

# THIRD CLASS POWER ENGINEER SYLLABUS - 2016



**TECHNICAL  
SAFETY BC**

Safe technical systems. Everywhere.



## INTRODUCTION

This syllabus has been approved by the Standardization of Power Engineers Examinations Committee (SOPEEC), the Association of Chief Inspectors (ACI), and has been adopted by Technical Safety BC.

This syllabus is intended to assist applicants studying for their ThirdClass Power Engineer certificate of qualification examination.

For more information on Third Class Power Engineer certification, visit our [website](#).

## CURRICULUM

Applicants should review the [SOPEEC curriculum](#) for more detailed information on the materials covered here. Applicants should also become familiar with the publications listed in the reference material posted on the SOPEEC website.

## EXAMINATION A PAPER 3A1

### 1. Applied Mathematics:

Use these mathematics disciplines to complete engineering calculations:

- a. Elementary Algebra (simple equations)
- b. Trigonometry
- c. Mensuration (areas, volumes of plane and solid figures)
- d. Natural and naperian logarithms (using calculators)

### 2. Applied Mechanics:

Explain theories, define terminologies, and perform problem-solving calculations involving the following topics:

- a. Applications of forces, vector diagrams
- b. Friction on level surfaces
- c. Linear and angular velocity stet acceleration.
- d. Work, power and energy
- e. Moments of force and simple machines; mechanical advantage; velocity ratio; efficiency
- f. Stress and strain; safe working stress; yield point and ultimate strength; factor of safety
- g. Bending of beams; equilibrium, shearing forces and bending moments
- h. *Density, specific gravity, fluid pressure and fluid flow. (Fluid Pressure and Fluid Flow added January 2014)*

### 3. Thermodynamics:

Explain theories, define terminologies and perform problem-solving calculations involving the following topics:

- a. Temperature measurement units/scales
- b. Expansion of solids (linear, area and volume) and liquids
- c. Quantities of heat; specific heat
- d. Changes of State: sensible and latent heat; heat content in mixtures of water, ice and steam; saturated and superheated steam
- e. Steam tables; temperature-enthalpy charts; critical temperature and pressure; dryness fraction; equivalent evaporation, factor of evaporation.
- f. Methods of heat transfer; conduction, convection, radiation.
- g. Work and heat; mechanical equivalent of heat; laws of thermodynamics
- h. Expansion and Compression of Gases: Boyle's and Charles's laws of perfect gases, general gas law, characteristic gas constant; isothermal, adiabatic and polytropic processes; pressure-volume diagrams; work done in cylinders; indicated horsepower; thermal efficiency

### 4. Applied Science:

- a. Basic Chemistry:
  - i. Molecules, atoms, elements compounds, mixtures
  - ii. Typical industrial applications of chemistry: water treatment, combustion; corrosion
  - iii. Simple organic chemistry; structure of hydrocarbons
  - iv. Properties of acids, bases, salts
  - v. Chemical formulae; balancing chemical equations
  - vi. Structure of the atom, atomic number, atomic weight, formula weights, the mole; molar mass calculations; periodic table of the elements
- b. Metallurgy and Engineering Materials:
  - i. ANSI and ASME classifications of metals; methods of steel and iron production
  - ii. Corrosion principles; types of corrosion, corrosion monitoring and prevention methods and devices, corrosion inspection
  - iii. Properties and applications of non-metallic materials; plastics, carbon fibers, ceramics, polymers
  - iv. Properties and applications of non-ferrous metals
  - v. Properties, grades and applications of steel; alloying metals and applications
  - vi. Properties, grades and applications of cast iron
- c. Industrial Drawings:

Identify components and interpret symbols for the following engineering drawings:

  - i. Process Flow Diagrams. (PFD)
  - ii. Material Balance.
  - iii. Equipment layout.
  - iv. Engineered construction drawings for pressure vessels and other equipment.
  - v. Piping and Instrument Diagrams (P & ID).

