Chapter 1 Introduction

This course is concerned with the thermalhydraulic design of the process systems that are required to transport heat energy away from the nuclear reactor source and transform this heat energy into useful work (generally electrical energy). This entails a number of interrelated systems:

reactor core
heat transport system
steam generators
turbines
pressure control system
coolant inventory control systems
power control systems;

a number of system components:

valves
pumps
pipes
vessels
heat exchangers;

and a number of engineering and science disciplines:

reactor physics
heat transfer
fluid mechanics
thermodynamics
chemistry
metallurgy
control
stress analysis.

The basic concept of the nuclear power plant is set by the overall objective:

Do useful shaft work using a thermodynamic heat engine (a turbine) utilizing a heat source (a reactor) and a heat sink (a lake, sea, or the atmosphere).

This is conceptualized in figure 1.1. Figure 1.2 shows an overview of typical plant process systems.

Although the basic concept is set, there are many possible variations on the theme. As mentioned, there are a number of inter-related systems, components and disciplines. These interact to form the design; limitations and characteristics of one affect the other. Consequently the process designer needs to have an appreciation of the characteristics and limitations of all the major pieces in order to carry out the detailed design of a particular system - i.e., in order to make intelligent choices. Design is, after all, the process of constraining the possible alternatives (in reaching a design objective) down to one choice. The overall goal is to provide an effective process within the context of the whole operation - this means the system must perform its process function safely and efficiently at a reasonable cost. Consequently, this course is not about any particular nuclear power plant design. Rather it is about the basic theory behind the major pieces and how these major themes interact.

To enable the reader to conceptualize the various reactor types, the design descriptions of PWRs, BWRs, PHWs, HTGCRs & LMFBRs are given. The focus will be on indirect cycle reactors, that is, those that incorporate an intermediate heat exchanger between the reactor and the turbine cycle. To understand some of the choices behind the main reactor types, design requirements and characteristics are discussed in Chapter 2.

In Chapter 3, the basic theory and equations behind the primary heat transport system and steam generator are given since this is central to the whole process design. The steam generator is a critical component since it is the interface between the primary and secondary sides. The focus is the heat duty diagram (see overview fig.) and central to the PHTS is the primary flow. The core heat transfer is the main limitation to power extraction from a nuclear reactor. Thus nuclear fuel heat transfer, temperature profiles, fluid flow and critical heat flux are addressed. The turbine cycle sets the overall plant efficiency and places requirements on the steam generator. Thus, the topic of thermodynamics is addressed in Chapter 4.

The course overview diagram, figure 1.3, places the above key issues into the overall plant process systems as a handy "big picture" map to the course. The interplay of these key concepts and systems constitute "the design process".

The final arbitrators in resolving the conflicting demands of each subsystem are

- low overall cost
- material limits (temperature, mechanical stress, erosion, corrosion, etc.)
- regulations
- past experience
- standardized design requirements
- quality assurance (QA)
- safety.

There is no one best solution to a given design task, nor is there even one best solution procedure. Good process design is evolutionary; we learn from past successes and failures, incorporate the latest experimental, theoretical and simulation results, employ sound engineering principles and a solid understanding of the basics to engineer each and every new design.

