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PE 3rd Class Curriculum

Curriculum Version: 2024.1

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This curriculum document is prepared by IPECC and is intended to elaborate on the information found in the SOPEEC / ACI syllabi.

The SOPEEC / ACI syllabi are the official governing document for SOPEEC examinations. To view the official SOPEEC / ACI syllabi, refer to the SOPEEC website, www.sopeec.org.

The curriculum documents are developed and approved by IPECC members as a reference document for SOPEEC examinations. These documents are posted on the IPECC website, www.ipecc-canada.ca.

Note that this curriculum document is designed to exactly mirror the layout of the syllabus. Any deviation from the list format and contents of the syllabus is considered an error that must be remedied by IPECC.

To this end, the syllabus statements are printed in this document as a series of colour-coded headers, with indents demarking the various list levels of the syllabus.

The only information that is ADDED by the curriculum document is the curriculum objectives. These are the displayed in WHITE cells, as the lowest list items. The curriculum objectives are numbered in order, with this order assigned by IPECC.

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EXAM PART A1
01. Applied Mathematics
a. Elementary Algebra (simple equations)
01. Apply the rules for addition, subtraction, multiplication and division of positive and negative quantities.
02. Simplify algebraic expressions and operations involving the removal or insertion of brackets.
03. Apply the rules for powers and roots to the multiplication and division of quantities and expressions.
04. Apply the rules of transposition to solve simple equations involving addition, subtraction, multiplication and division.
05. Solve equations involving roots, powers, and fractions.
b. Trigonometry
01. Identify the types of angles and specify angle size in degrees and radians.
02. Identify right, obtuse, and acute triangles and apply the naming convention for sides and angles.
03. Use Pythagoras' Theorem to calculate the side lengths of a right angle triangle and solve simple problems involving right triangles.
04. Explain the sine, cosine, and tangent of an angle and determine the values of these functions for all angles between 0º and 360º.
05. Using sine, cosine, and tangent, find the dimensions of right triangles and solve physical problems involving right triangles.
06. Define the Sine Rule and use these rules to determine the unknown dimensions of oblique triangles.
c. Mensuration (Areas, volumes of plane and solid figures)
01. Convert between Imperial and SI units of measure; convert unit magnitudes for area and volume within the SI system.
02. Calculate the areas of triangles, given base and height, or given the lengths of the sides.
03. Define the following quadrilaterals and calculate their areas: rectangle, square, rhomboid, rhombus, trapezoid, and trapezium.
04. Define the following polygons and calculate their areas: hexagon, octagon.
05. Define and calculate areas and dimensions of a circle, a segment of a circle, a sector of a circle, and an ellipse.
06. Solve problems involving the surface areas and volumes of cylinders and spheres.
07. Define terms and solve problems involving the surface areas and volumes of pyramids, cones, and frustums.
d. Natural and Naperian logarithms (using calculators)
01. Explain common Naperian (natural) logarithms.Using a calculator, perform mathematical operations and solve equations that contain logarithms.
02. Applied Mechanics
Explain theories, define terminologies, and perform problem-solving calculations involving the following:
a. Applications of forces; vector diagrams
01. Define coplanar and concurrent vectors and draw space diagrams for forces and displacements.
02. Draw a vector diagram and use it to graphically find the resultant and equilibrant of a force system.

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03. Use trigonometry to resolve forces into components and to calculate the resultant and equilibrant of a force system.
04. Given a coplanar, concurrent force system, calculate any unknown forces.
b. Friction on level surfaces.
01. Define static friction, sliding friction, and coefficient of friction, use the friction formula to calculate coefficient of friction.
02. Explain friction angle and perform friction calculations for forces applied parallel to the horizontal plane.
03. Calculate the coefficient of friction, object mass, and applied forces for objects moved on a horizontal surface by forces that are NOT parallel to the plane.
c. Linear and angular velocity and acceleration
01. Define, and show the relationships between, distance, displacement, speed, linear velocity, and linear acceleration.
02. Using linear motion relationships, calculate the displacements, velocities, and accelerations of bodies moving in a straight line.
03. Define and calculate angular displacement, angular velocity, and angular acceleration.
d. Work, power, and energy.
01. Define force, force due to gravity, and work. Calculate the work done in moving objects horizontally and vertically.
02. Define power and mechanical efficiency.Calculate the power expended when work is done, plus the power developed and mechanical efficiency of a reciprocating engine.
03. Define potential and kinetic energy.Calculate the energies of stationary and moving objects.
04. Calculate the work done to compress a spring.
e. Moments of force and simple machines; mechanical advantage; velocity ratio; efficiency.
01. For simple machines in general, define and calculate mechanical advantage (MA), velocity ratio (VR), and efficiency.
02. Calculate the efforts, loads, MA, VR, and efficiencies of wheel-and-axle systems.
03. Calculate the efforts, loads, MA, VR, and efficiencies of various pulley systems.
04. Calculate the efforts, loads, MA, VR, and efficiencies of a screw jack.
05. Calculate the efforts, loads, MA, VR, and efficiencies of levers and inclined planes.
06. Define moments of force.
f. Stress and strain; safe working stress; yield point and ultimate strength; factor of safety.
01. Define and explain, using appropriate formulas where applicable, terms that apply to materials under load, including stress, tensile, compressive, shear, strain, elastic limit, ultimate load, ultimate strength, allowable working stress, factor of safety, Hooke’s Law, Young’s Modulus of Elasticity proportional limit and breaking point.
02. Calculate stress, strain, ultimate strength, factor of safety, and/or modulus of elasticity for materials under various load situations.
03. Use a stress-strain diagram for mild steel to define and explain proportional limit, elastic limit, yield point, ultimate stress, and breaking point.
g. Bending of beams; equilibrium, shearing forces and bending moments.
01. Explain the types of beams, beam supports, and beam loads, and state the requirements for beam equilibrium.
02. Calculate the reaction forces for simple and cantilever beams, with point and distributed loads.

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03. Explain the effects of shear forces and bending moments in a beam and the compression/tension profile of a loaded beam.
04. Calculate the shear force at any given point in a simple or cantilever beam.
05. Calculate the bending moment at any given point in a simple or cantilever beam.
h. Density, specific gravity, Fluid pressure and fluid flow.
01. Define and state the relationships between mass density, relative density, weight density, specific weight, and specific gravity.
02. Given unknowns, calculate the densities, relative densities, masses and/or volumes of substances.
03. Calculate pressures exerted by columns of fluids, and convert between gauge pressure, absolute pressure, millimetres of mercury, and millimetres of water.
04. Calculate the pressure and force exerted by a liquid at various levels in a tank.
05. Explain flow continuity and calculate simple flows and velocities of liquids in a pipe.
03. Thermodynamics
Explain theories, define terminologies and perform problem-solving calculations involving the following topics:
a. Temperature measurement units/scales.
01. Define and explain internal energy, heat, specific heat, heat units, and temperature, and explain the relationship between the different temperature scales.
b. Expansion of solids (linear, area and volume) and liquids.
01. Explain the thermal conditions that cause expansion of solids and liquids and describe the relationship between linear, superficial (area) and volumetric expansion.
02. Given known conditions, calculate linear expansion or contraction, temperatures, and/or expansion coefficients for solids.
03. Given known conditions, calculate superficial expansion or contraction, temperatures, and/or expansion coefficients for solids.
04. Given known conditions, calculate volumetric expansion or contraction, temperatures, and/or expansion coefficients for solids or liquids.
05. Calculate the stress produced in a pipe or its supports when thermal expansion is restricted.
d. Changes of State: Sensible and latent heat; heat content in mixtures of water, ice and steam; saturated and superheated steam.
01. Define sensible heat and use the sensible heat equation to calculate the amount of heat required to change the temperature of a substance, the mass of the substance, and the temperature change if no change of state occurs.
02. Explain the changes of state and define latent heat, latent heat of fusion, and latent heat of evaporation.
03. Given start and end conditions, calculate the heat required to change the states of water and other substances.
04. Determine the final temperatures and the original masses for mixtures of ice, water, steam, and other substances.
05. Explain the working principle of a simple calorimeter and use the calorimeter equation to determine specific heat and final temperature.
06. Explain water equivalent and perform calculations involving calorimetry and heat water equivalents.
e. Steam tables;temperature-enthalpy charts;critical temperature and pressure;dryness fraction;equivalent evaporation,factor of evaporation.

