Chapter 1

Introduction

Thermodynamics is about different forms of energy and turning one form of energy into another. The term thermodynamics comes from ancient Greek and stems from the first attempts of turning heat into motion (work) (*therme*, $\Theta\epsilon\rho\mu\eta$, means 'heat' and *dunamis*, $\delta\upsilon\nu\alpha\mu\iota\zeta$ means 'motion'). Nowadays, the term is used in a broader sense and thermodynamics stands for all sorts of forms and transformations of energy, including the production of work and cold, and relations between quantities of matter. Examples include steam plants for the production of electricity, gas turbines for propulsion, combustion engines for cars and cooling or heating systems. The fields of physics and chemistry study the effects of changes in pressure, temperature and volume on (engineering) systems at a macroscopic scale. Figure 1.1 gives an example of a typical thermodynamic system.

Engineers use thermodynamics in practice when studying devices that are used to convert energy. They are especially interested in energies that are used and released when work, cold or heat form and how efficient energy conversions are. In practice, they use the laws of thermodynamics to study energy conversions. Moreover, they make ample use of tables and diagrams containing values for various energies and entropy to actually perform calculations about the engineering systems that convert energy. The tables are essential, because energy is not easily measured. Quantities like pressure, temperature, volume and mass can be measured quite easily. Some other quantities like density and specific volume can be derived from this through simple relations. However, quantities such as internal energy, enthalpy and entropy cannot be determined as easily, because they cannot be measured directly or related to quantities that can be measured through simple relations. As such,

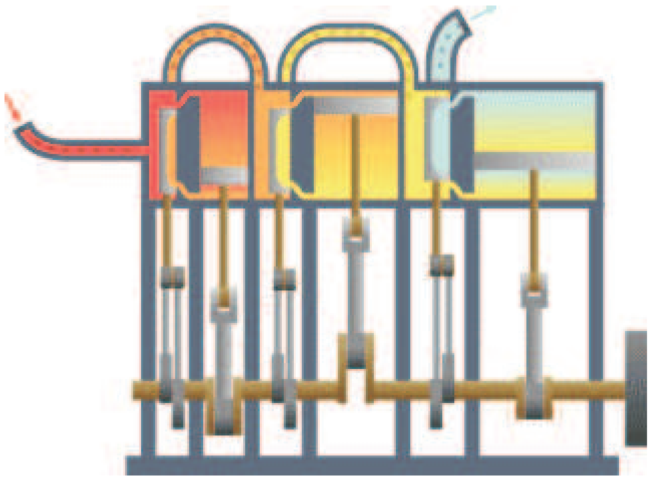

Figure 1.1: *The steam machine is a typical thermodynamic system in which heat is turned into work. On the left, heat from a heat source (e.g. a boiler) is introduced and on the right, cold is transported to a cold well (e.g. a condensor). Work is formed due to the motion of the pistons. Historically speaking, thermodynamics developed out of a need of increasing the yield of the first steam machines.*

it is essential to have a number of fundamental relations between oft-used thermodynamic quantities for the purpose of relating the quantities that cannot be measured to quantities that can be directly measured. In thermodynamics, these relations are often used without thought without deriving them (e.g. $du = c_v dT$).

Until now, Technical Thermodynamics is mainly focused on the application of such relations to energy systems and on using tables and diagrams. In order to read the tables and diagram and use the identified relations, you do not need to be able to derive them. However, in an academic programme, such derivations and insights contribute to knowledge at a fundamental and academic level. The goal of this document is to understand how tables, diagrams and relations were formed by using differentials. A method will be taught in which the changes of energies can be determined as a function of two random independent other variables by means of a systematic evaluation of partial derivatives. After all, according to the state postulate, the state of a simple thermodynamic system is completely determined by only two independent variables.

Because partial derivatives play a major part in all of this, chapter 2 begins with some theory regarding partial derivatives. Chapter 3 discusses the difference between exact and inexact differentials (state and path functions) and the importance of these differentials for thermodynamics will be explained. Chapter 4 introduces fundamental relations between thermodynamic quantities. A number of mathematical relations between partial derivatives will be derived in chapter 5. Subsequently, chapter 6 discusses the Maxwell relations that are the foundation for deriving many thermodynamic relations. Chapter 7 is dedicated to a number of definitions of partial derivatives. Chapter 8 provides a method for rewriting partial derivatives into measurable quantities. Along with these chapters, there are a number of tools that can be used to calculate the more fundamental aspects of thermodynamic systems. These are used to derive a number of important relations to explain remarkable properties.