Heat and Mass Transfer for Process Plants: Conduction, Convection, Radiation and Absorption

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London - Central London four-star

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Introduction:

Heat and mass transfer calculations sit behind almost every plant decision, yet many engineers rely on vendor figures or rules of thumb they cannot check, so insulation is under-specified, furnace tubes overheat, absorbers miss purity and cooling towers lose approach without explanation. This Core Concept course gives process, chemical and mechanical plant engineers a working method to calculate conduction, convection, boiling, condensation and radiation duties, quantify diffusion and mass transfer coefficients, and size absorption, drying and evaporative cooling steps. Participants assemble a Heat and Mass Transfer Calculation Pack for a case process unit.

Course Objectives:

- Apply energy balances, steam properties and pressure drop methods to set the thermal and hydraulic basis for a plant heat or mass transfer calculation
- Calculate conductive heat loss through walls, pipe insulation and finned surfaces and select an economic insulation thickness
- Estimate convective, boiling, condensing and radiant heat transfer coefficients with suitable correlations for pipes, vessels, reboilers, condensers and fired heaters
- Evaluate passive and active heat transfer enhancement options and transient heat-up or cool-down times against energy, friction and safety limits
- Determine diffusion rates, mass transfer coefficients and transfer units for absorbers, strippers, dryers and humidifiers using heat-mass analogies
- Build a calculation pack that links heat and mass transfer duties for a case process unit, including cooling tower and evaporator checks

Target Audience:

- Process and chemical engineers who calculate unit duties, check operating margins and review thermal design data
- Mechanical and static equipment engineers who specify insulation, heating jackets, tracing and fired equipment
- Technical services engineers who investigate underperforming heaters, condensers, absorbers and dryers
- Utility and energy engineers who run steam, cooling water and cooling tower systems
- Plant design and project engineers who check vendor thermal and separation calculations

Course Outline:

Day 1: Applied Thermodynamics Refresher for Thermal Calculations

- First Law Energy Balance on Open Systems with Shaft Work and Heat Duty
- Enthalpy, Specific Heat and Latent Heat Data from Property Tables
- Steam Tables and Mollier Chart for Saturated, Superheated and Flash Steam
- Ideal Gas and Real Gas Behaviour with Compressibility Factor
- Heat Duty Worksheet for Heating, Vaporising and Cooling Streams

Day 2: Fluid Flow Fundamentals Behind Heat and Mass Transfer

- Reynolds Number Regimes and Velocity Profile Development in Pipes
- Darcy Friction Factor from the Moody Chart and Colebrook Equation
- Fitting Losses with K-Values and Equivalent Length Methods
- Two-Phase Gas-Liquid Flow Patterns and Map Reading Overview
- Boundary Layer Concept Linking Momentum and Thermal Layers

Day 3: Conduction Through Walls, Insulation and Extended Surfaces

- Fourier Law and Thermal Conductivity of Metals, Refractories and Insulants
- Composite Plane and Cylindrical Wall Resistance Networks
- Critical Insulation Radius and Economic Insulation Thickness Calculation
- Fin Efficiency and Extended Surface Effectiveness for Finned Tubes
- Surface Temperature Check for Personnel Protection and Heat Tracing Loads

Day 4: Convection Correlations, Boiling and Condensation

- Nusselt, Prandtl and Grashof Numbers in Forced and Natural Convection
- Dittus-Boelter and Gnielinski Correlations for Turbulent Tube Flow
- Natural Convection from Hot Vessels, Horizontal Pipes and Tank Walls
- Pool and Flow Boiling Curve with Critical Heat Flux in Reboilers and Kettles
- Film and Dropwise Condensation with Nusselt Theory for Condensers

