PanGlobal

Partner in Education

Process Operator Series Book II

Book Outline

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Course Outline

Process Operator Series: Part A

Unit 1: Piping and Valves

Chapter 1 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, ASME, ANSI, ASTM codes and standards with respect to piping and pipe fittings. Differentiate between power piping (Code B31.1) and process 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 be 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 and cast iron.
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 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.

Chapter 2 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/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, bi-metallic, 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 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 good condition.

Chapter 3 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 factor 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.

Unit 2: Pumps and Compressors

Chapter 4 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-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: 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 5 Compressor Theory and 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, 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. 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.

Chapter 6 Compressor Auxiliaries and Operation

Learning Outcome

Explain the controls and system auxiliaries for a typical instrument air system and explain startup procedures for air compressors.

Learning Objectives

1. Describe the control devices and strategies for air compressors, including start-and-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.

Unit 3: Lubrication

Chapter 7 Types of Bearings and Lubrication

Learning Outcome

Describe bearing types, methods for care and maintenance of bearings, and bearing lubrication systems.

Learning Objectives

1. Define boundary and full fluid film lubrication.
2. Describe shell (sleeve) bearings.
3. Describe the construction and operation of antifriction and thrust bearings.
4. Describe how to clean and replace roller and ball type bearings.
5. Explain the causes of bearing failure.

Unit 4: Prime Movers and Heat Engines

Chapter 8 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 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 velocity/pressure 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, 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/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.
9. Explain the use and design of reducing gears attached to steam turbines.

Chapter 9 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 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 speed-sensitive governor systems: mechanical, mechanical-hydraulic, and electronic-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.

Chapter 10 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, 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 air-cooled and water-cooled, downflow 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. Explain vacuum pumps.
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 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.

Chapter 11 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 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 the various aspects of compressor design and centrifugal and axial types of compressors.
6. Describe the types, operation, components and arrangements of combustors.
7. Describe power 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. 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 12 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 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 gas 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.

Chapter 13 Internal Combustion Engines

Learning Outcome

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

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.

Answer Guide

Process Operator Series: Part B

Unit 5: Heat Exchangers and Fired Systems

Chapter 14 Heat Exchangers and Cooling Towers

Learning Outcome

Discuss the general principles, methods, and equipment used for the treatment of condenser water, and their effects on the cooling tower.

Learning Objectives

1. Describe the effects of water on condensers and cooling tower materials.
2. Describe condenser and cooling tower water treatment.
3. Describe cooling tower and condenser water tests for common treatment methods.

Chapter 15 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.

Unit 6: Electrotechnology

Chapter 16 Transformers

Learning Outcome

Describe the operating principles of electrical transformers.

Learning Objectives

1. Describe the principle of operation of transformers.
2. Perform basic transformer calculations as they relate to the construction and operation of single-phase transformers.
3. Describe the construction and operation of three-phase transformers.
4. Discuss special transformer types and their applications.
5. Discuss transformer cooling, safety, and maintenance.

Chapter 17 Electrical Distribution Circuits

Learning Outcome

Describe an electrical distribution system.

Learning Objectives

1. List and describe the standard types of electrical voltage systems.
2. Interpret electrical single-line diagrams and circuit symbols.
3. Describe the major components of an electrical distribution system.
4. Describe the function and operation of fuses and circuit breakers.
5. Describe the function and operation of alternate power supply system equipment.

Chapter 18 Electrical Theory and 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 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.
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.

Chapter 19 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, 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, 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 20 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, 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.

Unit 7: Instrumentation and Controls

Chapter 21 Electrical Control Systems

Learning Outcome

Describe the design and operation of electrical control systems.

Learning Objectives

1. Describe the basic construction and operation of various electric control system components.
2. Describe the function of control devices in electric control systems.
3. Explain the operating sequence of basic electric control circuits.

Chapter 22 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 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.

Chapter 23 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 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 gauge.
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 transmitters, capacitance probe, conductance probes, radiation and ultrasonic detectors, and load cells.

Chapter 24 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. 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. Explain a ladder logic diagram.
4. State the purpose and explain the general functioning of a communication and data acquisition system (eg. SCADA) as it relates to process control.

Unit 8: Plant Maintenance

Chapter 25 Powerhouse Maintenance II

Learning Outcome

Discuss and describe the safe and proper setup of equipment for hoisting and working above ground.

Learning Objectives

1. Describe the requirements for setting up work platforms in general and ladders and scaffolding in particular.
2. Describe the general safety precautions and calculations used when rigging equipment.
3. Describe the general safety precautions used when hoisting equipment.
4. Discuss the correct use and limitations of wire cable and rope, including cable attachments and rope knots.
5. List and describe common types of metal fasteners, such as screws, bolts, studs, nuts, and washers.

Answer Guide