EQUIPMENT DESIGN

LECTURE 1
INTRODUCTION TO DESIGN

CHAPTER 1

Introduction to Design

1.1. INTRODUCTION

This chapter is an introduction to the nature and methodology of the design process, and its application to the design of chemical manufacturing processes.

1.2. NATURE OF DESIGN

This section is a general, somewhat philosophical, discussion of the design process; how a designer works. The subject of this book is chemical engineering design, but the methodology of design described in this section applies equally to other branches of engineering design.

Design is a creative activity, and as such can be one of the most rewarding and satisfying activities undertaken by an engineer. It is the synthesis, the putting together, of ideas to achieve a desired purpose. The design does not exist at the commencement of the project. The designer starts with a specific objective in mind, a need, and by developing and evaluating possible designs, arrives at what he considers the best way of achieving that objective; be it a better chair, a new bridge, or for the chemical engineer, a new chemical product or a stage in the design of a production process.

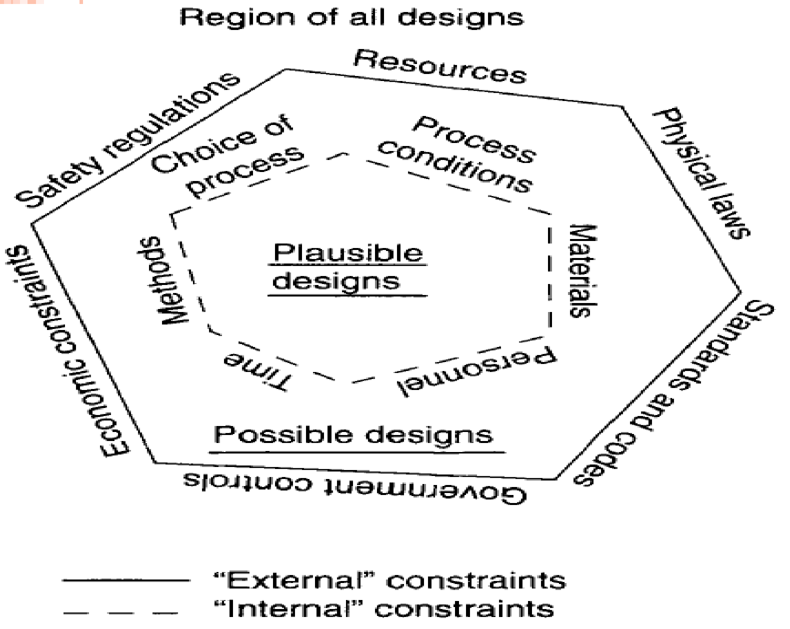

Figure 1.1. Design constraints

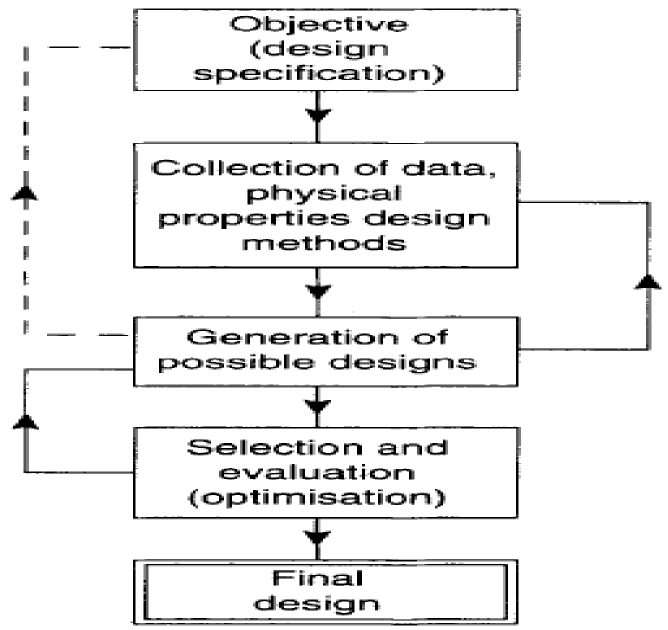

Figure 1.2. The design process

1.3. THE ANATOMY OF A CHEMICAL MANUFACTURING PROCESS

The basic components of a typical chemical process are shown in Figure 1.3, in which each block represents a stage in the overall process for producing a product from the raw materials. Figure 1.3 represents a generalised process; not all the stages will be needed for any particular process, and the complexity of each stage will depend on the nature of the process. Chemical engineering design is concerned with the selection and arrangement of the stages, and the selection, specification and design of the equipment required to perform the stage functions.

