

Belltes Academy

Mass and Energy Balance
(Food Engineering)

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Section A: Ten Explanations and Examples

1. Conservation of Mass and Energy

Explanation: This is the foundational law for all process calculations. It states that mass and energy cannot be created or destroyed, only transformed. In food engineering, we define a system boundary (e.g., a mixing tank or a dryer) and account for everything entering and leaving it. Steady-State: The conditions inside the system do not change with time ($\text{Input} = \text{Output}$). Unsteady-State: Conditions change over time ($\text{Input} - \text{Output} = \text{Accumulation}$).

Example: In a continuous fruit juice pasteurizer operating at steady-state, the mass flow rate of raw juice entering the pasteurizer must exactly equal the mass flow rate of pasteurized juice leaving it.

2. Units, Dimensions, and Basis of Calculation

Explanation: Food engineering formulas require dimensional consistency (all terms must have the same units). A crucial step in solving complex balance problems is choosing a Basis of Calculation—a specific quantity or flow rate (like 100 kg or 1 hour) used to anchor all calculations when total amounts are unknown. Converting moisture contents and material streams between the SI system (kg, kJ, C) and the Imperial system (lb, BTU, F) is standard practice.

Example: If a processing plant wants to scale up a recipe that uses 10 kg of sugar per batch, a food engineer will select a basis of 100 kg of total raw material to easily calculate the percentage requirements of all other ingredients like flour, water, and yeast.

3. Psychrometrics

Explanation: Psychrometrics is the study of the thermodynamic properties of air-water vapor mixtures. In food processing, air is frequently used to add moisture (humidification) or remove moisture (drying). Engineers use a psychrometric chart to determine properties like relative humidity, dew point, wet-bulb temperature, and enthalpy.

Example: When designing a spray dryer for milk powder, engineers use psychrometric charts to calculate how much hot, dry air is required to absorb the moisture from the liquid milk droplets without condensing inside the drying chamber.

4. Dehydration and Drying

Explanation: Drying involves removing water from a food product, shifting it from the solid/liquid phase to the vapor phase. Because water content changes drastically during this process, engineers distinguish between Wet-Basis (WB) and Dry-Basis (DB) moisture content. Dry-basis is preferred for calculations because the mass of dry solids remains constant throughout the process.

Example: A batch of 1,000 kg of fresh sliced apples at 80% moisture (wet basis) is dried to 10% moisture. The mass of dry apple solids remains 200 kg, yielding a final product mass of 222.2 kg, meaning 777.8 kg of water

was successfully removed.

5. Evaporation and Concentration

Explanation: Evaporation concentrates a liquid food (like juice, milk, or coffee) by boiling off water. It typically handles fluids with higher water contents than drying. In multiple-effect evaporators, the vapor produced in one boiling vessel is used to heat the next vessel, drastically saving energy across multi-stage operations.

Example: Concentrating tomato juice from 5% total solids (5 Brix) to a tomato paste of 30% total solids (30 Brix). For a feed rate of 5,000 kg/h, a component solids balance determines that the system yields 833.3 kg/h of thick paste and evaporates 4,166.7 kg/h of water vapor.

6. Blending and Mixing

Explanation: Blending calculations involve mixing two or more streams to achieve a specific target concentration of components (such as fat, protein, sugar, or total solids). These problems are solved mathematically using simultaneous linear equations based on total mass balance and individual component balances.

Example: Standardizing milk to a target of 3.5% fat by blending whole milk containing 4.2% fat with skim milk containing 0.1% fat to yield exactly 1,000 kg of standardized commercial milk.

7. Separation Processes

Explanation: Separation involves splitting a food stream into two or more distinct phases or products. This includes filtration (solid/liquid), centrifugation (separating cream from milk based on density), and membrane separation (Ultrafiltration or Reverse Osmosis). Mass balances track the recovery yields and the absolute purity of the streams.

Example: In whey protein concentration using ultrafiltration, a stream of cheese whey enters the membrane unit. The membrane allows water and lactose to pass through as permeate, while holding back the protein as a concentrated retentate stream.

8. Sensible and Latent Heat Calculations

Explanation: Energy balance relies heavily on calculating enthalpy changes when food changes temperature or physical state. Sensible Heat is the heat exchanged that causes a change in temperature without a phase change. Latent Heat is the heat exchanged during a phase change (like melting, freezing, or boiling) where temperature remains completely constant.

