A WORKING GUIDE TO SHELL-AND-TUBE HEAT EXCHANGERS

STANLEY YOKELL

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A Working Guide to Shell-and-Tube Heat Exchangers

ABOUT THE AUTHOR

Stanley Yokell, president of MGT Inc., specializes in tubular heat exchangers, factory management, pressure vessels, and process equipment. He holds a bachelor of chemical engineering degree from New York University. Mr. Yokell is a member of AIChE, ASME, AWS, NSPE, and ASNT; a licensed PE in Colorado, Illinois, and New Jersey; and a member of the Special Working Group on Heat Transfer Equipment, Section VIII, ASME Pressure Vessel Code Committee.

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Preface

In 1976 the author was asked to present a lecture on design and fabrication of heat exchangers in the fall lecture series *Practical Aspects of Heat Transfer*, offered jointly by the North Jersey and New Jersey sections of the American Institute of Chemical Engineers. It was specifically to be a detailed review of mechanical design and construction considerations of shell-and-tube heat exchangers. Fools rush in. . . . A lecture was prepared, given, well attended, and well received. The question-and-answer session extended almost until midnight.

Most of the chemical engineers present were well versed in the thermodynamic theory and fluid dynamics of tubular exchangers and the process considerations and requirements that apply. However, it quickly became apparent that they knew little about the mechanical and practical aspects. Remembering the depth of his ignorance when first confronted with heat exchanger problems, the author thought that it would be very helpful to many engineers to have a guidebook.

Some time later, the author agreed to present a 4-day intensive continuing-education course on heat exchangers. Aware that engineering education covers generally the basic knowledge that applies and that such courses had long been offered in the thermodynamics, thermal design, fluid dynamics, and stress analysis of tubular exchangers, he organized one called *Shell-and-Tube Heat Exchangers—Mechanical Aspects*, intended to bridge the gap between theory and practice. It consisted of a series of lectures and a visit to a heat exchanger factory.

The author had assumed that participants would be mostly chemical engineers. He expected them to come from chemical plants, oil refineries, resin and fibers plants, paper mills, steel mills, food- and drug-producing facilities, etc., and hoped that some power plant engineers would attend. Much to his surprise, most were mechanical engineers. A substantial number worked in fossil and nuclear power stations.

Being a believer in the ecumenical nature of engineering, the author had included in the course notes information about power plant heat exchangers, feedwater heaters, and steam generators. Therefore, he quickly adapted the lectures to suit the spectrum of participants. The course was well received and has been given many times in the United States, Canada, and Europe. In response to requests from power generation engineers, Carl F. Andreone and the author organized a similar course devoted to closed feedwater heaters.

This guide includes much that engineers who took part in these courses wanted to know. Although works abound on the stress analysis of heat exchanger components, on the thermodynamics, process, and thermal design, and on the fluid dynamics, few deal with practical requirements. This book is intended as a *working guide* that responds to these needs. It is addressed to mechanical and chemical engineers in the process, refining, food, and power generation industries and to designers, specifiers, purchasers, manufacturers, and maintainers of tubular heat exchangers.

Because engineering students have so much to learn, curricula cannot cover many of the working engineer's needs. Texts are unlikely to deal with such bread-and-butter things as heat exchanger construction, inspection, maintenance and repairs and troubleshooting. This work aims to fill the lack.

The author is indebted to many friends and colleagues for their help and advice. These include the members of the Special Working Group on Heat Transfer Equipment of the ASME Boiler and Pressure Vessel Code Committee. Friends and associates Abe Brothman and Leo J. Marin, who made suggestions and warned that no such work can ever be adequate or complete, have passed on. They cannot be thanked but only remembered.

This book is dedicated to my wife Edith Gersen Yokell, whose patience with the author is boundless.

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Chapter

1

Guide to Describing Heat Exchangers

Introduction

This chapter discusses the language of shell-and-tube heat exchangers and explains current usage for describing sizes, types, configurations, and installation positions.

