deaeration; carryover; blowdown; chemical feed systems; silica turbine blade deposits.
d. Analytical methods and equipment:
   i. Instruments: embrittlement detectors; steam purity; total solid meters; methods of steam sampling; measurement of pH.
   ii. Water analysis and interpretation of analytical results.
e. Cooling water treatment; slime and algae control, corrosion control.
f. Industrial waste treatment: effects caused by waste discharge; mechanical, chemical and biological methods of waste treatment.
g. Potable Water treatment and testing

2B1

J. HEAT ENGINES AND PRIME MOVERS:

a. Steam Turbines:

i. Applications of operating principles: impulse and reaction turbines, classifications.
ii. Construction: casings; rotors; dummy pistons; blading; diaphragms; glands; seals; flexible couplings; bearings; thrusts.
iii. Details: turning gears; drains; rotor adjustment; dynamic and static balancing; critical speed; lubricating oil systems; jacking oil pump; piping; reducing gears; expansion and anchoring.
iv. Control: governors; governor systems; control valves; grid type extraction valves; casing relief valves; overspeed trips; turbine supervisory equipment.
v. Operation: starting up and shutting down; normal operation; flow diagrams; efficiencies.
vi. Maintenance: repairs; shaft alignment; bearing; thrust, blade and packing clearances; blade fouling and erosion; cleaning after erection.
vii. Theory: nozzles; velocity diagrams; angle of entry and velocity calculations; work done on blades and blade characteristics.
viii. Condensing equipment
    a. Condensers: types and constructional details; backwashing and cleaning; leak testing.
    b. Condenser ancillary equipment: air ejectors; cooling water systems; intakes and intake screens; cooling towers and ponds; atmospheric exhaust valves; circulating pumps; condensate pumps.

b. Internal Combustion Engines:

i. Applications: two and four stroke, oil burning, gas and dual-fuel.
ii. Fuels: classification; properties; impurities; methods of purifying and clarifying; injection systems; ignition systems; scavenging and supercharging arrangements.
iii. Operation and maintenance: causes and prevention of incomplete combustion; starting up and shutting down: prevention of crankcase explosions; crankcase safety fittings; piston and cylinder troubles; repair and replacement of worn or broken parts.
iv. Cooling: piston and jacket cooling water systems; cooling water treatment and removal of deposits; lubricating oil systems.

c. Gas Turbines:

i. Applications of operating principles; types of gas turbines.
ii. Open and closed cycle systems; regeneration; intercooling and reheating.
iii. Gas turbine applications: dual shaft machines; free-piston gas generators, combined cycle.
iv. Construction: rotors; blading; compressors; combustors: combustion chambers.
v. Operation and control: starting up and shutting down; normal running procedures; control systems; safety devices.

K. LUBRICATION:

a. Plant lubrication programme: lubrication survey; types of lubricating systems, air compressor, gas turbine, internal combustion engine, steam turbine; lubricating oil / governing/seal oil systems;
b. Engine lubricating oil maintenance: causes of deterioration; additives; oil purification equipment.
c. Applications of ball and roller bearings and their lubrication; bearing seals.

L. **PIPING:**

a. Piping material identification and selection, appropriate Code procedures, inspection, leak tests.
b. Strength of piping; high temperature effects.
c. Support; expansion allowances; cold springing; drainage; insulation.
d. Theory and effects of water hammer.
e. Layouts of piping in Power and Pressure Plants.

M. **MECHANICAL DRAWING:**

a. Pictorial drawing; geometrical constructions.
b. Orthographic, auxiliary, axonometric and oblique projections.
c. Sectioning and dimensioning.
d. Flow diagrams; piping drawings; charts.
e. Industrial Drawings, types and interpretation.

2B2

N. **POWER PLANT SYSTEMS:**

a. Feed water systems; layout and operation. Regenerative feed heating cycle; closed feed systems; feed heaters; deaerators.
b. Steam Piping systems.
c. Fuel systems; layout and operation.
d. Steam Condensate system; layout and operation.
e. Cooling water systems; layout and operation.
f. Waste handling systems; layout and operation.
g. Integration of powerplant water systems.

