CH402 CHEMICAL ENGINEERING PROCESS DESIGN

Lesson 1: Course Admin & Piping Design

Read: Pages 485-507

Problems: 12-1, 12-2 (Problem Set 1)

Objectives (Cadets will be able to):

1. Apply the mechanical energy balance to calculate the power needed to drive fluid flow in pipes.

2. Determine frictional losses in pipe flow.

3. Determine equivalent length from frictional losses for pipe fittings.

4. Determine cost of piping and associated equipment and materials from cost correlations.

Definitions:

Fanning friction factor, Reynolds number, cost correlations, optimum economic pipe diameter

Cadet Notes:

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Lesson 2: Piping, Part 2

Read: Pages 485-507

Problems: 12-1, 12-2 (Problem Set 1)

Objectives (Cadets will be able to):

1. Describe the basic features of the mechanical design of valves.

2. Determine cost of different types of valves.

3. Determine cost of different types of fittings.

Definitions:

Globe valve, gate valve, valve coefficient, discharge coefficient

Cadet Notes:

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Lesson 3: Pumps

Read: Pages 508-536

Problems: 12-6 (Problem Set 2)

Objectives (Cadets will be able to):

1. Select a pump, compressor, or expander for a given application.

2. Perform pump sizing calculations using the system and characteristic curves.

3. Determine the cost of pumps, expanders, and related equipment.

Definitions:

NPSH, characteristic curve, system curve, head, efficiency, cavitation

Cadet Notes:

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Lesson 4: Agitators

Read: Pages 536-549

Problems: 12-13 (Problem Set 2)

Objectives (Cadets will be able to):

1. Design generic agitators and mixers.

2. Determine power requirements for agitators and mixers.

3. Determine the cost of an agitator or mixer.

Definitions:

Froude number, power number, Reynolds number for impellers, sparger, agitator.

Cadet Notes:

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Lesson 5: Flow Measurement and Storage of Fluids

Read: Pages 549-560

Problems: 12-14 (Problem Set 3)

Objectives (Cadets will be able to):

1. Describe how an orifice plate is used to measure flow rates.

2. Use the orifice plate in CHEMCAD.

3. Set up a sensitivity analysis in CHEMCAD.

4. Calculate pressure or storage vessel wall thickness.

5. Determine the cost of a pressure or storage vessel.

Definitions:

Orifice meter.

Cadet Notes:

Lesson 6: Handling Solids

Read: Pages 560-586

Problems: 12-15 (Problem Set 3)

Objectives (Cadets will be able to):

1. Qualitatively describe the attributes of the different types of conveyors and size-reduction equipment.

2. Determine the power requirements for screw, belt, and pneumatic conveyors.

3. Determine the cost of solids-handling equipment.

Definitions:

Pneumatic conveyor, belt conveyor, screw conveyor, ball mill

Cadet Notes:

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Lesson 7: Heat Exchanger Theory

Read: Pages 643-668

Problems: 14-2 (Problem Set 4)

Objectives (Cadets will be able to):

1. Describe the physical layout of tubular and shell-and-tube heat exchangers.

2. Calculate overall the overall heat transfer coefficient from local heat transfer resistances.

3. Calculate local heat transfer coefficients and pressure drops for fluids flowing inside and outside of pipes.

4. Determine the cost of tubular and shell-and-tube heat exchangers.

Definitions:

Double-pipe heat exchanger, shell-and-tube heat exchanger, tube sheet, fixed sheet, floating sheet, tube bundle, tube pitch

Cadet Notes:

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Lesson 8: Heat Exchanger Types and Costs

Read: Pages 669-694

Problems: 14-9 (Problem Set 4)

Objectives (Cadets will be able to):

1. Describe the physical layout and parts of the shell-and-tube and double-pipe heat exchangers.

2. Calculate overall the overall heat transfer coefficient from local heat transfer resistances.

3. Determine costs of different types of heat exchangers.

Definitions:

Fixed tube, floating head, U-tube, one shell pass, split flow (shell-side), cross flow (shell-side), divided flow (shell-side), kettle-type reboiler, scraped surface heat exchanger, spiral heat exchanger, gasketed and welded head heat exchanger, compact heat exchanger, air-cooled heat exchanger, evaporator

Cadet Notes:

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Lesson 9: Heat Exchanger Design I

Read: Pages 694-724

Problems: 14-15 (Problem Set 5)

Objectives (Cadets will be able to):

1. Design a shell-and-tube heat exchanger to meet process specifications.
2. Implement the 3-step CHEMCAD heat exchanger design procedure.

