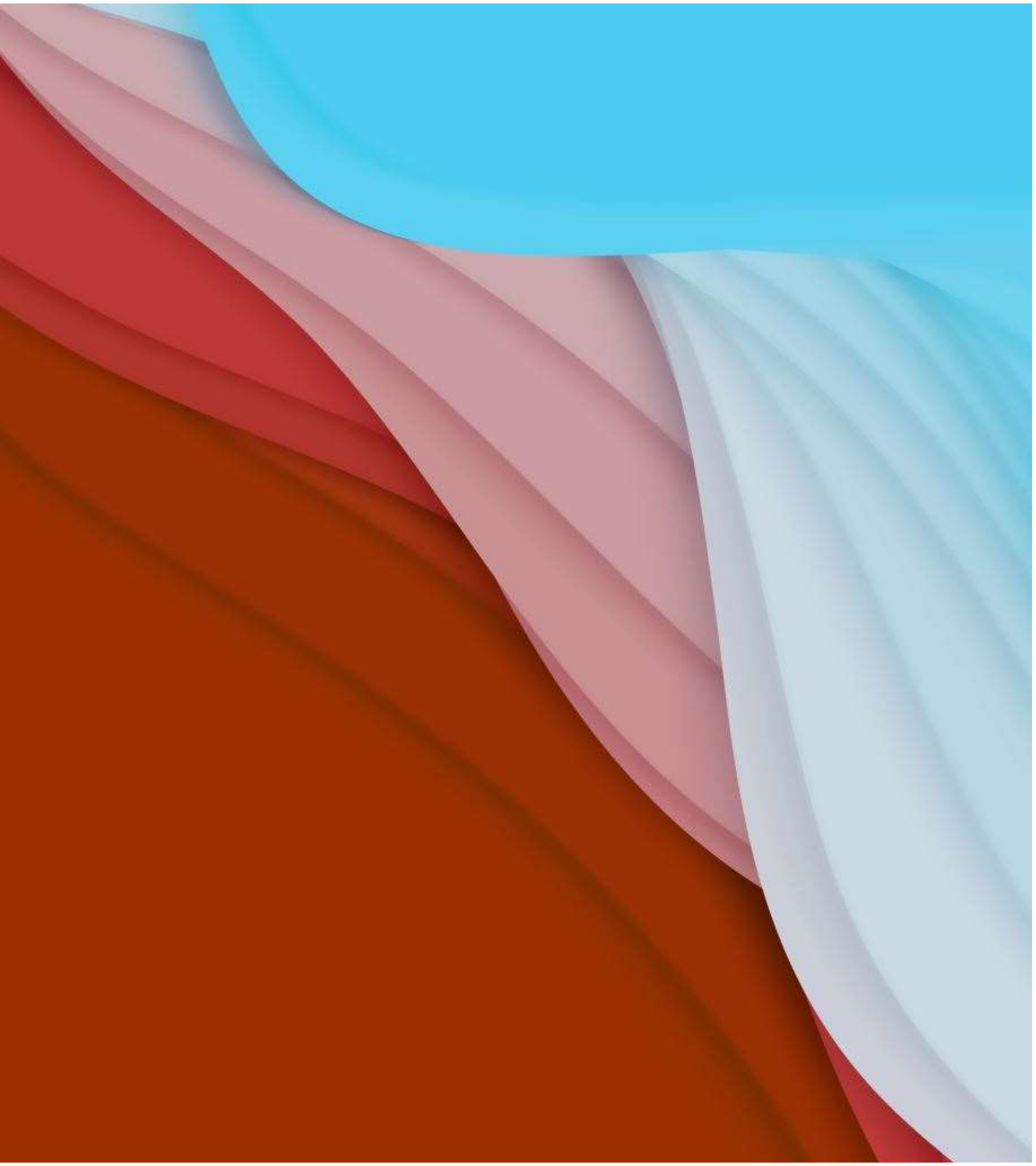

CEN4415
PROCESS DESIGN I

Tools for Evaluating Process Performance

Methods

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1. KEY RELATIONSHIPS

- **In analyzing equipment performance, there are certain key relationships that are used over and over again.**

Table 17.1 Typical Key Performance Relationships

Situation	Equation	Trends	Comments
Frictional loss for fluid flow	$\Delta P = \frac{2\rho f L_{eq} u^2}{D}$	$\lvert\Delta P\rvert \propto u^2$ $\lvert\Delta P\rvert \propto D^{-5}$ $\lvert\Delta P\rvert \propto L$	Assumes fully developed turbulent flow, i.e., constant friction factor; for laminar flow $\Delta P \propto D^{-4}$.
Heat transfer	Of form $\left(\frac{hD}{k}\right) = c\left(\frac{Du\rho}{\mu}\right)^a\left(\frac{\mu C_p}{k}\right)^b$	$h_i \propto v^{0.8}$ inside closed channels $h_o \propto v^{0.6}$ cross flow outside pipes	Equations given are for no phase change; if phase change, weak flow dependence, but some ΔT dependence.
Kinetics	$r = k\Pi c_i^{d_i}$ $k = k_o e^{-\left(\frac{E}{RT}\right)}$	$\ln k$ vs $1/T$ is linear	As $T\uparrow$, $k\uparrow$ for ideal gases $P\uparrow$, $c_i\uparrow$, so $r\uparrow$.
Reactor	mixed flow: $\frac{V}{F_{A0}} = \frac{\tau}{C_{A0}} = \frac{X}{-r_A}$ plug flow: $\frac{V}{F_{A0}} = \frac{\tau}{C_{A0}} = \int_0^X \frac{dX}{-r_A}$	$\tau \propto V$ as $\tau\uparrow$ or $V\uparrow$, $X\uparrow$	τ is space time, V is reactor volume, X is conversion of limiting reactant, A assumes one reaction and constant volumetric flowrate.
Separator using mass separating agent	Not necessarily described by a single equation	As flow of mass separating agent $\uparrow$, or as number stages or height of packed tower $\uparrow$, degree of separation $\uparrow$	For certain cases, there are limitations to the effect of increasing number of stages or packed tower height.
Distillation	Not necessarily described by a single equation	As reflux ratio $\uparrow$, degree of separation $\uparrow$	Complicated analysis; see Chapter 18.

2.Thinking with Equations

- It is possible to quantify equipment performance without resorting to extensive, detailed calculations.
- This involves using equations to understand trends.
- The first step is to identify the equations necessary to quantify a given situation.
- Wales and Stager have termed this “thinking with equations” and have used the acronym GENI to describe the associated problem-solving strategy.
- The second step involves predicting trends from equations. These methods are described and then illustrated in an example.

2.1. GENI

GENI is a method for solving quantitative problems.

1. Goal: Identify the goal.

2. Equation: Identify the equation that relates the unknown to known values or properties.

3. Need: Identify additional relationships that are needed to solve the equation in Step 2.

4. Information: List additional information that is available to determine whether what is needed in Step 3 is known

REFERENCES

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2. Turton R., Bailie R.C., Whitin W.C., Shaeiwitz J.A. 1998, Analysis, Synthesis and Design of Chemical Processes, Prentice Hall, New Jersey.