Advanced Concepts in Power Engineering (Edition 1.5)
Course Outline with Outcomes

These learning materials are designed to directly address the NIULPE International 3rd Class Power Engineer Certification.

Content

Part A1: Applied Mechanics, Thermodynamics & Chemistry

1. Algebraic Operations, Logarithms & 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 powers, roots, and fractions.
6. Explain common and Naperian (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.

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 Pythagoras' Theorem to calculate the side lengths of a right angle triangle and solve simple problems involving right triangles.
4. Explain the sine, cosine, and tangent of an angle and determine the values of these functions for all angles between 0 and 360 degrees.
5. Using sine, cosine, and tangent, find the dimensions of right triangles and solve physical problems involving right triangles.
6. Define the Sine Rule and the Cosine Rule and use these rules to determine the unknown dimensions of oblique triangles.

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 the SI system.
2. Calculate the areas of triangles given altitude and height, or 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 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.

4. Forces & 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; use the friction formula to calculate coefficient of friction
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.

5. Work, Power, Energy & Linear & Angular Motion

Learning Outcome

Explain concepts and solve problems involving work, power, energy, linear and angular motion.

Learning Objectives

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

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 formula where applicable, the following terms as they apply to materials under load: 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.
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 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.

7. Simple Machines; Pressure, Density, 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 (MA), velocity ratio (VR), 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. Define and state the relationships between mass density, relative density, weight density, specific weight, and specific gravity.
6. Given unknowns, calculate the densities, relative densities, masses and/or volumes of substances.
7. Calculate pressures exerted by columns of fluids and convert between gage pressure, absolute pressure, millimetres of mercury, millimetres of water.
8. Calculate the pressure and force exerted by a liquid at various levels in a tank.
9. Explain flow continuity and calculate simple flows and velocities of liquids in a pipe.

8. Heat, State Change, Calorimetry

Learning Outcome

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

Learning Objectives

1. Define and explain internal energy, heat, specific heat, heat units, temperature and explain the relationship between the different scales of temperature measurement.
2. Define sensible heat and use the sensible heat equation to calculate the heat required to change the temperature of a substance, the mass of the substance, and the temperature change, 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 principle of a simple calorimeter and use the calorimeter equation to determine specific heat and final temperature.
7. Explain water equivalent and perform calorimeter and heat calculations involving water equivalents.

9. Thermal Expansion & Heat Transfer

Learning Outcome

Explain concepts and perform calculations to determine the thermal expansions of solids and liquids and the amount of heat transferred through a substance.

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 flat walls and plates.

10. Steam Properties & 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 evaporation in 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, 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.

11. Gas Laws & Calculations

Learning Outcome

Define and 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, and the General Gas Law and use these to calculate pressure, temperature and/or volume changes 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.

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 the Elements, determine the atomic numbers and the atomic masses of elements.
3. Explain the electronegativity and the bonding of ions.
4. Explain the formation of chemical compounds, explain typical reactions and apply basic principles to the balancing of simple chemical reactions.
5. Calculate the amount of reactants or products required or 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, combustion, hydrocarbon processing, petrochemical and pulp and paper processes.

13. Metallurgy & 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 the following mechanical properties of a material: brittleness, hardness, ductility, malleability, plasticity, elasticity, and toughness.
2. Describe the following material tests: tension test, Brinell and Rockwell hardness tests, 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 each of the following alloying elements: nickel, chromium, molybdenum, vanadium, copper, lead, manganese and tungsten.
6. Explain the purposes for hot working, cold working and heat treating of 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.

14. Corrosion Principles

Learning Outcome

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

Learning Objectives

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

15. Industrial Drawings

Learning Outcome

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

1. State the purpose of a Process Flow Drawing (PFD), and identify the major information available on a typical PFD.
2. State the purpose of a Process & Instrument Drawing (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 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 equipment.
5. State the purpose and identify the components of a typical Equipment Layout Drawing.

Part A2: Boiler Codes, Electrical & Instrumentation Theory

1. Legislation & 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 Codes and Standards.
2. Explain the purpose and scope of the National Board of Boiler Inspectors (NBBI).
3. Explain the scope of the ASME and state the purpose and general content of the following sections of the ASME Codes: Section I, IV, V, VI, VII, VIII, IX.

2. Code Calculations - ASME Section I

Learning Outcome

Using USCS units of measure, extracts from ASME Code - Section I, and related tables, calculate the design thickness and pressure of boiler tubes and drums, and the capacity of safety valves.