Example: Calculating the total energy required to heat 500 kg of liquid water from 25 C to 100 C (sensible heat), and then completely converting it to steam at 100 C (latent heat) to power a steam jacketed cooking kettle.

9. Thermal Processing (Pasteurization & Sterilization)

Explanation: Thermal processing combines mass and energy balances to ensure food safety while preserving quality. Engineers evaluate indirect heat exchangers (like plate or tubular heat exchangers) or direct steam injection. The energy balance determines the flow rate of the utility heating medium (steam or hot water) needed to raise the food to its target pasteurization temperature.

Example: Determining how many kilograms of saturated steam at 121 C per hour must be supplied to a retorting system to safely sterilize 10,000 cans of canned beans, taking into account the heat absorbed by the beans, the steel cans, and ambient losses.

10. Freezing and Chilling

Explanation: Freezing calculations determine the refrigeration load required to preserve food. Unlike water, foods do not freeze at a single temperature because dissolved sugars and salts depress the freezing point. As water turns to ice, the remaining unfrozen solution becomes more concentrated, meaning freezing occurs over a temperature range.

Example: Calculating the size of a blast freezer needed to cool 2,000 kg/h of fresh beef patties from 4 C to -18 C, accounting for sensible cooling of meat liquids, the latent heat of fusion during water crystallization, and sub-zero sensible cooling.

Section B: One Hundred Descriptions, Examples, and Analogies

1. System Boundary

Description: A real or hypothetical geometric envelope enclosing the process equipment or region being analyzed.

Example: The stainless steel outer wall of a continuous juice pasteurizer.

Analogy: The property line fence around your house that defines what is 'inside' your yard versus 'outside'.

2. Steady-State

Description: A condition where process variables (temperature, flow rate, pressure) do not change over time.

Example: A continuous flour mill where 500 kg/h of wheat enters and 500 kg/h of flour leaves constantly.

Analogy: A highway where the number of cars entering a tunnel exactly equals the number of cars leaving it.

3. Unsteady-State (Transient)

Description: A state in which conditions vary with time, causing mass or energy accumulation within the system.

Example: Filling up a batch kettle with soup mix before turning on the heat.

Analogy: A bathtub filling up with water while the drain is plugged—the water level is continuously changing.

4. Accumulation

Description: The rate of change of mass or energy inside the system boundary over a given time interval.

Example: The buildup of milk curd inside a cheese vat during a batch setting process.

Analogy: Putting money into a piggy bank; the coins accumulate over time because 'input' is greater than 'output'.

5. Open System

Description: A system where both mass and energy can cross the defined system boundary.

Example: An industrial vegetable blancher where water steam and raw vegetables freely enter and exit.

Analogy: A boiling pot of water on the stove without a lid—steam escapes, heat enters, and you can add items.

6. Closed System

Description: A system that allows energy to cross its boundaries, but strictly prevents mass transfer.

Example: A sealed can of beans being heated inside a batch retort sterilizer.

Analogy: A tightly sealed glass jar of hot soup cooling down on a counter; heat escapes, but the soup stays inside.

7. Isolated System

Description: A theoretical system that exchanges absolutely no mass or energy with its surroundings.

Example: A perfectly insulated, sealed storage container used to hold liquid nitrogen.

Analogy: A high-quality, completely sealed thermos flask that keeps coffee hot without letting liquid or heat escape.

8. Mass Flow Rate

Description: The mass of a substance passing through a given cross-section per unit of time.

Example: A confectionery line pumping liquid chocolate at a rate of 25 kg per minute.

Analogy: A digital scale at a supermarket checkout line weighing items passing over it per minute.

9. Mass Fraction

Description: The ratio of the mass of a specific component to the total mass of the mixture.

Example: A sugar syrup stream with a mass fraction of 0.60, meaning it is 60% sugar and 40% water by weight.

Analogy: A bowl of trail mix weighing 100g containing 20g of chocolates has a chocolate mass fraction of 0.20.

10. Process Flow Diagram

Description: A visual schematic showing the flow of food materials and the sequence of unit operations.

Example: A blueprint mapping out how raw milk flows through separators, pasteurizers, and into bottling tanks.

Analogy: A subway map showing how trains move through different stations and where lines connect.

11. Dimension

Description: A physical variable or property that can be measured or calculated.