## EXAMINATION PART A PAPER 3A2

### 5. Industrial Legislation and Codes:

- a. General knowledge of the purpose, content and application of the boiler and pressure vessel codes and regulation, including the Power Engineers' Regulations in the student's jurisdiction.
- b. State the purpose and describe the general content of each of the following codes:
  - i. ASME Section I - Power Boilers  
ASME Section IV - Heating Boilers  
ASME Section V - Nondestructive Examination  
ASME Section VI - Recommended Rules for Care and Operation of Heating Boilers  
ASME Section VII - Recommended Guidelines for the Care of Power Boilers  
ASME Section IX - Welding & Brazing Qualifications
  - ii. CSA Standard B.5 - Boiler, Pressure Vessel & Pressure Piping Code  
CSA Standard B.52 - Mechanical Refrigeration Code
  - iii. National Board Inspection Code

### 6. Code Calculations, ASME Section I:

*Demonstrate an understanding of concepts in the following calculations (using SI units):*

- a. Designed thickness and allowable pressures of boiler tubes, drums, and blank dished heads
- b. Sizes and capacities of boiler safety valves

### 7. Fuels and Combustion:

- a. Requirements for efficient combustion of boiler fuels; complete and incomplete combustion
- b. Classification, properties and combustion characteristics of coal, fuel oil and natural gas; other (non-fossil) fuels
- c. Fuel analysis; proximate, ultimate, fuel heat value; calorimetry
- d. Combustion chemistry; combustion equations for coal, oil, and gas; molar masses for combustion products
- e. Combustion calculations; oxygen, air and excess air required, given fuel analysis
- f. Flue gas analysis methods and devices; CO; CO<sub>2</sub> and O<sub>2</sub>
- g. Control of emission standards: NO<sub>x</sub>, SO<sub>2</sub>, particulates

## 8. Piping:

- a. Codes and standards for pressure piping: ASME, CSA, ASTM; identification and sizes of piping; B31.1, B31.3; power piping vs. process piping
- b. Ferrous piping materials and methods of manufacture; specifications and service ratings; non-ferrous materials
- c. Non-metallic piping: materials and applications
- d. Strength of piping; effects of temperature on piping
- e. Piping connection methods: threaded, flanged, welded; design, materials, selection and installation of gaskets
- f. Designs and applications of expansion devices, supports and anchors.
- g. Steam Traps:
  - i. Types of steam traps
  - ii. trap sizing and selection
  - iii. trap installation configurations
  - iv. trap inspection and maintenance
  - v. trap flow calculation
- h. Water hammer: effects; causes; design and operational preventions
- i. Insulation: purposes; benefits; characteristics; common materials and their uses; methods of application; cladding; care of insulated piping systems; calculations using coefficient of thermal conductivity
- j. Common and specialty valves: purpose, design, operation and applications; valve flow configurations; valve trim; actuator types

## 9. Electrotechnology:

- a. Direct Current Theory:
  - i. Electron theory; theory of magnetism; magnetic field; force on conductor.
  - ii. Electromagnetic Induction: induced EMF; Faraday's and Lenz's Laws of Induction; Fleming's right-hand rule; self-induction in a coil; mutual induction.
- b. Direct Current Machines:
  - i. Generators: operating principles, construction, commutation, speed and voltage control; types (shunt, series and compound)
  - ii. Motors: principle of operation, torque development and measurement, armature reaction, interpoles, speed control, methods of starting, types (shunt, series and compound), protection devices
- c. Alternating Current Theory:
  - i. Generating an alternating EMF; sinusoidal wave forms; phase relationships
  - ii. Resistance in AC circuits; inductive and capacitive reactance; impedance; power and power factor; single and multi-phase circuits

d. Alternating Current Machines:

- i. Alternators: principle of operation, construction, voltage regulation, excitation methods, parallel operation, synchronizing procedures; automatic synchronizers, taking off the line, switchboard components (meters, breakers, machine protection relays)
- ii. Motors: principle and operation of induction and synchronous motors; construction; speed and slip; starting methods for induction motors; speed control; variable speed starting, step-starting
- iii. Transformers: operating theory; types (design and construction), losses and efficiency; methods of cooling; safety and fire protection

e. AC Systems, Switchgear, Safety:

- i. Components, layout, and operation of a typical industrial AC power system
- ii. Components of an AC generator panel
- iii. Circuit protective and switching equipment: fuses, safety switches; circuit breakers; circuit protection relays; automatic bus switchover (emergency supply to normal supply); grounding; lightning arresters
- iv. UPS/Inverter Systems: purpose, components, operation; battery design and maintenance
- v. Electrical safety for operators

**10. Electrical Calculations:**

Explain theories and perform calculations for:

- a. Current, voltage, resistance in series and parallel circuits; using Ohm's Law and Kirchhoff's Laws; Wheatstone Bridge  
*(b. Temperature coefficient of resistance, removed from syllabus and curriculum, January 2014)*
- b. Work, energy, power: relationship between electrical, mechanical and heat units
- c. Sinusoidal Wave Forms: maximum, average and root mean square root values; frequency; phase
- d. AC Circuits: inductive reactance, capacitive reactance, impedance, KVA; power factor
- e. Relationship between poles, frequency, speed for AC machines
- f. Transformer calculations; step up and step down

## 11. Control Instrumentation:

- a. Control loops and strategies:
  - i. Applications of pneumatic, electric and electronic (digital) control systems; components and operation of typical control loops
  - ii. on-off, proportional, reset, derivative control strategies
  - iii. Feed forward, feedback, cascade, ratio, split-range, select control
  - iv. Alarm and shutdown functions in a control loop; operator interfaces with control loops
- b. Instrument and Control Devices: design and principles of common temperature, pressure, flow, and level instruments
- c. Distributed and Logic Control Systems:
  - i. Components, layout, functions of distributed control system
  - ii. DCS operator interface components; trending; data logging; alarms and shut-downs
  - iii. Programmable logic controllers: purpose, design, components; applications; ladder diagrams
  - iv. Supervisory control and data acquisition systems (SCADA) as used in process control: purpose and general functions

## 12. Industrial Safety and Fire Protection:

- a. Safety Management Programs:
  - i. Introduction to OH&S Acts in general
  - ii. Workplace OH&S Programs: setting up a program; purpose and interaction with WCB; company and employee responsibilities; typical components of an OH&S program: safety committees, hazard identification, incident investigation, personal safety equipment; work permit systems (equipment lock-out, confined space entry, hot and cold work, excavations); WHMIS (overview); emergency response plans
- b. Fire Protection Systems:
  - i. Classes of fire; extinguishing methods
  - ii. Components and operation of industrial fire detection and alarm system
  - iii. Sprinkler systems (dry and wet stand pipe); pre-action and deluge; design and operation
  - iv. Fixed fire systems: firewater pump, loops, hydrants; vessel deluge system; foam systems
  - v. Industrial fire response

## EXAMINATION PART B PAPER 3B1

### 13. Boilers:

- a. Boiler Classification:
  - i. Definitions and designs of typical Watertube Boilers:
    - multi-drum bent tube;
    - D, A, O configurations; packaged,
    - once-through, forced circulation,
    - critical vs. super-critical boilers
  - ii. Special Boiler Designs: describe the design, components and operation of the following designs:
    - fluidized bed boilers,
    - heat recovery steam generators (HRSG), black liquor boilers,
    - waste heat boilers, refuse boilers,
    - Bio-mass,
    - high-pressure/high-temperature hot water boilers
- b. Boiler Construction:
  - i. Designs, fabrication, construction methods, and Code requirements for: shells, drums, tubes (include attachment methods), nozzles; headers; handholes/manholes
  - ii. Field assembly of a large watertube boiler
  - iii. Boiler metals – applications and purpose
- c. Boiler Heat Transfer Components:
  - i. Watertube boiler settings (brickwork and refractory), baffles; integral furnace designs and waterwalls: studded tubes; water-cooled walls: fin-tube, tangent-tube, flat-stud tube
  - ii. Superheaters: primary, secondary, convection, radiant, integral and separately-fired; operating characteristics;
  - iii. Reheater designs
  - iv. Economizers: integral and separate; tube styles, advantages/ disadvantages
  - v. Air Heaters: plate, tubular, rotary regenerative designs; heater corrosion control; advantages/ disadvantages
  - vi. Sootblowers: stationary and retractable, locations, shot cleaning



