

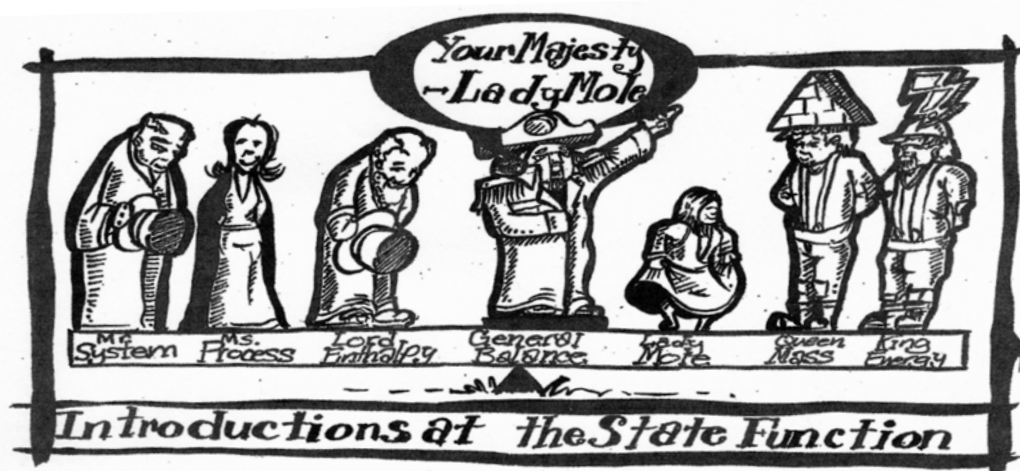
## An Introduction

A material and energy balance is essentially a quantitative account of the redistribution of material and/or energy that occurs when anything happens. This basic tool of process engineering can be used to solve many practical problems. The list below shows that such problems range from those of interest to engineers and scientists in their daily work (see *Refs. 1–2*) to those of relevance to all people concerned with the sustainability of life on planet Earth (see *Refs. 3–5*).

### USES OF MATERIAL AND ENERGY BALANCES

- Modelling and design of industrial chemical<sup>1</sup> processes
- Life-cycle analysis and industrial ecology
- Development of medical technology
- Modelling the global environment, geochemical cycles and climate change
- Management of resources (energy, food and water) for the population of planet Earth
- Design for space stations and interplanetary travel

This text focuses on the use of material and energy balances in the modelling and design of industrial chemical processes, but includes examples that illustrate the application of material and energy balances to chemical processes in other fields, such as those listed above.



<sup>1</sup> The term “chemical process” in this context means any change resulting in the redistribution of material and/or energy in a system, and embraces processes that involve *biochemical, electrochemical, photochemical, physico-chemical or thermochemical phenomena*. As used in this text the term “chemical process” excludes changes that involve the inter-conversion of mass and energy via nuclear reactions.

## PREREQUISITES

The principles involved in material and energy balance calculations are those that you probably learned in high school and/or the first year of university. These principles include, for example:

- The law of conservation
- Dimensions and units of physical quantities
- Chemical reactions and stoichiometry
- The ideal gas law
- Multi-phase equilibrium
- The first law of thermodynamics
- Basic thermochemistry and thermophysics
- Simple algebra and a little calculus
- Computer calculations with spreadsheets

These basics are reviewed in Chapters 1 and 2 then combined and extended in Chapters 3 to 7 to a formalised procedure for treating chemical processes, which is a key skill in the practice of chemical, biological and environmental engineering.

## DEALING WITH COMPLEX PROBLEMS

Material and energy balances provide a tool for students in many fields to grasp and to quantify the factors that determine the behaviour of both man-made and natural systems. Chemical processes (as defined broadly above) are complex and typically involve many interacting factors in non-linear relationships. In this respect, the material and energy balance techniques used by engineers to model industrial processes can be used as both an educational and a predictive tool to deal with complex natural phenomena such as, the global geochemical cycles, population dynamics and the thermal “greenhouse” effect on planet Earth.

The constraints of material and energy in natural systems appear poorly understood by our politicians, as well as by many economists and practitioners of the social sciences (see *Refs. 6–7*). Perhaps this text will help to provide the needed conceptual basis for dealing with the problems of material and energy flow that are basic to the progress and sustainability of our civilisation.

**FURTHER READING**

- [1] T. M. Duncan and J. A. Reimer, *Chemical Engineering Design and Analysis*, Cambridge University Press, Cambridge, 1998.
- [2] D. T. Allen and K. S. Rosselot, *Pollution Prevention for Chemical Processes*, John Wiley & Sons, New York, 1997.
- [3] J. A. Fava *et al.* (Eds.), *A Technical Framework for Life-Cycle Assessment*, Society of Environmental Toxicology and Chemistry, 1994.
- [4] M. Wackernagel and W. Rees, *Our Ecological Footprint — Reducing the Human Impact on Earth*, New Society Publishers, Gabriola Island, 1996.
- [5] A. Ford, *Modeling the Environment*, Island Press, Washington DC, 1999.
- [6] T. Homer-Dixon, *The Ingenuity Gap*, Alfred Knopf, New York, 2000.
- [7] R. Wright, *A Short History of Progress*, ANANSI, Toronto, 2004.