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01. Define and explain the following terms: saturation temperature, saturated steam, dry saturated steam, wet saturated steam, dryness fraction, superheated steam, enthalpy.
02. Identify, from the pressure-based and temperature-based steam tables, the properties of saturated steam at specified conditions.
03. Identify, from the superheated steam tables, the properties of superheated steam at specified conditions.
04. Calculate the heat required to produce dry saturated or superheated steam at given conditions, from feedwater at given conditions.
05. Calculate the dryness fraction of wet steam and/or the heat required to produce wet steam at a given dryness fraction.
06. Explain the properties of steam on a temperature-enthalpy diagram.
07. Define and calculate the heat rate, equivalent evaporation and factor of evaporation for a boiler.
f. Methods of heat transfer; conduction,convection,radiation.
01. Explain the methods of heat transfer: conduction, convection, and radiation.
02. Define thermal conductivity and calculate the quantity of heat conducted, the temperature difference, or the material thickness when heat is transferred through flats walls and plates.
g. Work and heat;mechanical equivalent of heat;laws of thermodynamics.
MISSING CURRICULUM STATEMENT
h. Expansion and Compression of Gases:Boyle's and Charles' 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.
01. Explain Boyle’s Law, Charles’ Law, Gay-Lussac’s Law, and the General Gas Law and use these laws to calculate changes in pressure, temperature and volume for perfect gases.
02. Explain the Characteristic Gas Constant and use the Characteristic Gas Equation to determine the mass, the conditions, and the constant for a gas.
03. Explain isothermal, adiabatic, and polytropic processes (expansion and compression) for a gas, state the formula for each process, and compare the processes on a pressure/volume diagram.
04. Calculate unknown pressures, volumes and temperatures for gases during isothermal, adiabatic, and polytropic processes.
05. Explain and calculate the work done in a cylinder under constant pressure.
06. Explain and calculate the work done in a cylinder during an isothermal expansion or compression.
07. Explain and calculate the work done in a cylinder during an adiabatic expansion or compression.
08. Explain and calculate the work done in a cylinder during a polytropic expansion or compression.
04. Applied Science
a. Basic Chemistry
i. Molecules, atoms, elements, compounds, mixtures.
01. Define each term and explain the relationship between atoms, ions, elements, molecules, compounds, and mixtures.
ii. Structure of the atom, atomic number, atomic weight, formula weights, the mole; molar mass calculations; periodic table of the elements.

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01. Using the Periodic Table of the Elements, determine the atomic numbers and the atomic masses of elements.
02. Explain electronegativity and the bonding of ions.
iii. Chemical formulae; balancing chemical equations.
01. Explain the formation of chemical compounds, explain typical reactions and apply basic principles to the balancing of simple chemical reactions.
02. Calculate the amount of reactants required or products produced in a chemical reaction.
iv. Properties of acids, bases, salts.
01. Define acids, bases, and salts and explain their properties.
v. Simple organic chemistry; structure of hydrocarbons.
01. Define organic chemistry and explain, in general terms, the structure and applications of hydrocarbons and hydrocarbon derivatives.
vi. Typical industrial applications of chemistry: water treatment, combustion; corrosion.
01. Explain typical applications of chemistry in industry, including water treatment and testing, corrosion control, combustion, hydrocarbon processing, petrochemical processes, and pulp and paper production.
b. Metallurgy and Engineering Materials
i. ANSI and ASME classifications of metals; methods of steel and iron production.
01. Define and explain the importance and application of mechanical properties of materials, including brittleness, hardness, ductility, malleability, plasticity, elasticity, and toughness.
02. Describe material testing, including tension test, Brinell and Rockwell hardness tests, Charpy and Izod impact tests.
04. Describe the production of carbon and alloy steel, using the open-hearth, basic oxygen and electric-arc furnace processes.
ii. Properties, grades and applications of cast iron
01. Describe the blast furnace and cupola furnace methods for iron production, and compare the characteristics of gray, white, malleable, and ductile cast iron.
iii. Properties, grades and applications of steel; alloying metals and applications.
01. Define steel and explain the compositions and characteristics of low carbon, medium carbon and high carbon steels.
02. Define alloy steels, and explain the benefits of alloying elements, including nickel, chromium, molybdenum, vanadium, copper, lead, manganese and tungsten.
03. Explain the purposes of hot working, cold working and heat treating metals.
iv. Properties and applications of non-ferrous metals.
01. Describe the properties and applications of non-ferrous metals and alloys.
v. Properties and applications of non-metallic materials; plastics, carbon fibers, ceramics, polymers.
01. Explain the basic structure, properties and applications of polymers, ceramics and composites.
vi. Corrosion principles; types of corrosion, corrosion monitoring and prevention methods and devices, corrosion inspection.
01. Define corrosion terms and explain the causes and characteristics of corrosion types, including galvanic, atmospheric, stray current, biological, stress cracking, hydrogen induced, sulphide stress cracking and chloride stress cracking.
02. Explain the nature and sources of corrosion on the waterside of boilers, including caustic corrosion, hydrogen-damage, and pitting.
03. Explain the environmental factors that affect corrosion.

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04. Explain the principles of corrosion inhibitor mechanisms, including adsorbed films, passivation, cathodic precipitates, and neutralization.
05. Describe the principles and applications of cathodic protection devices or systems, including sacrificial anodes, galvanic anodes, impressed current, and groundbeds.
06. Describe the principles and applications of corrosion monitoring devices, including coupons, electrical resistance probes, galvanic probes, and hydrogen probes.
07. Describe corrosion inspection procedures, including ultrasonics and radiography.
c. Industrial Drawings
Identify components and interpret symbols for the following engineering drawings:
i. Process Flow Diagrams (PFD)
01. State the purpose of a Process Flow Diagram (PFD) (Mechanical Flow Diagram (MFD)), and identify the major information available on a typical PFD.
ii. Process and Instrumentation Diagrams (P&IDs).
01. State the purpose of a Process & Instrumentation Diagram (P&ID), and identify the major information available on a typical P&ID. Explain the naming and symbol conventions for items found on a P&ID.
iii. Engineered construction drawings for pressure vessels and other equipment.
01. Interpret information provided on a typical, approved construction drawing for a pressure vessel and other mechanical equipment.
iv. Equipment layout.
01. State the purpose and identify the components of a typical Equipment Layout Drawing.
v. Material Balance.
01. State the purpose and interpret information provided on a Material Balance Drawing.

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EXAM PART A2
05. 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.
01. Explain the purpose and the legislated authority of the “Boiler Branch” jurisdictions in Canada.
02. Recognize the naming conventions of the various jurisdictions and explain how power engineers interact with their own jurisdiction.
03. Describe the general content of a typical “Boiler and Pressure Vessel Act” and its associated “Regulations”.
04. Explain the adoption of codes and standards by jurisdictions in Canada and identify the main standards that have been adopted with respect to boilers and pressure equipment.
05. Explain the purpose and scope of the National Board of Boiler Inspectors (NBBI).
06. Describe the general procedure and regulations that must be followed in order to construct, install, and place a new boiler or pressure vessel into service in Canada.
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**
01. Rules for construction of power boilers.
02. Rules for construction of heating boilers.
03. Explain the scope of the ASME, and state the purpose and general content of the following sections of the ASME Boiler and Pressure Vessel Code: Sections I, II, IV, V, VI, VII, VIII (Divisions I and II), and IX.
ii. CSA Standard B.51 -Boiler, Pressure Vessel & Pressure Piping Code **CSA Standard B.52 -Mechanical Refrigeration Code**
01. Describe the scope and general content of the CSA B51 Boiler, Pressure Vessel & Pressure Piping Code.
02. Describe the scope and general content of the CSA-B52 Mechanical Refrigeration Code.
iii. National Board Inspection Code
01. Explain the purpose and scope of the National Board of Boiler Inspectors (NBBI).
06. 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.
01. Given the tube material specification numbers and other necessary parameters, use the formulas in ASME BPVC Section I, PG-27.2.1 to calculate either the minimum required wall thickness or the maximum allowable working pressure for a boiler tube.
02. Given the required specifications and operating conditions, use formulae PG-29.1 to calculate the required thickness of a seamless, unstayed dished head.
03. Given the material specification, construction method, and other necessary parameters, use the formulae PG-27.2.2 to determine the required thickness and or maximum working pressure for boiler drums, headers, or piping.
b. Sizes and capacities of boiler safety valves.

