# Design of Heat Exchanger for Handling of Corrosive Fluid

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**Abstract- This report presents the information and knowledge gained during the project. A relation between heat transferred and energy loss, for turbulent flow. In different tube arrangements, is made. The conditions are determined which decide the dimensions and velocities for a heat exchanger. Also, a reference to the economic dimensioning of heat exchangers is presented. In this study, the conditions which a heat exchanger must satisfy represent the best balance between the amounts of material employed. The investigation is restricted to the case of turbulent flow. Most geothermal fluids, because of their elevated temperature, contain a variety of dissolved chemicals. These chemicals are frequently corrosive toward standard materials of construction. As a result, it is advisable in most cases to isolate the geothermal fluid from the process to which heat is being transferred.**

**Key words: Heat Changers, Corrosion In Heat Exchanger, Energy Loss, Economic Dimensioning, Counter Current flow, Cross Current flow and Parallel flow.**

## 1. INTRODUCTION

The heat exchanger is an equipment that allows heat transference between two fluids at different temperatures. Heat exchangers are extensively used in industry due to their wide variety of construction and applications in heat transference processes for producing conventional energy such as condensers, heaters, boilers or steam generators. They provide an adequate surface for heat transference to occur and their mechanical and thermal characteristics allow high pressure and high temperature processes. Heat exchangers are important, their optimization rises the competitiveness and allows energy saving. The necessity of saving and recovering energy for different processes in industry makes essential the develop of new manufacturing technology for heat exchangers in order to cover a wide range of operation conditions. In recent years, new software for design heat exchangers has been focus in adapting the equipment to the required process and new solutions have been found that make the design time shorter. Corrosion, a natural process we encounter everywhere, presents significant challenges in diverse industries. One industry greatly affected by this phenomenon is the realm of heat exchangers. Getting a handle on the basics of corrosion and how it specifically relates to heat exchangers becomes crucial. So, let's unpack it together. In this detailed exploration, we'll unravel the intricacies of corrosion, dissecting its various types as they pertain to heat exchangers. More importantly, we'll shine a light on why it's absolutely paramount to prevent and control corrosion. Think of this article as your guide, steering you through the maze of corrosion, ensuring you not only understand its nuances but also grasp the vital role of keeping it in check within the realm of heat exchangers. Stay with us as we break it down in simple terms, making the complex world of corrosion a bit more comprehensible. The task of heat transfer from the geothermal fluid to a closed process loop is most often handled by a plate heat exchanger. The two most common types used in geothermal applications are: bolted and brazed. For smaller systems, in geothermal resource areas of a specific character, downhole heat exchangers (DHEs) provide a unique means of heat extraction. These devices eliminate the requirement for physical removal of fluid from the well. For this reason, DHE-based systems avoid entirely the environmental and practical problems associated with fluid disposal. Shell and tube heat exchangers play only a minor role in low-temperature, direct-use systems. These units have been in common use in industrial applications for many years and, as a result, are well understood. For these reasons, shell and tube heat exchangers will not be covered in this chapter.

## 1.1 DEFINING CORROSION

Corrosion is the gradual deterioration of materials due to a reaction with their environment, leading to the loss of material and compromise of structural integrity. In the realm of heat exchangers, corrosion can be particularly detrimental, impacting efficiency, safety, and overall performance. The materials commonly used in heat exchangers, such as metals and alloys, are susceptible to corrosion under certain conditions.

### RELEVANCE OF CORROSION IN HEAT EXCHANGERS

Heat exchangers play a critical role in various industrial processes, facilitating the transfer of thermal energy between fluids. The efficiency of heat exchangers relies heavily on the integrity of their materials, making corrosion a significant concern. Corrosion in heat exchangers can manifest in several ways, affecting both the performance and lifespan of these vital components.

Figure 1.1 Corrosion

## 1.2 TYPES OF CORROSION IN HEAT EXCHANGERS

To address corrosion effectively, it is essential to understand the different types that can occur in heat exchangers. The following are some common corrosion types encountered in these systems:

### 1. Uniform Corrosion in Heat Exchangers

Uniform corrosion is characterized by its even distribution over the surface of the material, leading to a gradual reduction in thickness. This corrosion process occurs due to chemical reactions between the material and its surrounding environment. In the case of heat exchangers, which are frequently exposed to varying temperatures, pressures, and corrosive substances in the fluids they handle, the impact of uniform corrosion can be significant.