- e. Fuel, Draft, and Flue Gas Systems:
  - i. Solid Fuel firing equipment: mechanical, underfeed, crossfeed and overfeed stokers; pulverizers -impact, ball, ball-race and bowl mills; burner and furnace designs - turbulent vertical, tangential, cyclone; solid fuel feed systems; ash handling systems - hydro and air, bottom ash (Crossfeed stoker added, Coal removed and solid fuel is the new term for all solid fuels January 2014)
  - ii. Oil burning equipment: oil burner designs - steam, air and mechanical atomizing; components of large oil burner systems; start-up/shut-down of large oil burners; cleaning and maintenance
  - iii. Gas burning equipment: burner designs – spud, multi-spud and ring; burner gas supply system; start-up sequence for gas burner; high-efficiency, low NOx burners
  - iv. Draft equipment: natural, forced, induced, balanced draft; draft fan designs, control methods; fan performance curves; draft measurement; windbox and air louvers; primary and secondary air
  - v. Flue gas clean-up methods and equipment: precipitators, filters, ash handling systems; SO<sub>2</sub> recovery systems
- f. Boiler Operation and Maintenance:
  - i. Manual start-up and shut-down procedure for large, industrial boilers;
  - ii. Initial start-up (commissioning) of a new boiler
  - iii. Routine and emergency operations
  - iv. Causes and prevention of boiler furnace and pressure explosions
  - v. Chemical and mechanical boiler cleaning methods; boiling out
  - vi. Methods of cleaning and preparing a boiler for inspection
  - vii. Inspection: fire and water sides; safety
  - viii. Hydrostatic test

#### 14. Boiler Control Systems:

- a. Boiler Water Level Control: components, purpose and operation of single-element, two- element, and three-element control systems; explain swell and shrinkage
- b. Combustion control:
  - i. Design and operation of each of the following combustion control systems: direct pressure control of fuel and air, steam flow–air flow control, fuel flow–air flow control, air flow–fuel flow, multi-element control
  - ii. Safety devices and interlocks
  - iii. Flame failure detection: continuous, intermittent, interrupted pilots; photo-electric cells
  - iv. Automatic, programmed boiler start-up and shut-down sequence
- c. Steam temperature control:
  - i. desuperheating control
  - ii. attemperation
  - iii. gas recirculation
  - iv. gas bypass
  - v. tilting burners

#### 15. Feedwater Treatment:

- a. Feedwater impurities and their effects on boiler operation
- b. External, feedwater treatment: Explain the purpose, physical and/or chemical operating principles, system/equipment design and operation for each of the following: settling, coagulation and filtering, hot and cold lime-soda softening, hot phosphate softening, sodium and hydrogen zeolite softening, demineralization, dealkalization, mechanical deaeration, evaporation (multi-effect evaporators), reverse osmosis
- c. Internal Boiler Water Treatment:
  - i. Causes, effects and controls for boiler internal water problems
  - ii. pH control – magnetite layers, acidic and caustic corrosion
  - iii. Sludge conditioning and dispersion; modern sludge dispersants
  - iv. Chemical deaeration – oxygen corrosion; sulphite programs; hydrazine
  - v. Carryover – priming, misting, foaming
  - vi. Dissolved solids – blowdown control; conductance; simple and heat recovery blowdown systems; automatic blowdown systems
  - vii. Return line corrosion – neutralizing and filming amines
  - viii. Scale control – phosphate and chelate programs
- d. Chemical feed systems: shot and continuous feed systems; chemical feed pumps
- e. Feedwater and boiler water testing methods: automatic sampling systems and monitors; boiler and steam system parameters and test locations

**16. Pumps:**

- a. Theory of pumping: define and explain pump head terms, perform pump head and pressure calculations, explain cavitation
- b. Reciprocating pumps: pump drivers; single and double-acting designs; plunger type; diaphragm type; pump protection
- c. Centrifugal pumps:
  - i. Classification and principles of operation for volute, diffuser and turbine pumps; axial and mixed flow
  - ii. Construction and components: single and multi-stage; impeller types; wear rings; shaft sealing arrangements - stuffing box, lantern ring, mechanical seals; balance disc, drum; opposed impellers
  - iii. Operation: starting and stopping, priming
  - iv. Typical pump installation; auto-recycle valve
- d. Rotary pumps: design and operation of gear, lobe, screw