Definitions:

CHEMCAD heat exchanger icons, CHEMCAD shell-side flow, CHEMCAD tube-side flow

Cadet Notes:

Lesson 10: Heat Exchanger Design II

Read: Pages 724-738

Problems: 14-16 (Problem Set 5)

Objectives (Cadets will be able to):

1. Calculate heat exchanger annual operating costs.

2. Use CHEMCAD to optimize a heat exchanger based on operating conditions.

3. Use CHEMCAD and Excel to optimize a heat exchanger based on operating costs.

Definitions:

Utility option, TEMA, design criteria, design variable limits, tube wall thickness, tube outer diameter, tube pitch, tube pattern, trufin tube code, turbulator, tube sheet, inlet nozzle, baffle, material specifications, sealing strip, entrainment ratio

Cadet Notes:

Lesson 11: Heat Exchanger Design III (continuation of Lesson 12)

Read: Pages 738-745

Problems: 14-16 (Problem Set 5)

Objectives (Cadets will be able to):

1. Calculate heat exchanger annual operating costs.

2. Use CHEMCAD to optimize a heat exchanger based on operating conditions.

3. Use CHEMCAD and Excel to optimize a heat exchanger based on operating costs.

Definitions:

Utility option, TEMA, design criteria, design variable limits, tube wall thickness, tube outer diameter, tube pitch, tube pattern, trufin tube code, turbulator, tube sheet, inlet nozzle, baffle, material specifications, sealing strip, entrainment ratio

Cadet Notes:

Lesson 12: Written Partial Review I

Read: Pages 643-586 and 102-745

Problems: Refer to lesson sheets for Lessons 1-11.

Objectives (Cadets will be able to):

There are no new lesson objectives for this lesson. Refer to lesson sheets for Lessons 1-11 for individual lesson objectives that you are responsible for.

Definitions:

Refer to lesson sheets for Lessons 1-11.

Cadet Notes:

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Lesson 13: Flowsheet Synthesis and I/O Analysis

Read: Pages 125-148

Problems: 4-13 (Problem Set 6)

Objectives (Cadets will be able to):

1. Construct and analyze the I/O diagram for a process.
2. Research chemical reactions and process chemistry.
3. Use process chemistry to construct a functions diagram.
4. Use functions diagrams to construct a process flow diagram.

Definitions:

Cadet Notes:

Lesson 14: Cost estimation and Capital Investments

Read: Pages 226-239

Problems: 6-1, 6-2 (Problem Set 7)

Objectives (Cadets will be able to):

1. Relate the I/O analysis from lesson 13 to the different cash flows in a process.
2. Articulate the different types of cash flow in a chemical process (Figure 6-1).
3. Calculate equipment costs using capacity scaling factors.

Definitions:

Working capital, nonmanufacturing and manufacturing fixed costs, direct and indirect costs, total capital investment, gross profit, purchased equipment costs, operating labor costs, utility costs, depreciation, annual total product costs, cumulative cash position, cost capacity scaling factors

Cadet Notes:

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Lesson 15: Cost Components of Capital Investments

Read: Pages 239-258

Problems: 6-3, 6-4 (Problem Set 7)

Objectives (Cadets will be able to):

1. Use cost components to estimate capital costs for chemical processing facilities.

2. Estimate capital costs using Lang factors.

Definitions:

Percentage of delivered equipment method, percentage of fixed capital investment method, free on board (F.O.B.), direct costs, indirect costs, fixed capital investment, working capital, total capital investment, Lang factors.

Cadet Notes:

Lesson 16: Plant Cost Scaling and Breakeven

Read: Pages 258-278

Problems: 6-8, 6-9, 6-10 (Problem Set 8)

Objectives (Cadets will be able to):

1. Estimate capital costs using scaling factors.

2. Estimate capital costs based on turnover ratio.

3. Determine breakeven point given production data.

Definitions:

Grass-roots plant, battery limits, detailed item estimate, unit cost method, method of power factors, plant capacity ratio, cost per unit capacity, turnover ratio, breakeven point, Return on investment (ROI).

Cadet Notes:

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Lesson 17: Interest

Read: Pages 279-292

Problems: 7-1, 7-2, 7-4, 7-5 (Problem Set 9)

Objectives (Cadets will be able to):

1. Calculate profitability based on rate of production.

2. Calculate present and future time value of cash flows.

3. Perform interest calculations using interest factors.

Definitions:

Fixed costs, variable costs, gross earnings, rate of production, discrete single-payment future-worth factors (DSPFWF), discrete single-payment present-worth factors (DSPPWF).