O. **CONTROL INSTRUMENTATION:**

a. Electrical and Electronic Pressure measuring devices and component placement/installation.
b. Electrical and Electronic Temperature measuring instruments and component placement / installation.
c. Flow measurements with differential pressure flow meters:
   i. Primary elements: orifice plate; flow nozzle; venturi tube; pitot tube; flow-nozzle pipes.
   ii. Indicating mechanisms: manometer; ring balance; force balance; electric.
   iii. Component placement/installation.
d. Liquid level measurement and control and component installation: ball-float; displacement-type; hydrostatic head; electric and pneumatic level transmission; electric and magnetic type level-limit devices; remote water-level indicators.
e. Final control elements: types and flow characteristics of control valves; construction details of control valves; power operators ---solenoid, pneumatic-diaphragm, power cylinder, and electric motor.
f. One, two and three element boiler feedwater control systems.
g. Superheated/reheated steam temperature control; steam pressure reducing and desuperheating control systems.
h. Modes of automatic control; two position (; proportional; proportional-plus-reset and proportional-plus-reset-plus-rate.

i. Control Systems: Distributed Control Systems, Programmable Logic Controller.

P. FUELS AND COMBUSTION:

a. Combustion chemistry; chemical analysis of fuels.
b. Fuels: classification; heat values; properties; fuel handling.
c. Combustion: bomb calorimeter; analysis of flue gases; quantity of air required for combustion; draft calculations.
d. Furnace types and designs; refractories; arches; separately fired reheat furnace.
e. Firing equipment: pulverizes; oil and gas burners; storage and heating of oil; ash and slag disposal; ash fusion temperature, fuel burning systems.
f. Draft: systems and equipment.
g. Combustion Control:
    i. Classification of systems; methods of operation; pneumatic, electric and hydraulic mediums; control systems and installations for gas, oil and coal firing.
    ii. Flue-gas analysis; CO_2, O_2 and combustibles recorders.
    iii. Combustion safeguards: purge and fan-failure interlock systems; flame-failure control systems; photoelectric tubes; rectifier rods.
    iv. Packaged boiler-control systems: programming sequence; limiting devices and alarms.

Q. ENVIRONMENTAL PROTECTION:

a. Monitoring equipment and troubleshooting procedures: continuous emission monitoring systems; wastewater monitoring; data interpretation; troubleshooting.
c. Specific environmental controls and equipment: integrated environmental controls; technical knowledge and efficient operating practices and monitoring for the following:
    i. flue gas desulphurization
    ii. selective catalytic reduction
    iii. NO_x reduction
    iv. flue gas chemical conditioning
    v. baghouses and precipitators
d. Significance of measured parameters:
    i. Air quality particulates, stack opacity, SO_2 and NO_x concentration and mass flow, mercury, O_2, CO_2, hydrocarbons.
    ii Wastewater - iron, phosphorous, biological oxygen demand, chemical oxygen demand, hydrocarbons, temperature, flow, pH, nitrogen.

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R. ELECTROTECHNOLOGY:

a. A.C. Theory:
    i. The sine wave: generation of an alternating electromotive force; root mean square values; vector representation of sinusoidal quantities, peak, peak to peak.
    ii. Resistance, inductance and capacitance in single-phase A.C. circuits; inductive reactance; capacitive reactance, impedance, resonance.
    iii. Power in A.C. circuits; true and apparent power; practical importance of power factor; power factor correction.
    iv. Three-phase circuits: delta and star connected alternators and loads, current and voltage

relationships; three-phase power.

b. D.C. Machines:

i. Generators: principle of operation; construction; commutation; armature reaction; interpoles; compensating windings; lap and wave wound armatures; generator types and characteristics; parallel operation; voltage regulation; theory of self-excitation; efficiency and power losses; selection of generators and applications; parallel operation; ratings.

ii. Motors: principle of motor action; torque development; Fleming's left-hand rule; back electromotive force: voltage, current and speed computation; motor types and characteristics; starting arrangements; dynamic and regenerative braking; speed control; efficiency and power losses.

c. A. C. Machines:

i. Alternators: types; construction of stators, rotors and exciters; stator windings; relationship between speed, frequency and number of pole pairs; cooling systems; shaft sealing systems; voltage regulators; synchronizing; parallel operation; power factor control, voltage drops in armatures; rating, efficiency and power losses.

ii. Single-phase motors: universal, shaded pole and split-phase types; repulsion-start and reluctance-start types; capacitance starting method.

iii. Polyphase induction motors; principle of operation; rotating magnetic field; slip and rotor speed; stator and rotor construction; starting methods.

iv. Synchronous motors: general facts concerning synchronous motors; stator and rotor construction, starting methods.

v. Transformers: principle of transformer action; ratings; efficiency and losses; short and open circuit tests; types of construction; methods of cooling; connections; paralleling; instrument transformers.

vi. Protection of electrical systems: alternator stator and rotor protection devices; motor protection devices; transformer safety fittings.

vii. Circuit-protective equipment; interrupting capacity; fuses; switches; circuit-breakers; relays.