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01. Using ASME BPVC Section I, PG-67 to PG-73, identify code information with respect to pressure relief valves and, using Table A-44, calculate the required pressure relief valve capacity for a given boiler.
07. Fuels and Combustion
a. Requirements for efficient combustion of boiler fuels; complete and incomplete combustion.
01. Explain/define combustion, incomplete combustion, combustion products, and write balanced combustion equations.
02. Explain the purpose and benefits of excess air and calculate the theoretical and excess air required for the complete combustion of a given fuel.
b. Classification, properties and combustion characteristics of coal, fuel oil and natural gas; other (non-fossil) fuels .
01. Describe the properties, classifications and combustion characteristics of coal.
02. Describe the properties, classifications and combustion characteristics of Fuel oil.
03. Describe the properties, classifications and combustion characteristics of natural gas.
04. Explain the use and combustion characteristics of alternatives to traditional fossil fuels, including biomass fuels, coke, and oil emulsions.
c. Fuel analysis; proximate, ultimate, fuel heat value; calorimetry.
01. Explain proximate analysis, ultimate analysis, and heating value of a fuel and describe the use of calorimetry to determine calorific value.
02. Given the ultimate analysis of a fuel, use Dulong's Formula to calculate the heating value of the fuel.
d. Combustion chemistry; combustion equations for coal, oil, and gas; molar masses for combustion products.
01. Calculate the mass of combustion products using molar mass.
e. Combustion calculations; oxygen, air and excess air required, given fuel analysis.
01. Calculate quantities of oxygen, air, and excess air from a given flue gas analysis.Explain the analysis of flue gas for the measurement of oxygen (O2), carbon monoxide (CO), and carbon dioxide (CO2) in relation to combustion efficiency.
f. Flue gas analysis methods and devices; CO; CO2 and 02.
01. Explain the analysis of flue gas for the measurement of O2, CO, and CO2 in relation to combustion efficiency.Describe typical, automatic flue gas analyzers.
g. Control of emission standards: NOx, SO2, particulates.
01. Explain the formation, monitoring, and control of nitrogen oxides (NOX), sulfur dioxide (SO2), and particulates.
08. Piping
a. Codes and standards for pressure piping: ASME,CSA, ASTM; identification and sizes of piping; B31.1, power piping vs B31.3 process piping.
01. Identify and explain the general scope of the CSA Group, ASME, ANSI, and ASTM International codes and standards with respect to piping and pipe fittings.Differentiate between power piping (ASME-B31.1) and process piping (ASME-B31.3).
02. Identify the size of pipe required for a particular installation, process, or operating condition using pipe specifications and ASME BPVC sections I and II.
b. Ferrous piping materials and methods of manufacture; specifications and service ratings; non-ferrous materials.
01. Explain methods of pipe manufacturing, size specifications, and service ratings, and the material specifications and applications for ferrous pipe.

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02. Explain the materials, code specifications, and applications of common non-ferrous metal piping and cast-iron piping.
c. Non-metallic piping: materials and applications.
01. Explain the materials, construction, and approved applications of common non-metallic pipe.
d. Strength of piping; effects of temperature on piping.
01. Explain the effects of temperature on piping; explain the mechanisms and the dangers of expansion in piping systems, including attached equipment.
e. Piping connection methods: threaded, flanged, welded; design, materials, selection and installation of gaskets.
01. Describe screwed, welded, and flanged methods of pipe connection, and identify the fittings used for each method.
02. Describe the construction, designs, and materials of flange gaskets, and explain the confined, semi-confined, and unconfined flange styles.
f. Designs and applications of expansion devices, supports and anchors.
01. State the purpose and explain the designs, locations, and applications of simple and offset U-bend expansion bends.
02. Describe the designs, locations, care, and maintenance of slip, corrugated, bellows, hinged, universal, pressure-balanced, and externally pressurized expansion joints.
03. Describe the design, location, and operation of pipe support components, including hangers, roller stands, variable spring hangers, constant load hangers, anchors, and guides.
g. Types of steam traps; trap sizing and selection; trap installation configurations; trap inspection and maintenance; trap flow calculation.
01. Explain the dynamics, design, and components of steam and condensate return systems for steam lines and condensing vessels. Explain the roles and locations of separators and traps.
02. Describe the design, operation, and application of ball float, inverted bucket, thermostatic, bimetallic, impulse, controlled disc, and liquid expansion steam traps.
03. Explain the selection, sizing, and capacity of steam traps, and explain the factors that determine efficient trap operation.
04. Explain the procedures for the commissioning, testing, and maintainence of steam traps.
h. Water hammer: effects; causes; design and operational preventions.
01. Explain and compare condensate-induced and flow-induced water hammer in steam and condensate lines. Explain the typical velocities, pressures, and damage that can be created in steam and condensate lines due to water hammer.
02. Describe specific trap and condensate return arrangements that are designed to prevent water hammer in steam and condensate lines.
03. State the precautions that must be observed to prevent water hammer, and describe a typical steam system startup procedure that prevents water hammer.
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.
01. State the purposes of insulation for piping and process equipment and explain the properties required for a good insulating material. Explain thermal conductivity, K-Factor and R-Value.
02. Identify the most common industrial insulating materials, describe the composition and characteristics of each, and explain in what service each would be used.

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03. Describe common methods for applying insulation to piping and equipment, including wrap and clad, blanket, insulated covers, and boxes. Explain the care of insulation and cladding, and the importance of maintaining it in good condition.
j. Common and specialty valves: purpose, design, operation and applications; valve flow configurations; valve trim; actuator types.
01. Explain the factors that determine the suitability and applications for gate valves, globe valves, ball valves, plug valves, butterfly valves, and needle valves.
02. Explain the factors that determine the selection of valve materials, and describe examples of typical valve materials, trim, and identification for common valve services.
03. Describe the configurations and applications for gate valves, including gate designs (solid, split, flexible, sliding), stem configurations (rising, non-rising, outside screw-and-yoke, inside screw), and bonnet designs (flanged, screwed, welded).
04. Describe the designs and applications of globe valves, including conventional disc, composition disc, plug-type disc, and angle valves.Describe high-pressure plug-type control valves.
05. Describe the designs, application, and operation of single-seated and double-seated balance valves. Explain caged trim for balanced control valves.
06. Describe the designs and applications of typical plug valves, including tapered and cylindrical plug, four-way, eccentric, and jacketed.
07. Describe the designs and configurations for mixing and diverter valves.
08. Describe the designs and operations of diaphragm valves.
09. Describe designs and operations of butterfly valves, including vertical, horizontal, swing-through, lined, and high-performance.
10. Describe the design, application, and operation of gear, motor, air-diaphragm, and air-piston actuators for valves.
09. Electrotechnology
a. Direct Current Theory
i. Electron theory; theory of magnetism; magnetic field; force on conductor.
01. Explain the production of electron flow in a circuit, and define circuit voltage, amperage, and resistance.
02. Define the terms magnetism, magnetic field, temporary and permanent magnets, magnetic flux, reluctance, and magnetization of a coil.
03. Describe Weber's molecular theory of magnetism.
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.
01. Explain electromagnetic induction and how it produces generator action and motor action.
02. Describe Faraday's and Lenz's Laws of Induction.
03. Explain self-induction and mutual induction of a coil.
b. Direct Current Machines
i. Generators: operating principles, construction, commutation, speed and voltage control; types (shunt, series and compound)
01. Describe the design and operating principles of a DC generator or motor, clearly stating purposes of the armature, commutator, winding and poles.
02. Explain how back EMF, armature reaction, and torque are created and their influence on a DC generator.

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03. Given the speed, flux, number of poles, and number of conductors, calculate the back EMF created by a DC generator.
04. Explain separate and self excitation, and describe the voltage and load characteristics of shunt, series, and compound generators. State where the various types would be used.Explain how excitation of a DC generator is controlled.
05. State where the various types would be used.
06. Explain how excitation of a DC generator is controlled.
ii. Motors: principle of operation, torque development and measurement, armature reaction, interpoles, speed control, methods of starting, types (shunt, series and compound), protection devices
01. Explain the speed and load characteristics of shunt, series, and compound DC motors; define and calculate percent speed regulation, and explain how speed is controlled in DC motors.
02. Explain DC motor torque characteristics and describe the starting mechanisms for DC motors.
c. Alternating Current Theory
i. Generating an alternating EMF; sinusoidal wave forms; phase relationships.
01. Explain the creation of single-phase and three-phase alternating power, and define cycle, frequency, and phase relationships (voltage/current) for AC sine waves.
ii. Resistance in AC circuits; inductive and capacitive reactance; impedance; power and power factor; single and multi-phase circuits.
01. Define the following terms and explain their relationship in an AC circuit: inductance, capacitance, reactance, impedance, power factor, and alternator ratings (kVA and KW).
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)
01. Describe the stator and rotor designs, operation, and applications for salient pole and cylindrical rotor alternators.
02. Describe water, air, and hydrogen cooling systems for large generators.
03. Explain parallel operations of alternators, and state the requirements for synchronization. Describe manual and automatic synchronization.
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
01. Describe the design, applications, and operating principles for large three-phase squirrel cage and wound rotor induction motors.
02. Describe the design and operating principle of synchronous motors.
03. Explain variable speed control, variable speed starting, and step starting for large induction motors.
iii. Transformers: operating theory; types (design and construction), losses and efficiency; methods of cooling; safety and fire protection
01. Explain the principles and applications of power transformation.
02. Describe the designs and components of typical core and shell-type transformers, including cooling components.
e. AC Systems, Switchgear, Safety
i. Components, layout, and operation of a typical industrial AC power system