Example: The height of an industrial fermentation tank represents the dimension of length.

Analogy: The general concept of 'distance,' regardless of whether you measure it in miles, steps, or meters.

12. Unit

Description: A specific, standardized scale chosen to measure or quantify a physical dimension.

Example: Measuring the mass of raw cocoa beans explicitly in kilograms (kg) or pounds (lbs).

Analogy: Choosing to say a piece of wood is 3 'inches' long rather than just saying it has 'length'.

13. Basis of Calculation

Description: A reference quantity (mass, moles, or time) chosen at the start of a problem to simplify calculations.

Example: Choosing 100 kg of raw potato feed to calculate the yield of potato chips when hourly rate is unknown.

Analogy: Creating a cake recipe based on exactly '1 cup of flour' as your reference anchor, then scaling to it.

14. Dimensional Consistency

Description: The rule stating that terms added, subtracted, or equated in an equation must possess identical dimensions.

Example: You cannot add a flow rate (kg/h) directly to a static mass (kg) in a material balance equation.

Analogy: You cannot add 3 apples to 5 hours and get 8 'apple-hours'. The categories must match.

15. Conversion Factor

Description: A multiplier or ratio equal to one that changes the units of a quantity without changing its value.

Example: Multiplying a weight by 2.204 to convert kilograms into pounds.

Analogy: Exchanging a note for coins; the value stays identical, but the units look different.

16. Density

Description: The mass of a substance contained within a unit volume (mass/volume).

Example: Honey has a density of roughly 1.42 kg/L, meaning it weighs much more than 1L of water.

Analogy: Packing a suitcase tightly with heavy books versus packing the same suitcase loosely with fluffy pillows.

17. Volumetric Flow Rate

Description: The volume of fluid that passes through a given surface or pipe per unit of time.

Example: A dairy pump moving milk into a holding silo at a rate of 500 liters per minute.

Analogy: A garden hose filling up a 10-liter bucket in 1 minute (10 L/min).

18. Scaling Up

Description: Converting a food process from a small laboratory or pilot scale to a massive industrial production scale.

Example: Multiplying a kitchen recipe for 1 loaf of bread to produce 10,000 loaves per hour in a commercial bakery.

Analogy: Taking a miniature architectural 3D model of a house and building the actual full-sized building.

19. Molarity

Description: A concentration unit defined as the number of moles of a solute dissolved per liter of solution.

Example: Preparing a 0.1 M citric acid solution for adjusting the acidity level in fruit beverages.

Analogy: Counting the exact number of standard crowds (moles) packed into a festival arena (liter).

20. Weight Percent

Description: The mass of a solute divided by the total mass of the solution, multiplied by 100.

Example: Brine solution for pickling made by dissolving 5 kg of salt into 95 kg of water.

Analogy: If a group of 100 people includes 15 children, the children make up 15% of the group's population.

21. Relative Humidity

Description: The ratio of actual water vapor pressure to the maximum possible vapor pressure at that temperature.

Example: Air inside a meat curing room held at 85% RH to prevent the sausages from drying out too fast.

Analogy: A sponge that is currently holding 85% of the total water it can possibly absorb before dripping.

22. Humidity Ratio

Description: The absolute mass of water vapor carried per unit mass of perfectly dry air.

Example: A spray dryer operating with inlet air carrying 0.015 kg of moisture per kg of dry air.

Analogy: The exact weight of passengers sitting inside an empty bus chassis.

23. Dry-Bulb Temperature

Description: The ambient air temperature measured by an ordinary thermometer shielded from moisture.

Example: A digital thermostat reading the air temperature inside a bakery warehouse as 25 C.

Analogy: The temperature shown on your standard outdoor home thermometer on a normal day.

24. Wet-Bulb Temperature

Description: The lowest temperature air can reach via evaporative cooling of water into it.

Example: Using a psychrometer in a grain silo to evaluate the cooling potential of ambient air.

Analogy: How cold your skin feels when you step out of a swimming pool on a windy day as water evaporates.

25. Dew Point

Description: The temperature at which air becomes completely saturated and moisture begins to condense into liquid.

Example: Condensation forming on the outside walls of a cold beverage tank when the factory room air cools.

Analogy: The droplets of water that form on the outside of a glass of ice-cold drink on a hot afternoon.

26. Enthalpy of Air

Description: The total thermal energy contained within a unit mass of moist air (dry air plus vapor energy).

