Third Class (Edition 3)

Course Outline with Outcomes

The material in this series is aligned with the SOPEEC Third Class Syllabus, January 2014, and the IPECC Curriculum, updated January 2021.

PART A SET

Part A1 (720 pages)

Chapter 1 Algebraic Operations, Logarithms, and Problem Solving

Learning Outcome

Solve problems using algebraic operations, including equations and logarithms.

Learning Objectives

1. Apply the rules for addition, subtraction, multiplication, and division of positive and negative quantities.
2. Simplify algebraic expressions and operations involving the removal or insertion of brackets.
3. Apply the rules for powers and roots to the multiplication and division of quantities and expressions.
4. Apply the rules of transposition to solve simple equations involving addition, subtraction, multiplication, and division.
5. Solve equations involving roots, powers, and fractions.
6. Explain common and natural logarithms. Using a calculator, perform mathematical operations and solve equations that contain logarithms.
7. Apply an organized, systematic approach to solving a problem and presenting the solution.

Chapter 2 Trigonometry

Learning Outcome

Explain trigonometric concepts and solve problems involving trigonometry.

Learning Objectives

1. Identify the types of angles and specify angle size in degrees and radians.
2. Identify right, obtuse, and acute triangles, and apply the naming convention for sides and angles.
3. Use the Pythagorean theorem to calculate the side lengths of a right angle triangle and solve simple problems involving right triangles.
4. Using sine, cosine, and tangent, find the dimensions of right triangles and solve physical problems involving right triangles.
5. Explain the sine, cosine, and tangent of an angle, and determine the values of these functions for all angles between 0 and 360 degrees.
6. Define the sine rule and the cosine rule, and use these rules to determine the unknown dimensions of oblique triangles

Chapter 3 Mensuration

Learning Outcome

Solve problems involving the areas of plane figures and the surface areas and volumes of three-dimensional objects.

Learning Objectives

1. Convert between Imperial and SI units of measure; convert unit magnitudes for area and volume within SI.
2. Calculate the areas of triangles, given base and height, or given the lengths of the sides.
3. Define the following quadrilaterals and calculate their areas: rectangle, square, rhomboid, rhombus, trapezoid, and trapezium.
4. Define the following polygons and calculate their areas: hexagon, octagon.
5. Define and calculate areas and dimensions of a circle, a segment of a circle, a sector of a circle, and an ellipse.
6. Solve problems involving the surface areas and volumes of cylinders and spheres.
7. Define terms and solve problems involving the surface areas and volumes of pyramids, cones, and frustums.

Chapter 4 Forces and Friction

Learning Outcome

Explain concepts and solve problems involving vectors, force systems, and friction.

Learning Objectives

1. Define coplanar and concurrent vectors, and draw space diagrams for forces and displacements.
2. Draw a vector diagram and use it to graphically determine the resultant and equilibrant of a force system.
3. Use trigonometry to resolve forces into components and to calculate the resultant and equilibrant of a force system.
4. Given a coplanar, concurrent force system, calculate any unknown forces.
5. Define static friction, sliding friction, and coefficient of friction, and use the coefficient formula to calculate the coefficient, force, or mass in a simple friction problem.
6. Explain friction angle and perform friction calculations for forces applied parallel to the horizontal plane.
7. 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.

Chapter 5 Work, Power, Energy: Linear and Angular Motion

Learning Outcome

Explain concepts and solve problems involving velocity and acceleration, the Laws of Motion and work, and power and energy.

Learning Objectives

1. Define force, force due to gravity, and work. Calculate the work done in moving objects horizontally and vertically.
2. Define power and mechanical efficiency. Calculate the power expended when work is done, plus the power developed and mechanical efficiency of a reciprocating engine.
3. Define potential and kinetic energy. Calculate the energies of stationary and moving objects.
4. Define, and show the relationships between, distance, displacement, speed, linear velocity, and linear acceleration.
5. Using linear motion relationships, calculate the displacements, velocities, and accelerations of bodies moving in a straight line.
6. Define and calculate angular displacement, angular velocity, and angular acceleration.
7. Calculate the work done to compress a spring.

Chapter 6 Strength of Materials: Bending of Beams

Learning Outcome

Explain concepts and solve problems involving material stresses and bending of beams.

Learning Objectives

1. Define and explain, using appropriate formulas, 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.
2. Calculate stress, strain, ultimate strength, factor of safety, and/or modulus of elasticity for materials under various load situations.
3. Explain the types of beams, beam supports, and beam loads, and state the requirements for beam equilibrium.
4. Calculate the reaction forces for simple and cantilever beams, with point and distributed loads.
5. Explain the effects of shear forces and bending moments in a beam and the compression/tension profile of a loaded beam.
6. Calculate the shear force at any given point in a simple or cantilever beam.
7. Calculate the bending moment at any given point in a simple or cantilever beam.
8. Use a stress/strain diagram for mild steel to define and explain proportional limit, elastic limit, yield point, ultimate stress, and breaking point.

Chapter 7 Simple Machines: Pressure, Density, and Flow

Learning Outcome

Explain concepts and solve problems involving simple machines and fluids.

Learning Objectives

1. For simple machines in general, define and calculate mechanical advantage, velocity ratio, and efficiency.
2. Calculate the efforts, loads, MA, VR, and efficiencies of wheel-and-axle systems.
3. Calculate the efforts, loads, MA, VR, and efficiencies of various pulley systems.
4. Calculate the efforts, loads, MA, VR, and efficiencies of a screw jack.
5. Calculate the efforts, loads, MA, VR, and efficiencies of levers and inclined planes.
6. Define and state the relationships between mass density, relative density, specific weight, and specific gravity.
7. Given unknowns, calculate the densities, relative densities, masses and/or volumes of substances.
8. Calculate pressures exerted by columns of fluids and convert between gauge pressure, absolute pressure, millimetres of mercury, and millimetres of water.
9. Calculate the pressure and force exerted by a liquid at various levels in a tank.
10. Explain flow continuity and calculate simple flows and velocities of liquids in a pipeline.

Chapter 8 Heat, State Change, Calorimetry

Learning Outcome

Explain terminology regarding heat, and perform calculations regarding heat during changes of state and calorimeter tests.

Learning Objectives

1. Define and explain internal energy, heat, specific heat, heat units, temperature, and the relationship between the different temperature scales.
2. Define sensible heat, and use the sensible heat equation to calculate the mass of a substance, the temperature change of a substance, and the amount of heat required to change the temperature of a substance, if no change of state occurs.
3. Explain the changes of state and define latent heat, latent heat of fusion, and latent heat of evaporation.
4. Given start and end conditions, calculate the heat required to change the states of water and other substances.
5. Determine the final temperatures and the original masses for mixtures of ice, water, steam, and other substances.
6. Explain the working principle of a simple calorimeter, and use the calorimeter equation to determine specific heat and final temperature.
7. Explain water equivalent, and perform calculations involving calorimetry and water equivalents.

Chapter 9 Thermal Expansion and Heat Transfer

Learning Outcome

Explain concepts and perform calculations involving the thermal expansion of solids and liquids and heat transfer by conduction.