Day 5: Radiation in Fired Equipment, Overall Coefficient and Week-One Case

- Emissivity, View Factors and Grey Body Exchange in Furnace Radiant Sections
- Flue Gas Radiation from Carbon Dioxide and Water Vapour Bands
- Series Resistance Summation of Film, Wall and Deposit Terms
- Fouling Allowance Effect on Required Area and Clean Versus Dirty Duty
- Guided Case: Jacketed Reactor Heat-Up and Steam Main Heat Loss Calculation

Day 6: Heat Transfer Enhancement and Transient Heating and Cooling

- Passive Enhancement with Twisted Tape, Coil-Spring and Rib Inserts
- Rough Surfaces, Helically Coiled Tubes and Secondary Flow Effects
- Enhancement Payback: Coefficient Gain Versus Friction and Pumping Penalty
- Lumped Capacitance Method and Biot Number Test for Transient Heating
- Heisler Chart Use for Slab, Cylinder and Sphere Cool-Down Times

Day 7: Mass Transfer Fundamentals: Diffusion, Coefficients and Analogies

- Fick Law, Molecular Diffusivity and Equimolar Versus One-Way Diffusion
- Film Theory, Penetration Theory and Two-Resistance Interface Model
- Sherwood, Schmidt and Peclet Numbers in Mass Transfer Correlations
- Chilton-Colburn J-Factor Analogy Linking Friction, Heat and Mass Transfer
- Overall Gas-Phase and Liquid-Phase Mass Transfer Coefficient Estimation

Day 8: Gas Absorption and Stripping Calculations

- Henry Law Equilibrium Data and Operating Line Construction
- Minimum Solvent Rate and Absorption Factor Selection
- Height of a Transfer Unit and Number of Transfer Units for Packed Columns
- Stripping Factor and Steam or Air Stripper Performance Estimation
- Packing Wetting, Flooding Approach and Their Effect on Transfer Rate

Day 9: Humidification, Drying and Simultaneous Heat and Mass Transfer

- Psychrometric Chart Use: Humidity, Dew Point and Wet-Bulb Temperature
- Drying Rate Curve with Constant-Rate and Falling-Rate Periods
- Cooling Tower Range, Approach and Evaporation Loss Balance
- Merkel Enthalpy Driving Force Method for Tower Characteristic
- Single and Multiple-Effect Evaporator Steam Economy Overview

Day 10: Modelling Build: Heat and Mass Transfer Calculation Pack

- Case Unit Data Sheet Review and Calculation Basis Agreement
- Worked Calculation: Fired Heater Radiant Flux and Insulated Line Heat Loss
- Worked Calculation: Absorber Transfer Units and Cooling Tower Approach Check
- Sensitivity Runs on Fouling, Flow Rate and Ambient Wet-Bulb Temperature
- Heat and Mass Transfer Calculation Pack Presentation and Peer Critique

Skills You Will Gain:

- Thermal Duty Estimation
- Insulation Thickness Selection
- Convective Correlation Selection
- Radiant Heat Flux Calculation
- Transient Heat-Up Analysis
- Transfer Unit Sizing
- Psychrometric Analysis
- Evaporative Cooling Assessment

Why Attend This Course:

- Leave with a Heat and Mass Transfer Calculation Pack for a case process unit that can be adapted to equipment on your own site
- Challenge vendor thermal and separation figures with hand calculations you can defend in design reviews
- Explain lost heater, condenser, absorber or cooling tower performance to operations using transfer coefficients rather than guesswork
- Work through calculations with process, chemical and mechanical engineers from refining, petrochemicals, power, fertiliser and water sectors

Conclusion:

Plant engineers who can calculate heat and mass transfer from first principles make sounder decisions on insulation, heaters, condensers, absorbers and cooling towers. Week one rebuilds thermodynamics, fluid flow, conduction, convection, phase change, radiation and the overall coefficient. Week two adds what a shorter course leaves out: enhancement economics, transient heating, diffusion and mass transfer coefficients, absorption and stripping, humidification, drying and evaporative cooling. The final day turns these methods into a Heat and Mass Transfer Calculation Pack for a case process unit.