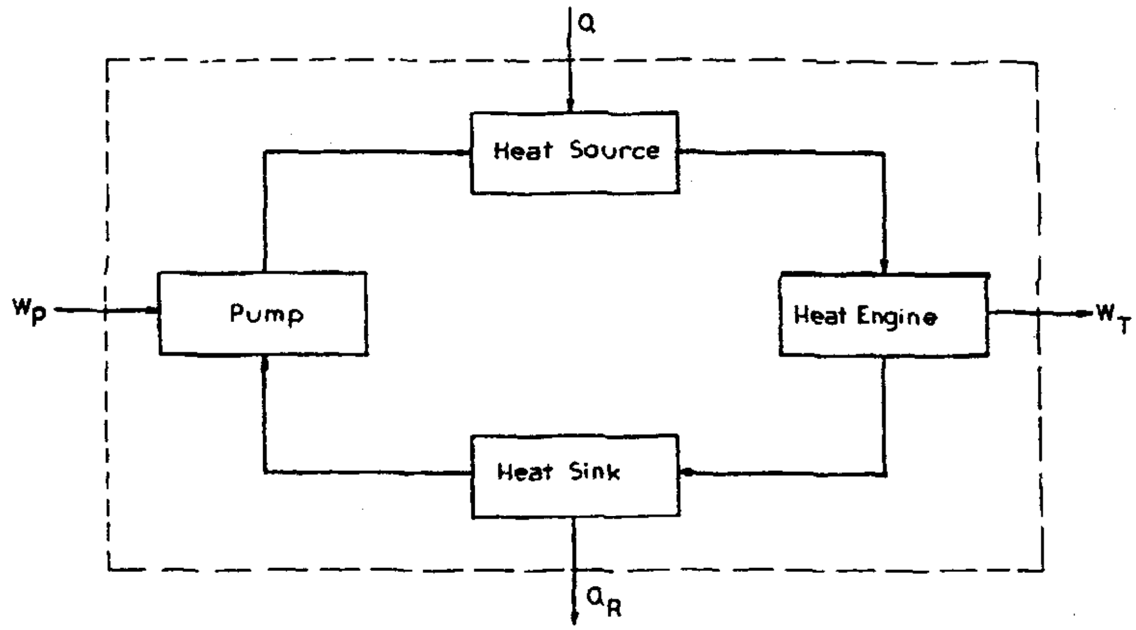

Figure 1.1 Schematic diagram for a reactor power cycle [Source: Rust figure 2.7]

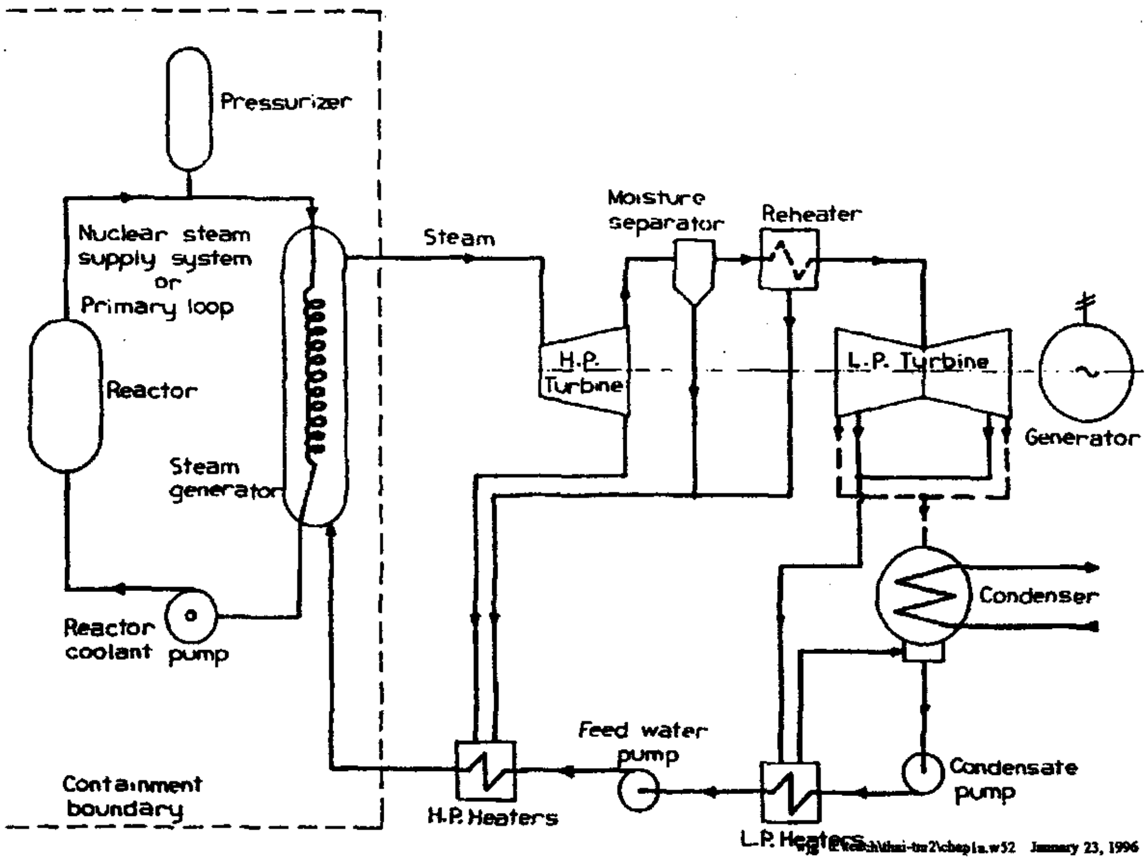

Figure 1.2 Simplified diagram of a pressurized water reactor system [Source: Rust figure 1.1]