Impact on Heat Exchangers:

While uniform corrosion may not result in immediate failure, its consequences become increasingly pronounced over time. The primary concern lies in the gradual thinning of the metal, which compromises the structural integrity of heat exchanger components.

The reduced thickness can lead to several adverse effects:

1. Diminished Heat Transfer Efficiency: As the metal thins due to uniform corrosion, the heat exchanger's ability to efficiently transfer thermal energy between fluids is compromised. Thinner walls may result in decreased heat transfer rates, leading to reduced overall performance.
2. Increased Vulnerability to Other Forms of Corrosion: The weakened metal surface, resulting from uniform corrosion, becomes more susceptible to other types of corrosion. For example, pitting corrosion may initiate in areas where uniform corrosion has thinned the protective layer on the metal surface.
3. Structural Integrity Concerns: Over time, the continuous loss of material due to uniform corrosion can raise concerns about the structural integrity of the heat exchanger. This may lead to the development of leaks or, in extreme cases, catastrophic failure.

### 2. GALVANIC CORROSION IN HEAT EXCHANGERS

Galvanic corrosion is a process that ensues when two dissimilar metals come into direct contact while being exposed to an electrolyte, such as water or other conductive fluids. This phenomenon results in the accelerated corrosion of one of the metals, acting as the anode, while the other metal acts as the cathode. The driving force behind galvanic corrosion is the electrochemical potential difference between the two metals.

2.1 Impact on Heat Exchangers:

Heat exchangers, by their very design, often incorporate different metals in close proximity due to diverse operational requirements. This makes them particularly susceptible to galvanic corrosion. The consequences of galvanic corrosion in heat exchangers can be significant:

1. Accelerated Corrosion: The galvanic couple formed by dissimilar metals sets the stage for accelerated corrosion of the more electrochemically active metal. This can lead to localized corrosion and structural deterioration.
2. Reduced Lifespan of Components: The intensified corrosion in specific areas compromises the structural integrity of heat exchanger components. Over time, this can contribute to premature failure and a shortened lifespan of the equipment.
3. Impaired Heat Transfer Efficiency: Galvanic corrosion may result in the formation of corrosion by-products that can impede the flow of fluids within the heat exchanger. This impediment can reduce the efficiency of heat transfer between the fluids, affecting overall performance.

Figure 2.1 Cleaning of Heat Exchanger With High Pressure Hydraulic Unit

3. PITTING CORROSION IN HEAT EXCHANGERS

Pitting corrosion is characterized by the localized formation of small pits or craters on the metal surface. Unlike uniform corrosion that occurs uniformly across the entire surface, pitting corrosion concentrates its attack in specific areas. The initiation of pits is often associated with the breakdown of protective films on the metal surface, allowing aggressive ions to attack localized spots. Pitting corrosion is particularly insidious because the pits can penetrate deeply into the material, even though their size may be relatively small. This makes detection challenging, and the impact can be severe, leading to compromised structural integrity.

Impact on Heat Exchangers:

In the context of heat exchangers, where the efficiency and reliability of thermal energy transfer are paramount, the consequences of pitting corrosion can be significant:

1. Development of Holes and Leaks: Pitting corrosion can lead to the creation of small, yet deep, pits on the metal surface. Over time, these pits can propagate and coalesce, resulting in the development of holes and leaks in the heat exchanger tubes and surfaces.
2. Reduced Heat Transfer Efficiency: As pitting progresses, the metal surface in affected areas becomes uneven, disrupting the smooth flow of fluids and hindering the efficient transfer of heat. This can lead to reduced heat transfer efficiency and decreased overall performance.
3. Structural Compromises: The localized nature of pitting corrosion means that critical structural components may be compromised. This can result in weakened areas that are more susceptible to mechanical stresses, potentially leading to catastrophic failure.