Learning Objectives

1. Explain the thermal conditions that cause expansion of solids and liquids, and describe the relationship between linear, superficial (area), and volumetric expansion.
2. Given known conditions, calculate linear expansion or contraction, temperatures, and/or expansion coefficients for solids.
3. Given known conditions, calculate superficial expansion or contraction, temperatures, and/or expansion coefficients for solids.
4. Given known conditions, calculate volumetric expansion or contraction, temperatures, and/or expansion coefficients for solids or liquids.
5. Calculate the stress produced in a pipe or its supports when thermal expansion is restricted.
6. Explain the methods of heat transfer: conduction, convection, and radiation.
7. 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.

Chapter 10 Steam Properties and Calculations

Learning Outcome

Define properties of saturated and superheated steam and, using information from the steam tables, calculate the heat required to produce steam at various conditions; determine the equivalent and factor of evaporation for steam boilers.

Learning Objectives

1. Define and explain the following terms: saturation temperature, saturated steam, dry saturated steam, wet saturated steam, dryness fraction, superheated steam, and enthalpy.
2. Identify, from the pressure-based and temperature-based steam tables, the properties of saturated steam at specified conditions.
3. Identify, from the superheated steam tables, the properties of superheated steam at specified conditions.
4. Calculate the heat required to produce dry saturated or superheated steam at given conditions, from feedwater at given conditions.
5. Calculate the dryness fraction of wet steam and/or the heat required to produce wet steam at a given dryness fraction.
6. Explain the properties of steam on a temperature-enthalpy diagram.
7. Define and calculate the heat rate, equivalent evaporation, and factor of evaporation for a boiler.

Chapter 11 Gas Laws and Calculations

Learning Outcome

Explain the laws of perfect gases and perform calculations involving the expansion and compression of gases.

Learning Objectives

1. 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.
2. Explain the characteristic gas constant and use the characteristic gas equation to determine the mass, the conditions, and the constant for a gas.
3. 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.
4. Calculate unknown pressures, volumes, and temperatures for gases during isothermal, adiabatic, and polytropic processes.
5. Explain and calculate the work done in a cylinder under constant pressure.
6. Explain and calculate the work done in a cylinder during an isothermal expansion or compression.
7. Explain and calculate the work done in a cylinder during an adiabatic expansion or compression.
8. Explain and calculate the work done in a cylinder during a polytropic expansion or compression.

Chapter 12 Chemistry Fundamentals

Learning Outcome

Explain the fundamental principles in the structure, formation, and interaction of chemical compounds and the importance of chemistry in industrial operations.

Learning Objectives

1. Define each term and explain the relationship between atoms, ions, elements, molecules, compounds, and mixtures.
2. Using the periodic table of elements, determine the atomic numbers and the atomic masses of elements.
3. Explain electronegativity and the bonding of ions.
4. Explain the formation of chemical compounds, explain typical reaction equations, and apply fundamental principles to the balancing of simple chemical reaction equations.
5. Calculate the amount of reactants required or products produced in a chemical reaction.
6. Define acids, bases, and salts, and explain their properties.
7. Define organic chemistry and explain, in general terms, the structure and applications of hydrocarbons and hydrocarbon derivatives.
8. Explain typical applications of chemistry in industry, including water treatment and testing, corrosion control, combustion, hydrocarbon processing, petrochemical processes, and pulp and paper production.

Chapter 13 Metallurgy and Materials

Learning Outcome

Explain the production, properties, and applications of metallic and non-metallic materials.

Learning Objectives

1. Define and explain the importance and application of mechanical properties of materials, including brittleness, hardness, ductility, malleability, plasticity, elasticity, and toughness.
2. Describe material testing, including tension test, Brinell and Rockwell hardness tests, and Charpy and Izod impact tests.
3. Describe the blast furnace and cupola furnace methods for iron production, and compare the characteristics of gray, white, malleable, and ductile cast iron.
4. Define steel and explain the compositions and characteristics of low-carbon, medium-carbon, and high-carbon steels.
5. Define alloy steels, and explain the benefits of alloying elements, including nickel, chromium, molybdenum, vanadium, copper, lead, manganese, and tungsten.
6. Explain the purposes of hot working, cold working, and heat treating metals.
7. Describe the production of carbon and alloy steel, using the open-hearth, basic oxygen, and electric arc furnace processes.
8. Describe the properties and applications of non-ferrous metals and alloys.
9. Explain the basic structure, properties, and applications of polymers, ceramics, and composites.

Chapter 14 Corrosion Principles

Learning Outcome

Explain the mechanisms that cause corrosion and the methods used to monitor and control corrosion.

Learning Objectives

1. Define corrosion terms and explain the causes and characteristics of corrosion types, including galvanic, atmospheric, stray current, biological, stress (including sulfide and chloride stress), and hydrogen induced cracking.
2. Explain the nature and sources of corrosion on the waterside of boilers, including caustic corrosion, hydrogen-damage, and pitting.
3. Explain the environmental factors that affect corrosion.
4. Explain the principles of corrosion inhibitor mechanisms, including adsorbed films, passivation, cathodic precipitates, and neutralization.
5. Describe the principles and applications of cathodic protection devices or systems, including sacrificial anodes, galvanic anodes, impressed current, and groundbeds.
6. Describe the principles and applications of corrosion monitoring devices, including coupons, electrical resistance probes, galvanic probes, and hydrogen probes.
7. Describe corrosion inspection procedures, including ultrasonics and radiography.

Chapter 15 Industrial Drawings

Learning Outcome

Identify and interpret components of typical engineered drawings used in industry.

Learning Objectives

1. State the purpose of a process flow diagram (PFD), and identify the major information available on a typical PFD.
2. State the purpose of a piping and 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.
3. State the purpose of a material balance drawing, and interpret information provided on a material balance drawing.
4. Interpret information provided on a typical approved construction drawing for a pressure vessel and other mechanical equipment.
5. State the purpose of an equipment layout drawing, and identify the components of a typical equipment layout drawing.

Part A2 (840 pages)

Chapter 1 Legislation and Codes for Power Engineers

Learning Outcome

Explain the purpose of, general content of, and interaction with the legislation and codes that pertain to the design and operation of boilers and related equipment.

Learning Objectives

1. Explain the purpose and the legislated authority of the “Boiler Branch” jurisdictions in Canada, and explain how Power Engineers interact with their own jurisdiction.
2. Describe the general content of a typical boiler and pressure vessel act and its associated regulations.
3. Explain the adoption of codes and standards by jurisdiction in Canada and identify the main standards that have been adopted with respect to boilers and pressure equipment.
4. Explain the purpose and scope of the National Board of Boiler and Pressure Vessel Inspectors (NBBI).
5. 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.
6. Describe the scope and general content of the CSA-B51 Boiler, Pressure Vessel, and Piping Code for the construction and inspection of boilers and pressure vessels.
7. Describe the scope and general content of the CSA-B52 Mechanical Refrigeration Code.
8. 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.