Industry practice for shell-and-tube equipment is to use the terms *heat exchanger, tubular exchanger*, and *exchanger* interchangeably without regard to function, and they will be used that way throughout this book. However, *heat exchanger* is also used to describe units that transfer sensible heat from one stream to another in order to conserve energy.

Exchangers are also named to describe their functions. For example, a chiller cools a liquid flowing through one side by transferring some of its heat to a vaporizing refrigerant flowing through the other side, reboilers and vaporizers boil or vaporize a liquid by extracting heat from a hotter fluid, and condensers condense a vapor to a liquid by transferring its latent heat to a colder fluid.

Heat exchangers used in heating, ventilating, air conditioning, and refrigeration, petroleum refining, chemical and petrochemical processing, and general industrial manufacturing are categorized as *process heat exchangers*. Auxiliary shell-and-tube exchangers used in power generation are called *power plant heat exchangers*. Specialized units used to heat boiler feedwater with turbine extraction steam are called *closed feedwater heaters* but may be termed feedwater heaters or simply heaters.

Process heat exchanger nomenclature is based upon the *Standards of the Tubular Exchanger Manufacturers Association* (*TEMA Standards*).[1] These standards also have systems for describing process exchanger types and for designating sizes and operating positions. With some modifications these systems are used worldwide. American Petroleum Institute (API) Standard 660 incorporates the TEMA nomenclature and terminology by incorporating *TEMA Mechanical Standards*, Class R, by reference.[2]

Similar but somewhat different nomenclature is used in North America by the power generation industry. The Heat Exchange Institute (HEI) has developed standards for power plant heat exchangers (HEI PPS), closed feedwater heaters (HEI CFHS), and steam surface condensers used in power generation.[3–5] The HEI PPS has nomenclature for power plant heat exchangers and its own system for describing types of exchangers, but it has no system for designating sizes. Moreover, there is no HEI CFHS system for describing closed feedwater heater types or sizes.

This chapter provides illustrated guidelines to feedwater heater configurations and reviews current terminology.

Nomenclatures

Figure 1.1, adapted from the *TEMA Standards*, shows cross sections through elevations of schematic drawings of six types of heat exchangers. Figure 1.2, adapted from the HEI PPS, shows cross sections through elevations of schematic drawings of heat exchanger components. The glossary at the end of this chapter defines related terms and expands some of the TEMA and HEI PPS definitions. Figures 1.3 through 1.5 illustrate some frequently used terms.

Designating Size

The *TEMA Standards* size-numbering system is straightforward and simple. It is in general use for process and commercial heat exchangers and is also suitable for designating the sizes of power plant exchangers and feedwater heaters.

In this system, the size number indicates the shell inside diameter (ID) in inches (millimeters), rounded to the nearest integer, and straight tube length (L) in inches (millimeters). For all but kettle-type reboilers, the size number is ID $\times$ L. For kettle-type reboilers, the size number is the port ID through which the bundle enters (ID′), the shell diameter (ID), and the length (L) in the form ID′/ID $\times$ L.

For U-tube exchangers, the straight tube length is the distance from the outermost tubesheet face to the bend line. For straight-tube units, tube length is the length over the outermost tubesheet faces.

Examples of the TEMA size-numbering system

Example 1.1 What is the size number of a straight-tube blowdown cooler that has a 24-in (610-mm) pipe shell, ⅜ in (9.5 mm) thick, and tubes that are 20 ft (6096 mm) long?

answer

English units

Diameter	24 − (2 × ⅜) = 23¼, rounded to the nearest integer = 23
Length	20 × 12 = 240
Size number	23-240

Metric units

Diameter	610 − (2 × 9.5) = 591
Length	6096
Size number	591-6096

Example 1.2 What is the size number of a closed feedwater heater with 24-ft (7315-mm) straight-length U tubes and a 48-in-OD (1219-mm-OD) shell, ½ in (12.7 mm) thick?