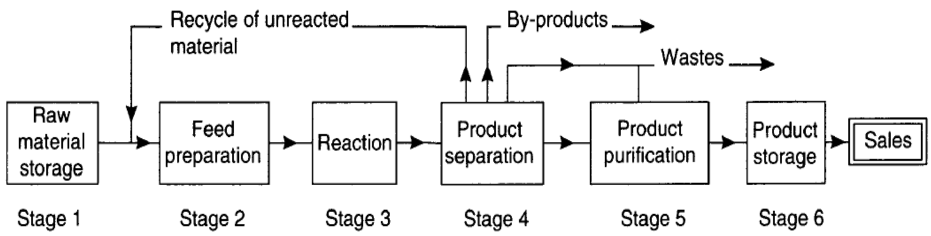

Figure 1.3. Anatomy of a chemical process

1.6. CODES AND STANDARDS

The need for standardisation arose early in the evolution of the modern engineering industry; Whitworth introduced the first standard screw thread to give a measure of interchangeability between different manufacturers in 1841. Modern engineering standards cover a much wider function than the interchange of parts. In engineering practice they cover:

1. Materials, properties and compositions.
2. Testing procedures for performance, compositions, quality.
3. Preferred sizes; for example, tubes, plates, sections.
4. Design methods, inspection, fabrication.
5. Codes of practice, for plant operation and safety.

The terms STANDARD and CODE are used interchangeably, though CODE should really be reserved for a code of practice covering say, a recommended design or operating procedure; and STANDARD for preferred sizes, compositions, etc.

1.6 CODES & STANDARDS

British Standards Institution (BSI)
American National Standards Institute (ANSI)
American Petroleum Institute (API)
American Society for Testing Materials (ASTM)
American Society of Mechanical Engineers (ASME) (pressure vessels).
Burklin (1979) gives a comprehensive list of the American codes and standards.
The International Organisation for Standardisation (ISO) coordinates the publication of international standards.

1.7. FACTORS OF SAFETY (DESIGN FACTORS)

Design is an inexact art; errors and uncertainties will arise from uncertainties in the design data available and in the approximations necessary in design calculations. To ensure that the design specification is met, factors are included to give a margin of safety in the design; safety in the sense that the equipment will not fail to perform satisfactorily, and that it will operate safely: will not cause a hazard. "Design factor" is a better term to use, as it does not confuse safety and performance factors.

In mechanical and structural design, the magnitude of the design factors used to allow for uncertainties in material properties, design methods, fabrication and operating loads are well established. For example, a factor of around 4 on the tensile strength, or about 2.5 on the 0.1 per cent proof stress, is normally used in general structural design. The selection of design factors in mechanical engineering design is illustrated in the discussion of pressure vessel design in Chapter 13.

Design factors are also applied in process design to give some tolerance in the design. For example, the process stream average flows calculated from material balances are usually increased by a factor, typically 10 per cent, to give some flexibility in process operation.

EQUIPMENT DESIGN

LECTURE 2
Design Information and Data

Design Information and Data

Data collection

To proceed with a design, the designer must first assemble all the relevant facts and data required. For process design this will include information on possible processes, equipment performance, and physical property data. This stage can be one of the most time consuming, and frustrating, aspects of design. Sources of process information and physical properties are reviewed in Chapter 8.

Many design organisations will prepare a basic data manual, containing all the process "know-how" on which the design is to be based. Most organisations will have design manuals covering preferred methods and data for the more frequently used, routine, design procedures.