Example: Calculating the total energy load required to run an HVAC system in a chocolate packaging facility.

Analogy: The total amount of money in a wallet that contains both paper notes and heavy coins.

27. Saturation Curve

Description: The boundary line on a psychrometric chart representing 100% relative humidity.

Example: The air condition inside a steam blanching tunnel where fog and water droplets are actively suspended.

Analogy: A sponge soaked to its ultimate limit—add one single drop more, and it immediately spills over.

28. Adiabatic Saturation

Description: A process where air is humidified and cooled without any net heat exchange with the environment.

Example: Evaporative cooling systems used to drop temperatures in large vegetable storage warehouses.

Analogy: Spraying a fine mist of water into a sealed room; the air gets wetter and cooler, but no heat left.

29. Specific Volume of Air

Description: The volume occupied by one kilogram of dry air plus its associated water vapor.

Example: Designing the volumetric capacity of exhaust fans to extract moist air from a noodle cooker.

Analogy: A 1 kg bag of feathers takes up a massive physical volume compared to a 1 kg block of lead.

30. Sensible Heating (Air)

Description: Increasing the temperature of air without altering its absolute moisture content.

Example: Pass outdoor air over steam coils to heat it up before blowing it into a grain dryer.

Analogy: Turning on the heater in your car during winter with windows closed; the air gets hotter, not wetter.

31. Wet Basis Moisture

Description: The mass of water divided by the total weight of the food sample, multiplied by 100.

Example: Fresh strawberries are composed of roughly 90% wet-basis moisture.

Analogy: Saying that in a 10 kg wet backpack, 2 kg is water weight and 8 kg is gear weight (20%).

32. Dry Basis Moisture

Description: The mass of water divided strictly by the mass of completely dry solids in the food sample.

Example: Freeze-dried coffee granules might have a dry-basis moisture value of 0.04 kg water/kg solids.

Analogy: Expressing wet gear by saying there are 2 kg of water attached to the 8 kg of dry gear (25%).

33. Dry Solids

Description: The non-water structural components of food that remain constant during drying.

Example: The solid fiber, starch, and sugar left over after baking liquid batter into a crispy cracker.

Analogy: The physical structure of a ceramic mug that never changes, regardless of liquid content.

34. Constant Rate Period

Description: The initial drying phase where free surface water evaporates rapidly at a constant speed.

Example: The first hour of drying sliced mangoes where the surface stays fully wet and glistening.

Analogy: Hanging a soaking-wet towel on a clothesline; water evaporates quickly as long as it's drenched.

35. Falling Rate Period

Description: The subsequent drying phase where water must travel from deep inside the food, slowing water removal.

Example: The final hours of beef jerky drying, where the surface looks dry and removal slows drastically.

Analogy: Trying to squeeze the last few drops of water out of a damp sponge; it takes way more effort.

36. Critical Moisture

Description: The specific moisture level marking the transition point between constant and falling rate periods.

Example: The exact moment during biscuit baking when the surface moisture slick disappears completely.

Analogy: The sudden moment your car runs out of easy fuel from the main tank and switches to reserve.

37. Equilibrium Moisture

Description: The final moisture content a food product stabilizes at when exposed to a specific environment.

Example: Dried potato flakes left open in a humid room will absorb moisture until they balance out.

Analogy: Leaving a dry cracker on a kitchen counter in a humid city; it eventually stops absorbing and goes soft.

38. Water Activity

Description: The ratio of vapor pressure of water in food to pure water; dictates microbial growth.

Example: Jam stays shelf-stable because its high sugar content binds water, lowering water activity.

Analogy: Money tied up in a long-term investment property versus cash sitting in your wallet available to spend.

39. Case Hardening

Description: A defect where rapid surface drying forms an impermeable crust that traps moisture inside.

Example: Drying pieces of fruit too fast at extreme heat, leaving them sticky inside but hard outside.

Analogy: Searing a steak too fast over an intense flame; the outside burns while the inner center stays raw.

40. Lyophilization

Description: Dehydration by freezing a product and causing sublimation under vacuum conditions.

Example: Producing high-end premium instant coffee crystals that retain original shape and nutrients.

Analogy: Dry ice disappearing directly into foggy smoke on a stage without melting into a liquid puddle first.

41. Brix

Description: A scale measuring the weight percentage of total dissolved sugar solids in an aqueous solution.