Learning Objectives

1. Given the tube material specification numbers, and other necessary parameters, use the formulae in 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 formulae in PG-27.2.2 to determine the required thickness and or maximum working pressure for boiler drums, headers, or piping.
3. Given the required specifications and operating conditions, use formula PG-29.1 to calculate the required thickness of a seamless, unstayed dished head.
4. Given the required specifications and operating conditions, use the formulae in paragraphs PG-29.11 and PG-29.12 to calculate the required thickness of an unstayed, full-hemispherical head.
5. Explain the ASME requirements for safety valves and safety relief valves.

3. Fuels, Combustion, Flue Gas Analysis

Learning Outcome

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

Learning Objectives

1. Explain/define complete combustion, incomplete combustion, combustion products, and write balanced combustion equations
2. Explain the purpose and benefits of excess air and calculate the theoretical and excess air required for the complete combustion of a given fuel.
3. Explain proximate analysis, ultimate analysis, and heating value of a fuel and describe the use of calorimetry to determine calorific value.
4. Given the ultimate analysis of a fuel, use Dulong's Formula to calculate the heating value of the fuel.
5. Describe the properties, classifications and combustion characteristics of coal.
6. Describe the properties, classifications and combustion characteristics of fuel oil.
7. Describe the properties and combustion characteristics of natural gas.
8. Explain the use and combustion characteristics of non-fossil fuels, including biomass, wood wastes, solid municipal wastes, coke, oil emulsions.
9. Explain the analysis of flue gas for the measurement of O_2, CO, and CO_2 in relation to combustion efficiency. Describe typical, automatic flue gas analyzers.
10. Explain the formation, monitoring and control of nitrogen oxides (NOx), sulphur dioxide, and particulates

4. Piping Design, Connections, Support

Learning Outcome

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

Learning Objectives

1. Identify and explain the general scope of the ASME, ANSI, NB, ASTM codes and standards with respect to piping and pipe fittings. Differentiate between power piping (Code B31.1) and pressure piping (Code B31.3).
2. Explain methods of pipe manufacture; size specifications and service ratings, and the material specifications and applications for ferrous pipe.
3. Using pipe specifications and the ASME code Sections I and II you will able to identify the size of pipe required for a particular installation, process or operating condition.
4. Explain the materials, code specifications and applications of common, non-ferrous metal 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 Ubend expansion bends.
10. Describe designs, locations, care and maintenance of slip, corrugated, bellows, hinged, universal, pressure-balanced, and externally pressurized expansion joints.
11. Describe design, location, operation of pipe support components, including hangers, roller stands, variable spring hangers, constant load hangers, anchors, and guides.

5. Steam Traps, Water Hammer, Insulation

Learning Outcome

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

Learning Objectives

1. Explain the dynamics, design, and components of steam/condensate return systems for steam lines and condensing vessels. Explain 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 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/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 precautions that must be observed to prevent water hammer and describe a typical steam system start-up procedure that will prevent water hammer.
8. State the purposes of insulation for piping and process equipment and explain the properties required for a good insulating material.
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 good condition.

6. Valves & 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 application of the major valve styles; gate, globe, ball, plug, butterfly and needle.
2. Explain the factors that determine the selection of valve materials and describe examples of typical valve body and trim materials. Describe how are common control valves identified.
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 doubleseated 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 operation of diaphragm valves.
9. Describe designs and operation 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.

7. Electrical Theory & DC Machines

Learning Outcome

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

Learning Objectives

1. Explain the production of electron flow in a circuit and define circuit voltage, amperage and resistance.
2. Explain electromagnetic induction and how it produces generator action and motor action.
3. Describe the design and operating principles of a DC generator or motor, clearly stating the purposes of the armature, brushes, windings and poles.
4. Explain how back EMF, 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 back emf created in a DC generator.
5. Explain separate and self excitation and describe the voltage/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.
6. Explain the speed/load characteristics of shunt, series and compound DC motors; define and calculate percent speed regulation and explain how speed is controlled in DC motors.
7. Explain DC motor torque characteristics and describe the starting mechanisms for DC motors.

8. AC Theory & Machines

Learning Outcome

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

Learning Objectives 1. Explain the creation of single phase and three-phase alternating power; define cycle, frequency

and phase relationships (voltage/current) for AC sine waves.