Chapter 2 Code Calculations – ASME Section I

Learning Outcome

Use ASME BPVC Section I and ASME BPVC Section II, Part D, Table 1A to calculate the design thickness and pressure of boiler tubes, drums, and piping, and calculate the capacities of pressure relief valves.

Learning Objectives

1. 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.
2. Given the material specification, construction method, and other necessary parameters, use the formulas in ASME BPVC Section I, PG-27.2.2 to determine the minimum required thickness and/or maximum allowable working pressure for boiler drums, headers, or piping.
3. Given the required specifications and operating conditions, use the formula in ASME BPVC Section I, PG-29.1 to calculate the minimum required thickness of a seamless, unstayed dished head.
4. 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.

Chapter 3 Fuels, Combustion, and Flue Gas Analysis

Learning Outcome

Explain the properties and combustion of common fuels and the analysis of combustion flue gas.

Learning Objectives

1. Calculate the mass of combustion products using molar mass.
2. Explain/define combustion, incomplete combustion, combustion products, and write balanced combustion equations.
3. Explain the purpose and benefits of excess air, and calculate the theoretical and excess air required for the complete combustion of a given fuel.
4. Explain proximate analysis, ultimate analysis, and heating value of a fuel, and describe the use of calorimetry to determine heating value. Explain higher and lower heating values.
5. Given the ultimate analysis of a fuel, use Dulong's formula to calculate the heating value of fuel.
6. Describe the properties, classifications, and combustion characteristics of coal. Analyze combustion equations for coal.
7. Describe the properties, classifications, and combustion characteristics of fuel oil. Analyze combustion equations for fuel oil.
8. Describe the properties and combustion characteristics of natural gas. Analyze combustion equations for natural gas.
9. Explain the use and combustion characteristics of alternatives to traditional fossil fuels, including biomass fuels, coke, and oil emulsions.
10. 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 (O_2), carbon monoxide (CO), and carbon dioxide (CO_2) in relation to combustion efficiency.
11. Describe typical automatic flue gas analyzers.
12. Explain the formation, monitoring, and control of nitrogen oxides (NO_X), sulfur dioxide (SO_2), and particulates.

Chapter 4 Piping Design, Connections, and Support

Learning Outcome

Discuss the codes, designs, specifications, and connections for ferrous, non-ferrous, and non-metallic piping, and explain expansion and support devices common to piping systems.

Learning Objectives

1. 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).
2. Explain methods of pipe manufacturing, size specifications, and service ratings, and the material specifications and applications for ferrous pipe.
3. Identify the size of pipe required for a particular installation, process, or operating condition using pipe specifications and ASME BPVC Sections I and II.
4. Explain the materials, code specifications, and applications of common non-ferrous metal piping and cast-iron piping.
5. Describe screwed, welded, and flanged methods of pipe connection, and identify the fittings used for each method.
6. Describe the construction, designs, and materials of flange gaskets, and explain the confined, semi- confined, and unconfined flange styles.
7. Explain the materials, construction, and approved applications of common non-metallic pipe.
8. Explain the effects of temperature on piping; explain the mechanisms and the dangers of expansion in piping systems, including attached equipment.
9. State the purpose and explain the designs, locations, and applications of simple and offset U-bend expansion bends.
10. Describe the designs, locations, care, and maintenance of slip, corrugated, bellows, hinged, universal, pressure-balanced, and externally pressurized expansion joints.
11. Describe the design, location, and operation of pipe support components, including hangers, roller stands, variable spring hangers, constant load hangers, anchors, and guides.

Chapter 5 Steam Traps, Water Hammer, and Insulation

Learning Outcome

Explain the designs and operation of steam trap systems, the causes and prevention of water hammer, and the designs and applications of pipe insulation.

Learning Objectives

1. 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.
2. Describe the design, operation, and application of ball float, inverted bucket, thermostatic, bimetallic, impulse, controlled disc, and liquid expansion steam traps.
3. Explain the selection, sizing, and capacity of steam traps, and explain the factors that determine efficient trap operation.
4. Explain the procedures for the commissioning, testing, and maintenance of steam traps.

5. 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.
6. Describe specific trap and condensate return arrangements that are designed to prevent water hammer in steam and condensate lines.
7. State the precautions that must be observed to prevent water hammer, and describe a typical steam system startup procedure that prevents water hammer.
8. State the purposes of insulation, and explain the properties required of a good insulating material. Explain thermal conductivity, K factor, and R value.
9. Identify the most common industrial insulating materials, describe the composition and characteristics of each, and explain in what service each would be used.
10. 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.

Chapter 6 Valves and Actuators

Learning Outcome

Describe the designs, configurations, and operation of the common valve designs that are used in power and process piping.

Learning Objectives

1. Explain the factors that determine the suitability and applications of the major valve styles, namely gate, globe, ball, plug, butterfly, and needle.
2. Explain the factors that determine the selection of valve materials, and describe examples of typical valve materials, trim, and identification for common valve services.
3. 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).
4. 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.
5. Describe the designs, application, and operation of single-seated and double-seated balance valves. Explain caged trim for balanced control valves.
6. Describe the designs and applications of typical plug valves, including tapered and cylindrical plug, four- way, eccentric, and jacketed.
7. Describe the designs and configurations for mixing and diverter valves.
8. Describe the designs and operations of diaphragm valves.
9. 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.

Chapter 7 Electrical Theory and DC Machine

Learning Outcome

Explain basic concepts in the production of electricity and the design, characteristics, and operation of DC generators and motors.

Learning Objectives

1. Define the terms magnetism, magnetic field, temporary and permanent magnets, magnetic flux, reluctance, and magnetization of a coil.
2. Describe Weber's molecular theory of magnetism.
3. Explain self-induction and mutual induction of a coil.
4. Explain the production of electron flow in a circuit, and define circuit voltage, amperage, and resistance.
5. Explain electromagnetic induction and how it produces generator action and motor action.
6. Describe the design and operating principles of a DC generator or motor, and clearly state the purposes of the armature, brushes, windings, and poles.
7. Explain how generated voltage, armature reaction, and torque are created and their influence on a DC generator. Given the speed, flux, number of poles, and number of conductors, calculate the EMF induced in a DC generator.
8. 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.
9. 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.
10. Explain DC motor torque characteristics and describe the starting mechanisms for DC motors.

Chapter 8 AC Theory and Machines

Learning Outcome

Explain formation and characteristics of AC power, and describe the design, construction, and operating principles of AC generators, motors, and transformers.

Learning Objectives

1. Explain the creation of single-phase and three-phase alternating power, and define cycle, frequency, and phase relationships (voltage/current) for AC sine waves.
2. Define the following terms and explain their relationship in an AC circuit: inductance, capacitance, reactance, impedance, power factor, and alternator ratings (kVA and KW).
3. Describe the stator and rotor designs, operation, and applications for salient pole and cylindrical rotor alternators.
4. Describe water, air, and hydrogen cooling systems for large generators.
5. Explain parallel operations of alternators, and state the requirements for synchronization. Describe manual and automatic synchronization.
6. Describe the design, applications, and operating principles for large three-phase squirrel cage and wound rotor induction motors.

