ABSA
the pressure equipment safety authority

REFERENCE SYLLABUS

For

THIRD CLASS
POWER ENGINEER'S

CERTIFICATE of COMPETENCY
EXAMINATION

AB-53

Edition 1, Revision 1, 2017-09

REFERENCE SYLLABUS
For
THIRD CLASS
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EXAMINATION

GENERAL INFORMATION

Introduction

The Standardization of Power Engineers Examination Committee (SOPEEC) has developed a Third Class Power Engineer's Syllabus (SOPEEC Syllabus) which has been approved by the Association of Chief Inspectors (ACI) to be used across Canada.

As provided for under the *Power Engineers Regulation*, the Administrator in the pressure equipment discipline has established this Syllabus to identify the examination subjects for Third Class Power Engineer's Certificate of Competency examinations. The subjects described in this Syllabus are identical to the subjects in the SOPEEC Syllabus.

The requirements to qualify for a Third Class Power Engineer's Certificate of Competency examinations are outlined in the Power Engineers Regulation.

A candidate may write the Third Class examinations at any scheduled examination after obtaining a Fourth Class Power Engineer's Certificate of Competency.

Recommended Study Program:

It is recommended that, before undertaking this examination, the candidate completes the Third Class Power Engineering Course offered through a recognized Educator.

In addition to the foregoing course, it is recommended that the candidate becomes familiar with the publications listed in the "Reference Material for Power Engineering Students and Examination Candidates" which is obtainable from the various technical institutes or from the SOPEEC website. (www.sopeec.org)

Application to Undertake Examination:

A candidate must submit an application and the prescribed fee at least twenty-one (21) days before the date of examination.

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Examination Instructions:

The examination consists of four (4) examination papers, each of 3 ½ hours duration. Each of the papers consists of 150 multiple-choice questions.

To pass a 3rd Class Power Engineer's Certificate of Competency examination, a candidate must obtain at least 65% of the total marks allotted for each examination paper.

A candidate is allowed to use the following items in the examination room:

- The Safety Codes Act and Regulations under the Safety Codes Act;
- CSA B51, Boiler, Pressure Vessel and Pressure Piping Code;
- CSA B52, Mechanical Refrigeration Code;
- Extract for CSA B51 and CSA B52 Codes;
- ASME Boiler & Pressure Vessel Codes except for Sections VI and VII;
- The 2007 ASME Boiler & Pressure Vessel Code Academic Extract and Supplement produced by PanGlobal Training Systems;
- ASME/ANSI B31.1 Pressure Piping Code and B31.3 Process Piping Code;
- Handbook of Formulae and Physical Constants, Steam Tables and Refrigeration Tables are normally provided;
- A non-technical English language dictionary;
- Pens and pencils;
- Non-programmable calculator and
- Drawing instruments and drawing templates.

Note:

- The candidate must provide picture ID to the Examiner prior to the examination.
- No cell phone or any electronic communication devices are allowed to be brought into the examination room.
- The items referenced above must be shown to the Examiner for approval.
- No other reference material is allowed.
- The information in the 1983 Edition of the ASME Boiler and Pressure Vessel Code Academic Extract is outdated. Using this 1983 Edition of the ASME Extract for any power engineering examination is not recommended. Besides using the 2007 Edition of the ASME Academic Extract and Supplement, candidates may use the current edition of the ASME Code.

GENERAL INFORMATION

Part 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-enthalphy 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 Charle'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.

GENERAL INFORMATION

4. **Applied Science:**

a. Basic Chemistry:

i. Molecules, atoms, elements compounds, mixtures.
ii. Structure of the atom, atomic number, atomic weight, formula weights, the mole; molar mass calculations; periodic table of the elements.
iii. Chemical formulae; balancing chemical equations.
iv. Properties of acids, bases, salts.
v. Simple organic chemistry; structure of hydrocarbons.
vi. Typical industrial applications of chemistry: water treatment, combustion; corrosion.

b. Metallurgy and Engineering Materials:

i. ANSI and ASME classifications of metals; methods of steel and iron production.
ii. Properties, grades and applications of cast iron.
iii. Properties, grades and applications of steel; alloying metals and applications.
iv. Properties and applications of non-ferrous metals.
v. Properties and application s of non-metallic materials; plastics, carbon fibers, ceramics, polymers.
vi. Corrosion principles; types of corrosion, corrosion monitoring and prevention methods and devices, corrosion inspection.

c. Industrial Drawings:

Identify components and interpret symbols for the following engineering drawings:

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

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.51	- 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_2 and O_2.
g. Control of emission standards: NOx, SO_2, 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.

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

d. High Pressure Boiler Fittings:

Design, installation/location, operation, testing and Code requirements for each of the following boiler fittings:

i. Water columns and gauge glasses; types of remote level indicators; illumination; safety shut-off

ii. Safety valves; setting

iii. Low-water fuel cut-offs; float and probe designs

iv. Steam outlet fittings and non-return designs

v. Pressure gauges; feedwater connections; vents; and blowdown valve designs; blowdown procedures; blowdown tank

vi. Drum Internals: baffles, scrubbers, separators, driers, piping circulation and separation of steam and water

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 (*Crossfeeed 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_2 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 used

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

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

GENERAL INFORMATION

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

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