answer

English units

Diameter	48 − (2 × ½) = 47
Length	24 × 12 = 288
Size number	47-288

Metric units

Diameter	1219 − (2 × 12.7) = 1193.6, rounded to the nearest integer = 1194
Length	7315
Size number	1194-7315

Example 1.3 What is the size number of a vaporizer with a 24-in-OD × ⅜-in (610-mm-OD × 9.5-mm) bundle nozzle that enters an eccentric conical transition to a 45-in-ID (1143-mm-ID) shell and receives a 16-ft (4877-mm) straight-length U-tube bundle?

answer

English units

Port ID	24 − (2 × ⅜) = 23¼, rounded to the nearest integer = 23
Shell ID	45
Length	16 × 12 = 192
Size number	23/45-192

Metric units

Port ID	610 − (2 × 9.5) = 591
Shell ID	1143
Length	4877
Size number	591/1143-4877

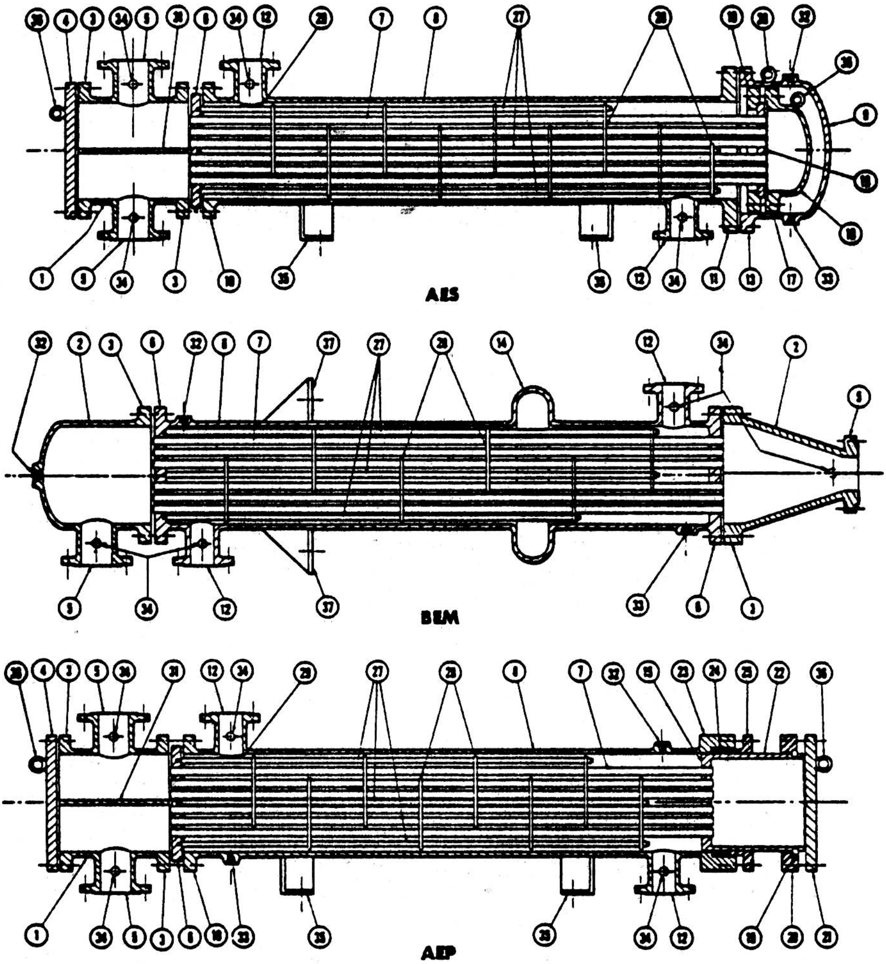

Figure 1.1 TEMA heat exchanger nomenclature. (*Adapted from the* TEMA Standards, *7th ed., by permission of the Tubular Exchanger Manufacturers Association.*)

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