S. PRINCIPLES OF AIR AND GAS COMPRESSION:

a. Applications of air and gas compression: effects of altitude, temperature, and humidity.
b. Reciprocating, axial, centrifugal and rotary compressors: operation, applications; construction; regulation and control; drive selection criteria and preventive maintenance.
c. Ancillary equipment: valves; coolers; receivers; oil and water separators; filters; unloaders; safety/relief valves; instruments; piping layouts, dryers.

T. INDUSTRIAL/COMMERCIAL REFRIGERATION:

a. Applications of refrigeration: compression and absorption systems; thermoelectric refrigeration; hermetic cycles; cascade systems; heat pump systems.
b. Refrigerating plants: types; layouts; installation details.
c. Plant equipment: compressors; condensers; evaporators; liquid receivers; oil separators; absorbers; generators; heat exchangers; rectifiers; driers; scale traps; piping and fittings; cold room construction.
d. Operation of refrigerating plants: starting up and shutting down; charging; hand and automatic purging; automatic expansion valves; compressor lubrication; brine solutions; leak testing; trouble shooting.
e. Safety and control: Code requirements; safety fittings; compressor and system instrumentation and controls; cooling water system controls.

f. Computations of capacities and performances of refrigerating plants; ideal and practical refrigerant cycles; theoretical piston displacement; heat pump effect; theoretical power; pressure-enthalpy charts

Certification Information

Eligibility to Write
An examination candidate is required to be in the possession of a current/valid Operating Engineers 3rd Class Ontario Certificate of Qualification. Those with an expired/cancelled 3rd Class certificate must first reinstate their certificate before they are eligible to write the 2nd class examinations.

Practical Time Requirements: *(effective June 27, 2001, as per new OE Regulations)*
Practical operating time served shall be in a plant that is required to be attended by an Operating Engineer. *Please refer to Table 8 of the Operating Engineers Regulation for plant rating/capacity* and also Table 8 in the Director's Order.

- The practical operating training requirement is **18 months** if you have not completed a full-time TSSA "approved-for-time-reduction" 2nd Class Operating Engineer program.
- The practical operating time requirement is **13 months** for candidates having successfully completed a full-time TSSA "approved-for-time-reduction" 2nd Class Operating Engineer program.

Qualifying Experience attained in a Canadian Jurisdiction outside Ontario
Qualifying time experience toward Operating/Power Engineering attained in a Canadian Jurisdiction outside Ontario must be attained in the operation and management of boilers at least of the type and capacities indicated on Tables 3 of the Operating Engineers Regulation, Ontario Regulation 219/01. The following information must be demonstrated to TSSA in a request for certification:

- A letter addressed to the candidate, on company letter head and signed, from the Chief Operating/Power Engineer, indicating the number of boilers trained on, the boiler types, boiler manufacturer, boiler(s) pressure, capacities in Kilowatts or Boiler Horsepower and the time periods where the experience was gained (dates). The Chief Operating/Power Engineer must indicate their certificate number and classification, as well as their formal position and contact information (i.e. telephone number, email address, etc.).

Training Providers

As a convenience for students, TSSA has compiled a list of organizations, and/or institutions currently offering 'TSSA Approved for Time Reduction', training. The list can be found in the 'Operating Engineer section', of our TSSA Corporate website located at www.tssa.org.

It is recommended that before undertaking examinations, the candidate complete a Second Class Power Engineering Course offered through a recognized Technical Institute or Training Provider.

Note: The process for 'TSSA approval' began in December of 2001. Trainers successful in obtaining TSSA approval, to offer "practical-time-reduction-training", will be identified accordingly by being listed on TSSA's Training Providers list.

Examination Information

There are six (6) essay style examinations that must be written that is 3 ½ hours in duration.

- The 2A-1, 2A-2, 2A-3, 2B-1, 2B-2 & 2B-3 examinations requires the candidate to answer any five (5), of the seven (7) questions. Only the first five (5) questions attempted will be marked. Read the introduction carefully as some examinations have mandatory questions, which must be attempted.

The minimum passing mark for each examination is 65%, rewrites are allowed after 60 days.