4. CREVICE CORROSION IN HEAT EXCHANGERS

Crevice corrosion is characterized by its occurrence in small, enclosed spaces, where a stagnant electrolyte can accumulate. These spaces can be naturally present in the design of heat exchangers, typically in joints, seams, or other areas where metal surfaces are in close proximity but limited exposure to the surrounding environment. The stagnant electrolyte may contain corrosive ions, and the restricted access to oxygen can create localized conditions conducive to corrosion. The corrosion process in these confined spaces often leads to the degradation of the material in and around the crevice, which can have detrimental effects on the overall performance of the heat exchanger.

Figure 4.1. Boiler Tube Bundle Open For Maintenance

Impact on Heat Exchangers:

Importance of Corrosion Prevention and Control Given the critical role of heat exchangers in various industries, preventing and controlling corrosion is paramount. Several strategies can be employed to mitigate the adverse effects of corrosion on heat exchangers:

1. Material Selection: Choosing corrosion-resistant materials for heat exchanger components is the first line of defense. Stainless steels, titanium, and certain alloys exhibit high resistance to corrosion.
2. Protective Coatings: Applying protective coatings or corrosion inhibitors can create a barrier between the metal surface and the corrosive environment, extending the lifespan of heat exchangers.
3. Cathodic Protection: Utilizing cathodic protection methods, such as sacrificial anodes or impressed current systems, can help prevent galvanic corrosion by shifting the corrosion potential of the metal.
4. Regular Maintenance and Inspection: Implementing a routine maintenance and inspection schedule is crucial for detecting and addressing corrosion at an early stage, preventing extensive damage.
5. Fluid Treatment: Treating the fluids circulating in the heat exchanger with corrosion inhibitors or other additives can mitigate corrosion by altering the chemical properties of the environment.

GASKATED PLATE HEAT EXCHANGERS

The plate heat exchanger is the most widely used configuration in geothermal systems of recent design. A number of characteristics particularly attractive to geother- mal applications are responsible for this. Among these are:

1.Superior thermal performance.

Plate heat exchangers are capable of nominal approach temperatures of 10oF compared to a nominal 20oF for shell and tube units. In addition, overall heat transfer coefficients (U) for plate type exchangers are three to four times those of shell and tube units.

2.Availability of a wide variety of corrosion resistant alloys.

Since the heat transfer area is constructed of thin plates, stainless steel or other high alloy construction is significantly less costly than for a shell and tube exchanger of similar material.

3.Ease of maintenance.

The construction of the heat exchanger is such that, upon disassembly, all heat transfer areas are available for inspection and cleaning. Disassembly consists only of loosening a small number of tie bolts.

4.Expandability and multiplex capability.

The nature of the plate heat exchanger construction permits expansion of the unit should heat transfer requirements increase after installation. In addition, two or more heat exchangers can be housed in a single frame, thus reducing space requirements and capital costs.

5.Compact design.

The superior thermal performance of the plate heat exchanger and the space efficient design of the plate arrangement results in a very compact piece of equipment. Space requirements for the plate heat exchanger generally run 10% to 50% that of a shell and tube unit for equivalent duty. In addition, tube cleaning and replacing clearances are eliminated.

Figure 4. presents an introduction to the terminology of the plate heat exchanger. Plate heat exchanger, as it is used in this section, refers to the gasketed plate and frame variety of heat exchanger. Other types of plate heat exchangers are available; though among these, only the brazed plate heat exchanger has found application in geothermal systems.
As shown in Figure 4, the plate heat exchanger is basically a series of individual plates pressed between two heavy end covers. The entire assembly is held together by the tie bolts. Individual plates are hung from the top carrying bar and are guided by the bottom carrying bar. For single-pass circuiting, hot and cold side fluid connections are usually located on the fixed end cover. Multi-pass circuiting results in fluid connections on both fixed and moveable end covers.