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01. Using a one-line electrical drawing, identify the layout of a typical industrial AC power system with multiple generators, and explain the interaction of the major components.
ii. Components of an AC generator panel
01. Explain the function of the typical gauges, meters, and switches on 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.
01. Explain the purpose and function of the circuit protective and switching equipment associated with an AC generator: fuses, safety switches, circuit breakers, circuit protection relays, automatic bus switchover, grounding and lightning arrestors.
iv. UPS/Inverter Systems: purpose, components, operation; battery design and maintenance.
01. Explain the components and operation of a typical uninterruptible power supply (UPS) system.
v. Electrical safety for operators
01. Explain safety procedures and precautions that must be exercised when working around and operating electrical system components. Explain grounding.
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.
01. Use Ohm’s law and Kirchhoff’s laws to calculate current, resistance, or voltage drop in series or parallel multi-resistor circuits.
02. Calculate unknown resistances using a Wheatstone Bridge circuit.
b. Work, energy, power: relationship between electrical, mechanical and heat units.
01. Explain and perform calculations involving electrical power, work, and energy.
c. Sinusoidal Wave Forms: maximum, average and root mean square root values; frequency; phase.
01. Calculate the frequency, period, and phase angle for an AC sine wave. Identify the relationships between poles, frequency, and speed for AC machines.
02. Define terms and calculate the peak-to-peak, root mean square, and maximum values for ac voltage and current.
d. AC Circuits: inductive reactance, capacitive reactance, impedance, KVA; power factor
01. Given required parameters, calculate the inductive reactance, capacitive reactance, total reactance, and impedance for an ac circuit, plus circuit frequency and current flow.
02. Calculate real power, imaginary power, and power factor for an AC circuit.
03. Given the load, voltage, and power factor of a three-phase generator, calculate the kVA and kW ratings of the generator.
e. Relationship between poles, frequency, speed for AC machines
01. Identify the relationships between poles, frequency and speed for AC machines.
f. Transformer calculations; step up and step down
01. Perform transformer calculations.
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
01. Describe the operation, components, and terminology for a typical control loop.

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02. Describe the operation and components of a purely pneumatic control loop.Explain the function of each component.
03. Describe the operation and components of an analog/electronic control loop.Explain the function of each component.
04. Describe the operation and components of a digital control loop.Explain the function of each component.
ii. on-off, proportional, reset, derivative control strategies
01. Explain the purpose, operation, and give examples of on-off, proportional, proportional-plus-reset, and proportional-plus-reset-plus-derivative control.
02. Define proportional band and gain.
iii. Feed forward, feedback, cascade, ratio, split-range, select control
01. Describe and give typical examples of feedforward, feedback, cascade, ratio, split-range, and auto-select control.
iv. Alarm and shutdown functions in a control loop; operator interfaces with control loops
01. Explain, with examples, the purpose and incorporation of alarms and shutdowns into a control loop/system.
02. Explain the interactions that occur and the interfaces that exist between an operator and the various components of a control loop/system, including the components of a controller interface.
b. Instrument and Control Devices: design and principles of common temperature, pressure, flow, and level instruments
01. Describe the design, operation, and applications of the following temperature devices: bimetallic thermometer, filled thermal element, thermocouple, RTD, thermistor, radiation pyrometers, and optical pyrometers.
02. Describe the design, operation, and applications of the following pressure devices: Bourdon tubes, bellows, capsules, diaphragms, and absolute pressure gauges.
03. Describe the design, operation, and applications of the following flow devices: orifice plate, venturi tube, flow nozzle, square root extractor, pitot tube, elbow taps, target meter, variable area, nutating disc, rotary meter, and magnetic flowmeter.
04. Describe the design, operation, and applications of the following level devices: atmospheric and pressure bubblers, diaphragm box, differential pressure transmitters, capacitance probe, conductance probes, radiation and ultrasonic detectors, and load cells.
c. Distributed and Logic Control Systems
i. Components, layout, functions of distributed control system
01. Explain distributed control and describe the layout and functioning of a typical distributed control system.
02. Explain the function of each major components of the system.
ii. DCS operator interface components; trending; data logging; alarms and shut-downs.
01. Identify and explain the functions of the major components of the operator interface unit (OIU), including controller interfaces, displays, alarms, and shutdown.
iii. Programmable logic controllers: purpose, design, components; applications; ladder diagrams.
01. State typical applications and explain the purpose and functioning of a programmable logic controller, including the operator interfaces. Explain a ladder logic diagram.
iv. Supervisory control and data acquisition systems (SCADA) as used in process control: purpose and general functions

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01. State the purpose and explain the general functioning of a communication and data acquisition system (e.g., SCADA) as it relates to process control.
12. Industrial Safety and Fire Protection
a. Safety Management Programs
i. Introduction to OH&S Acts in general
01. Explain the general intent, power, and scope of Occupational Health and Safety (OH&S) Legislation.
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
01. Explain the intent and scope of a workplace OH&S program, and state the responsibilities of the company, employees, and the OH&S committee within the program.
02. Define and give examples of typical workplace hazards and describe a system of hazard identification and control.
03. Explain the purpose of work permits and describe typical hot and cold work permit systems.
04. Explain the purpose of equipment lockout, describe lockout devices, and describe a typical equipment lockout procedure.
05. Define and identify confined spaces, and describe a typical confined space entry permit and entry procedure.
06. Explain the hazards of excavation, and describe typical excavation procedures and permits.
07. Explain the purpose and describe the typical components of an emergency response plan.
08. State the purpose of WHMIS, explain the use of labels and material safety data sheets, and explain the responsibilities of employer and employee.
09. Explain the purpose, requirements, and procedures for incident and accident investigation and reporting.
b. Fire Protection Systems
i. Classes of fire; extinguishing methods
01. Explain the classifications of fires, and describe the extinguishing media that are appropriate for each classification.
ii. Components and operation of industrial fire detection and alarm system
01. Describe the components and operation of a typical fire detection and alarm system in an industrial setting.
iii. Sprinkler systems (dry and wet stand pipe); pre-action and deluge; design and operation
01. Describe the design and operation of a typical standpipe system.
02. Describe the wet pipe, dry pipe, preaction, and deluge designs for sprinkler systems.
iv. Fixed fire systems: firewater pump, loops, hydrants; vessel deluge system; foam systems
01. Describe the layout, components and operation of a typical firewater system with fire pump and hydrants.
02. Explain seasonal considerations for a firewater system.
03. Describe the construction and operation of a typical fire hydrant.
04. Explain the purpose of and describe a typical deluge water system for hydrocarbon storage vessels.

05. Explain the purpose of and describe a typical foam system for process buildings and tanks.
v. Industrial fire response
01. Describe a typical fire response procedure for an industrial setting.

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EXAM PART B1
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
01. Explain the difference between packaged, shop assembled, and field-erected watertube boilers. Explain how boilers are rated.
02. Explain the process of water circulation in a watertube boiler and the factors that influence circulation.
03. Identify examples of and describe the A, D, and O design configurations, and explain the water and gas circulation patterns for each. Define integral furnace.
04. Define integral furnace.
05. Explain the water and gas circulation patterns for integral furnace A, D, and O boiler configurations.
06. Define a steam generating unit, identify oil and gas-fired units, and explain the components, heating surfaces, and flow patterns through a typical unit. State typical temperatures throughout the unit.
07. State typical temperatures throughout the unit.
08. Differentiate between critical and super-critical boilers.
09. Explain the purpose and advantage of forced circulation and describe the flow through a typical controlled circulation boiler.
10. Explain the purpose and design of a once-through boiler.
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
01. Describe typical designs, components and operating strategies for once-through (OTSG) boilers.
02. Describe typical designs, components and operating strategies for heat recovery (HRSG) boilers.
03. Describe typical designs, components and operating strategies for fluidized bed boilers.
04. Describe typical designs, components and operating strategies for black liquor recovery boilers used in pulp mills.
05. Describe typical designs, components and operating strategies for refuse boilers used in waste disposal.
06. Describe typical designs, components and operating strategies for wasteheat biomass boilers.
07. Describe typical design, components, and operation strategies for 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
01. Explain top and bottom support and describe the support techniques for various components of a large boiler, including lateral supports for furnace walls. Explain allowances for expansion.