Example: Raw orange juice enters an evaporator at 11 Brix and leaves concentrated at 65 Brix.

Analogy: Counting how many sweet red marbles are dissolved in a clear glass jar containing 100 total marbles.

42. Feed

Description: The initial dilute liquid stream entering a processing unit to be concentrated or treated.

Example: Raw, watery skim milk pumped straight from storage into the primary stage of an evaporator.

Analogy: The pile of dirty laundry you carry over to place inside the washing machine.

43. Concentrate

Description: The final thick, enriched product stream exiting an evaporator after water has been stripped.

Example: Thick tomato paste harvested from the bottom outlet of an industrial evaporator system.

Analogy: The thick, muddy sludge left at the bottom of a bucket after leaving muddy water out to dry.

44. Vapor

Description: The gaseous phase of water boiled off and separated from the liquid food during concentration.

Example: Steam rising off boiling sugarcane juice inside a large industrial refinery vessel.

Analogy: The white cloud steam rising out from the spout of a whistling tea kettle on your stove.

45. Single-Effect Evaporator

Description: An evaporator setup that utilizes fresh steam from a boiler inside a single vessel.

Example: A basic craft brewery boiling down wort in an open kettle vessel.

Analogy: Boiling a pot of soup on your stove where all the rising steam escapes directly into your kitchen air.

46. Multiple-Effect Evaporator

Description: A sequence of evaporators where vapor from one vessel heats the next lower-pressure vessel.

Example: Large-scale dairy operations utilizing 4 to 7 connected evaporator stages to save fuel energy.

Analogy: Passing your old school textbooks down to your younger sibling—maximum reuse of resources.

47. Boiling Point Elevation

Description: The phenomenon where a solution boils at a higher temperature than pure water due to solids.

Example: Concentrated sugar syrup requiring a temperature of 106 C to boil instead of 100 C.

Analogy: Trying to lift a heavy backpack; the more books inside, the harder you have to work to lift it.

48. Fouling

Description: The unwanted accumulation of burned crust or mineral deposits on heat exchanger surfaces.

Example: Milk proteins burning onto the inside heating tubes of an evaporator, slowing heat transfer.

Analogy: Carbon grime building up on the bottom of a frying pan, making it take longer to fry an egg.

49. Flash Evaporation

Description: The sudden partial boiling of a hot liquid that occurs when entering a lower-pressure vessel.

Example: Pumping hot apple juice into a vacuum chamber where water instantly vaporizes without extra heat.

Analogy: Popping open a warm can of soda; the sudden drop in pressure causes bubbles to violently fizz up.

50. Economy (Evaporator)

Description: A performance metric defined as the mass of water evaporated per unit mass of steam supplied.

Example: A triple-effect evaporator achieving an economy score of 2.5 by recycling vapor heat.

Analogy: Fuel efficiency in a hybrid car—getting 25 kilometers of distance out of only 1 liter of petrol.

51. Standardisation

Description: Adjusting the composition of a food item to precise, defined component targets.

Example: Adjusting milk fat levels up or down to guarantee every carton contains exactly 3.5% fat.

Analogy: Tuning a guitar string until it hits the exact, uniform frequency required by a digital tuner.

52. Component Balance

Description: An accounting calculation focused strictly on tracking one specific ingredient across streams.

Example: Setting up an algebraic equation to balance total salt mass when mixing spice powders with meat.

Analogy: Counting only the blue M&Ms; when mixing two different candy bags together into a single bowl.

53. Pearson Square

Description: A geometric shortcut method used to calculate blending proportions to hit a target value.

Example: Determining how much 40% cream and 1% skim milk to mix to hit an ice cream mix target of 12% fat.

Analogy: Figuring out how much boiling water and ice-cold water to mix to get a warm bath temperature.

54. Simultaneous Equations

Description: A set of algebraic equations solved together because they share common variables.

Example: Solving for variables X (kilograms of oil) and Y (kilograms of vinegar) to make a dressing batch.

Analogy: Solving a riddle: 'I have 10 coins in my pocket totaling R20. How many are R5 and how many are R1?'

55. Dilution

Description: Reducing the concentration of a solute or component by adding more solvent, usually water.

Example: Adding filtered water to pure orange juice concentrate to recreate normal drinking juice.

Analogy: Adding a cup of water to a cup of black coffee that tastes way too bitter, making it weaker.