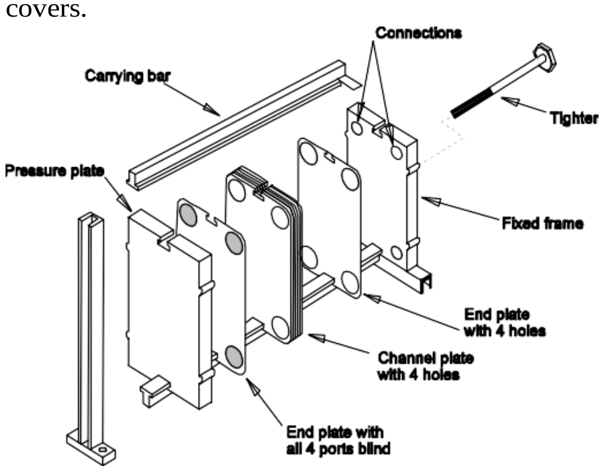

Figure 4.2. The plate heat exchanger

Illustrates the nature of fluid flow through the plate heat exchanger. The primary and secondary fluids flow in opposite directions on either side of the plates. Water flow and circuiting are controlled by the placement of the plate gaskets. By varying the position of the gasket, water can be channeled over a plate or past it. Gaskets are installed in such a way that a gasket failure cannot result in a mixing of the fluids. In addition, the outer circumference of all gaskets is exposed to the atmosphere. As a result, should a leak occur, a visual indication is provided.

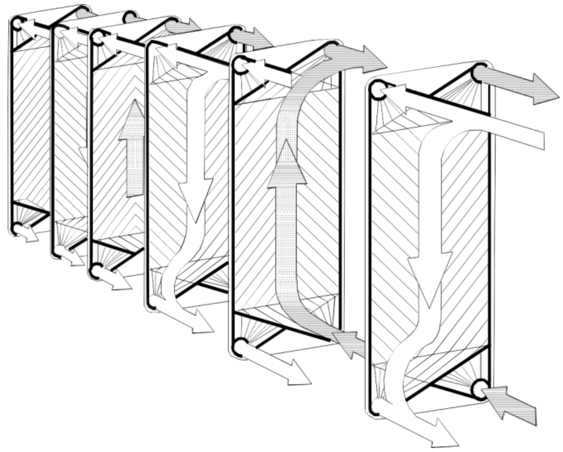
Figure 4.3. Nature of fluid flow through the plate heat exchanger.

GENERAL CAPABILITIES
In comparison to shell and tube units, plate and frame heat exchangers are a relatively low pressure/low temperature device. Current maximum design ratings for most manufacturers are: temperature, 400oF, and 300 psig (Tranter, undated). Above these values, an alternate type of heat exchanger would have to be selected. The actual limitations for a particular heat exchanger are a function of the materials selected for the gaskets and plates; these will be discussed later. Individual plate area varies from about 0.3 to 21.5 ft2 with a maximum heat transfer area for a single heat ex- changer currently in the range of 13,000 ft2. The minimum plate size does place a lower limit on applications of plate heat exchangers. For geothermal applications, this limit generally affects selections for loads such as residential and small commercial space heating and domestic hot water. The largest units are capable of handling flow rates of 6000 gallons per minute (gpm) and the smallest units serviceable down to flows of approximately 5 gpm. Connection sizes are available from 3/4 to 14 in. to accommodate these flows.

MATERIALS
Materials selection for plate heat exchangers focuses primarily upon the plates and gaskets. Since these items significantly effect first cost and equipment life, this procedure should receive special attention.

Plates:

One of the features which makes plate-type heat exchangers so attractive for geothermal applications is the availability of a wide variety of corrosion-resistant alloys for construction of the heat transfer surfaces. Most manufac- turers offer the alloys listed below:

1. 304 Stainless Steel
2. 316 Stainless Steel
3. 317 Stainless Steel
4. Titanium
5. Tantalum
6. Incaloy 825
7. Hastelloy
8. Inconel
9. Aluminum Bronze
10. Monel.

