The use of titanium for heat transfer in the chemical processing industry

The transfer of heat from one fluid to another is an essential component of all chemical processes. Whether it is to cool down a chemical after it has been formed during an exothermic reaction, or to heat-up components before starting a reaction to make a final product, understanding the elements to design an effective, efficient heat transfer system is the key to cost-effective manufacturing of most chemicals today. This understanding not only includes having the knowledge of various fluids' physical characteristics and chemical makeup but also flow rates, system temperatures, and allowable pressures and pressure drops.

Titanium, which has been in the heat exchanger service for almost 60 years in refineries and nuclear power facilities, offers several different alloy grades that can be used in heat transfer equipment in the chemical process industry.

By Chuck Young, Metallurgist and Business Development Manager, Tricor Metals

A titanium shell and tube cooler/condenser. Image courtesy of Tricor Metals

Different grades for different purposes

There are many different grades of titanium, and they all have various characteristics that make them ideal for specific sectors of the chemical process industry. Titanium grades 1, 2, 7, 9, and 12 have been used in the past for high-quality, corrosion-resistant heat transfer equipment. The most commonly-used grades of titanium for heat transfer equipment are grade 2, unalloyed (commercially pure) titanium are grade 7, and basic grade 2 with a palladium addition for increased corrosion resistance. Grade 1 is used primarily for plate and frame exchangers, while grade 9 (with aluminum and vanadium additions) is used for shell and tube exchangers when higher strength is required for the tubing. Grade 12 is an alloy of titanium with a small amount of molybdenum and nickel and is used for slightly high strength and higher corrosion resistance, especially where crevice or under-deposit corrosion may be an issue.

Titanium tubes can be used in applications where the fluid in the tubes move at high velocities and are normally used with a zero-corrosion limit, thus reducing the required wall thickness. Titanium is resistant to fouling, has a high corrosion fatigue limit, and is resistant to impingement or erosion attack. Therefore, titanium is ideally suited for a wide variety of heat transfer applications – especially those involving seawater, brackish water cooling, or steam heating.

When the corrosivity of the chemicals make it necessary to use higher alloys like titanium, it is essential that the system be designed for maximum efficiency to ensure that the overall cost of the heat transfer is minimized. This will stand true regardless of the design used for the heat exchanger.

Shell and tube exchangers

Shell and tube exchangers are the most widely used type of heat transfer in the chemical processing industry because of their flexibility in design and ability to handle fluids with varying levels of solids. The shell is basically a small pressure vessel that must withstand the corrosiveness of one of the fluids while also containing the system pressure. The shell provides no heat transfer and is often insulated from the ambient environment.

The tube side is composed of tubing, tube sheets, baffles (for vibration protection and to maximize heat transfer), and inlet and outlet bonnets. All of these components must be corrosion-resistant to at least one, if not both of the fluids. The tube side must also contain whatever pressure is on that specific side of the process and maintain its structure while under pressure on the shell side. Therefore, both thermal and mechanical design tools must be used to effectively design a system. Typically the tube side contains the more corrosive chemical while the shell side contains the less corrosive chemical and in many cases, this is steam used to heat or water to cool. This minimizes the amount of titanium that is needed in the overall design of the heat exchanger, unless both sides are subject to a highly-corrosive fluid.

There are many different software tools that are used to determine the thermal design of the heat exchanger, while the mechanical design is to ASME code in the U.S.A. and other national codes in other areas of the world. A heat transfer expert is necessary for the thermal design, while a professional engineer who is familiar and has experience with the code to be used, is needed for the mechanical design.

The Tubular Exchangers Manufacturing Association (TEMA) has designations for the various types of shell and tube exchangers, as shown in Figure 1. The designation 'BEL' would have a one-pass shell with a bonnet on one end, and a channel and removable cover on the other. The actual design can be determined by the end-user, the chemical company, or can be recommended by the fabricator after an analysis of the system requirements.