7. Describe the design and operating principle of synchronous motors.
8. Explain variable speed control, variable speed starting, and step starting for large induction motors.
9. Explain the principles and applications of power transformers. Perform transformer calculations.
10. Describe the designs and components of typical core and shell-type transformers, including cooling components.

Chapter 9 AC Systems, Switchgear, and Safety

Learning Outcome

Identify the components of typical AC systems and switchgear, and discuss safety around electrical systems and equipment.

Learning Objectives

1. 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.
2. Explain the function of the typical gauges, meters, and switches on an AC generator panel.
3. 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, and automatic bus switchover.
4. Explain the components and operation of a typical uninterruptible power supply (UPS) system.
5. Explain safety procedures and precautions that must be exercised when working around and operating electrical system components. Explain grounding.

Chapter 10 Electrical Calculations

Learning Outcome

Define terms and perform simple calculations involving DC and AC power circuits.

Learning Objectives

1. Use Ohm's law and Kirchhoff's laws to calculate current, resistance, or voltage drop in series or parallel multi-resistor circuits.
2. Calculate unknown resistances using a Wheatstone bridge circuit.
3. Explain and perform calculations involving electrical power, work, and energy.
4. Calculate the frequency, period, and phase angle for an AC sine wave. Identify the relationships between poles, frequency, and speed for AC machines.
5. Define and calculate the peak-to-peak, root mean square, and maximum values for AC voltage and current.
6. Given required parameters, calculate the inductive reactance, capacitive reactance, total reactance, and impedance for an AC circuit.
7. Calculate real power, imaginary power, and power factor for an AC circuit.
8. Given the load, voltage, and power factor of a three-phase generator, calculate the kVA and kW ratings of the generator.

Chapter 11 Control Loops and Strategies

Learning Outcome

Explain the operation and components of pneumatic, electronic, and digital control loops, and discuss control modes and strategies.

Learning Objectives

1. Describe the operation, components, and terminology for a typical control loop.
2. Describe the operation and components of a purely pneumatic control loop. Explain the function of each component.
3. Describe the operation and components of an analog control loop and an electronic control loop. Explain the function of each component.
4. Describe the operation and components of a digital control loop. Explain the function of each component.
5. Explain the purpose and operation of on-off, proportional, proportional plus reset, and proportional plus reset plus derivative control systems, and give examples of each. Define proportional band and gain.
6. Describe and give typical examples of feedforward, feedback, cascade, ratio, split-range, and auto-select control.
7. Explain, with examples, the purpose and incorporation of alarms and shutdowns into a control loop/ system.
8. 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.

Chapter 12 Instrument and Control Devices

Learning Outcome

Explain the operating principles of various instrument devices that are used to measure and control process conditions.

Learning Objectives

1. Describe the design, operation, and applications of the following temperature devices: bimetallic thermometer, filled thermal element, thermocouple, RTD, thermistor, radiation pyrometers, and optical pyrometers.
2. Describe the design, operation, and applications of the following pressure devices: Bourdon tubes, bellows, capsules, diaphragms, and absolute pressure gauges.
3. 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.
4. 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.

Chapter 13 Distributed and Logic Control

Learning Outcome

Explain the general purpose, design, components, and operation of distributed and programmable logic control systems.

Learning Objectives

1. Explain distributed control, and describe the layout and functioning of a typical distributed control system. Explain the function of each major component of the system.
2. State the purpose and explain the general functioning of a communication and data acquisition system (e.g., SCADA) as it relates to process control.
3. Identify and explain the functions of the major components of the operator interface unit (OIU), including controller interfaces, displays, alarms, and shutdown.
4. Identify AND, OR, and NOT logic gates and associated truth tables.
5. State typical applications of programmable logic controllers, including the operator interfaces, and explain their purpose and functioning. Explain a ladder logic diagram.
6. Identify a function block.

Chapter 14 Safety Management Systems

Learning Outcome

Discuss typical legislation and programs that manage safety in the industrial workplace.

Learning Objectives

1. Explain the general intent, power, and scope of Occupational Health and Safety (OH&S) Legislation.
2. Explain the intent and scope of a workplace OH&S program, and state the responsibilities of the company, the employees, and the OH&S committee within the program.
3. Define and give examples of typical workplace hazards, and describe a system of hazard identification and control.
4. Explain the purpose of safe work permits, and describe typical hot and cold work permit systems.
5. Explain the purpose of equipment lockout, describe lockout devices, and describe a typical equipment lockout procedure.
6. Define and identify confined spaces, and describe a typical confined space permit and entry procedure.
7. Explain the hazards of excavation, and describe typical excavation procedures and permits.
8. Explain the purpose and describe the typical components of an emergency response plan.
9. State the purpose of the Workplace Hazardous Materials Information System (WHMIS), explain the use of labels and safety data sheets (SDSs), and explain the responsibilities of the employer and employee under the WHMIS program.
10. Explain the purpose, requirements, and procedures for incident and accident investigation and reporting.

Chapter 15 Fire Protection Systems

Learning Outcome

Discuss the classes and extinguishing media of fires, and explain systems that are used to detect and extinguish industrial fires.

Learning Objectives

1. Explain the classifications of fires, and describe the extinguishing media that are appropriate for each classification.
2. Describe the components and operation of a typical fire detection and alarm system in an industrial setting.
3. Describe the design and operation of a typical standpipe system.
4. Describe the wet pipe, dry pipe, preaction, and deluge designs for sprinkler systems.
5. Describe the layout, components, and operation of a typical firewater system with fire pumps and hydrants. Explain seasonal considerations for a firewater system.
6. Describe the construction and operation of a typical fire hydrant.
7. Explain the purpose of and describe a typical deluge water system for hydrocarbon storage vessels.
8. Explain the purpose of and describe a typical foam system for process buildings and tanks.
9. Describe a typical fire response procedure for an industrial setting.

PART B SET

Part B1 (672 pages)

Chapter 1 Watertube Boiler Designs

Learning Outcome

Describe common designs, configurations, and circulation patterns for modern bent-tube watertube boilers and steam generators, and explain how boilers are rated.

Learning Objectives

1. Explain the difference between packaged, shop assembled, and field-erected watertube boilers. Explain how boilers are rated.
2. Explain the process of water circulation in a watertube boiler and the factors that influence circulation.
3. 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.
4. 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.
5. Differentiate between critical and supercritical boilers.
6. Explain the purpose and advantage of forced circulation, and describe the flow through a typical controlled circulation boiler.
7. Explain the purpose and design of a once-through boiler.

Chapter 2 Special Boiler Designs

Learning Outcome

Describe the designs, components, firing methods, and operating considerations for some special boilers used in industry.

Learning Objectives

1. Describe typical designs, components, and operating strategies for once-through steam generators (OTSGs) for steam assisted gravity drainage (SAGD).
2. Describe typical designs, components, and operating strategies for fluidized bed boilers.
3. Describe typical designs, components, and operating strategies for heat recovery steam generators.
4. Describe typical designs, components, and operating strategies for black liquor recovery boilers used in pulp mills.
5. Describe typical designs, components, and operating strategies for refuse boilers used in waste disposal.
6. Describe typical designs, components, and operating strategies for waste-heat biomass boilers.
7. Describe typical designs, components, and operating strategies for high-pressure, high-temperature hot water boilers.