**17. Welding Procedures and Inspection:**

- a. Welding Processes (overview): describe and state where each of these processes would be used - metal arc, shielded arc, submerged arc, gas (TIG), MIG
- b. Electrodes: classification, types and uses; where and why each would be use
- c. Fabrication and repairs: weld preparation; preheating, performing a boiler tube repair, postweld heat treatment (stress relieving)
- d. Causes and effects of common weld defects
- e. Weld inspection procedures: non-destructive examination techniques; destructive examination techniques
- f. Welding Procedure and Welder's Performance Qualifications per ASME Code, Sect. 9

**18. Pressure Vessels**

- a. Explain design, construction, operation and repair regulation of pressure vessels, including stamping and nameplate details
- b. Head, nozzle, manway designs
- c. Loads and stresses on pressure vessels
- d. Typical components/fittings on a pressure vessel
- e. Safe operating and maintenance consideration, including hydro and pneumatic testing; inspection

## EXAMINATION PART B PAPER 3B2

### 19. Prime Movers:

- a. Steam Turbines:
  - i. Impulse and reaction principles; nozzles; blade shapes;
  - ii. Turbine arrangements: staging and compounding: principles and p-v diagrams for pressure, velocity and pressure-velocity compounding
  - iii. Turbine components: purpose, design, operation of the following: casings, disc and drum rotors, dummy pistons, journal and thrust bearings, barring gear, blade and shaft sealing glands, couplings, interceptor valves on reheat turbines
  - iv. Explain purpose and arrangements of condensing, bleeder, topping, extraction, cross and tandem compounded turbines
  - v. Turbine governor types; speed-sensitive, pressure-sensitive, nozzle, throttle, bypass; mechanical, mechanical hydraulic, electronic-hydraulic; droop and isochronous operation
  - vi. Starting and shutting down condensing and extraction turbines
  - vii. Steam turbine condensers: types, air-cooled, water-cooled, Panier style; condenser auxiliaries; condenser operation; feedwater heater system
- b. Gas Turbines:
  - i. Applications, advantages and disadvantages of gas turbines
  - ii. Basic cycle and improvements: open and closed cycles defined, regeneration, dual shaft arrangement, intercooling and reheating, typical gas turbine operating parameters and efficiency, combined steam and gas turbine cycles
  - iii. Main gas turbine components: radial and axial compressors, combustor arrangements and operation, turbine rotor designs
  - iv. Gas turbine support systems: fuel supply systems; lubrication; barring gear; steam injection; intake and exhaust components
  - v. Supervisory, protective, and control systems
  - vi. Starting and stopping procedures and sequences; turbine washing
- c. Internal Combustion Engines:
  - i. Gasoline engines: spark ignition defined, two-stroke cycle, four-stroke cycle, carburetion; carburetor design and operation, spark ignition components, fuel injection
  - ii. Diesel engines: compression ignition defined, two-stroke cycle, four-stroke cycle, scavenging, fuel injection; fuel injectors; purpose and design of the major mechanical/structural components of a diesel engine; starting and maintenance procedures
  - iii. Engine support systems: fuel systems, lubrication, governing, starting systems and methods, magneto system, cooling systems, supercharging and turbo-charging
  - iv. Thermodynamic heat engine cycles: explain the Otto, Diesel and Brayton cycles

**20. Cogeneration:**

- a. Purpose, advantages, components of cogeneration systems
- b. simple and combined cycle
- c. using gas turbines and internal combustion engines
- d. single and dual shaft arrangements
- e. control strategies and components
- f. environmental considerations
- g. heat recovery boilers and water heaters
- h. operating procedures
- i. typical industrial cogeneration applications