There are other corrosion-resistant alloys (CRAs) used in the chemical processing industry besides titanium. These are austenitic stainless steels, duplex stainless steels, nickel alloys, zirconium,

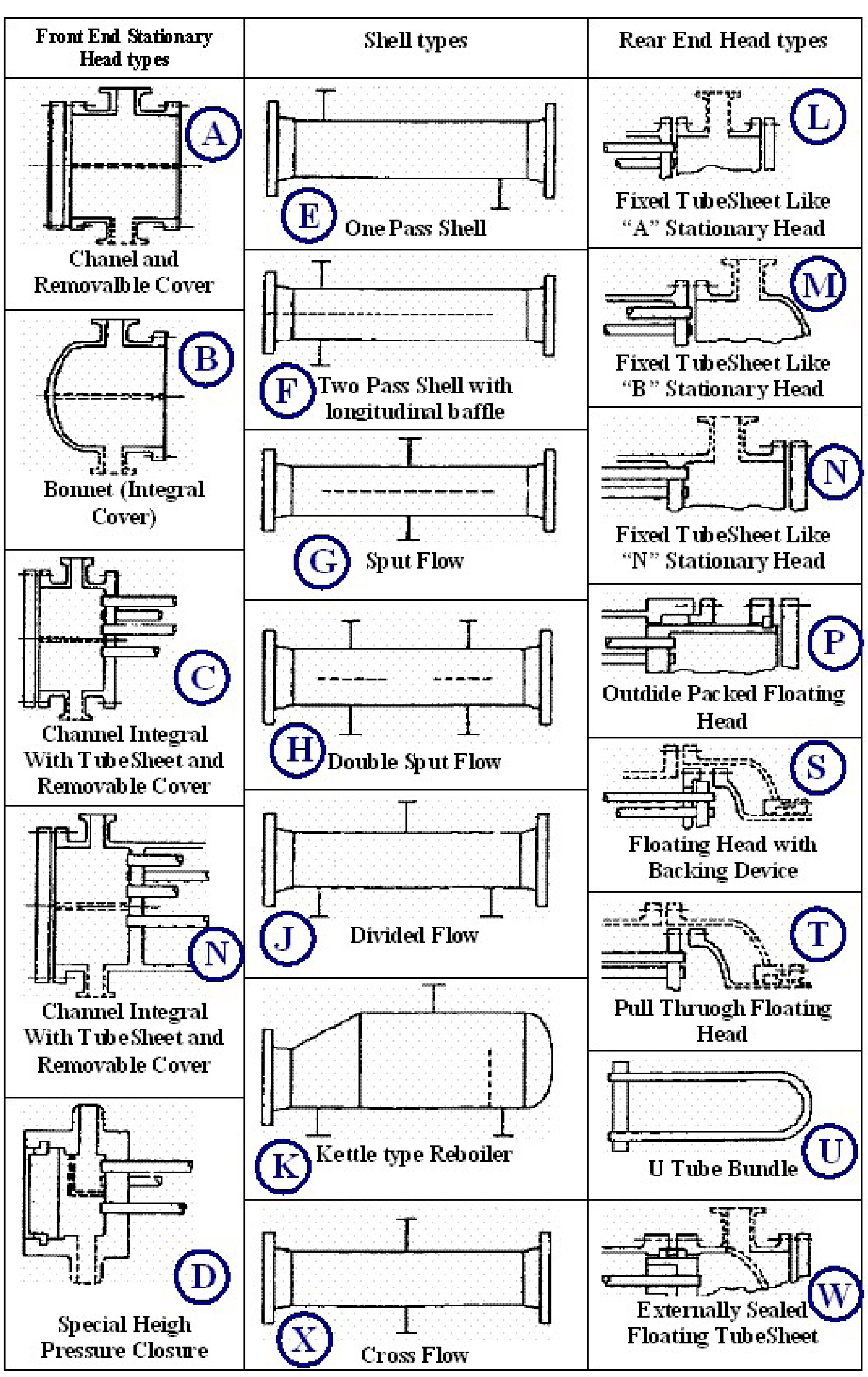

Figure 1: TEMA designations.