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02. Explain the purpose, design, locations and installation methods for boiler casing insulation, refractory, and cladding.
03. Describe the methods used to fabricate boiler tubes.
04. Describe the preparation, fabrication, and testing of boiler drums.
05. Describe methods of attaching tubes to drums and headers, including expanding and welding, and explain where each method would be used.
06. Explain code requirements for, and describe the designs and installation of, manholes and handholes, including welded handholes.
07. Explain procedures for removing and installing covers.
08. Describe acceptable nozzle attachment methods, including reinforcements; describe inspection openings.
ii. Field assembly of a large watertube boiler
01. Describe the field assembly of a large boiler or steam generating unit.
iii. Boiler metals – applications and purpose
01. Explain the fundamental properties and applications for materials used in boiler construction
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
01. Describe baffle designs and locations, and explain their significance to boiler heat transfer.
02. Describe the designs of integral furnace sidewall and header arrangements, including tube-and-tile, tangent tube, and membrane.
ii. Superheaters: primary, secondary, convection, radiant, integral and separately-fired; operating characteristics;
01. Define primary, secondary, convection, radiation, platen, and pendant as they apply to superheaters.
02. Describe the locations of superheaters within a steam generator and state the operating characteristics of convection and radiant superheaters.
03. Explain the purpose and design of a separately fired superheater.
iii. Reheater designs
01. Explain the position of and flow through the reheater in relation to the superheaters.
02. Explain the purpose and describe the locations of reheaters.
iv. Economizers: integral and separate; tube styles, advantages/ disadvantages
01. Describe designs and locations of integral and separate economizers.
v. Air Heaters: plate, tubular, rotary regenerative designs; heater corrosion control; advantages/disadvantages
01. Describe the designs, operation, and location of plate, tubular, and rotary regenerative air heaters.
vi. Sootblowers: stationary and retractable, locations, shot cleaning
01. Explain operating care and considerations that must be given to the various heat transfer sections of the boiler.
02. Describe sootblowing systems and describe the procedures for operating sootblowers.
03. Explain a typical water and gas temperature profile through a large steam generating unit.
d. High Pressure Boiler Fittings

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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
01. Describe common designs, connections, and components of high-pressure water columns and flat gauge glasses, including illumination, quick shut-off devices, and bull's eye glasses.
02. Explain testing and maintenance of a high-pressure gauge glass.
ii. Safety valves; setting
01. Describe the design, installation, operation, and setting of a high-pressure safety valve.
02. Explain the Code requirements for size, capacity and location of safety valves on a boiler.
iii. Low-water fuel cut-offs; float and probe designs
01. Describe the float and probe designs for low-water level cutoffs and explain how these are tested.
iv. Steam outlet fittings and non-return designs
01. Describe boiler steam outlet arrangements and fittings, including gate, angle, and globe stop valves and globe, Y-type, angle, and spring-cushioned non-return valves.
v. Pressure gauges; feedwater connections; vents; and blowdown valve designs; blowdown procedures; blowdown tank
01. Describe the code requirements for boiler pressure gauges, including attachment and locations.
02. Describe manual blowdown piping arrangements.
03. Describe the design and operation of sliding disc, seatless sliding plunger, seat and disc, and combination valves.
04. Explain manual blowdown procedures.
05. Describe the requirements for a blowdown tank.
vi. Drum Internals: baffles, scrubbers, separators, driers, piping circulation and separation of steam and water
01. Explain the components of the steam drum internals of a watertube boiler.
02. Describe the design and operation of various steam separation devices, including baffles, primary and secondary separators, and scrubbers.
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)
01. Describe a solid fuel supply system from stockpiles to burners for a typical pulverized solid fuel furnace.
02. Describe the design and operation of a pulverized coal burner, and explain turbulent vertical, tangential, and cyclone furnaces.
03. Describe the design and operation of ball, impact, ball race, and bowl mill pulverizers.
04. Describe the designs and operations of underfeed, overfeed, and crossfeed stokers for furnaces burning solid fuels.
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

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01. Describe a complete fuel oil supply system from storage tanks to burners, and explain the function of each system component.
02. Describe the design and operation of air, steam, and mechanical atomizing burners.
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
01. Describe a complete fuel gas supply system from the fuel gas header to boiler burners, and explain the function of each component, including control and shut-off valves, auto-vents, and instruments.
02. State the typical operating pressures of a fuel gas supply system.
03. Describe the design and operation of spud and ring burners, and explain high-efficiency, low NOX designs.
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
01. Define and explain the applications and designs of natural, forced, induced, and balanced draft.
02. Explain how draft is measured, monitored, and controlled in a large, balanced draft boiler.
03. Explain the position of control dampers.
04. Describe typical draft fan designs, single and double inlet arrangements, and explain methods used to control fan output.
05. Explain the start-up and the running checks that must be made on draft fans.
06. Describe typical windbox and air louver arrangements and distinguish between primary and secondary air.
v. Flue gas clean-up methods and equipment: precipitators, filters, ash handling systems; SO2 recovery systems
01. Describe the design and operation of flue gas particulate clean-up equipment, including mechanical and electrostatic precipitators and baghouse filters.
02. Describe the design and operation of ash handling systems, including hydro and air systems, bottom ash systems, and scraper conveyor systems.
03. Describe the designs and operation of SO2 recovery systems, including lime and wet gas scrubbing.
f. Boiler Operation and Maintenance
i. Manual start-up and shut-down procedure for large, industrial boilers
01. List the steps for a manual start-up and shut-down of a typical large industrial boiler.
ii. Initial start-up (commissioning) of a new boiler
01. Explain the steps involved in the commissioning of a new boiler or before restarting a boiler after major repairs, including: hydrostatic test, external and internal inspections, drying out refractory, boiling out, and testing shutdowns and safety devices.
iii. Routine and emergency operations
01. Explain routine tasks and visual monitoring that must be performed by the operator on a large operating boiler.
iv. Causes and prevention of boiler furnace and pressure explosions
01. Explain the procedures and precautions that an operator must exercise to avoid furnace and pressure-side explosions.
v. Chemical and mechanical boiler cleaning methods; boiling out

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01. Describe typical equipment and procedures for cleaning the water side of a boiler mechanically and chemically.
vi. Methods of cleaning and preparing a boiler for inspection
01. Describe the wet and dry methods when laying up a boiler for an extended time, including nitrogen blanketing.
02. Describe the proper shut down and preparation of a boiler for internal inspection.
vii. Inspection: fire and water sides; safety
01. Describe a thorough inspection of the water and furnace sides of a boiler.
viii. Hydrostatic test
01. Describe the typical steps involved in a 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
01. Describe on-off and single-element control of boiler feedwater.
02. Explain swell and shrinkage in a boiler.
03. Describe the components and operation of a two-element feedwater control system, explaining the interaction of the controllers.
04. Describe the components and operation of a three-element feedwater control system.
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
01. Describe the components and operation of a direct combustion control system.
02. Describe the components and operation of a ‘steam-flow-airflow’ combustion control system.
03. Describe the components and operation of a ‘fuel flow-airflow’ combustion control system.
04. Describe the components and operation of an ‘airflow-fuel flow’ combustion control system.
05. Describe the components and operation of a multi-element combustion control system.
ii. Safety devices and interlocks
01. Describe combustion safety devices and interlocks.
iii. Flame failure detection: continuous, intermittent, interrupted pilots; photo-electric cells
01. Differentiate between continuous, intermittent, and interrupted pilots.
02. Define failure detection (photoelectric cells).
iv. Automatic, programmed boiler start-up and shut-down sequence
01. Describe the automatic, programmed start-up sequence for a gas-fired boiler.
c. Steam temperature control
i. desuperheating control
01. Describe steam temperature control methods and equipment, including attemperation (desuperheating), gas recirculation, gas bypass, and tilting burners.
ii. attemperation
XX. Explained in curriculum objective for syllabus statement B1.14.c.i.01
iii. gas recirculation
XX. Explained in curriculum objective for syllabus statement B1.14.c.i.01
iv. gas bypass
XX. Explained in curriculum objective for syllabus statement B1.14.c.i.01