**21. Compressors:**

- a. Theory of Compression:
  - i. Adiabatic and isothermal compression; pressure volume relationships; compression ratio, capacity, multi-staging; effect of altitude and moisture
  - ii. Applications for compression, including air and gas.
- b. Positive Displacement Compressors: design, operating principles
  - i. Reciprocating compressors: clearance volume; indicator diagrams; calculations for displacement and volumetric efficiency.
  - ii. Rotary Compressors: sliding vane, lobe, and screw types (industrial screw type in detail, including control panel)
- c. Dynamic Compressors:
  - i. Design and operation of centrifugal and axial flow compressors; application as blowers (21.c.ii. *Free Piston Compressor has been removed from the syllabus*)
  - ii. Compressor surge: causes and prevention; P-V curve; surge line, anti-surge system and control
- d. Starting and stopping procedures for positive displacement and dynamic compressors
- e. Compressor Auxiliaries:
  - i. Intercoolers/aftercoolers; moisture separators
  - ii. Compressor control systems and devices: start and stop, variable and constant speed; safety devices
  - iii. Lubrication: internal and external
  - iv. Compressor installation and piping layouts
- f. Compressed air system components:
  - i. Typical system layout; air receivers (wet and dry) fittings and operation; filters
  - ii. Air dryers: system design, flows, operation; dewpoint monitoring

## 22. Refrigeration:

- a. Refrigerant classifications, properties, characteristics
- b. Compression systems:
  - i. Principle of compression refrigeration; typical system temperatures and pressures for simple refrigeration systems
  - ii. Multi-stage systems: 2-stage with duplex compressors; 2-stage with booster compressor; low-temperature multi-stage
  - iii. Direct vs. indirect systems
  - iv. Typical refrigeration applications
- c. Absorption system: ammonia absorption system description and operating parameters
- d. Refrigeration system auxiliaries:
  - i. System controls: expansion valves, low-side float, high-side float, capillary tube
  - ii. Compressor controls: temperature and pressure-actuated
  - iii. Condenser cooling water control
  - iv. Safety devices and controls: pressure relief devices, high-pressure cut-out, low- pressure lube oil cut-out
- e. CSA B52 Regulations:
  - i. overview of the code for the safe operation, installation and repair of refrigeration equipment
- f. System Operation:
  - i. leak testing,
  - ii. charging,
  - iii. purging,
  - iv. troubleshooting (condenser, regulator, refrigerant strength,
  - v. compressor discharge temperature);
  - vi. effects of moisture in system; effects of oil in the refrigerant;
  - vii. oil removal using oil separators,
  - viii. oil traps,
  - ix. oil still;
  - x. operating and maintaining brine systems

### 23. Special Industrial Equipment:

Describe the general applications, designs, components, operation for the following:

- a. Heat exchangers:
    - i. double pipe designs
    - ii. shell-and-tube configurations
    - iii. head designs
    - iv. reboiler and feedwater heater fittings
    - v. plate frame
    - vi. overhead aerial coolers
    - vii. aerial steam condensers, including operation and control
  - b. Cooling towers:
    - i. natural draft
    - ii. atmospheric
    - iii. hyperbolic
    - iv. mechanical draft designs
    - v. operation and control
  - c. Fired Heaters:
    - i. multi-burner vertical designs
    - ii. burner components and styles
    - iii. fuel supply and control
    - iv. interlocks and safety devices
    - v. indirect-fired heaters
    - vi. horizontal designs
    - vii. start-up and shutdown procedures
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- ### 24. Wastewater Treatment:
- a. Purpose of WWT; typical wastewater pollutants and systems
  - b. Theory and equipment for specific treatment process:
    - i. removal of suspended solids (screening, floatation, sedimentation);
    - ii. removal of colloidal solids (chemical coagulation, flocculation, clarification)
    - iii. biological treatment (activated sludge, rotating biological contactors, trickling filters)
  - c. Operating parameters, controls and tests: nutrients, BOD, COD, pH, settleability
  - d. Safety in wastewater treatment plants

**25. Plant Maintenance and Administration:**

Explain the purpose, typical design and administration of the following plant functions:

- a. Communication and accountability structures
- b. Scheduled and preventative maintenance programs
- c. Record keeping; logbooks; logsheets
- d. Project control; critical path (applied to a complete boiler turnaround, as an example)
- e. Operating standards and procedures
- f. Training and development practices; job skill profiles
- g. Environmental practices and supervision