A titanium u-tube bundle. Image courtesy of Tricor Metals and tantalum. Each of these metals and alloys have corrosion resistance to certain chemicals and can be used in chemical plants for long lifecycles. Titanium, and its alloys, are used in a wide variety of industries, including seawater cooling in the nuclear industry, heating and cooling in the production of chlorine, the bleach industry, the terephthalic acid industry, and many others. The titanium grades to be used for each industry and process are typically determined by the chemical company or engineering firm, however it is often after consulting with a metallurgist at the fabrication company. Knowledge of corrosion and having an understanding of titanium alloys are critical in determining which titanium grade to use. The overall goal is to ensure a cost-effective system with a long service life.

An essential consideration when determining the titanium grade that will be used is to ensure that all aspects of the fluid chemistry is known. Often, as companies tweak processes, the corrosivity of the fluids change and an alloy that was used in the past my not be as effective today. In this situation the need to change to a titanium alloy may be the cost effective, long-life solution. In this case, a metallurgist with extensive knowledge and an experienced background in corrosion is needed to determine which titanium grade is best.

One example of this situation would be when a plant uses river water for cooling, and has changed the material to a duplex alloy because of assumed cost savings and longer life. However, the river water chemistry was different than initially thought, and the duplex stainless steel alloy developed microbiological induced corrosion (MIC) that significantly shortened the life of the exchanger. The company had to, again, change out the duplex exchanger and upgrade to titanium grade 2 for the entire exchanger, since titanium is immune to MIC corrosion and could also handle the process fluid. These titanium exchangers will give the plant a long service life without any maintenance or corrosion issues.

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Plate and frame exchangers

Plate and frame exchangers (PFEs) are used in certain areas of the chemical processing industry as an alternative to shell and tube exchangers. The PFEs require less space than a shell and tube for a similar heat transfer but also have some limitations in terms of the process fluids and conditions in which they can be used. PFEs are available in titanium grade 1 plates. Heat transfer is determined by the overall dimensions of the plates as well as the number of plates in the exchanger.

The PFEs are composed of two end plates, designed to hold the plates together, with a number of heat transfer plates in between. Gaskets are required to separate the two fluids going through the system on each of the internal plates and ports are fabricated into one or both of the end plates. The PFE system is limited by the temperature and pressure that the gaskets can withstand, which is less than 365°F or 360 psi pressure. It is also limited to fluids that have no solids in them, as the channels on the internal plates are very narrow and can plug easily. One advantage with the PFE is the ability to add internal plates at any time to increase the heat transfer.

Other types of heat transfer

There are other types of heat transfer equipment used in the chemical processing industry, but they are used much less often than the shell and tube or plate and frame exchangers. Some of these are internal coils, external coils, half pipe coils on the outside of vessels, block exchangers, and welded plate exchangers, just to name a few.

Final words

A large part of the heat transfer in the chemical processing industry is accomplished using shell and tube exchangers constructed of the titanium alloys – grade 2 (commercially pure), grade 7 (with palladium), grade 9 (with aluminum and vanadium), or grade 12 (with molybdenum and nickel). Plate and frame exchangers, with titanium grade 1 (commercially pure) plates, are used to a lesser extent and are limited in their applicability. Using a well-known, reliable fabricator to assist in the thermal and mechanical design, as well as the choice of the best titanium grade to handle the corrosion in the system, is essential to ensure that the end result is a cost-effective, long-lasting heat transfer system.

Plate and frame exchangers. Image courtesy of Tricor Metals

A titanium shell and tube bundle. Image courtesy of Tricor Metals

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Young has more than 45 years of experience in technical sales and marketing in the metals industries, specializing in the uses of corrosion-resistant materials. Young has been with Tricor Metals for more than 10 years and has additional experience in the titanium, specialty metal, clad metal, copper flat-rolled and tubing, as well as the zinc, and galvanizing industries.