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v. tilting burners
XX. Explained in curriculum objective for syllabus statement B1.14.c.i.01
15. Feedwater Treatment
a. Feedwater impurities and their effects on boiler operation
01. Identify boiler feedwater impurities.
02. Evaluate the effects of boiler feedwater impurities 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
01. Describe the design and explain the terms, purpose and operation for a clarifier, using coagulation and flocculation.
02. Describe the design and explain the terms, purpose, and operation of gravity and pressure filters.
03. Describe the design and explain the terms, purpose, and operation, including chemical reactions, for a cold lime softener.
04. Describe the design and explain the terms, purpose, and operation of a hot lime softener. Describe the components of a complete system.
05. Explain the principles of ion exchange softening in general, identifying the common anions and cations in untreated water.
06. Describe the design, components, and operation of a sodium zeolite softening system, including chemical reactions.
07. Describe the design, components, and operation of a hydrogen zeolite softening system, including chemical reactions.
08. Describe the design, components, and operation of a dealkalization system, including chemical reactions.
09. Describe the design, components, and operation of a demineralizer system, including mixed bed and degasification.
10. Explain the principle and operation of a reverse osmosis system.
11. Describe the design, principle, and operation controls of a typical deaerator.
12. Describe the design, components, and operation of evaporators for external water treatment.
13. Describe the operation of a hot phosphate softener.
c. Internal Boiler Water Treatment
i. Causes, effects and controls for boiler internal water problems
01. Explain the causes and effects of boiler scale; explain the most common internal methods of scale control, including phosphate treatment, chelate treatment, sludge conditioning and dispersion.
ii. pH control – magnetite layers, acidic and caustic corrosion
01. Explain the causes and effects of boiler and condensate return line corrosion; explain treatment methods for acidic, caustic, oxygen, and carbon dioxide corrosion, including sulphite, hydrazine, and amine treatment.
iii. Sludge conditioning and dispersion; modern sludge dispersants
01. Explain the most common methods of sludge conditioning and dispersion.
iv. Chemical deaeration – oxygen corrosion; sulphite programs; hydrazine
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v. Carryover – priming, misting, foaming
01. Explain the mechanical and chemical causes, effects, and types of carryover; explain methods of carryover control, including the use of anti-foam and blowdown.
vi. Dissolved solids – blowdown control; conductance; simple and heat recovery blowdown systems; automatic blowdown systems
01. Describe the design and explain the operation of simple, heat recovery, and automatic blowdown systems.
vii. Return line corrosion – neutralizing and filming amines
01. Explain the causes and effects of boiler and condensate return line corrosion; explain treatment methods for acidic, caustic, oxygen, and carbon dioxide corrosion, including sulphite, hydrazine, and amine treatment.
viii. Scale control – phosphate and chelate programs
MISSING CURRICULUM STATEMENT
d. Chemical feed systems: shot and continuous feed systems; chemical feed pumps
01. Describe typical chemical feed systems, including pot feeders, continuous feed systems with day tanks, and continuous feed systems with pump tanks.
e. Feedwater and boiler water testing methods: automatic sampling systems and monitors; boiler and steam system parameters and test locations
01. Explain, in general terms, the sampling and testing strategies for boiler internal conditions.Describe typical sampling and automatic monitoring equipment.
16. Pumps
a. Theory of pumping: Define and explain pump head terms, perform pump head and pressure calculations, explain cavitation
01. Explain the relationship between the height of a liquid, the density of the liquid and the pressure exerted at the bottom of the liquid.
02. Perform simple calculations involving this relationship.
03. Define equivalent head, and calculate equivalent heads for water and other liquids.
04. Define static suction head, static suction lift, static discharge head, total static head, and pressure head, and calculate each of these for a given pump arrangement.
05. Define and calculate friction head and velocity head.
06. Define dynamic suction head, dynamic suction lift, dynamic discharge head, and total dynamic head, and calculate each of these for a given pump arrangement.
07. Explain vapor pressure, cavitation, and net positive suction head (NPSH).
08. Calculate the required suction pressure for a water pump, given the manufacturers required NPSH.
b. Reciprocating pumps: pump drivers; single and double-acting designs; plunger type; diaphragm type; pump protection
01. Explain the principle of operation and describe the components of typical piston and plunger reciprocating pumps.
c. Centrifugal pumps
i. Classification and principles of operation for volute, diffuser and turbine pumps; axial and mixed flow
01. Explain the designs and operating principles of volute and diffuser centrifugal pumps, including impeller designs.
02. Describe centrifugal pump arrangements, including vertical, horizontal, single and double suction, opposed impellers, multi-stage, split casings, and barrel casings.
03. Describe the design and applications of axial and mixed-flow pumps.

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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
01. Describe the design and components of a multistage centrifugal pump, clearly stating the purpose and general design of wear rings, shaft sleeves, seals, bearings and lubrication components, vents, and drains.
02. Explain design features that eliminate thrust in large centrifugal pumps.
iii. Operation: starting and stopping, priming
01. Explain priming, startup, capacity control, and operating cautions for centrifugal pumps.
iv. Typical pump installation; auto-recycle valve
01. Describe systems used to maintain minimum flow through a centrifugal pump.
d. Rotary pumps: design and operation of gear, lobe, screw
01. Explain the designs and operating principles of the external gear, internal gear, sliding vane, lobe, and screw type rotary pumps.
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
01. Describe the equipment, procedures, and applications of shielded metal arc welding (SMAW). Explain the classification of arc welding electrodes.
02. Describe the equipment, procedures, and applications of submerged arc welding (SAW).
03. Describe the equipment, procedures, and applications of gas tungsten arc welding (GTAW).
04. Describe the equipment, procedures, and applications of gas metal arc welding (GMAW).
b. Electrodes: classification, types and uses; where and why each would be used
01. Explain the classification of arc welding electrodes.
c. Fabrication and repairs: weld preparation; preheating, performing a boiler tube repair, postweld heat treatment (stress relieving)
01. Explain weld preparation and terminology of a butt weld; explain preheating and post weld heat treatment.
d. Causes and effects of common weld defects
01. Describe common defects in welds, including undercut, lack of penetration, porosity, slag inclusion, and cracking; explain how each occurs and its effect on the integrity of the weld.
e. Weld inspection procedures: non-destructive examination techniques; destructive examination techniques
01. Explain the equipment and procedures for dye penetrant, magnetic particle, radiographic, and ultrasonic inspection of a weld; explain the potential weld defects revealed by each test.
f. Welding Procedure and Welder's Performance Qualifications per ASME Code, Sect.9
01. Explain the requirements and process for Weld Procedure and Welder Performance Qualification, per the ASME Code, Section 9.
18. Pressure Vessels
a. Explain design, construction, operation and repair regulation of pressure vessels, including stamping and nameplate details
01. Define “pressure vessel” and explain, in general terms, how pressure vessels are regulated in design, construction and repair (including purpose of Section VIII, ASME).
02. Explain the stamping/nameplate requirements for pressure vessels, and identify terms and specifications on a typical nameplate.

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b. Head, nozzle, manway designs
01. Describe the weld locations on a typical pressure vessel, and identify head designs, including ellipsoidal, torispherical, hemispherical, conical, and toriconical.
02. Describe acceptable nozzle attachment methods, including reinforcements; describe INSPECTION OPENINGS.
c. Loads and stresses on pressure vessels
01. Explain the loads that contribute to stresses in pressure vessels, including pressure, thermal, attachments, static, wind, seismic, and cyclic loads.
d. Typical components/fittings on a pressure vessel
01. Explain the components and fittings of a typical pressure vessel.
e. Safe operating and maintenance consideration, including hydro and pneumatic testing; inspection
01. Explain operating and maintenance considerations for the safe operation of pressure vessels, including the appropriate use of hydrostatic and pneumatic testing.

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EXAM PART B2
19. Prime Movers
a. Steam Turbines
i. Impulse and reaction principles; nozzles; blade shapes
01. Explain impulse turbine operating principles.
02. Describe convergent and divergent nozzles, and the pressure-velocity profiles through an impulse section.
03. Explain reaction turbine operating principles and describe the pressure-velocity profiles through reaction blading.
ii. Turbine arrangements: staging and compounding: principles and p-v diagrams for pressure, velocity and pressure-velocity compounding
01. Explain pressure, velocity, and pressure-velocity compounding of impulse turbines.
02. Describe the pressure-velocity profiles and the purposes and applications of each.
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
01. Describe the designs of typical turbine casings, and state the purpose and location of casing fittings, including drains and sentinel valves.
02. Describe the designs and principles of casing/shaft seals.
03. Describe the designs and applications of disc and drum rotors.
04. Describe methods of rotor and casing blade attachment and explain blade-sealing arrangements.
05. Explain thrust in a large turbine, and describe methods to offset thrust, including thrust bearings, dummy piston, and thrust-adjusting gear.
06. Identify typical designs and components for large industrial turbines. Explain typical size/capacity rating specifications and explain typical applications.
07. Explain the use and design of reducing gears attached to steam turbines.
08. Describe typical lube oil systems for small and large steam turbines.
09. Explain the purpose and describe the design and operation of barring gear and jacking oil systems on a large turbine.
10. Describe a condensing turbine circuit and explain typical operating parameters.
11. Explain the purpose and operation of the auxiliary equipment on a condensing and an extraction turbine.
12. Explain the operation and purpose of the following equipment: Turbine gland seal system; Blowdown valve packing on a re-heat turbine with combined HP/LP opposed flow sections; The Ventilator (dump) valve on a large load rejection - turbine trip
13. Identify typical designs and components for small industrial turbines. Explain typical size/capacity rating specifications and explain typical applications.
iv. Explain purpose and arrangements of condensing, bleeder, topping, extraction, cross and tandem compounded turbines
01. Explain the purpose, general operating principles and arrangement for each of the following turbine types: condensing, condensing-bleeder, backpressure, extraction, topping, mixed-pressure, cross-compounded tandem compounded double flow and reheat..
v. Turbine governor types; speed-sensitive, pressure-sensitive, nozzle, throttle, bypass; mechanical, mechanical hydraulic, electronic-hydraulic; droop and isochronous operation
01. Explain and state the applications, where applicable, of the following governor types: speed-sensitive, pressure-sensitive, nozzle, throttle, and bypass.

