S&T HEAT EXCHANGERS, Part I: Arrangement, Tube thk, TEMA Tubesheet and Flat Covers.

STUDY NOTES

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# Table of contents

Introduction ........................................................................................................ 4

1. Terminology .................................................................................................. 9
   1.1) Fluids ................................................................................................. 9
   1.2) Pressure .......................................................................................... 9
   1.3) Temperature .................................................................................. 10
   1.4) External loads ............................................................................... 11
   1.5) Other definitions .......................................................................... 12

2. Shell and tube heat exchangers ................................................................. 13
   2.1) Parts of heat exchangers ............................................................... 14
   2.2) Types of heat exchangers ............................................................. 16
   2.3) Main components ......................................................................... 18
   2.4) TEMA heat exchanger selection ................................................... 21

3. Design codes ............................................................................................. 22
   3.1) TEMA code (Tubular Exchangers Manufacturers Association) .... 23
   3.2) HEI Standard (Heat Exchange Institute) ..................................... 26
   3.3) API 660–American Petroleum Institute .................................... 28
   3.4) ASME VIII Div.1 Code, UHX part .............................................. 29
   3.5) ASME VIII Div.1 Code, pressure parts ...................................... 30
   3.6) Scope and precedence ................................................................. 34

4. Material Selection ..................................................................................... 36
   4.1) Corrosion ...................................................................................... 37
   4.2) Corrosion types ............................................................................ 38
   4.3) Corrosion allowance ................................................................. 41
   4.4) Essential properties of materials .................................................. 43
   4.5) Technical-economical selection .................................................. 47
   4.6) Product forms .............................................................................. 48
   4.7) Material designation ................................................................. 49
   4.8) Recommended good practices .................................................... 51

5. Shell and tube heat exchangers arrangement .......................................... 55
   5.1) Tube pattern ............................................................................... 55
   5.2) Tube side number of passes ........................................................ 59
   5.3) Shell side number of passes ......................................................... 60

6. Tube bundle design .................................................................................... 63
6.1) Tubesheet ....................................................................................... 64
6.2) Tube bundle assembly ................................................................... 70
6.3) Transverse baffles ....................................................................... 72
6.4) Longitudinal baffle ....................................................................... 75
6.5) Tubes ............................................................................................. 77
6.6) Tube – tubesheet joint .................................................................. 79
6.7) Floating head ................................................................................ 83
6.8) Impingement plate ....................................................................... 86
6.9) Pulling devices ............................................................................. 88
7.  Design of external elements ............................................................. 89
   7.1) Main parts .................................................................................. 89
   7.2) Flat covers ................................................................................ 95
8.  Bibliography ...................................................................................... 98
**Introduction**

There are many different applications that are covered by each type of heat exchanger, but in general, they are used to recover heat between two fluid streams in a particular process plant.

The term *heat exchanger* encompasses all devices used to transfer energy from one fluid to another. Some examples of this group are: radiators, water heaters, refrigeration batteries, evaporators, steam generators, etc.

**Classification**

Heat exchangers are broadly classified based on the following considerations.

1. **Classification based on transfer process**

   According to this criterion, heat exchangers can be generally classified as direct contact and indirect contact.

   **Direct contact** – In this type of heat exchangers, heat transfer takes place between two immiscible fluids like a gas and a liquid coming into direct contact. Common examples of direct contact heat exchangers are cooling towers, mix condensers and desuperheaters.

   **Indirect contact** – In indirect contact type of heat exchangers, the hot and cold fluids are separated by an impervious surface. The surface acts like a physical barrier, separating the two fluid flows, thus there is no possibility of direct contact or contamination between the fluids, except in case of damage of the separation barrier. Examples of this type of heat exchangers are shell and tube exchangers.
2. Classification based on type of construction

Based on the type of construction heat exchangers are classified as follows:

Additionally, multi-tubular or shell and tube heat exchangers can be classified as per the number of times each particle of the fluid travels the entire exchanger length, a process called a “pass”.

3. Classification based on flow arrangement

Based on the flow arrangement heat exchangers are classified into the following principal types.

**Parallel-flow** - In this heat exchanger, the hot and the cold fluids enter at the same end of the heat exchanger and flow through in the same direction and leave together at the other end.

**Co-current flow** - In this heat exchanger hot and cold fluids enter at the same ends of the heat exchanger and flow in the same directions.