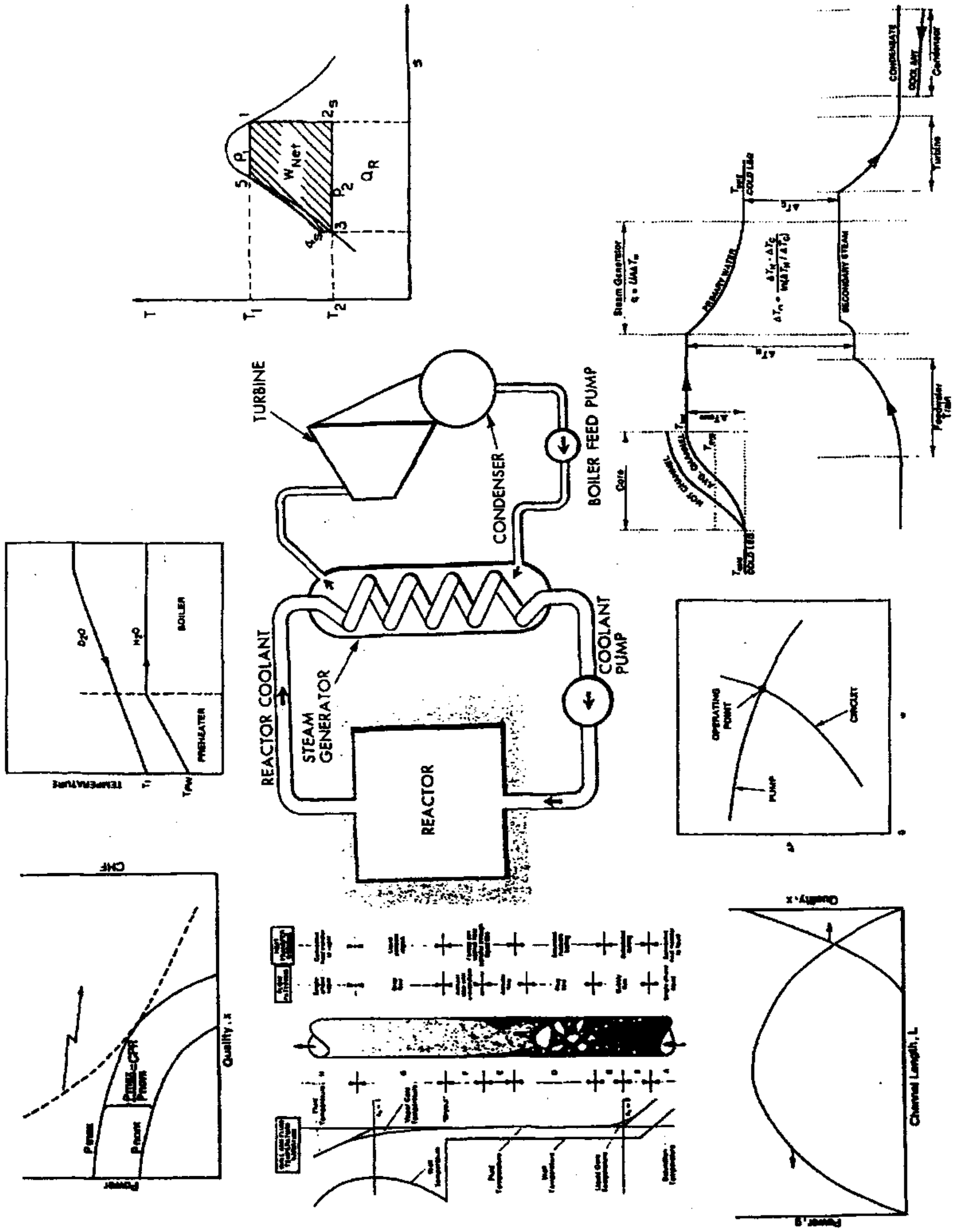

Figure 1.3 Course overview