CHAPTER 1

Introduction

Although air is much more freely available than water and costs nothing, process cooling has historically been accomplished by cooling water. This is attributable to the much lower cost of cooling by water, thanks to its substantially higher thermal conductivity and lower temperature. However, with increasing shortages of cooling water and a consequent increase in its cost, air cooling has become more and more popular. Today, air-cooled heat exchangers (ACHEs) are a common sight in the chemical process industries (CPIs).

The first cost of an ACHE is much greater than that of a water-cooled heat exchanger for the same heat duty, but its operating cost is usually much less. The operating cost with water cooling comprises the cost of the initial raw water itself, makeup water, treatment chemicals, apportioned cost of the cooling tower, and of course the pumping cost. For air-cooled heat exchangers, the operating cost is only the cost of the power required to make the air flow across the tube bundles. Thus, on an overall cost basis, ACHEs often compare quite favorably with water-cooled heat exchangers.

The design of ACHEs comprises two distinct activities, namely, thermal design and mechanical design. In thermal design the basic sizing of the heat exchanger is accomplished, whereas in mechanical design the thicknesses and precise dimensions of the various components are determined and a bill of materials is produced. Detailed engineering drawings are then prepared based on which actual fabrication drawings are made. In this book, as the title suggests, we shall talk principally about thermal design.

With the availability of sophisticated software, there has been an undue dependence on them as "black boxes," without the designer being truly in control of the design process and understanding the nuances of design. A proper and sound understanding of the fundamental principles and interplay of parameters is essential in order to produce an optimum design. The principal purpose of writing this book is to help the heat exchanger thermal designer attain such an understanding.

Presently, there is no book available on "practical" ACHE thermal design. This book is based on the author's experience of over 36 years in the thermal design of ACHEs for the chemical process industry, and reflects many real-life situations that were far from straightforward. This book has been written in a structured, logical, and didactic manner, and special effort has been made at bringing out the interplay of parameters for a thorough understanding of basic issues.

As "*Example is better than precept*," several case studies are presented in this book in order to vividly bring out a particular methodology, principle, or practice that has been advocated. The reader is invited to run these examples with further variations in the parameters being examined, in order to develop a comprehensive understanding.

It is well known that the thermal design of ACHEs is still largely an enigma, with far fewer engineering and fabricating companies practicing the trade than the thermal design shell-and-tube heat exchangers. This is really quite surprising, considering that thermal design of ACHEs is simpler and more straightforward than that of shell-and-tube heat exchangers! This book will have served its purpose if it encourages more companies to overcome this diffidence and take up the thermal design of ACHEs.

Now, coming to the individual chapters themselves, Chapter 2 dwells on the advantages and disadvantages of air cooling, while Chapter 3 discusses the optimization of air and water cooling. In some instances, only cooling by air need be employed, whereas in others only cooling by water is adequate. However, in the vast majority of cases that fall between these two extremes, cooling by both air and water is favorable.

Chapter 4 gives a detailed rundown of the various components and constructional features of ACHEs, since a good understanding of the same is vital to the thermal design of this equipment. This chapter will also be of considerable interest to mechanical designers of ACHEs, since it explains the implications of several constructional features on thermal design.

Chapter 5 discusses various basic concepts that form much of the foundation of knowledge for ACHE design. The simultaneous optimization of airside and tubeside calculations is certainly not an easy task. However, with the help of logical explanations, arguments, and case studies, the design methodology is made easy to understand and apply.

Chapter 6 is on the thermal design of condensing ACHEs. After a brief classification of condensers and a brief account of the mechanisms of condensation, practical guidelines for thermal design are discussed. These include isothermal, narrow-range and wide-range condensation, the effect of pressure, the handling of desuperheating and subcooling, nozzle sizing, and the handling of condensing profiles and physical property profiles.

In Chapter 7, with the help of numerous case studies, optimization of ACHEs is demonstrated vis-à-vis tube OD, fin height, fin spacing, number of tube rows, fan power consumption, tube pitch, and the number of tube passes.

In Chapter 8, physical properties and heat release profiles are discusses at length. The reader is offered guidance on how to feed heat release profiles, a matter that is not as simple as it may appear.

Chapter 9 explains why overdesign is provided, and elaborates on the modalities of overdesign for single-phase and condensing services.

After reviewing the various categories of fouling and the parameters that affect it, suggestions are offered in Chapter 10 on how to specify fouling resistance. Comprehensive guidelines are then suggested and analyzed in order to minimize fouling.

Chapter 11 is on the control of ACHEs, where various methods of control are discussed in detail. Unlike water-cooled shell-and-tube heat exchangers, ACHEs offer very good control on the process.

Chapter 12 deals with operating problems in air-cooled heat exchangers. Various potential problems and ways to avoid them are discussed for both the tubeside and the airside cases.

In Chapter 13, many special applications are elaborated on, including combined services, recirculation ACHEs, humidified ACHEs, tube inserts, variable finning density, natural convection, and vacuum steam condensers.