Chapter 3 Boiler Construction

Learning Outcome

Explain code requirements in general terms, and describe construction and assembly methods for the major components of a large boiler.

Learning Objectives

1. 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.

2. Explain the purpose, design, locations, and installation methods for boiler casing, insulation, refractory, and cladding.
3. Describe the methods used to fabricate boiler tubes.
4. Describe the preparation, fabrication, and testing of boiler drums.
5. Describe methods of attaching tubes to drums and headers, including expanding and welding, and explain where each method would be used.
6. Explain code requirements/sizes for, and describe the designs and installation of, manholes and handholes, including welded handholes. Explain procedures for removing and installing covers.
7. Describe the field assembly of a large boiler or steam-generating unit.

Chapter 4 Boiler Heat Transfer Components

Learning Outcome

Explain the purpose, location, design and operating conditions for the major heat transfer components of a large watertube boiler or steam generator.

Learning Objectives

1. Describe baffle designs and locations, and explain their significance to boiler heat transfer.
2. Describe the designs of integral furnace sidewall and header arrangements, including tube-and-tile, tangent tube, and membrane.
3. Define primary, secondary, convection, radiation, platen, and pendant as they apply to superheaters. Describe the locations of superheaters within a steam generator, and state the operating characteristics of convection and radiant superheaters.
4. Explain the purpose and design of a separately fired superheater.
5. Explain the purpose and describe the locations of reheaters. Explain the position and flow through reheaters in relation to superheaters.
6. Describe designs and locations of integral and separate economizers.
7. Describe the designs, operation, and location of plate, tubular, and rotary regenerative air heaters.
8. Explain operating care and considerations that must be given to the various heat transfer sections of the boiler.
9. Explain a typical water and gas temperature profile through a large steam generating unit.

Chapter 5 High-Pressure Boiler Fittings

Learning Outcome

Describe the design and operation of common external and internal fittings attached to the pressure side of a high-pressure boiler.

Learning Objectives

1. Describe the design, installation, operation, and setting of a high-pressure pressure relief valve. Explain the code requirements for size, capacity, and locations of the pressure relief valves on a boiler.
2. Describe the code requirements for boiler pressure gauges, including attachment and locations.
3. 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.
4. Explain testing and maintenance of a high-pressure gauge glass.
5. Describe the float and probe designs for low-water fuel cut-offs and explain how these are tested.
6. 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.
7. Describe manual blowoff piping arrangements.
8. Explain the code requirements for blowoff tanks, blowoff tank piping, and blowoff tank valve arrangements.

9. Describe the following types of blowoff valves: sliding disc, seatless sliding plunger, seat and disc, and combination.
10. Explain manual blowdown procedures.
11. Explain the components of the steam drum internals of a watertube boiler. Describe the design and operation of various steam separation devices, including baffles, primary and secondary separators, and scrubbers.

Chapter 6 Burner Designs and Supply Systems

Learning Outcome

Describe the typical components of fuel supply systems, and describe common burner/furnace designs for gas, oil, and solid fuel fired boilers.

Learning Objectives

1. 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. State the typical operating pressures.
2. Describe the design and operation of spud and ring burners, and explain high-efficiency, low NOX designs.
3. Describe a complete fuel oil supply system from storage tanks to burners, and explain the function of each system component.
4. Describe the design and operation of air, steam, and mechanical atomizing burners.
5. Describe a solid fuel supply system, from stockpiles to burners, for a typical pulverized solid fuel furnace.
6. Describe the design and operation of a pulverized coal burner, and explain turbulent vertical, tangential, and cyclone furnaces.
7. Describe the design and operation of ball, impact, ball race, and bowl mill pulverizers.
8. Describe the designs and operation of underfeed, overfeed, and crossfeed stokers for furnaces burning solid fuels.

Chapter 7 Boiler Draft and Flue Gas Equipment

Learning Outcome

Explain boiler draft systems and fans, and describe the equipment used to remove ash from flue gas.

Learning Objectives

1. Define and explain the applications and designs of natural, forced, induced, and balanced draft.
2. Explain how draft is measured, monitored, and controlled in a large, balanced draft boiler. Explain the position of control dampers.
3. Describe typical draft fan designs, single and double inlet arrangements, and explain methods used to control fan output.
4. Explain the start-up and the running checks that must be made on draft fans.
5. Describe typical windbox and air louvre arrangements, and distinguish between primary and secondary air.
6. Describe the design and operation of flue gas particulate clean-up equipment, including mechanical and electrostatic precipitators and baghouse filters.
7. Describe the design and operation of ash handling systems, including hydro and air systems, bottom ash systems, and scraper conveyor systems.
8. Describe the designs and operation of SO_2 recovery systems, including lime and wet gas scrubbing.

Chapter 8 Boiler Control Systems

Learning Outcome

Explain the components and operation of automatic control systems for boiler water level, combustion, steam temperature, and start-up.

Learning Objectives

1. Describe on-off and single-element control of boiler feedwater.
2. Explain swell and shrinkage in a boiler. Describe the components and operation of a two-element feedwater control system, explaining the interaction of the controllers.
3. Describe the components and operation of a three-element feedwater control system.
4. Describe the components and operation of a direct combustion control system.
5. Describe the components and operation of a steam-flow/airflow combustion control system.
6. Describe the components and operation of a fuel-flow/airflow combustion control system.
7. Describe the components and operation of an airflow/fuel-flow combustion control system.
8. Describe the components and operation of a multi-element combustion control system.
9. Describe steam temperature control methods and equipment, including attemperation (desuperheating), gas recirculation, gas bypass, and tilting burners.
10. Describe combustion safety devices and interlocks.
11. Differentiate between continuous, intermittent, and interrupted pilots.
12. Define flame failure detection (photoelectric cells).
13. Describe the automatic, programmed start-up sequence for a gas-fired boiler.

Chapter 9 Boiler Procedures

Learning Outcome

Describe common procedures in the operation and maintenance of high-pressure boilers.

Learning Objectives

1. 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.
2. Describe the wet and dry methods when laying up a boiler for an extended time, including nitrogen blanketing.
3. Describe the proper shutdown and preparation of a boiler for internal inspection.
4. Describe a thorough inspection of the water- and furnace-sides of a boiler.
5. Describe typical equipment and procedures for cleaning the waterside of a boiler mechanically and chemically.
6. Explain routine tasks and visual monitoring that must be performed by the operator on a large operating boiler.
7. Explain the procedures and precautions that an operator must exercise to avoid furnace- and pressure-side explosions.
8. Describe soot blowing systems and describe the procedures for operating soot blowers.

Chapter 10 Internal Water Treatment for Boilers

Learning Outcome

Discuss internal water treatment methods and systems for the control of scale, corrosion, and carryover, and explain testing and monitoring strategies.