56. Master Batch

Description: A highly concentrated initial mix prepared in advance, intended to be diluted down later.

Example: Mixing a concentrated syrup of colors and flavors before dosing it into carbonated water.

Analogy: Buying a tiny bottle of concentrated cleaner juice that you mix into a big bucket of water.

57. Segregation

Description: The undesirable separation of mixed components during handling due to size or density differences.

Example: Powdered beverage mixes settling in a container, leaving sugar at top and color dust at bottom.

Analogy: Shaking a bag of muesli, which causes large nuts to rise to the top while fine flakes fall down.

58. Working Volume

Description: The actual operational fluid capacity of a mixing tank, accounting for headspace.

Example: A 1,000-liter stainless steel blending tank only being filled with 800 liters of soup mix.

Analogy: Not filling a blender cup right to the brim with milk to avoid it exploding out of the lid.

59. Agitation Intensity

Description: A measure of the mixing energy and shear forces applied to a fluid by an impeller.

Example: Running an industrial mixer at maximum RPM to emulsify oil droplets into egg yolks for mayonnaise.

Analogy: Gently folding cake batter with a spatula versus whipping egg whites violently with an electric mixer.

60. Mass Fraction Sum

Description: The fundamental law stating that the sum of mass fractions in any single stream must equal 1.0.

Example: If a sauce contains 0.1 salt, 0.2 sugar, and 0.3 fat, the water fraction must be exactly 0.4.

Analogy: Cutting a pizza into wedges; no matter how you cut them, they must add up to 100% of one whole pizza.

61. Retentate

Description: The stream containing particles or large molecules blocked and retained by a membrane.

Example: The concentrated protein stream kept back by an ultrafiltration membrane filtering whey.

Analogy: The pasta noodles left behind inside a plastic colander when you pour a pot into the sink.

62. Permeate

Description: The liquid or solvent stream that successfully passes through the pores of a membrane.

Example: The clear water and dissolved salts that pass through a reverse osmosis membrane.

Analogy: The hot water that drips down into a coffee pot after flowing through a paper filter mesh.

63. Centrifugation

Description: A method that spins liquid mixtures at high speeds to separate components based on density.

Example: Spinning raw fresh milk to separate lighter fat globules from the heavier skim milk phase.

Analogy: A washing machine spin cycle spinning wet clothes at high speeds to force water out through holes.

64. Extraction

Description: Removing a desired solute flavor or compound from a matrix using a specific solvent.

Example: Using hot water to dissolve and extract caffeine and flavors from ground coffee beans.

Analogy: Steeping a bag of rooibos tea in hot water; the color and flavor move from leaves into the water.

65. Yield (Separation)

Description: The percentage of a target component recovered in product stream relative to the feed input.

Example: Achieving a 92% yield of sunflower oil from raw seeds during a mechanical pressing operation.

Analogy: Mining 10 grams of gold out of dirt that contained exactly 10 grams total means a 100% yield.

66. Filter Cake

Description: The thick accumulation of solid material deposited on a filter medium after liquid passes.

Example: The compressed layer of spent fruit pulp that builds up inside a frame filter press.

Analogy: The thick layer of gray lint that collects on the screen filter of a tumble clothes dryer.

67. Ultrafiltration

Description: A pressure-driven membrane process that separates large molecules from smaller molecules.

Example: Concentrating milk proteins on a dairy farm before shipping milk to a cheese plant.

Analogy: A chain-link fence that lets small tennis balls pass through easily but blocks soccer balls.

68. Reverse Osmosis

Description: A high-pressure membrane separation process capable of filtering out dissolved salt ions.

Example: Concentrating maple sap into pure water and thick syrup before the final boiling stage.

Analogy: A mesh screen so incredibly tight that only microscopic ants can walk through, blocking sand.

69. Supercritical Extraction

Description: A separation technique using compressed gas in a fluid state to cleanly dissolve targets.

Example: Using high-pressure supercritical CO₂ to remove caffeine from green coffee beans.

Analogy: A magic dissolving mist that sweeps through a room, picks up only wallets, and flies out.

70. Sedimentation

Description: The process of suspended solid particles settling out of a liquid due to gravity.

Example: Allowing unrefined wine to sit quietly in an oak cask until yeast and dirt fall to the floor.