When answering examination questions, the candidate is expected to give sufficient information to warrant the marks assigned. For questions involving calculations, the candidate is expected to state the formula, insert given data, work through the steps and state your answer with the correct units in an appropriate closing statement.

The examination candidate is expected to write legible, neat, and in pen. Sketches or drawings are to be in pencil and properly labeled. Rulers and (drawing) templates are to be used as neatness is considered in the marking scheme.

Examinations may be written at either MTCU Exam Centres or at TSSA in Toronto. To locate nearest centre, refer to "Examination Centres" listing on our web page**,** www.tssa.org. To write at TSSA or the MTCU Centres please call (416) 734-3300.

On the day of the examination, candidates must produce at least one piece of government issued photo identification (i.e. valid driver's licence, Passport, or a Provincial Identification Card).

A SOPEEC binder, non-programmable calculator and pencils are provided by the examination centre, examination candidates are not permitted to bring their own materials, with the exception of drawing instruments.

Examination security will be strictly enforced. The examination administrator or invigilator reserves the right to revoke an examination at any time if the examination candidate is found to be in violation of the TSSA examination or MTCU procedures. The examination candidate will be subject to further investigation, which may result in the revocation of an authorization or restrictions may be applied to all future examinations.

Examination candidates are eligible to submit a formal request for a review of their essay examination result within 60 days from the issuance of the formal correspondence issued by TSSA. Candidates who wish to obtain a review of their essay examination, must submit a written request to TSSA, via certandexams@tssa.org, with the administrative fee of $50.00 + HST ($56.50). Note the following:

- The purpose of the review is to assist the candidate when preparing to rewrite the examination.
- As a result of the review, the Operating Engineers Examiner will contact the candidate via telephone to discuss the strengths and weaknesses of the examination. Be advised that specific examination questions will not be discussed with the candidate.
- If the Operating Engineers Examiner finds justification to re-score the examination, a revised result will be issued to the candidate.

Important: Candidates for any class of certification as an Operating Engineer or Operator who have passed the required examinations, or any parts thereof, MUST obtain their certificate of qualification within five (5) years of such passing or re-writing of the examination will be required.

Suggested Study Materials

It is recommended that the candidate becomes familiar with the publications listed in the Reference Material for Power Engineering Students and Examination Candidates, listed below:

- **Technical Standards & Safety Act,** the **Operating Engineers Regulation** and the **Boilers and Pressure Vessels Regulation**; along with all pertinent **Director's Orders**, are posted on TSSA Website and can be printed off for use in your studies.

- **'2nd class Power Engineering'** available from PanGlobal Publishing
- **Reed's Marine Engineering Series**
- **"Metals & How to Weld Them"** by Jefferson & Woods
- **2007 ASME Boiler and Pressure Vessel Code** – Academic Extract contains materials from Sections I, II, IV and VIII of the 2007 ASME Boiler and Pressure Vessel Code and is available from PanGlobal Publishing
- **CSA B51: "Boilers, Pressure Vessel and Piping Code"** available from the CSA Group
- **CSA B52: "Mechanical Refrigeration Code"**
- **2007 ASME Extract**
- **ASME Section I:** Rules for the Construction of Power Boilers Extract
- **ASME Code Simplified**
- **ASME Section VI:** Recommended Guidelines for the Care and Operation of Heating Boilers
- **ASME Section VII:** Recommended Guidelines for Care and Operation of Power Boilers
- **ASME Section IX:** Welding and Brazing Qualifications
- **Stationary Engineering, Fourth Edition,** 2008, by American Technical Publishers, Inc. Author(s) Fredrick M. Steingress, Harold J. Frost and Daryl R. Walker

Additional engineering text and reference materials are available from a broad range of authors and publishers and no specific text or reference material beyond the Act, Regulations and Codes should be considered as official. More information is made available at www.sopeec.org.

Obtaining Certificate

Upon successful completion of the examination and the completion of the required practical operating training period, the candidate may apply to TSSA for their **"Certificate of Qualification"** by forwarding:

- A completed '*Application for an Ontario Certificate of Qualification as an Operating Engineer or Operator';*
- A completed Form 1 entitled **'Testimonial of Qualifying Experience';** and,
- The certification fee, please view the **OE Fee schedule** from the Operating Engineers web page, under Forms & Fees, for initial certificate payment amount, made payable to "Technical Standards and Safety Authority" or to "TSSA" *and forward to*:

Technical Standards and Safety Authority
Operating Engineers Program
345 Carlingview Drive
Toronto, ON
M9W 6N9