Learning Objectives

1. Explain the most common internal methods of scale control, including phosphate treatment, chelant treatment, sludge conditioning, and dispersion.
2. Explain the treatment methods for acidic, caustic, oxygen, and carbon dioxide corrosion, including sulfite, hydrazine, and amine treatment programs.
3. Explain the mechanical and chemical causes, effects, and types of carryover; explain methods of carryover control, including the use of anti-foam and blowdown.
4. Describe the design and explain the operation of simple, heat recovery, and automatic blowdown systems.
5. Use general terms to explain the sampling and testing strategies for boiler internal conditions; describe typical sampling and automatic monitoring equipment.
6. Describe typical chemical feed systems, including pot feeders, continuous feed systems with day tanks, and continuous feed systems with pump tanks.

Chapter 11 Boiler Water Pretreatment

Learning Outcome

Explain the purpose, principles, equipment, and monitoring of boiler water pretreatment processes.

Learning Objectives

1. Identify boiler feedwater impurities.
2. Evaluate the effects of boiler feedwater impurities on boiler operation.
3. Describe the design and explain the terms, purpose, and operation of a clarifier that uses coagulation, flocculation, and subsidence.
4. Describe the design and explain the terms, purpose, and operation of gravity and pressure filters
5. Describe the design and explain the terms, purpose, and operation, including chemical reactions, for a cold lime softener.
6. Describe the design and explain the terms, purpose, and operation of a hot lime softener. Describe the components of a complete system.
7. Explain the principles of ion exchange softening in general, identifying the common anions and cations in untreated water.
8. Describe the design, components, and operation of a sodium zeolite softening system, including chemical reactions.
9. Describe the design, components, and operation of a hydrogen zeolite softening system, including chemical reactions.
10. Describe the design, components, and operation of a dealkalization system, including chemical reactions.
11. Describe the design, components, and operation of a demineralizer system, including mixed bed and degasification.
12. Explain the principles and operation of a reverse osmosis system.
13. Describe the design, principle, and operation controls of a typical deaerator.
14. Describe the design, components, and operation of evaporators for external water treatment.

Chapter 12 Pump Designs and Operation

Learning Outcome

Describe the designs, principles, components, and operating procedures for common industrial pumps.

Learning Objectives

1. Explain the principle of operation and describe the components of typical plunger, piston, and diaphragm reciprocating pumps.
2. Explain the designs and operating principles of the external gear, internal gear, sliding vane, lobe, and screw type rotary pumps.
3. Explain the designs and operating principles of volute and diffuser centrifugal pumps, including impeller designs.
4. Describe centrifugal pump arrangements, including vertical, horizontal, single and double suction, opposed impellers, multi-stage, split casings, and barrel casings.
5. Describe the design and applications of axial and mixed-flow pumps.
6. Describe the design and components of a multi-stage centrifugal pump, clearly stating the purpose and general design of wear rings, shaft sleeves, seals, bearings and lubrication components, vents, and drains.
7. Explain design features that eliminate thrust in large centrifugal pumps.
8. Describe systems used to maintain minimum flow through a centrifugal pump.
9. Explain priming, start-up, capacity control, and operating cautions for centrifugal pumps.

Chapter 13 Pump Head Calculations

Learning Outcome

Define terms associated with pumping, and perform pump head calculations.

Learning Objectives

1. Explain the relationship between the height of a liquid, the density of the liquid, and the pressure exerted at the bottom of the liquid. Perform simple calculations involving this relationship.
2. Define equivalent head, and calculate equivalent heads for water and other liquids.
3. 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.
4. Define and calculate friction head and velocity head.
5. Define dynamic suction head, dynamic suction lift, dynamic discharge head, and total dynamic head, and calculate each of these for a given pump arrangement.
6. Explain vapour pressure, cavitation, and net positive suction head (NPSH). Calculate the required suction pressure for a water pump, given the manufacturer's required NPSH.

Chapter 14 Welding Procedures and Inspection

Learning Outcome

Explain the processes and applications of different welding techniques, and describe the testing of welds and procedures.

Learning Objectives

1. Describe the equipment, procedure, and applications of shielded metal arc welding (SMAW). Explain the classification of arc welding electrodes.
2. Describe the equipment, procedure, and applications of submerged arc welding (SAW).
3. Describe the equipment, procedure, and applications of gas tungsten arc welding (GTAW).
4. Describe the equipment, procedure, and applications of gas metal arc welding (GMAW).
5. Explain weld preparation and terminology of a butt weld; explain preheating and post-weld heat treatment.
6. 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.
7. Explain the equipment and procedures for liquid penetrant, magnetic particle, radiographic, and ultrasonic inspection of a weld; explain the potential weld defects revealed by each test.
8. Explain the requirements and process for welding procedure and welding performance qualifications per the ASME BPVC, Section IX.

Chapter 15 Pressure Vessels

Learning Outcome

Explain pressure vessel design, stresses, and operating considerations.

Learning Objectives

1. Define pressure vessel, and explain, in general terms, how pressure vessels are regulated in design, construction, and repair (including the purpose of ASME BPVC, Section VIII).
2. Explain the stamping/nameplate requirements for pressure vessels, and identify terms and specifications on a typical nameplate.
3. Describe the weld locations on a typical pressure vessel, and identify head designs, including ellipsoidal, torispherical, hemispherical, conical, and toriconical.
4. Describe acceptable nozzle attachment methods, including reinforcements; describe inspection openings.
5. Explain the loads that contribute to stresses in pressure vessels, including pressure, thermal, attachments, static, wind, seismic, and cyclic loads.
6. Explain the components and fittings of a typical pressure vessel.
7. Explain operating and maintenance considerations for the safe operation of pressure vessels, including the appropriate use of hydrostatic and pneumatic testing.

Part B2 (768 pages)

Chapter 1 Steam Turbine Principles and Design

Learning Outcome

Describe designs, operating principles, and major components of steam turbines.

Learning Objectives

1. Explain impulse turbine operating principles. Describe convergent and divergent nozzles, and describe the pressure-velocity profiles through an impulse section.
2. Explain reaction turbine operating principles, and describe the pressure-velocity profiles through reaction blading.
3. Explain pressure, velocity, and pressure-velocity compounding of impulse turbines. Describe the pressure-velocity profiles and the purpose and applications of each.
4. Explain the purpose, general operating principles, and arrangement for each of the following turbine types: condensing, condensing-bleeder, back-pressure, extraction, topping, mixed-pressure, cross-compounded, tandem-compounded, double flow, and reheat.
5. Describe the designs of typical turbine casings, and state the purpose and location of casing fittings, including drains and sentinel valves. Describe the designs and principles of casing and shaft seals.
6. Describe the designs and applications of disc rotors and drum rotors. Describe methods of rotor and casing blade attachment, and explain blade-sealing arrangements.
7. Explain thrust in a large turbine, and describe methods to offset thrust, including thrust bearings, dummy piston, and thrust-adjusting gear.
8. Identify typical designs and components for small industrial turbines. Describe typical size and capacity rating specifications and typical applications.
9. Identify typical designs and components for large industrial turbines. Describe typical size and capacity rating specifications and typical applications.
10. Explain the use and design of reducing gears attached to steam turbines.