2. Define the following terms and explain their relationships in an ac circuit: capacitance, inductance, reactance, impedance, power factor, 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 operation 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 transformation. Perform transformer calculations.
10. Describe the designs and components of typical core and shell type transformers, including cooling components.

9. AC Systems, Switchgear, 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 gages, 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, automatic bus switchover, grounding and lightning arrestors.
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.

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.
5. Define terms 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, plus circuit frequency and current flow.
7. Calculate real power, imaginary power and power factor for an ac circuit.
8. Given the load, voltage and power factor of a 3-phase generator, calculate the kVA and kW ratings of the generator.

11. Control Loops & 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 terminologies 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/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, operation, and give examples of on-off, proportional, proportional-plus-reset, and proportional-plus-reset-plus-derivative control. Define proportional band and gain.
6. Describe and give typical examples of feed forward, feed back, cascade, ratio, split-range, and 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.

12. Instrument & 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 for the following temperature devices: bimetallic thermometer, filled thermal element, thermocouple, RTD, thermistor, radiation and optical pyrometers.
2. Describe the design, operation and applications for the following pressure devices: bourdon tubes, bellows, capsules, diaphragms, and absolute pressure gage.
3. Describe the design, operation and applications for 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 for the following level devices: atmospheric and pressure bubblers, diaphragm box, differential pressure transmitter, capacitance probe, conductance probes, radiation and ultrasonic detectors and load cells.

13. Distributed & 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. Identify and explain the functions of the major components of the operator interface unit (OIU), including controller interfaces, displays, alarms and shutdown.
3. State typical applications and explain the purpose and functioning of a programmable logic controller, including the operator interfaces.
4. Identify, state purposes of, and interpret in simple terms, ladder logic diagrams for programmable controllers.
5. State the purpose and explain the general functioning of a communication and data acquisition system (eg. SCADA) as it relates to process control.

14. Safety Management Programs

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 and Safety Health Act (OSHA).
2. Explain the intent and scope of a workplace OSHA program and state the responsibilities of company, employees, and the OSHA 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 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 a confined space and a permit-required confined space, 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 OSHA Hazard Communication Standard, explain the use of labels and material safety data sheets, and explain the responsibilities of employer and employee.
10. Explain the purpose, requirements, and procedures for incident and accident investigation and reporting.

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, pre-action and deluge designs for sprinkler systems.
5. Describe the layout, components and operation of a typical firewater system with fire pump and hydrants. Explain seasonal considerations for a firewater system.
6. Describe the construction and operation of a typical fire hydrant.
7. Explain the purpose and describe a typical deluge water system for hydrocarbon storage vessels.
8. Explain the purpose and describe a typical foam system for process buildings and tanks.
9. Describe a typical fire response procedure for an industrial setting.

Part B1: Pumps & Boilers

1. Watertube Boiler Designs

Learning Outcome

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

Learning Objectives

1. Explain the difference between packaged, shop assembled and fielderected 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, O, and D 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 temperatures throughout the unit.
5. Differentiate between critical and super-critical 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.

2. Special Boiler Designs

Learning Outcome

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

Learning Objectives

1. Once-through, steam flood boilers
2. Fluidized Bed Boilers
3. Heat Recovery Steam Generators
4. Black Liquor Recovery boilers used in pulp mills
5. Refuse boilers used in waste disposal
6. Waste heat, bio-mass boilers

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 bottom and top support and describe the support techniques for various components of a large boiler, including lateral supports for furnace walls.
2. Explain allowances for expansion.
3. Explain the purpose, design, locations and installation methods for boiler casing insulation, refractory and cladding.
4. Describe the methods used to fabricate boiler tubes.
5. Describe the preparation, fabrication and testing of boiler drums.
6. Describe methods of attaching tubes to drums and headers, including expanding and welding, and explain where each method would be used.
7. Describe methods of attaching nozzles to boiler drums and headers and explain Code requirements for such attachments.
8. Explain code requirements/sizes for, and describe the design and installation of manholes and handholes, including welded handholes. Explain procedures for removing and installing covers.
9. Describe the field assembly of a large boiler or steam generating unit.

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 superheates. 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 of and flow through the reheater in relation to the superheaters.
6. Describe designs and locations for 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.