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02. Explain governor droop and isochronous control.
03. Explain the operation and the major components of the three main speed-sensitive governor systems: mechanical, mechanical-hydraulic, and electronic-hydraulic.
04. Explain the operation and describe the components of typical mechanical and electronic overspeed trip systems.
vi. Starting and shutting down condensing and extraction turbines
01. Explain the sequence followed for the cold startup and shutdown of a non-condensing steam turbine.
02. Explain the sequence followed for the cold startup and the shutdown of a condensing extraction steam turbine.
vii. Steam turbine condensers: types, air-cooled, water-cooled, Panier style; condenser auxiliaries; condenser operation; feedwater heater system
01. Explain the purposes of a turbine condenser in a steam plant cycle, and describe a typical condensing circuit, with operating temperatures and pressures.
02. Explain the design, operation, and applications of the jet condenser, including the ejector type.
03. Explain the design and applications of the surface condenser, including air-cooled and water-cooled, down flow and central flow.
04. Describe basic condenser construction and how to operate and troubleshoot surface condensers.
05. Explain the effects of air in a condenser, and describe the design and operation of single and two-stage air ejectors.
06. Explain the detection of condenser air leaks.
07. Explain vacuum pumps.
08. Explain the devices and operating considerations used to protect a condenser against high backpressure, high condensate level, and cooling water contamination. Describe a cooling water leak test.
09. Describe the operating conditions and corresponding design considerations for condensate extraction pumps and cooling water pumps.
10. Sketch and describe an open and a closed condenser cooling water system.
11. Describe a feedwater heater system in conjunction with a steam condenser and explain the designs of low-pressure and high-pressure feedwater heaters.
12. Explain the purpose and operation of the auxiliary equipment on a condensing and extraction turbine.
b. Gas Turbines
i. Applications, advantages and disadvantages of gas turbines
01. Explain gas turbine advantages and disadvantages, background and industrial application.
02. Identify the types of gas turbines, their major components and describe the operating principles of a simple gas turbine.
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
01. Explain single and dual shaft arrangements for gas turbines.
02. Describe open cycle and closed cycle operation.
03. Describe a typical open cycle gas turbine installation, including buildings or enclosures, intake and exhaust systems, and reducing gear.

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04. Explain the efficiency and rating of gas turbines and describe the purpose and applications of gas turbine cycle improvements, including intercooling, regenerating, reheating, and combined cycle.
05. Explain the typical operating parameters of a gas turbine; describe the effects of compressor inlet temperature, compressor discharge pressure, and turbine inlet temperature on gas turbine performance.
iii. Main gas turbine components: radial and axial compressors, combustor arrangements and operation, turbine rotor designs
01. Describe the various aspects of compressor design and centrifugal and axial types of compressors.
02. Describe the types, operation, components, and arrangements of combustors.
03. Describe turbine section design and operation especially with respect to blading and materials.
iv. Gas turbine support systems: fuel supply systems; lubrication; barring gear; steam injection; intake and exhaust components
01. Describe the types of bearings used in a gas turbine, and explain the components, operation, protective devices, and routine maintenance of a typical lube oil system.
02. Describe and explain the operation and routine maintenance of a typical fuel gas supply system for a gas turbine.
03. Describe and explain the operation and routine maintenance of a typical fuel oil supply system for a gas turbine.
04. Explain the control of NOX from a gas turbine and describe the purpose and operation of water/steam injection and dry low NOX systems.
05. Explain the purpose, location, and operation of the gas turbine starting motor and turning gear.
06. Describe the compressor intake and the turbine exhaust components.
07. Describe a typical jacking oil system for a gas turbine.
v. Supervisory, protective, and control systems
01. Explain the types and functions of the control systems and instrumentation needed for gas turbine operation.
vi. Starting and stopping procedures and sequences; turbine washing
01. Describe the preparation and complete start-up and loading sequence for a gas turbine.
02. Describe the shutdown sequence and procedure for a gas turbine.
03. Explain the purpose and describe typical on-line and off-line water wash procedures for gas turbine blades.
c. Internal Combustion Engines
01. Explain the operating principles, designs, support systems, and operation of internal combustion engines (ICE).
i. Gasoline engines: spark ignition defined, two-stroke cycle, four-stroke cycle, carburetion; carburetor design and operation, spark ignition components, fuel injection
01. Explain the principles of spark ignition and compression ignition. Describe the operating cycles for two-stroke and four-stroke designs.
02. State the purpose of the major mechanical components of an internal combustion engine.
03. Describe carburetor, fuel injection, battery ignition, and magneto ignition systems for a spark ignition engine.

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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
01. Describe individual pump, distributor, and common rail fuel injection systems for a diesel engine.
02. Explain the monitoring, protection and control devices on a large industrial diesel, including shutdowns and governing.
03. Explain a typical startup procedure for a large industrial Diesel engine, plus the routine monitoring requirements of a running engine.
iii. Engine support systems: fuel systems, lubrication, governing, starting systems and methods, magneto system, cooling systems, supercharging and turbo-charging
01. Explain the purpose and describe the operation of superchargers and turbochargers.
02. Describe and explain the operation of a typical cooling system for an industrial ICE.
03. Describe and explain the operation of a typical lubrication system for an industrial ICE.
04. Describe engine starting devices and systems for Diesel and gas engines.
iv. Thermodynamic heat engine cycles: explain the Otto, Diesel and Brayton cycles
01. Explain the Otto, Diesel, and Brayton thermodynamic heat engine cycles.
20. Cogeneration
a. Purpose, advantages, components of cogeneration systems
01. Define cogeneration and explain its purpose, advantages, and applications.
b. simple and combined cycle
01. Describe typical cogeneration systems that use internal combustion engines (gas or diesel) and heat recovery water heaters (HRWHs).
c. using gas turbines and internal combustion engines
01. Explain typical industrial cogeneration components and applications.
d. single and dual shaft arrangements
01. Explain single-shaft and multi-shaft combined-cycle power plants.
e. control strategies and components
01. Explain the control strategies and components, for both power and steam production, including diverter and duct burner operation.
f. environmental considerations
01. Explain the environmental considerations and techniques in the operation of a cogeneration system.
g. heat recovery boilers and water heaters
01. Describe the various designs of heat recovery steam generators (HRSGs) and explain their industrial applications.
h. operating procedures
01. Explain a typical start-up procedure for a combined cycle cogeneration system.
i. typical industrial cogeneration applications
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21. Compressors
a. Theory of Compression
i. Adiabatic and isothermal compression; pressure volume relationships; compression ratio, capacity, multi-staging; effect of altitude and moisture
01. Explain compressor terminologies, including compression ratio, capacity, staging, intercooling and aftercooling.
02. Explain the effects of moisture in compressed gases.

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03. Explain the effects of altitude on the compression process.
ii. Applications for compression, including air and gas.
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b. Positive Displacement Compressors: design, operating principles
01. Describe the operation and common arrangements of reciprocating compressors, including single-acting, double-acting, and tandem arrangements.
02. Identify the components of a reciprocating compressor, and describe the operation of plate and channel valves.
i. Reciprocating compressors: clearance volume; indicator diagrams; calculations for displacement and volumetric efficiency.
01. Interpret an indicator diagram as it relates to compressor performance.
02. Define clearance volume as it relates to reciprocating compressors.
03. Perform calculations relating to reciprocating compressor performance.
ii. Rotary Compressors: sliding vane, lobe, and screw types (industrial screw type in detail, including control panel)
01. Describe the design and explain the operating principles of rotary compressors, including sliding vane, rotary lobe, and rotary screw.
02. Identify the components for a packaged industrial screw compressor.
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)
01. Describe designs and principles of centrifugal compressors / blowers, including single and multi-stage designs.
02. Describe designs and principles of axial flow compressors/blowers.
ii. Compressor surge: causes and prevention; P-V curve; surge line, anti-surge system and control
01. Explain the design and operation of an anti-surge system for a dynamic compressor.
d. Starting and stopping procedures for positive displacement and dynamic compressors
01. Explain the startup procedure for a positive displacement compressor.
02. Explain the startup procedure for a dynamic compressor/blower.
e. Compressor Auxiliaries
i. Intercoolers/aftercoolers; moisture separators
01. Describe the designs of water and air-cooled aftercoolers and intercoolers, with separators.
ii. Compressor control systems and devices: start and stop, variable and constant speed; safety devices
01. Describe the control devices and strategies for air compressors, including start-and-stop, variable speed, and constant speed; describe pilot and unloader devices.
iii. Lubrication: internal and external
01. Describe internal and external lubrication systems for reciprocating compressors. (Other compressor lubrication systems explained with the compressors)
iv. Compressor installation and piping layouts
01. Identify the components in the piping layout of a compressor system.
f. Compressed air system components
i. Typical system layout; air receivers (wet and dry) fittings and operation; filters
01. Describe the design, fittings, and operating consideration for air receivers.