Cadet Notes:

Lesson 18: Depreciation and Taxes

Read: Pages 292-303

Problems: 7-9, 7-17, 7-18 (Problem Set 9)

Objectives (Cadets will be able to):

1. Decide what cost components are depreciable.
2. Calculate depreciation under various schedules.
3. Incorporate depreciation into tax calculations.
4. Calculate present worth and future value for cash flows including depreciation and taxes.

Definitions:

Straight-line depreciation, modified accelerated cost recovery system (MACRS), sum-of-the-digits depreciation.

Cadet Notes:

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Lesson 19: Profitability

Read: Pages 319-352

Problems: 8-1, 8-2, 8-4, 8-6 (Problem Set 10)

Objectives (Cadets will be able to):

1. Describe the commonly used profitability standards.

2. Assess profitability using the commonly used standards.

Definitions:

Return on investment (ROI), payback period (PBP), net present worth (NPW), discounted cash flow rate of return (DCFR)

Cadet Notes:

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Lesson 20: Review and Bonds

Read: Pages 226-303 and 319-352

Problems: No new problems are assigned. This will be an in-class review with problems provided by the instructor.

Objectives (Cadets will be able to):

1. Describe bonds and bond calculations using the "to…given…" method.

2. Calculate cash flow patterns for bonds.

Definitions:

Bonds.

Cadet Notes:

Lesson 21: Written Partial Review II

Read: Pages 226-303 and 319-352

Problems: Refer to lesson sheets for Lessons 13-21.

Objectives (Cadets will be able to):

There are no new lesson objectives for this lesson. Refer to lesson sheets for Lessons 12 and 14-19 for individual lesson objectives that you are responsible for.

Definitions:

Refer to lesson sheets for Lessons 13-20.

Cadet Notes:

Lesson 22: Introduction to Design Projects

Read: Pages 469-484

Problems: None

Objectives (Cadets will be able to):

1. Understand the requirements for the capstone design project.

2. Construct a table of contents for the project.

Definitions:

None.

Cadet Notes:

CH402 CHEMICAL ENGINEERING PROCESS DESIGN

Lab 1: Pump & Piping Design

Read: Project Handout and pages 485 to 507 in PTW.

Problems: None

Objectives (Cadets will be able to):

1. Update the cost index in CHEMCAD.

2. Use CHEMCAD to perform an optimized design and pricing of a section of pipeline.

3. Use CHEMCAD to determine the power requirements and purchased price for a pump.

4. Correctly apply the "Rating" and "Design" modes in the CHEMCAD pipe size and rating (PIPE) tool.

Definitions:

CHEMCAD rating mode, CHEMCAD design mode.

Cadet Notes:

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Lab 2: Hydraulics & Pump Characteristics – Part 1 – By Hand

Read: Project Handout

Problems: None

Objectives (Cadets will be able to):

1. Determine the hydraulic operating point from a pump characteristic curve and system curve.

Definitions:

None.

Cadet Notes:

CH402 CHEMICAL ENGINEERING PROCESS DESIGN

Lab 3: Hydraulics & Pump Characteristics – Part 2 – CHEMCAD

Read: Project Handout

Problems: None

Objectives (Cadets will be able to):

1. Determine the hydraulic operating point from a pump characteristic curve and system curve using CHEMCAD.

Definitions:

None.

Cadet Notes:

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Lab 4: Condenser, Reflux Drum, Reflux Pump, and Reboiler Costs in Distillation

Read: Project Handout

Problems: None

Objectives (Cadets will be able to):

1. Use realistic design constraints with CHEMCAD to design a condenser, reflux drum, reflux pump, and reboiler for a distillation process.

2. Use CHEMCAD with design heuristics to design heat exchangers.

3. Use safety data sheets to make preliminary safety and environmental assessments of a process.

4. Run a dynamic simulation in CHEMCAD

Definitions:

None.

Cadet Notes:

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Lab 5: Introduction to Process Control

Read: Project Handout

Problems: None

Objectives (Cadets will be able to):

1. Use CHEMCAD to design a temperature controller on a heat exchanger.
2. Use the CHEMCAD control valve and ramp control.
3. Calculate a valve coefficient, Cv.
4. Run a dynamic simulation in CHEMCAD

Definitions:

None.

Cadet Notes:

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Lab 6: Breakeven Analysis

Read: Project Handout, and PTW pages 231-232 and page 323

Problems: None

Objectives (Cadets will be able to):

1. Prepare a breakeven chart.
2. Identify and measure the breakeven point in a breakeven chart.
3. Calculate the return on investment given economic data.
4. Apply economic data to determine an optimal economic course of action

Definitions:

Return on Investment (ROI), Breakeven Point.

Cadet Notes: