458.401 Process & Product Design

01

Introduction

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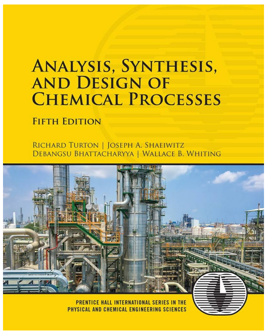
Textbook

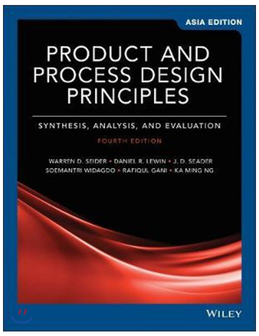


R. Turton, et al.

Analysis, Synthesis, and Design of Chemical Processes (Pearson, 5th Ed., 2018)

도서관 지정도서 (reserve collection in SNU library)

Reference



W. D. Seider, et al.

Product and Process Design Principles

Synthesis, Analysis, and Evaluation (Wiley, 4th Ed., 2017)

Source: www.naceweb.org (National Association of Colleges and Employers)

Home > Job Market > Compensation

CHEMICAL ENGINEERING GRADS PROJECTED TO BE TOP-PAID ENGINEERING MAJORS

February 07, 2020 | By NACE Staff

Chemical engineering majors are projected to have the highest starting salary among Class of 2020 engineering graduates earning bachelor's degrees, according to NACE's Winter 2020 *Salary Survey*.

It is important to note, however, that it is early in the Class of 2020 salary-reporting cycle. Thus, not all majors met the 20-salary threshold to be considered for the highest starting salary at this point.

Among engineering majors with 20 or more reported salaries, chemical engineering majors have a projected average salary of $73,719. Three other engineering majors—electrical engineering, software engineering, and computer engineering—have average starting salaries that are projected to top $70,000. (See Figure 1.)

Figure 1: Projected Top-Paid Class of 2020 Engineering Majors at the Bachelor's-Degree Level*

MAJOR	AVERAGE PROJECTED STARTING SALARY
Chemical engineering	$73,719
Electrical engineering	$72,518
Software engineering	$72,307
Computer engineering	$71,107
Mechanical engineering	$69,913

Q. Why?

Towler and Sinnott, 2nd Ed.

- Chemical engineering has consistently been one of the highest paid engineering professions.

- Demand for chemical engineers

  Process Industries: chemicals, polymers, fuels, foods, pharmaceuticals, and paper

  Other Sectors: Electronic materials and devices, consumer products, mining and metals extraction, biomedical implants, and power generation

A. "Design" - a creative activity

Starting from a vaguely defined problem statement such as a customer need or a set of experimental results, chemical engineers can develop an understanding of the important underlying physical science relevant to the problem and use this understanding to create a plan of action and set of detailed specifications, which, if implemented, will lead to a predicted financial outcome.

Engineering Design

Definition by The Accreditation Board for Engineering and Technology (ABET)

…the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and engineering sciences are applied to convert resources optimally to meet a state objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation

Chemical Process Design

Goals

- To conceive, invent, draw, size and test chemical processes
- To estimate their capital and operating costs cost engineering

Hence, we study

Process Synthesis (invention) and Cost Estimation

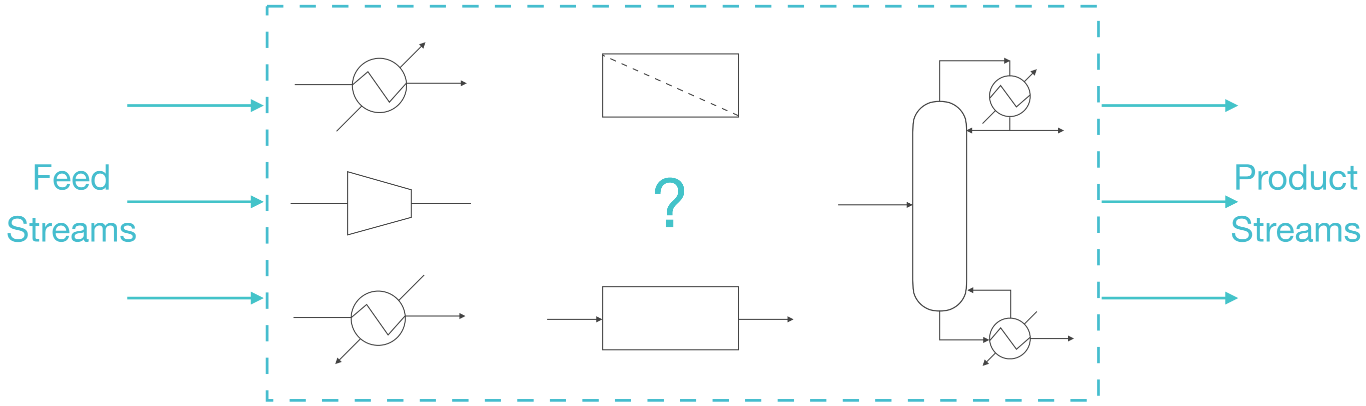
(Chemical) Process Design

Examples

Petrochemicals	Benzene to cyclohexane
Petroleum products	Recovery of paraffins from NG
Industrial gases	Krypton and Xenon from air
Foods	Polysaccharides from microalgae
Pharmaceuticals	Penicillin by fermentation
Polymers	Vinyl chloride monomer from ethylene
Electronic materials processing	Effluent remediation from wafer fabrication

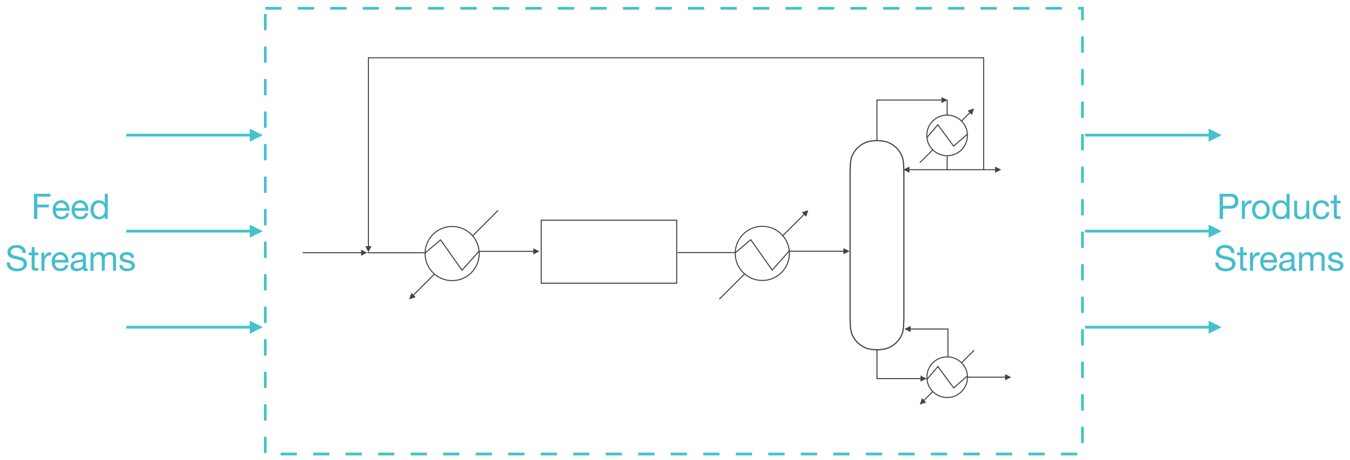
Process Synthesis

- Individual transformation steps are selected
- These individual transformations are interconnected to form a complete process that achieves the required overall transformation



Process Simulation

- Predicts how a process would behave if it was constructed.



Types of Process Simulators

Sequential-Modular Simulators

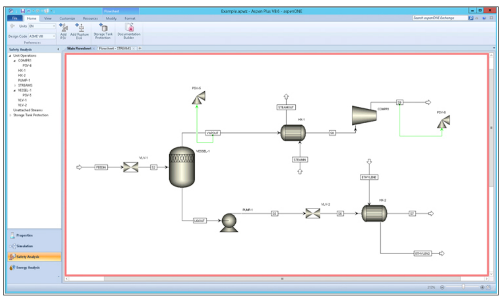
- Each processing unit is described by a “sub-routine”
- A self-contained, standardized, piece of software
- Contains the modeling relationships describing the behavior of the processing unit
- Contains the solution procedure for the modeling relationships
- Units are executed in sequence
- Special provisions account for the recycle streams
- Are convenient, used extensively in industry but are quite rigid
- Represent the historical origins of steady-state simulation

Equation-Oriented Simulators

- The process is modeled by a set of equations, representing the behavior of all processing units and their interconnections
- The set of equations is solved simultaneously, yielding the behavior of the overall process
- Is very flexible and can handle readily both simulation and design problems
- Represents the current state-of-the-art simulators and the form of future evolutions

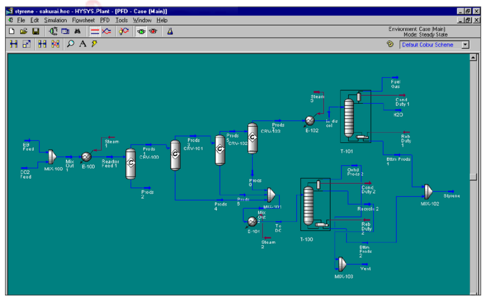
Process Simulators (Sequential-Modular)

aspentech



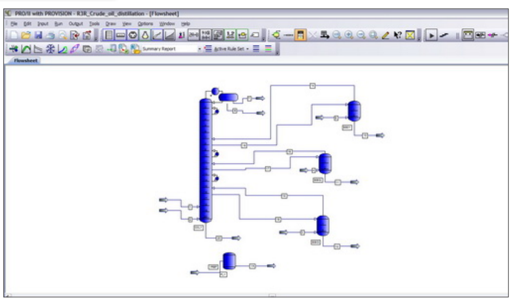
Aspen Plus

Honeywell



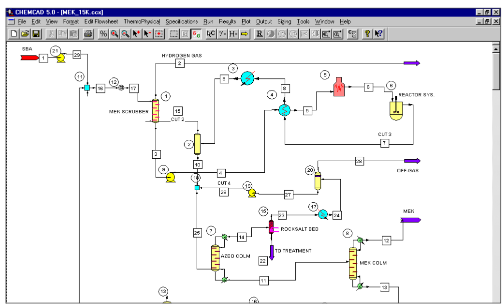
Aspen Hysys / Honeywell Unisim

SimSci by AVEVA



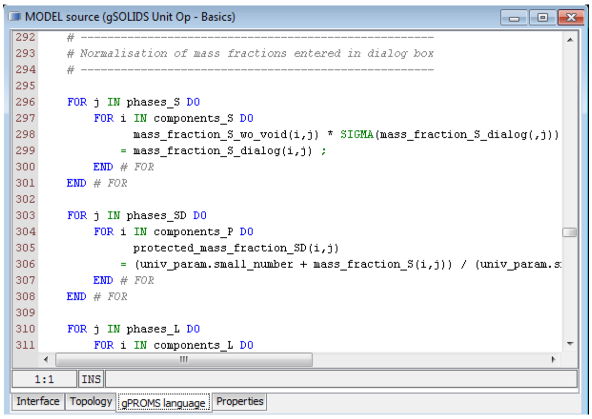
Pro/II

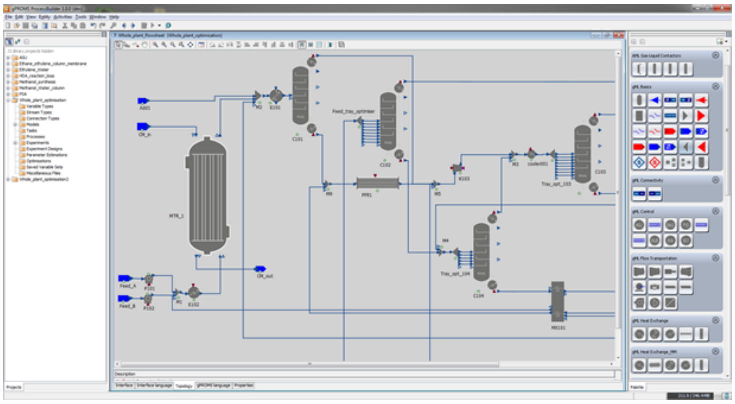
Chemstations™



CHEMCAD

Process Simulators (Equation-Oriented)

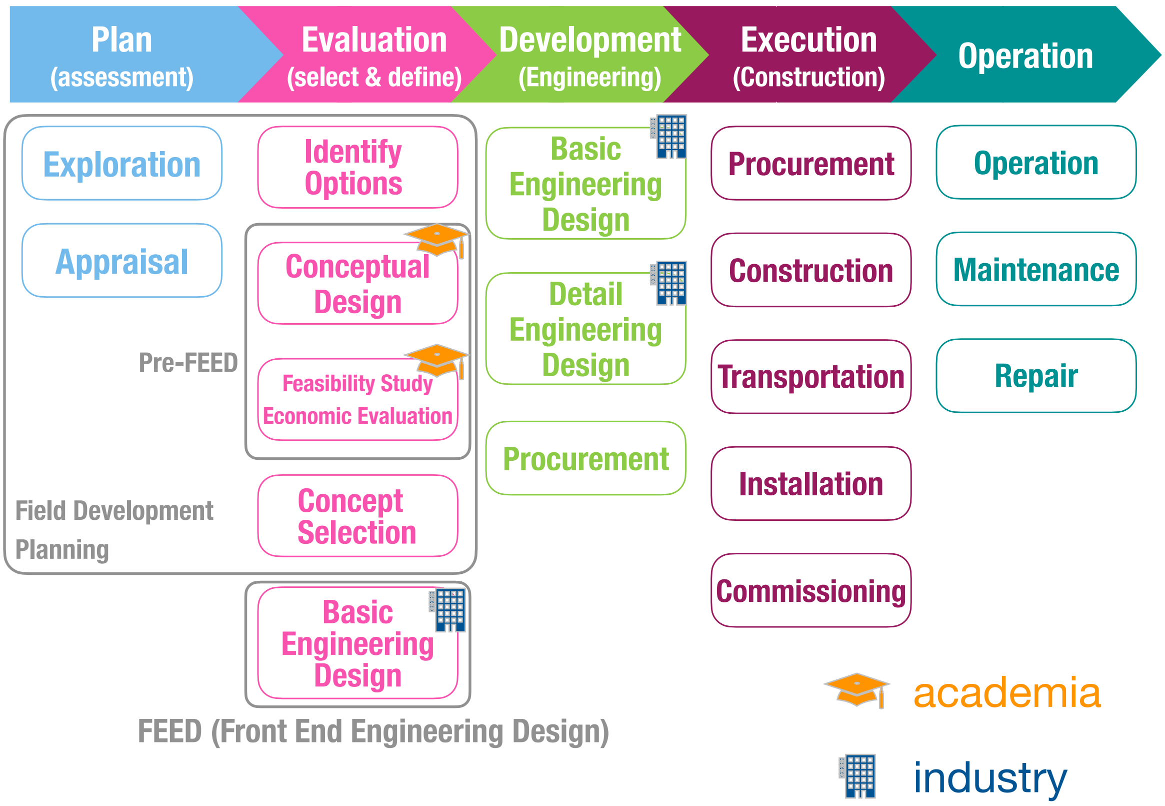




RES Group Inc.

JACOBIAN

Typical Life Cycle of Engineering Projects



Always maintain a focus on the overall problem

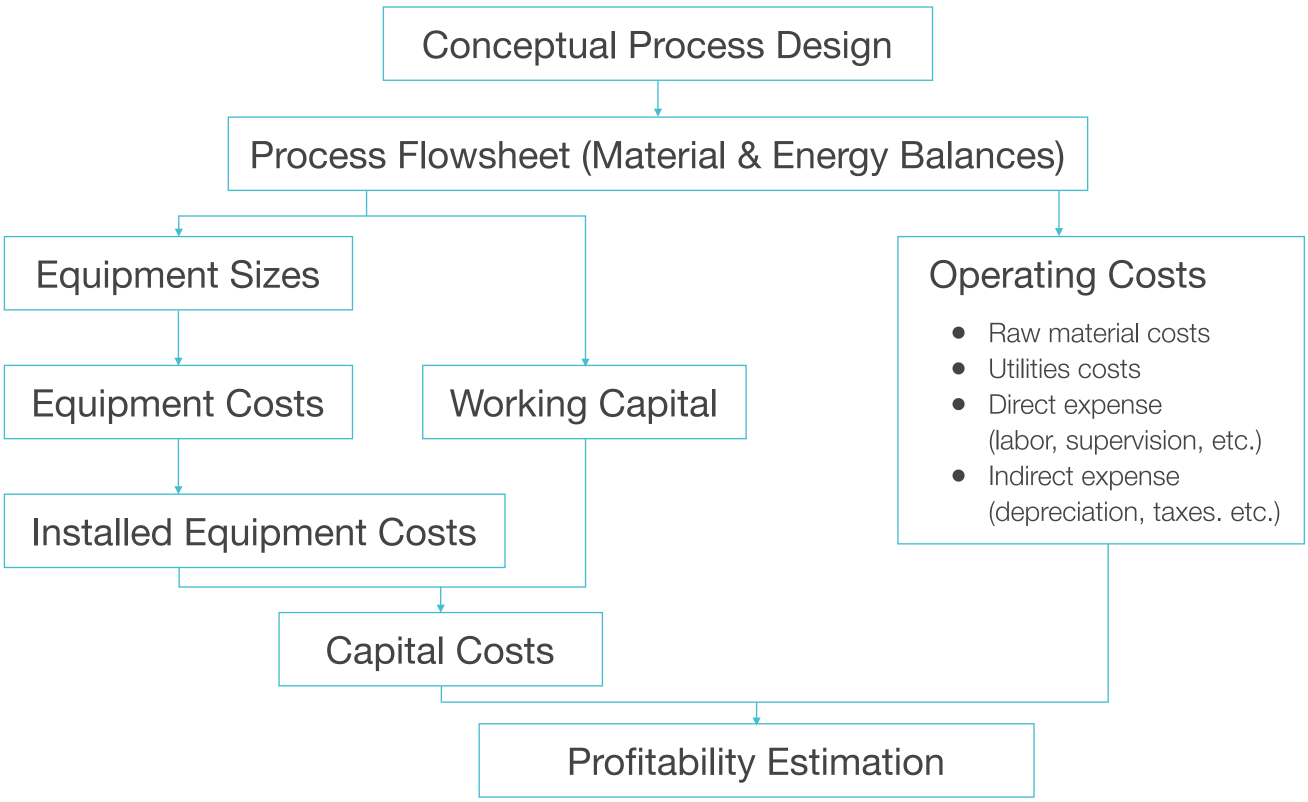
If little added value comes from much additional effort, the effort is not worthwhile.

Types of design estimates

1. Order-of-magnitude estimate (ratio estimate) based on similar previous cost data; probable accuracy exceeds **±40%**
2. Study estimate (factored estimate) based on knowledge of equipment; probable accuracy up to **±25%**
3. Preliminary estimate (budget authorization estimate; scope estimate) based on sufficient data to permit the estimate to be budgeted; probable accuracy within **±12%**
4. Definitive estimate (project control estimate) based on almost complete data, but before completion of drawings and specifications; probable accuracy within **±6%**
5. Detailed estimate (contractor's estimate) based on complete engineering drawings, specifications, and site surveys; probably accuracy within **±3%**

(A. Pikulik and H. E. Diaz, "Cost Estimating Major Process Equipment", Chem. Eng., 84(21), 106, 1977)

Economic Analysis (in Academia)



Hierarchical Approach to Process Design

1. Develop a very simple solution

2. Add successive layers of detail

Example: Hydrodealkylation of toluene (HDA) process

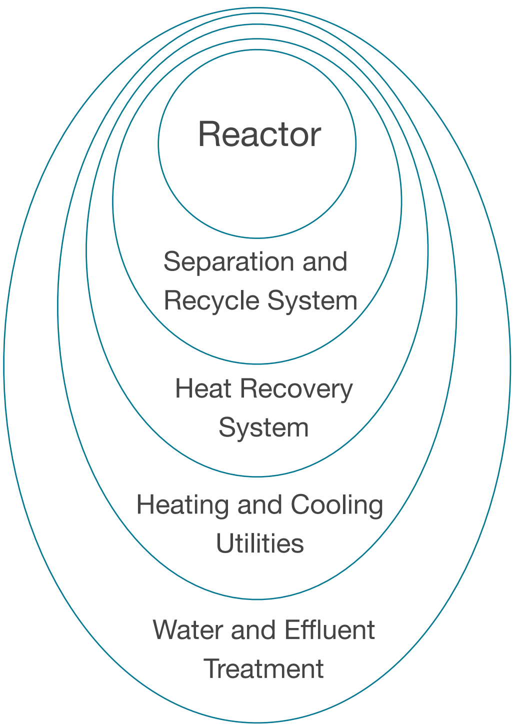
$$\text{Toluene} + H_2 \rightarrow \text{Benzene} + CH_4$$

$$2\ \text{Benzene} \longleftrightarrow \text{Biphenyl} + H_2$$

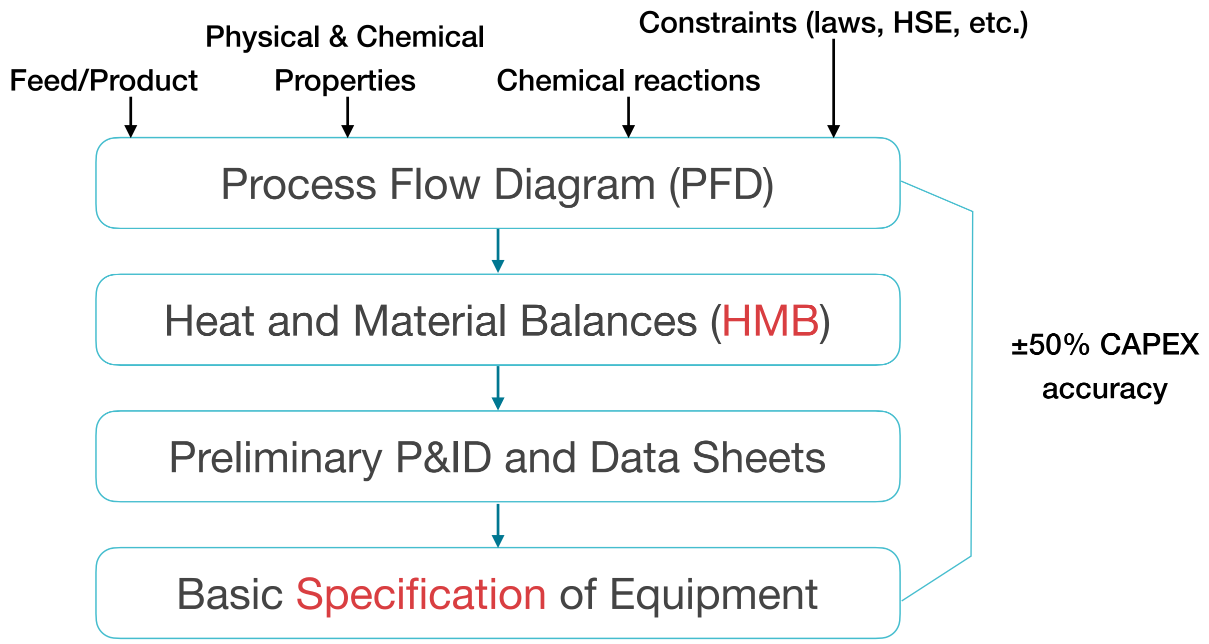
1. Batch vs. Continuous
2. Input-output structure of the flowsheet
3. Recycle structure of the flowsheet
4. General structure of the separation system
   (Vapor recovery system / Liquid recovery system)
5. Heat-exchanger network

Onion Model of Process Design

Smith, 2nd Ed.



Conceptual Design in Industry

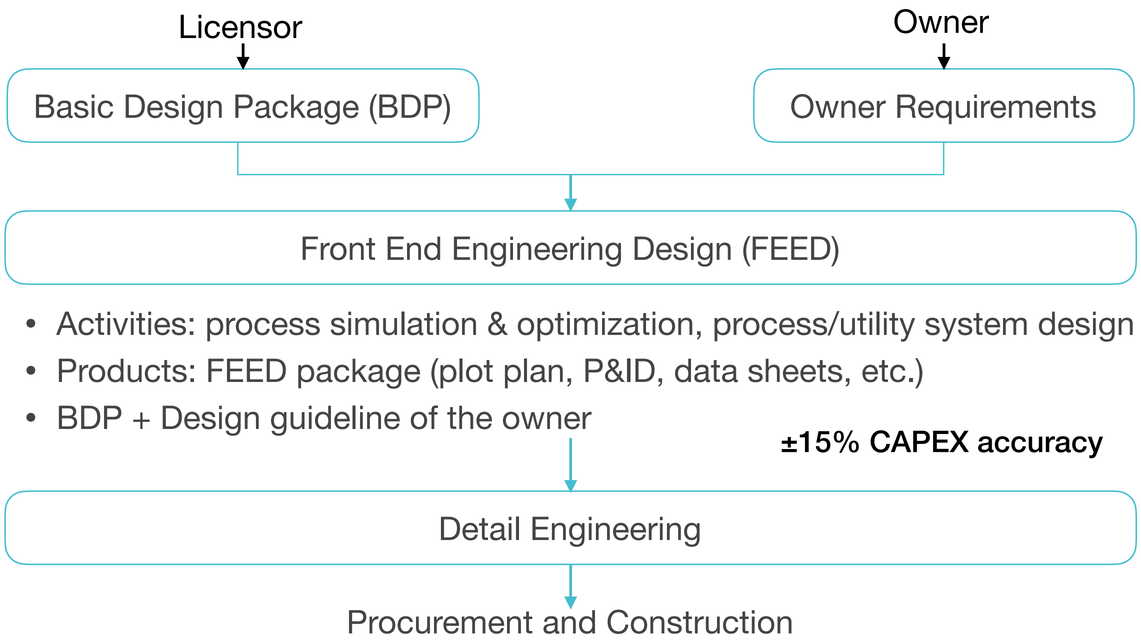


- Basic Design Package

: from licensor, conceptual design with reactor and patent process

Front End Engineering Design (FEED)

- To determine **project budget** and **scope of work**
- Based on the results of conceptual design
- **Plot plan** / Piping & Instrumentation Diagram (**P&ID**) / **Equipment spec**ification



FEED (Front End Engineering Design)

- Conducted after completion of Conceptual Design or Feasibility Study
- At this stage, before start of EPC (Engineering, Procurement and Construction), various studies take place to figure out technical issues and estimate rough investment cost
- Normally contracted to EPC contractors, as an optional contract or through bidding. The product of the activity is called "FEED Package" which amounts up to dozens of files and will be the basis of bidding for EPC Contract.
- It is important to reflect client's intentions and project specific requirements into the FEED Package without fail, in order to avoid significant change during EPC Phase. The FEED Work takes about 1 year in case of a large-sized project such an LNG plant. As it is essential to maintain close communication with client, it is a common practice that client stations at Contractor's office during the work execution

Basic Engineering Design Report

- Often used at the end of the process design phase to collect and review information before beginning the plant design phase and detailed design of equipment, piping, plot layout, etc.
- To ensure that all the information necessary for detailed design has been assembled, reviewed , and approved
- To document the decisions and assumptions made during the design and the comments and suggestions made during design review meetings

A sample contents list for a BEDR (adapted from Towler and Sinnott, 2nd Ed.)

1. Process description and basis
    1.1. Project definition (customer, location, key feeds, and products)
    1.2. Process description (brief description of process flowsheet and chemistry, including block flow diagrams)
    1.3. Basis and scope of design (plant capacity, project scope, design basis table)
2. Process flow diagrams
3. Mass and energy balances
    3.1. Base case stream data (stream temperature and pressure, mass flow and molar flow of each component in all streams, stream mass and molar composition, and total stream mass and molar flow, usually given as tables)
    3.2. Modified cases stream data (same data for each variant design case, for example winter/summer cases, start of run/end of run, different product grades, etc.)
    3.3. Base case physical property data (physical properties required by detailed design groups, such as stream density, viscosity, thermal conductivity, etc.)
4. Process simulation (description of how the process was simulated and any differences between the simulation model and process flow diagram that detailed design groups need to understand)
5. Equipment list
6. Equipment specifications
    6.1. Pressure vessels
    6.2. Heaters
    6.3. Heat exchangers
        6.3.1. Tubular
        6.3.2. Air cooled
    6.4. Fluid handling equipment
        6.4.1. Pumps
        6.4.2. Compressors
    6.5. Solid handling equipment
    6.6. Drivers
        6.6.1. Motors
        6.6.2. Turbines
    6.7. Unconventional or proprietary equipment
    6.8. Instrumentation
    6.9. Electrical specifications
    6.10. Piping
    6.11. Miscellaneous
7. Materials of construction (what materials are to be used in each section of the plant and why they were selected, often presented as a table or as a marked up version of the process flow diagram)
8. Preliminary hydraulics (pump-and-line calculations of pressure drop used as a basis for sizing pumps and compressors)
9. Preliminary operating procedures (describe the procedures for plant start-up, shutdown, and emergency shutdown)
10. Preliminary hazard analysis (description of major materials and process hazards of the design)
11. Capital cost estimate (breakdown of capital cost, usually for each piece of equipment plus bulks and installation, usually given as a table or list)
12. Heat integration and utilities estimate (overview of any pinch analysis or other energy optimization analysis, composite curves, table giving breakdown of utility consumption and costs)

(continued)

(continued)

13. Design decisions and assumptions (description of the most significant assumptions and selection decisions made by the designers, including references to calculation sheets for alternatives that were evaluated and rejected)
14. Design review documentation
    14.1. Meeting notes (notes taken during the design review meeting)
    14.2. Actions taken to resolve design review issues (description of what was done to follow up on issues raised during the design review)
15. Appendices
    14.1. Calculation sheets (calculations to support equipment selection and sizing, numbered and referenced elsewhere in the report)
    14.2. Project correspondence (communications between the design team, marketing, vendors, external customers, regulatory agencies and any other parties whose input influenced the design)

Detail Engineering

- Equipment purchase / Vendor information
- Construction drawings
- Hazard and operability (HAZOP)