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02. Describe the components, arrangement, and parameters of a typical, complete instrument air system, including wet and dry receivers and air dryers.
ii. Air dryers: system design, flows, operation; dewpoint monitoring
01. Describe the components and operating principles and sequences of instrument air dryers.
02. Explain dewpoint monitoring of air systems.
22. Refrigeration
01. Identify major refrigeration applications.
a. Refrigerant classifications, properties, characteristics
01. Explain the required properties of a refrigerant and describe the six group classifications for refrigerants.
02. Identify the properties of common refrigerants.
b. Compression systems
i. Principle of compression refrigeration; typical system temperatures and pressures for simple refrigeration systems
01. Explain the ammonia compression refrigeration cycle, explaining the purpose of each major component and stating typical pressures and temperatures in the system.
ii. Multi-stage systems: 2-stage with duplex compressors; 2-stage with booster compressor; low-temperature multi-stage
01. Describe and explain the operation of a two-stage duplex compressor system with a brine cooler.
02. Describe and explain the operation of a two-stage refrigeration system with a rotary booster compressor.
03. Describe and explain the operation of a low-temperature multi-stage refrigeration system.
iii. Direct vs.indirect systems
01. Explain direct and indirect refrigeration.
02. Describe a centrifugal compression system, using chilled water.
iv. Typical refrigeration applications
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c. Absorption System: ammonia absorption system description and operating parameters
01. Explain the components and operating principle of an ammonia absorption system.
d. Refrigeration system auxiliaries
i. System controls: expansion valves, low-side float, high-side float, capillary tube
01. Explain the purpose, design, and operation of the following controls on a compression refrigeration system: expansion valve, low-side float, and high-side float.
ii. Compressor controls: temperature and pressure-actuated
01. Describe temperature and pressure-actuated compressor controls.
iii. Condenser cooling water control
01. and condenser cooling water control
iv. Safety devices and controls: pressure relief devices, high-pressure cut-out, low-pressure lube oil cut-out
01. Explain the purpose of the following refrigeration system safety devices: high-pressure cutout, oil pressure cutout, and pressure relief devices.
e. CSA B52 Regulations
i. overview of the code for the safe operation, installation and repair of refrigeration equipment

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01. Explain refrigeration safety and environmental issues.
f. System Operation
i. leak testing
01. Explain leak testing of a system, and describe the procedure for adding refrigerant.
ii. charging
XX. Explained in curriculum objective for syllabus statement B2.22.f.i.
iii. purging
01. Explain the effects and location of non-condensable gases.
02. Describe the operation of manual and automatic purge devices.
iv. troubleshooting (condenser, regulator, refrigerant strength,
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v. compressor discharge temperature)
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vi. effects of moisture in system; effects of oil in the refrigerant
01. Explain the effects of moisture in a refrigeration system, and describe its removal.
02. Explain the effects of oil in ammonia and Freon systems and describe the location and operation of an oil separator and oil still.
vii. oil removal using oil separators
XX. Explained in curriculum objective for syllabus statement B2.22.f.vi.
viii. oil traps
01. Explain how oil is manually drained from these systems.
ix. oil still
XX. Explained in curriculum objective for syllabus statement B2.22.f.vi.
x. operating and maintaining brine systems
01. Explain the principles of brine control in an indirect system, and explain the procedures for charging and controlling brine strength.
23. Special Industrial Equipment
Describe the general applications, designs, components, operation for the following:
a. Heat Exchangers
i. double pipe designs
01. Describe double pipe heat exchangers, including jacketed pipe, U-tube, and concentric pipe designs.
ii. head designs
01. Describe common front and rear head designs, shell flow configurations, and explain the purpose of baffles.
iii. shell-and-tube configurations
01. Describe shell-and-tube heat exchangers including fixed straight tube and U-tube designs.
iv. reboiler and feedwater heater fittings
01. Explain the operation and the typical fittings/equipment on the steam/condensate side of a reboiler and a feedwater heater.
v. plate frame
01. Describe the design and operation of a plate-and-frame exchanger.
vi. overhead aerial coolers
01. Describe the design and components of overhead, aerial coolers, including fan and cooler arrangements.
02. Explain cooler control.
vii. aerial steam condensers, including operation and control

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01. Describe the design and components, including controls, of an overhead, aerial condenser.
02. Explain condenser operation, control and precautions when used to condense excess steam.
b. Cooling Towers
i. natural draft
01. Describe the design and explain the operation of natural draft cooling towers, including atmospheric and hyperbolic styles.
ii. atmospheric
XX. Explained in curriculum objective for syllabus statement B2.23.b.i.
iii. hyperbolic
XX. Explained in curriculum objective for syllabus statement B2.23.b.i.
iv. mechanical draft designs
01. Describe the design and operation of mechanical draft cooling towers, including forced draft, induced draft counterflow, and induced draft crossflow.
v. operation and control
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c. Fired Heaters
i. multi-burner vertical designs
01. Describe the common process applications for direct-fired heaters.
02. Describe the design, identify the tube banks and explain the fluid and combustion gas flows through a multi-burner, vertical fired heater.
ii. burner components and styles
01. Explain direct-fired heater designs and classifications.
02. Describe typical burner designs and configurations, identifying burner components, including air registers, pilots, and flame scanners.
iii. fuel supply and control
01. Describe burner operation.
02. Describe the fuel gas supply system to the burners, and explain the purpose of the major fittings.
iv. interlocks and safety devices
01. Describe the monitoring, control, and shutdown devices on a typical heater.
v. indirect-fired heaters
XX. Explained in curriculum objective for syllabus statement B2.23.c.vi.
vi. horizontal designs
01. Describe the design, components, and operation of a typical horizontal, indirect-fired heater such as a salt bath heater.
vii. start-up and shutdown procedures
01. Explain heater start-up procedure, including the lighting of additional burners once flame is established.
02. Explain heater shutdown procedure.
03. Explain start-up and shutdown procedures for an indirect-fired heater.
24. Wastewater Treatment
a. Purpose of WWT; Typical wastewater pollutants and systems
01. State the purpose of wastewater treatment, list typical waste liquids, and explain legislation and permitting, including parameters, for the disposal of wastewater.

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02. Sketch an industrial wastewater treatment system, and describe the processes that occur at each stage of treatment.
b. Theory and equipment for specific treatment process:
i. removal of suspended solids (screening, floatation, sedimentation)
01. Describe the equipment and process involved in the removal of suspended solids from wastewater, including screening, flotation, and sedimentation.
ii. removal of colloidal solids (chemical coagulation, flocculation, clarification)
01. Describe the equipment and process involved in the removal of colloidal solids from wastewater, including chemical coagulation, flocculation, and clarification.
iii. biological treatment (activated sludge, rotating biological contactors, trickling filters)
01. Describe the equipment and process involved in the biological removal of solids from wastewater, including activated sludge, rotating biological contactors, and trickling filters.
c. Operating parameters, controls and tests: nutrients, BOD, COD, pH, settleability
01. Describe the control strategy for a wastewater treatment system.
02. Define and explain the control of and sampling points for the main control parameters, including nutrients, BOD, COD, pH, and settleability.
d. Safety in wastewater treatment plants
01. Identify hazards associated with wastewater treatment.
02. Identify the safety protocols to mitigate the hazards associated with wastewater treatment.
25. Plant Maintenance and Administration
a. Communication and accountability structures
01. Explain typical communication and accountability structures within a large facility, including the responsibilities for external communication.
b. Scheduled and preventative maintenance programs
01. Describe the typical components and responsibilities of scheduled and preventive maintenance management programs.
c. Record keeping; logbooks; logsheets
01. Explain the importance and extent of record keeping and describe the quality and content requirements for operating logbooks and records.
d. Project control; critical path (applied to a complete boiler turnaround, as an example)
01. Using a complete boiler turnaround and inspection as an example, describe project management using two methods, Gantt Chart and critical path.
e. Operating standards and procedures
01. Explain the importance of procedures in the operation of a facility and describe the application of well-written procedures to personnel training and daily operation.
f. Training and development practices; job skill profiles
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g. Environmental practices and supervision
01. Explain typical environmental monitoring and management programs for operating facilities.