SOURCES OF INFORMATION ON MANUFACTURING PROCESSES

The most comprehensive collection of information on manufacturing processes is probably the *Encyclopedia of Chemical Technology edited by Kirk and Othmer (1978,* 1991), which covers the whole range of chemical and associated products. Another encyclopedia covering manufacturing processes is that edited by McKetta (1977). Several books have also been published which give brief summaries of the production processes used for the commercial chemicals and chemical products. The most well known of these is probably Shreve's book on the chemical process industries, now updated by Austin, Austin (1984). Others worth consulting are those by Faith *et al, (1965), Groggins (1958),* Stephenson (1966) and Weissermal and Arpe (1978). Cornyns (1993) lists named chemical manufacturing processes, with references.

SOURCES OF INFORMATION ON MANUFACTURING PROCESSES

The extensive German reference work on industrial processes, *Ullman's Encyclopedia of Industrial Technology, is now available in an English translation, Ullman (1984).*

Specialised texts have been published on some of the more important bulk industrial chemicals, such as that by Miller (1969) on ethylene and its derivatives; these are too numerous to list but should be available in the larger reference libraries and can be found by reference to the library catalogue.

Books quickly become outdated, and many of the processes described are obsolete, or at best obsolescent. More up-to-date descriptions of the processes in current use can be found in the technical journals. Chemical Engineering, *Hydrocarbon Processing, Ind. Eng. Chemistry*

SOURCES OF INFORMATION ON MANUFACTURING PROCESSES

World ***Wide Web*** Internet

It is worthwhile searching the Internet for information on processes, equipment and products. Many manufacturers and government departments maintain web sites. In particular, up-to-date information can be obtained on the health and environmental effects of products.

GENERAL SOURCES OF PHYSICAL PROPERTIES

International Critical Tables (1933) is still probably the most comprehensive compilation of physical properties, and is available in most reference libraries. Though it was first published in 1933, physical properties do not change, except in as much as experimental techniques improve, and ICT is still a useful source of engineering data.

Tables and graphs of physical properties are given in many handbooks and textbooks on Chemical Engineering and related subjects. Many of the data given are duplicated from book to book, but the various handbooks do provide quick, easy access to data on the more commonly used substances.

An extensive compilation of thermophysical data has been published by Plenum Press, Touloukian (1970-77). This multiple-volume work covers conductivity, specific heat, thermal expansion, viscosity and radiative properties (emittance, reflectance, absorptance and transmittance),

APPENDIX D
Physical Property Data Bank

Inorganic compounds are listed in alphabetical order of the principal element in the empirical formula.

Organic compounds with the same number of carbon atoms are grouped together, and arranged in order of the number of hydrogen atoms, with other atoms in alphabetical order.

NO = Number in list
MOLWT = Molecular weight
TFP = Normal freezing point, deg C
TBP = Normal boiling point, deg C
TC = Critical temperature, deg K
PC = Critical pressure, bar
VC = Critical volume, cubic metre/mol
LDEN = Liquid density, kg/cubic metre
TDEN = Reference temperature for liquid density, deg C
HVAP = Heat of vaporisation at normal boiling point, J/mol
VISA, VISB = Constants in the liquid viscosity equation:

LOG[viscosity] = [VISA] * [(1/T) − (1/VISB)], viscosity mNs/sq.m, T deg K.

DELHF = Standard enthalpy of formation of vapour at 298 K, kJ/mol.
DELGF = Standard Gibbs energy of formation of vapour at 298 K, kJ/mol.

APPENDIX D
Physical Property Data Bank

CPVAPA, CPVAPB, CPVAPC, CPVAPD = Constants in the ideal gas heat capacity equation:

Cp = CPVAPA + (CPVAPB) *T + (CPVAPC) *T **2 + (CPVAPD) *T **3,
Cp J/mol K, T deg K.

ANTA, ANTB, ANTC = Constants in the Antione equation:
Ln (vapour pressure) = ANTA − ANTB/ (T + ANTC), vap. press. mmHg, T deg K.

To convert mmHg to N/sq.m multiply by 133.32.
To convert degrees Celsius to Kelvin add 273.15.

TMN = Minimum temperature for Antoine constant, deg C
TMX = Maximum temperature for Antoine constant, deg C

Most of the values in this data bank were taken, with the permission of the publishers, from: The Properties of Gases and Liquids, by Reid, R. C., Sherwood, T. K. and Prausnitz, J. M., 3rd edn, McGraw-Hill.