Chapter 2 Steam Turbine Auxiliaries and Operation

Learning Outcome

Describe auxiliary support and control systems for steam turbines, and explain start-up and shutdown procedures.

Learning Objectives

1. Describe typical lube oil systems for small and large steam turbines.
2. Explain the purpose, and describe the design and operation, of the barring gear and the jacking oil systems on a large turbine.
3. Describe a condensing turbine circuit and explain typical operating parameters.
4. Explain and state the applications of the following governor types: speed-sensitive including nozzle, throttle, and bypass, and pressure-sensitive including back-pressure and extraction. Explain governor droop and isochronous control.
5. Explain the operation and the major components of the three main speed-sensitive governor systems: mechanical, mechanical-hydraulic, and electro-hydraulic.
6. Explain the operation and describe the components of typical mechanical and electronic overspeed trip systems.
7. Explain the sequence followed for the cold start-up and shutdown of a non-condensing steam turbine.
8. Explain the sequence followed for the cold start-up and the shutdown of a condensing and extracting steam turbine.
9. Explain the operation and purpose of the following equipment: a turbine gland seal system, a packing blowdown valve on a reheat turbine with combined HP-LP opposed flow sections, and a ventilator dump valve on a large load rejection-turbine trip.
10. Explain the purpose and operation of the auxiliary equipment on a condensing turbine and an extraction turbine.

Chapter 3 Turbine Condenser Systems

Learning Outcome

Explain typical designs, components, and operating principles of steam turbine condensers.

Learning Objectives

1. Explain the purposes of a condenser in a steam plant cycle, and describe a typical condensing circuit and its operating temperatures and pressures.
2. Explain the design, operation, and applications of the contact (jet) condenser, including the barometric condenser and the ejector condenser.
3. Explain the design and applications of the surface condenser, including the water-cooled condenser, the air-cooled condenser, the downflow condenser, and the central flow condenser.
4. Describe basic condenser construction and how to operate and troubleshoot surface condensers.
5. Explain the effects of air in a condenser, and describe the design and operation of single and two-stage air ejectors. Explain vacuum pumps. Explain the detection of condenser air leaks.

6. Explain the devices and operating considerations used to protect a condenser against high back pressure, high condensate level, and cooling water contamination. Describe a cooling-water leak test.
7. Describe the operating conditions and corresponding design considerations for condensate extraction pumps and cooling water pumps.
8. Describe a feedwater heater system in conjunction with a steam condenser, and explain the designs of low-pressure and high-pressure feedwater heaters.
9. Sketch and describe an open-condenser cooling-water system and a closed-condenser cooling-water system.

Chapter 4 Gas Turbine Principles and Designs

Learning Outcome

Explain common designs, major components, operating principles, and arrangements for industrial gas turbines.

Learning Objectives

1. Explain gas turbine advantages, disadvantages, background, and industrial applications. Identify the types of gas turbines and their major components, and describe the operating principles of a simple gas turbine.
2. Explain single-shaft and dual-shaft arrangements for gas turbines.
3. Describe open cycle and closed cycle operation.
4. Describe a typical open cycle gas turbine installation, including buildings or enclosures, intake and exhaust systems, auxiliary systems, and reducing gear.
5. Explain the efficiency and rating of gas turbines. Describe the purpose and applications of gas turbine cycle improvements, including intercooling, regenerating, reheating, and combined cycle.
6. Describe the various aspects of compressor design and centrifugal and axial types of compressors.
7. Describe the types, operation, components, and arrangements of combustors.
8. Describe power turbine section design and operation, especially with respect to blading and materials.
9. Explain the types and functions of the control systems and instrumentation needed for gas turbine operation.
10. 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.

Chapter 5 Gas Turbine Auxiliaries and Operation

Learning Outcome

Describe the support auxiliaries for a gas turbine, and explain common operational, control, and maintenance procedures.

Learning Objectives

1. 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.
2. Describe a typical jacking oil system for a gas turbine.
3. Describe and explain the operation and routine maintenance of a typical fuel gas supply system for a gas turbine.
4. Describe and explain the operation and routine maintenance of a typical fuel oil supply system for a gas turbine.
5. Explain the control of NO_X from a gas turbine. Describe the purpose and operation of water/steam injection and dry low NO_X systems.
6. Explain the purpose, location, and operation of the gas turbine starting motor and turning gear.
7. Describe the compressor intake and the turbine exhaust components.
8. Describe the preparation and complete start-up sequence for a gas turbine.
9. Describe the shutdown sequence and procedure for a gas turbine.
10. Explain the purpose and describe typical on-line and off-line waterwash procedures for gas turbine blades.

Chapter 6 Internal Combustion Engines

Learning Outcome

Explain the operating principles, designs, support systems, and operation of industrial internal combustion engines (ICEs).

Learning Objectives

1. Explain the principles of spark ignition and compression ignition; describe the operating cycles for two- stroke and four-stroke designs.
2. State the purpose of the major mechanical components of an internal combustion engine.
3. Describe fuel injection and battery ignition systems for a spark ignition engine.
4. Describe individual pump, distributor, and common rail fuel injection systems for a diesel engine.
5. Explain the purpose and describe the operation of superchargers and turbochargers.
6. Describe and explain the operation of a typical cooling system for an industrial internal combustion engine.
7. Describe and explain the operation of a typical lubrication system for an industrial internal combustion engine.
8. Describe engine starting devices and systems for diesel and gas engines.
9. Explain the monitoring, protection, and control devices on a large industrial diesel or gas engine, including shutdowns and governing.
10. Explain the typical start-up procedure for a large industrial diesel engine, and explain the routine monitoring requirements of a running engine.
11. Explain the Otto, diesel, and Brayton thermodynamic heat engine cycles.

Chapter 7 Cogeneration Systems and Operation

Learning Outcome

Explain cogeneration, and describe common configurations, components, and applications.

Learning Objectives

1. Define cogeneration and explain its purpose and advantages.
2. Explain typical industrial cogeneration components and applications.
3. Explain single-shaft and multi-shaft combined-cycle power plants.
4. Explain the general control strategies and components for both power and steam production, including diverter and duct burner operation.
5. Describe the various designs of a heat recovery steam generator (HRSG), and explain their industrial applications.
6. Explain the environmental considerations and techniques in the operation of a cogeneration system.
7. Describe typical cogeneration systems that use internal combustion engines (gas or diesel) and heat recovery water heaters (HRWHs).
8. Explain a typical start-up procedure for a combined cycle cogeneration system.

Chapter 8 Compressor Theory and Designs

Learning Outcome

Explain the classification, designs, and operating principles of industrial air and gas compressors.

Learning Objectives

1. Explain compressor terminology, including compression ratio, capacity, staging, intercooling, and aftercooling. Explain the effects of moisture in compressed gases. Explain the effects of altitude on the compression process.
2. Describe the operation and common arrangements of reciprocating compressors, including single- acting, double-acting, and tandem arrangements.
3. Identify the components of a reciprocating compressor, and describe the operation of plate and channel valves.
4. Describe internal and external lubrication systems for reciprocating compressors.
5. Interpret an indicator diagram as it relates to compressor performance.
6. Define clearance volume as it relates to reciprocating compressors.
7. Perform calculations relating to reciprocating compressor performance.
8. Describe the design and explain the operating principles of rotary compressors, including sliding vane, rotary lobe, and rotary screw.
9. Identify the components and controls for a packaged industrial screw compressor.
10. Identify the components in the piping layout of a compressor system.
11. Describe designs and principles of centrifugal compressors and blowers, including single and multi-stage designs.
12. Describe designs and principles of axial compressors and blowers.

Chapter 9 Compressor Auxiliaries and Operation

Learning Outcome

Explain the controls and system auxiliaries for a typical instrument air system, and explain start-up procedures for air compressors.

Learning Objectives

1. Describe the control devices and strategies for air compressors, including start-and-stop, variable speed, and constant speed. Describe pilot and unloader devices.
2. Explain the design and operation of an anti-surge system for a dynamic compressor.
3. Describe the designs of water- and air-cooled aftercoolers and intercoolers, with separators.
4. Describe the components, operating principles, and sequences of instrument air dryers. Explain dew point monitoring of air systems.
5. Describe the design, fittings, and operating considerations for air receivers.
6. Explain the start-up procedure for a positive displacement compressor.
7. Explain the start-up procedure for a dynamic compressor/blower.

Chapter 10 Refrigeration Principles and Systems

Learning Outcome

Explain the classification and properties of refrigerants, and describe the operating principles and components of compression and absorption systems.

Learning Objectives

1. Identify major refrigeration applications.
2. Explain the required properties of a refrigerant, and describe the six group classifications for refrigerants. Identify the properties of common refrigerants.
3. Explain the ammonia compression refrigeration cycle, explaining the purpose of each major component and state typical pressures and temperatures in the system.
4. Explain direct and indirect refrigeration. Describe a centrifugal compression system used to produce chilled water.
5. Describe and explain the operation of a two-stage duplex compressor system with a brine cooler.
6. Describe and explain the operation of a two-stage refrigeration system with a rotary booster compressor.
7. Describe and explain the operation of a low-temperature multi-stage refrigeration system.
8. Explain the components and operating principles of an ammonia absorption system.

Chapter 11 Refrigeration Auxiliaries and Operation

Learning Outcome

Explain control and safety devices on a compression refrigeration system, and explain procedures and equipment to control oil, non-condensables, moisture, refrigerant, and brine.

Learning Objectives

1. Explain the purpose, design, and operation of the following controls on a compression refrigeration system: expansion valve, low-side float, and high-side float.
2. Describe temperature- and pressure-actuated compressor controls.
3. Describe condenser cooling water control.
4. Explain the purpose of the following refrigeration system safety devices: high-pressure cut-out, oil pressure cut-out, and pressure relief devices.
5. Explain the effects of oil in ammonia and Freon systems, and describe the location and operation of an oil separator and oil still. Explain how oil is manually drained from these systems.
6. Explain the effects and location of non-condensable gases. Describe the operation of manual and automatic purge devices.
7. Explain the effects of moisture in a refrigeration system, and describe its removal.
8. Explain leak testing of a system, and describe the procedure for adding refrigerant.
9. Explain the principles of brine control in an indirect system, and explain the procedures for charging and controlling brine strength.
10. Explain refrigeration safety and environmental issues.

Chapter 12 Heat Exchangers and Cooling Towers

Learning Outcome

Describe the design, operation, and applications of various types of industrial heat exchangers.

Learning Objectives

1. Describe double-pipe heat exchangers, including jacketed pipe, U-tube, and concentric pipe designs.
2. Describe shell-and-tube heat exchangers including fixed straight tube and U-tube designs. Describe common front and rear head designs and shell flow configurations, and explain the purpose of baffles.
3. Explain the operation and the typical fittings/equipment on the steam/condensate side of a reboiler and a feedwater heater.
4. Describe the design and operation of a plate-and-frame exchanger.
5. Describe the design and components of overhead, aerial coolers, including fan and cooler arrangements. Explain cooler control.
6. Describe the design and components, including controls, of an overhead, aerial condenser. Explain condenser operation, control, and precautions when the condenser is used to condense excess steam.
7. Describe the design and explain the operation of natural draft cooling towers, including atmospheric and hyperbolic styles.
8. Describe the design and operation of mechanical draft cooling towers, including forced draft, induced draft counterflow, and induced draft crossflow.

Chapter 13 Fired Heaters

Learning Outcome

Describe the design, components, operation, and applications of direct-fired and indirect-fired natural draft process heaters.

Learning Objectives

1. Describe the common process applications for direct-fired heaters. Explain direct-fired heater designs and classifications.
2. Describe the design, identify the tube banks and explain the fluid and combustion gas flows through a multi-burner, vertical fired heater.
3. Describe typical burner designs and configurations, identifying burner components, including air registers, pilots, and flame scanners. Describe burner operation.
4. Describe the fuel gas supply system to the burners, and explain the purpose of the major fittings.
5. Describe the monitoring, control, and shutdown devices on a typical heater.
6. Explain a heater start-up procedure, including the lighting of additional burners once flame is established. Explain heater shutdown procedure.
7. Describe the design, components, and operation of a typical horizontal, indirect-fired heater such as a salt bath heater.
8. Explain start-up and shutdown procedures for an indirect-fired heater.

Chapter 14 Wastewater Treatment

Learning Outcome

Explain the purpose, designs, processes, and control of industrial wastewater treatment.

Learning Objectives

1. State the purpose of wastewater treatment, list typical waste liquids, and explain the legislation and permitting, including parameters, for the disposal of wastewater.
2. Sketch an industrial wastewater treatment system, and describe the processes that occur at each stage of treatment.
3. Describe the equipment and process involved in the removal of suspended solids from wastewater, including screening, flotation, and sedimentation.
4. Describe the equipment and process involved in the removal of colloidal solids from wastewater, including chemical coagulation, flocculation, and clarification.
5. Describe the equipment and process involved in the biological removal of solids from waste water, including activated sludge, rotating biological contactors, and trickling filters.
6. Describe the control strategy for a wastewater treatment system. Define and explain the control of and sampling points for the main control parameters, including nutrients, BOD, COD, the pH, and settleability.
7. Identify hazards associated with wastewater treatment.
8. Identify the safety protocols to mitigate the hazards associated with wastewater treatment.

Chapter 15 Plant Maintenance and Administration

Learning Outcome

Explain typical components of maintenance and administration programs for utilities and process facilities.

Learning Objectives

1. Explain typical communication and accountability structures within a large facility, including the responsibilities for external communication.
2. Describe the typical components and responsibilities of scheduled and preventive maintenance management programs.
3. Explain the importance and extent of record keeping, and describe the quality and content requirements for operating logbooks and records.
4. Using a complete boiler turnaround and inspection as an example, describe project management using two methods: Gantt chart and critical path.
5. 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.
6. Explain typical environmental monitoring and management programs for operating facilities.