Analogy: Shaking up a snow globe full of glitter and watching all the shiny flakes drift slowly down.

71. Sensible Heat

Description: Thermal energy absorbed or released by a substance causing a change in temperature.

Example: Heating milk up from 4 C to 72 C inside a heat exchanger before pasteurizing it.

Analogy: Stepping on the accelerator pedal of your car and watching the speedometer needle climb.

72. Latent Heat

Description: Heat energy absorbed or released during a phase transition occurring at constant temperature.

Example: The massive amount of energy required to convert boiling water at 100 C into steam at 100 C.

Analogy: A car stuck idling at a red traffic light; gas is being burned but speed stays at zero.

73. Specific Heat Capacity

Description: The amount of heat energy needed to raise the temperature of 1 kg of substance by 1 C.

Example: Water requires a lot of energy to heat up compared to vegetable oil due to higher Cp.

Analogy: A heavy stone brick takes a long time to warm up in the sun compared to a thin metal sheet.

74. Latent Heat of Vaporisation

Description: The specific quantity of heat needed to completely change a liquid substance into gas.

Example: The 2257 kJ/kg of energy needed to vaporize boiling water into steam inside an oven.

Analogy: The huge breakthrough price you have to pay to buy your way out of a strict long-term contract.

75. Latent Heat of Fusion

Description: The heat energy that must be extracted to freeze a liquid, or added to melt a solid.

Example: Extracting 334 kJ of energy for every single kilogram of water turned to ice in a maker.

Analogy: The energy cost required to break down a rigid brick wall and turn it back into loose stones.

76. Enthalpy

Description: A thermodynamic property representing total heat energy content per unit mass from a baseline.

Example: Calculating the difference in total heat content between cold raw meat and cooked loaves.

Analogy: The total financial net worth balance showing on your bank account screen at any given moment.

77. Phase Diagram

Description: A graphic chart plotting pressure versus temperature to show phase boundaries.

Example: Using a diagram to calculate the vacuum pressure needed for sublimation during freeze-drying.

Analogy: A country map with clear border lines dividing different states or provinces neatly.

78. Steam Table

Description: Standard reference data charts listing thermodynamic properties of water and steam.

Example: A food engineer looking up a steam table to find the temperature of steam at 2 bar pressure.

Analogy: A dictionary or index where you look up a word to find its exact meaning and pronunciation.

79. Saturated Steam

Description: Steam that is in equilibrium with liquid water at its boiling point without water droplets.

Example: The utility heating gas fed into the jacket walls of an industrial jam boiling kettle.

Analogy: A room packed with exactly the maximum number of people it can hold comfortably—no more inside.

80. Superheated Steam

Description: Water vapor that has been heated to a temperature significantly higher than its boiling point.

Example: Using dry, ultra-hot steam to flash-bake snack surfaces or sterilize dry packaging lines.

Analogy: A hot dry desert wind that has been heated far past the temperature of normal ambient air.

81. Pasteurisation

Description: A mild thermal heat treatment designed to destroy pathogens and extend shelf-life.

Example: Heating raw liquid milk to 72 C for exactly 15 seconds to kill pathogens before bottling.

Analogy: A bouncer at a club door filtering out bad troublemakers but letting normal guests inside.

82. Commercial Sterilisation

Description: A high-heat process intended to destroy all viable pathogens and heat-resistant spores.

Example: Retorting canned corn at 121 C for 20 minutes to eliminate bacterial spores for shelf stability.

Analogy: A complete reset option on a computer that wipes the hard drive clean of every single file.

83. D-Value

Description: The time in minutes required at a specific temperature to destroy 90% of microbes.

Example: A bacterial population dropping from 10,000 cells down to 1,000 cells after 2 minutes at 70 C.

Analogy: A retail store sale where a clearance event clears out 90% of all leftover stock every hour.

84. Z-Value

Description: The temperature increase required to reduce the D-value of a microbe by a factor of 10.

Example: Increasing heat from 110 C to 120 C cutting a bacteria's survival time from 4 mins to 0.4 mins.

Analogy: Changing the gear on a bicycle; stepping up a gear makes you travel faster for the same effort.

85. F-Value

Description: The equivalent time in minutes spent at a reference temperature required for safe processing.

Example: Designing a canning cycle to achieve an $F_0 = 6$ minutes to ensure a huge safety margin.

Analogy: The total score earned on a test, calculated by combining points scored across all sections.