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 safety valve. Explain the Code requirements for size, capacity and locations of safety valves on a boiler.
2. Describe the code requirements for boiler pressure gages, including attachment and locations.
3. Describe common designs, connections and components of high-pressure water columns and flat gage glasses, including illumination and quick shut-off devices and bulls-eye glasses. Explain testing and maintenance of a highpressure gage glass.
4. Describe the float and probe designs for low-water level cutoffs and explain how these are tested.
5. Describe boiler steam outlet arrangements and fittings including gate, angle, and globe stop valves and globe, Y, angle, and spring-cushioned non-return valves.
6. Describe manual blowdown piping arrangements. Describe the design and operation of sliding disc, seatless sliding plunger, seat and disc, and\ combination valves. Explain manual blowdown procedures. Describe the requirements for a blowdown tank.
7. 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.

6. Burner Designs & Supply Systems

Learning Outcome

Describe the typical components of fuel supply systems and describe common burner and furnace designs for gas, oil and coal-fi red boilers.

Learning Objectives 1. Describe a complete fuel gas supply system from fuel gas header to burner 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 coal supply system from stockpiles to burners for a typical pulverized coal 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 impact, ball, ball-race, and bowl mill pulverizers.
8. Describe the designs and operation of underfeed, crossfeed, and overfeed furnaces for burning solid fuels.

7. Boiler Draft & 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 running checks that must be made on draft fans.
5. Describe typical windbox and air louver 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 SO2 recovery systems, including lime and wet gas scrubbing.

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 the automatic, programmed start-up sequence for a gas-fired boiler.

9. Boiler Procedures

Learning Outcome

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

Learning Objectives

1. Explain the steps involved in the commissioning of a new boiler or before starting a boiler after major repairs, including:
   a) general order and purpose of the major commissioning tasks
   b) hydrostatic test
   c) drying out refractory
   d) boiling out
   e) 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 shut down 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 water side of a boiler:
   a) mechanically
   b) chemically
6. Explain routine tasks and visual monitoring that the operator must perform 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 sootblowing systems and describe the procedures for operating sootblowers.

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 causes and effects of boiler scale; explain the most common internal methods of scale control, including phosphate treatment, chelate treatment, sludge conditioning and dispersion.
2. 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.
3. Explain the mechanical and chemical causes, effects and types of carryover; explain methods of carryover control, including the use of antifoam and blowdown.
4. Describe the design and explain the operation of simple blowdown, heat\ recovery, and automatic blowdown systems.
5. Explain, in general terms, 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 with day tanks, and continuous feed with pump tanks.

11. Boiler Water Pretreatment

Learning Outcome

Explain the purpose, principles, components and operating procedures for common industrial pumps and perform calculations involving pump head.

Learning Objectives

1. Describe the design and explain the terms, purpose and operation for a clarifier, using coagulation and flocculation.
2. Describe the design and explain the terms, purpose and operation of gravity and pressure filters.
3. Describe the design and explain the terms, purpose and operation, including chemical reactions for a cold lime softener.
4. Describe the design and explain the terms, purpose and operation of a hot lime softener.
5. Explain the principles of ion exchange softening in general, identifying the common anions and cations in untreated water.
6. Describe the design, components, and operation of a sodium zeolite softening system including chemical reactions.
7. Describe the design, components, and operation of a hydrogen zeolite softening system including chemical reactions.
8. Describe the design, components, and operation of a dealkalization system including chemical reactions.
9. 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. Pump Designs & Operation

Learning Outcome

Describe the designs, principles, components and operating procedures for common industrial pumps and perform calculations involving pump head.

Learning Objectives

1. Explain the principle of operation and describe the components of typical piston and plunger 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-staging, split and barrel casings.
5. Describe the design and applications of axial and mixed flow pumps.
6. Describe the design and components of a multistage centrifugal pump, clearly stating the purpose and general design of: wearing rings, shaft sleeves, seals, bearings and lubrication components, vents and drains.
7. Explain design features that eliminate thrust in large centrifugal pumps.
8. Describe a complete piping system for a multistage centrifugal pump, including the purpose and design of the automatic recirculation (minimum flow) valve.
9. Explain proper priming, start-up procedures and operating considerations for pumps.

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, 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, total dynamic head, and calculate each of these for a given pump arrangement.
6. Explain vapour pressure, cavitation, and net positive suction head. Calculate the required suction pressure for a water pump, given the manufacturers required NPSH.

14. Welding Procedures & 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. Describe a typical weld procedure on a large pipe, including the purpose and methods for preheating and for postweld heat treatment (stress-relieving)
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 dye 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 Weld Procedure and Welder Performance qualification, per the ASME Code, Section 9.