**Counter flow** - In this heat exchanger hot and cold fluids enter in opposite ends of the heat exchanger and flow in opposite directions.

**Cross flow** - In this heat exchanger, the two fluids flow at right angles to each other. In this arrangement, the flow may be mixed or unmixed.

Parallel flow heat exchangers mostly used in industrial plants are: plate and frame type, double tube, shell and tube and hair pin.

Design

To design a shell and tube heat exchanger it is mandatory to have the inputs indicated in the data sheet of the equipment. The data sheet is nothing more than a compilation of information obtained during the thermal study of the process in which the exchanger is included. With this information, the mechanical elements can be determined and designed individually.
The design methods of the parts that could be included in a shell and tube heat exchanger will be described in the following chapters of this document. However, not every element described herein will be involved in the design of every shell and tube heat exchanger. Elements should be selected according to the needs and requirements specified in the data sheet. For example, this means that a TEMA heat exchanger type "NEN" will not require a floating head or torispherical head. These elements are described in this course for the cases which do required them.

For the calculation and design of the different components of heat exchangers shown in this course, the criteria set by the TEMA code is will be followed. The most relevant requirements of the ASME and HEI codes are also included in this course.
1. **Terminology**

1.1) **Fluids**

1.1.1) **Tube side**
The fluid flowing inside the tubes (that belong to the tube bundle) is called the “tube side” of a shell and tube heat exchanger.

1.1.2) **Shell side**
The fluid flowing inside the shell is called the “shell side” of a shell and tube heat exchanger.

1.2) **Pressure**

1.2.1) **Internal Pressure**
The difference between the operation (Po) and design pressure (Pd) is a safety margin. This margin exists because sometimes it is difficult to establish operation conditions with certainty. If we need to design but only have operating pressure, a workaround could be as follows:

If Po > 300 psi → Pd = 1.1. Po.

If Po ≤ 300 psi → Pd = Po + 30 psi

Where Pd is the design pressure, and Po is the operating pressure.

When determining the design pressure (Pd), the hydrostatic head (pressure of the fluid column) should be considered, especially in vertical cylindrical vessels.
1.2.2) **External pressure**

If under operating conditions the equipment gets depressurized or operates under vacuum, at that moment the atmospheric pressure is acting outside the pressure vessel.

At sea level, atmospheric pressure is 1 atm. According to the location (height above sea level) at which the equipment is to be installed, we should see the atmospheric pressure decreasing. To simplify the calculations, and to be on the safe side, usually 1 atm external pressure is taken without considering the height above sea level.

*Steam out or blanketing*

When performing a steam out operation (used to clean the vessel) using high or medium steam pressure, steam can condense due to a temperature change and produce vacuum. Depending on the temperature of the steam used, it is advisable to calculate the equipment under external pressure due to vacuum.

1.2.3) **Maximum allowable working pressure (MAWP)**

MAWP is the maximum continuous working pressure that the vessel could operate, assuring that the equipment will not deform plastically.

Is MAWP the same as the design pressure? The answer is NO. Adopted thicknesses usually exceed the required thickness by calculation. This excess is what generates the pressure to jump up to the MAWP.

The MAWP is a consequence of over-thickness due to: commercial thicknesses, margin of safety and manufacturing methods.

When dealing with shell and tube heat exchangers, it is important to mention that many of the parts of this equipment face the effect of pressure, temperature or corrosion from both the tube side and the shell side. Since design conditions may be different for the tube side and for the shell side, the most critical condition should be always specified.

1.2.4) **Test pressure (Pt)**

The test pressure is commonly known as hydrostatic test pressure. The test is carried out once the heat exchanger manufacturing process is completed. This test consists in filling the equipment with water while it is subjected to pressure as indicated by the ASME code (to be discussed later).

1.3) **Temperature**

1.3.1) **Minimum temperature**

It is the minimum temperature at which membrane stress occurs due to an environmental or process condition. The client or process department must provide this information. If this information is not available and there are no
8. **Bibliography**

This document has been compiled using different books and references. The most important ones are:

- **Boiler and Pressure Vessel Code:** ASME II, part D
  
  ASME VIII, Division 1

- **Pressure Vessel Design Manual** – DENNIS MOSS

- **Standards of Tubular Exchanger Manufacturers Association (TEMA)**

- **Power Plant Heat Exchangers from Heat Exchange Institute (HEI)**

- **API Standard 660.**

- **Process Equipment Design** Brownell, Lloyd. E. 1959