86. Fouling Resistance

Description: The thermal barrier caused by layers of food solids baking directly onto heat exchangers.

Example: A layer of egg protein baking onto a plate heat exchanger, reducing thermal efficiency.

Analogy: A thick layer of ice forming over a windshield that prevents the car heater from warming it.

87. Co-Current Flow

Description: A heat exchanger arrangement where product and utility fluids flow in identical directions.

Example: Heating sensitive purees where hot steam and cold product enter the same side of a pipe loop.

Analogy: Two cars driving right alongside each other down a multi-lane highway in the exact same direction.

88. Counter-Current Flow

Description: A heat exchanger arrangement where product and utility fluids travel in opposite directions.

Example: A plate heat exchanger where cold juice enters from the left while hot water enters from the right.

Analogy: Passing a baton package out the window to a passenger in a train traveling in the opposite direction.

89. Holding Tube

Description: A calibrated pipe loop designed to hold hot food at pasteurization temperature for a fixed time.

Example: A pipe loop taking exactly 15 seconds for hot milk to travel through before cooling.

Analogy: A slow security corridor at an airport where passengers must walk at a fixed scanning speed.

90. Lethality

Description: A mathematical measurement of the micro-organism destruction rate achieved over time.

Example: Integrating the lethal effects achieved during heating, holding, and cooling inside a retort.

Analogy: The total damage points accumulated over time against a boss monster in a video game battle.

91. Refrigeration Load

Description: The continuous rate of heat energy that must be extracted from a cold storage room.

Example: A blast freezer needing 50 kilowatts of cooling capacity to freeze 2 tons of fish per hour.

Analogy: The speed at which you must scoop water out of a leaking boat to prevent it from sinking.

92. Freezing Point Depression

Description: The lowering of the initial freezing temperature of a food caused by dissolved solutes.

Example: Ice cream mix only starting to freeze at around -2.5 C due to its rich sugar content.

Analogy: Spreading coarse salt over an icy driveway in winter to force the ice to melt below zero.

93. Unfrozen Water Fraction

Description: The percentage of water inside food that stays liquid at sub-zero temperatures due to solutes.

Example: At -10 C, nearly 15% of the total water inside a piece of beef remains liquid and unfrozen.

Analogy: A few smart survivalists staying awake inside a shelter while the town falls asleep in a blizzard.

94. Plank's Equation

Description: An engineering equation used to estimate the total time required to freeze a food item.

Example: Calculating whether a thick block of meat will take 4 hours or 6 hours to freeze solid.

Analogy: Using a formula to estimate how long a thick block of ice will take to melt based on its thickness.

95. Eutectic Point

Description: The exact lowest temperature at which concentrated water and solute freeze solid together.

Example: The specific point (-21.1 C) where a salty brine solution completely freezes into a single mass.

Analogy: The exact final temperature where two distinct business partners agree to pool all cash together.

96. Thermal Conductivity of Ice

Description: A measure of how fast heat moves through ice, which is four times faster than liquid water.

Example: Frozen food transferring heat out of its core fast because ice crystals act like heat highways.

Analogy: Walking over a copper walkway that pulls heat from your feet faster than thick wood planks.

97. Blast Freezing

Description: Rapidly freezing food items by circulating ultra-cold air at high velocities across surfaces.

Example: Freezing individual berries on a moving mesh conveyor belt to prevent them from sticking.

Analogy: Standing directly in front of a giant industrial fan inside an air-conditioned room in summer.

98. Individual Quick Freezing

Description: A process that freezes small food items independently so they do not fuse into a single block.

Example: Buying a bag of frozen green peas where every single pea is loose and rolls around freely.

Analogy: Freezing marbles separately in tiny individual ice trays rather than dumping them into one bucket.

99. Cryogenic Freezing

Description: Ultra-fast freezing achieved by exposing food directly to extremely cold liquefied gases.

Example: Flash-freezing high-value lobster tails to preserve texture and minimize drip loss.

Analogy: Pouring liquid nitrogen over an object to make it brittle enough to shatter with a hammer tap.

100. Freezer Burn

Description: Product quality damage caused by moisture sublimating out of frozen food due to dry air exposure.

Example: Grayish-brown, dry leather-like patches appearing on chicken breasts left unprotected.

Analogy: A wet clay pottery piece left out in the desert sun until its surface cracks and turns gray.