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 purpose of Section VIII, ASME)
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 manway cover designs.
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: Prime Movers & Refrigeration

1. Steam Turbine Principles & 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 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, backpressure, extraction, topping, mixed-pressure, cross-compounded and tandem compounded.
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/shaft seals.
6. Describe the designs and applications of disc 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 and large industrial turbines. Explain typical size/capacity rating specifications and explain typical applications.

2. Steam Turbine Auxiliaries & 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 barring gear and jacking oil systems on a large turbine.
3. Describe a condensing turbine circuit and explain typical operating parameters.
4. Explain and state the applications, where applicable, of the following governor types: speed-sensitive, pressure-sensitive, nozzle, throttle, and bypass. Explain governor droop and isochronous control.
5. Explain the operation and the major components of the three main speedsensitive governor systems: mechanical, mechanical-hydraulic, and electronichydraulic.
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 the 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.

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 turbine condenser in a steam plant cycle and describe a typical condensing circuit, with operating temperatures and pressures.
2. Explain the design, operation and applications of the jet condenser, including the ejector type.
3. Explain the design, operation and applications of the surface condenser, including aircooled and water-cooled, down flow and central flow.
4. Describe construction details for surface condensers, including shells, tube attachment, supports, and allowances for expansion.
5. Explain the effects of air in a condenser and describe the design and operation of single and two-stage air ejectors. Explain the detection of condenser air leaks.
6. 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.
7. Describe the operating conditions and corresponding design considerations for condensate extraction pumps.
8. Describe a feed water heater system in conjunction with a steam condenser and explain the designs of low-pressure and high-pressure feed water heaters.

4. Gas Turbine Principles & Designs

Learning Outcome

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

Learning Objectives

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

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

6. Internal Combustion Engines

Learning Outcome

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

Learning Objectives

1. Explain the principles of spark ignition and compression ignition; describe the operating cycles for two-stroke and four-stroke designs.
2. Identify and state the purpose of the major mechanical components of an internal combustion engine.
3. Describe carburetor, fuel injection, battery ignition, and magneto 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 ICE.
7. Describe and explain the operation of a typical lubrication system for an industrial ICE.
8. Describe engine-starting devices/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 a typical start-up procedure for a large industrial diesel engine, plus the routine monitoring requirements of a running engine.

7. Cogeneration Systems & Operation

Learning Outcome

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

Learning Objectives

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

8. Compressor Theory & Designs

Learning Outcome

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

Learning Objectives

1. Explain compressor terminologies, 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, tandem arrangements and free piston.
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. Describe the design and explain the operating principles of rotary compressors, including sliding vane, rotary lobe, and rotary screw.
6. Identify the components and controls for a packaged industrial screw compressor.
7. Describe designs and principles of centrifugal compressors/blowers, including single and multi-stage designs.
8. Describe designs and principles of axial compressors/blowers.

9. Compressor Auxiliaries & Operation

Learning Outcome

Explain the control 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-stop, variable speed, 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, arrangement, and parameters of a typical, complete instrument air system, including wet and dry receivers, dryers.
5. Describe the components and operating principles and sequences of instrument air dryers. Explain dewpoint monitoring of air systems.
6. Describe the design, fittings, and operating consideration for air receivers.
7. Explain the start-up procedure for a positive displacement compressor.
8. Explain the start-up procedure for a dynamic compressor/blower.

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

11. Refrigeration Auxiliaries & Operation

Learning Outcome

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

Learning Objectives

1. Explain the purpose, design and operation of the following controls on a compression refrigeration system: expansion valve, low-side float, high-side float, compressor controls (temperature and pressure-actuated), and condenser cooling water control.
2. Explain the purpose of the following refrigeration system safety devices: highpressure cutout, oil pressure cutout and pressure relief devices.
3. 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.
4. Explain the effects and location of non-condensable gases. Describe the operation of manual and automatic purge devices.
5. Explain the effects of moisture in a refrigeration system and describe its removal.
6. Explain leak testing of a system and describe the procedure for adding refrigerant.
7. Explain the principles of brine control in an indirect system and explain the procedures for charging and controlling brine strength.
8. Explain refrigeration safety and environmental issues.

12. Heat Exchangers & 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, 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 feed water 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 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.

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 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.

14. Wastewater Treatment

Learning Outcome

Describe the design, operation and monitoring of processes and equipment used to treat waste water.

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 wastewater, 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, pH, and settleability.

15. Plant Maintenance & 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.