Chapter 9
Lecture # 1-2

- Introduction
- Role of Experience in the Design Process

Overview of Chapter 9

Title:

Utilizing Experience-Based Principles to Confirm the Suitability of a Process Design

Topics:

1. Introduction
2. Role of Experience in the Design Process
3. Tables of Technical Heuristics and Guidelines

Introduction

Uses of Experienced-based Short-cut Methods and Guidelines

1. Checking new process designs
2. Providing equipment size and performance estimates
3. Helping to troubleshoot problems with operating systems
4. Verifying the reasonableness of results of computer calculations and simulations
5. Providing reasonable initial values for the input to a process simulator required to achieve program convergence
6. Obtaining approximate costs for process units
7. Developing preliminary process layouts

Introduction

Technical Heuristics and Short-cut Methods

A heuristic is a statement concerning equipment size, operating conditions and equipment performance that reduces the need for calculations.

Introduction

Limitations of Heuristics

1. A heuristic does not guarantee a solution.
2. It may contradict other heuristics.
3. It can reduce the time to solve a problem.
4. Its acceptance depends on the immediate context instead of on an absolute standard.

Role of Experience in the Design Process

An experienced engineer retains a body of information, made up largely of heuristics and short-cut calculation methods, that is available to help solve new problems.

Role of Experience in the Design Process

The PAR Process

The process by which an engineer uses information and create new heuristics consists of 3 steps. These are:

- **P**redict.
- **A**uthenticate
- **R**e-evaluate

Role of Experience in the Design Process

PAR Process to Maximize Benefits of Experience—(*P*)redict, (*A*)uthenticate, (*R*)eevaluate

1. Predict: This is a precondition of the PAR process. It represents your "best prediction" of the solution. It often involves making assumptions and applying heuristics based on experience. Calculations should be limited to "back-of-the-envelope" or short-cut techniques.

2. Authenticate/Analyze: In this step you seek out equations and relationships, do research relative to the problem, and perform the calculations that lead toward a solution. The ability to carry out this activity provides a necessary but not sufficient condition to be an engineer. When possible, information from actual operations are included in order to achieve "the best possible solution."

3. Reevaluate/Rethink: The "best possible solution" from Step 2 is compared with the predicted solution in Step 1. When the prediction is not acceptable, it is necessary to correct the reasoning that lead to the poor prediction. It becomes necessary to remove, revise, and replace assumptions made in Step 1. This is the critical step in learning from experience.

Role of Experience in the Design Process

Example 9.1

Evaluate the heat transfer coefficient for water at 93°C (200°F) flowing at 3.05 m/s (10 ft/s) inside a 38 mm (1.5 inch) diameter tube. From previous experience, you know that the heat transfer coefficient for water, at 21°C (70°F) and 1.83 m/s (6 ft/s), in these tubes is 5250 W/m^2°C. Follow the PAR process to establish the heat transfer coefficient at the new conditions.

Role of Experience in the Design Process

Step 1—Predict:

Assume that the velocity and temperature have no effect

Predicted Heat Transfer Coefficient = 5250 W/m^2°C.

Step 2—Authenticate/Analyze:

Using the properties given below we find that the Reynolds Number for the water in the tubes is

$$Re = u\rho D_{pipe}/\mu = (1.83)(997.4)(1.5)(0.0254)/(9.8 \times 10^{-4}) = 71 \times 10^{3} \rightarrow \text{Turbulent Flow}$$

Use the Sieder-Tate Equation [2] to check the prediction

$$hD/k = (0.023)(Du\rho/\mu)^{0.8}(C_p\mu/k)^{1/3} \quad (9.1)$$

Role of Experience in the Design Process

Property	21°C (70°F)	93°C (200°F)	Ratio of (new/old)
ρ (kg/m^3)	997.4	963.2	0.966
k (W/m°C)	0.604	0.678	1.12
C_p (kJ/kg°C)	4.19	4.20	1.00
μ (kg/m/s)	9.8×10^{-4}	3.06×10^{-4}	0.312

Role of Experience in the Design Process

Take the ratio of Equation 9.1 for the two conditions given above, rearrange and substitute numerical values. Using ʹ to identify the new condition at 93°C, we get:

$$h'/h = (D/D)^{0.2}(u'/u)^{0.8}(\rho'/\rho)^{0.8}(\mu/\mu')^{0.47}(C_p'/C_p)^{0.33}(k'/k)^{0.67} \tag{9.2}$$

$$= (1)(1.50)(0.973)(1.73)(1.00)(1.08) = 2.725 \tag{9.3}$$

$$h' = (2.725)(5250)\ \mathrm{W/m^2{}^\circ C} = 14{,}300\ \mathrm{W/m^2{}^\circ C}$$

The initial assumption that the velocity and temperature do not have a significant effect is incorrect. Equation 9.3 reveals a velocity effect of a factor of 1.5 and a viscosity effect of a factor of 1.73. All other factors are close to 1.0.

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Step 3—Re-evaluate/Rethink: The original assumptions that velocity and temperature had no effect on the heat transfer coefficient have been rejected. Improved assumptions for future predictions are:

1. The temperature effect on viscosity must be evaluated.
2. The effects of temperature on C_p, ρ, and k are negligible.
3. Pipe diameter has a small effect on h (all other things being equal).
4. Results are limited to the range where the Sieder-Tate equation is valid.

With these assumptions, the values for water at 21°C are substituted into Equation 9.2. This creates a useful heuristic for evaluating the heat transfer coefficients for water.

$$h'(\mathrm{W/m^{2\circ}C}) = 125u'^{0.8}/\mu'^{0.47} \text{ for } u'(\mathrm{m/s}),\ \mu'\ (\mathrm{kg/m\ s})$$