In addition to these, a larger number of optional alloys are available by special order. Most manufacturers will quote either 304 or 316 stainless steel as the basic material. For direct use geothermal applications, the choice of materials is generally a selection between 304 stainless, 316 stainless, and titanium. The selection between 304 and 316 is most often based upon a combination of temperature and chloride content of the geothermal fluid. At temperature/chloride concentrations which fall into the region below the curve, the particular alloy in question is considered safe to use. Combinations of temperature and chloride content that are located above the curve offer the potential for localized pitting and crevice corrosion. Fluid characteristics above the curve for a particular alloy do not guarantee that corrosion will abso- lutely occur. However, this curve, based on oxygen-free environments, does provide a useful guide for plate selection. Should oxygen be present in as little as parts per billion (ppb) concentrations, the rates of localized corrosion would be significantly increased (Ellis and Conover, 1981). Should the system for which the heat exchanger is being selected offer the potential for oxygen entering the circuit, a more conservative approach to materials selection is recommended. Titanium is only rarely required for direct use applications. In applications where the temperature/chloride requirements are in excess of the capabilities of 316 stainless steel, titanium generally offers the least cost alternative. Austenitic stainless alloys with higher chromium and molybdenum contents could be recommended for this application also. These alloys, however, are generally not avail- able as standard plate materials as is titanium (Ellis and Conover, 1981). A typical application in which titanium has been employed is in geothermal systems that serve loads in which the secondary fluid is heavily chlorinated. The most common of these is swimming pools. The nature of swimming pools is such that the pool water is both high in chloride and oxygen content. As a result, titanium is the alloy generally selected. Plates made of 316 stainless steel, in the heat exchanger serving the swimming pool at Oregon Institute of Technology, Klamath Falls, Oregon, failed in less than 2 years as a result of localized corrosion. The first cost premium for titanium over stainless steel plates is approximately 50%.

## PERFORMANEC

Superior thermal performance is the hallmark of plate heat exchangers. Compared to shell-and-tube units, plate heat exchangers offer overall heat transfer coefficients 3 to 4 times higher. These values, typically 800 to 1200 Btu/- hr·ft2 oF (clean), result in very compact equipment. This high performance also allows the specification of very small approach temperature (as low as 2 to 5ºF) which is some-times useful in geothermal applications. This high thermal performance does come at the expense of a somewhat higher pressure drop. It presents a generalized relationship for overall heat transfer and pressure drop in plate exchangers, based on several different total fouling factors Selection of a plate heat exchanger is a trade-off between U-value (which influences surface area and hence, capital cost) and pressure drop (which influences pump head and hence, operating cost). Increasing U-value comes at the expense of increasing pressure drop. Fouling considerations for plate heat exchangers are considered differently than for shell-and-tube equipment. There are a variety of reasons for this; but, the most important is the ease with which plate heat exchangers can be disassembled and cleaned. As a result, the units need not be over-designed to operate in a fouled condition. Beyond this, the nature of plate heat exchanger equipment tends to reduce fouling due to:

1. High turbulence.
2. Narrow high-velocity flow channels which eliminate low flow areas found in shell-and-tube equipment.
3. Stainless steel surfaces that are impervious to corrosion in most groundwater applications.

## INSTALLATION AND MAINTENANCE

The question of whether to use multiple heat exchangers instead of a single unit is more a function of the building use than system design. Going to a multiple heat exchanger design always increases costs. In general, two exchangers should only be necessary in applications where system downtime cannot be tolerated (detention facilities, hospitals, computer facilities, etc.). The time required to disassemble and clean plate heat exchangers is a function of size and number of plates; but, in most applications, the work can be accomplished in less than 8 hours by two workers. Small units require less time and labor. This work can easily be accomplished during off-hours in a building used less than 24 hours per day. Protective shields for heat exchangers are typically included in quotes from vendors. These shields are in-stalled over the plate pack and are intended to protect the plates from damage. Cost of the shields is approximately 3% to 5% of exchanger cost. Unless there is regular activity around the exchanger by personnel not associated with the mechanical equipment, these shields are not necessary. Piping and location of the heat exchanger should be designed to allow easy access to the unit for disassembly and cleaning. If piping must be attached to the movable end plates (sometimes necessary in multi-pass designs), the piping should be of flanged or grooved end material which allows removal for maintenance purposes. Sufficient clearance should be allowed for plate removal from the frame.

## RESULT AND CONCLUSION

This article has provided a comprehensive overview of corrosion, its various types in the context of heat exchangers, and highlighted the significance of corrosion prevention and control measures. By implementing these strategies, industries can ensure the longevity, efficiency, and safety of their heat exchanger systems, ultimately contributing to enhanced operational performance. As technology evolves, ongoing research and innovation in materials and corrosion prevention techniques will continue to play a pivotal role in mitigating the impact of corrosion on heat exchangers. This paper identifies the advantages of having the appropriate exchanger with working conditions, environmental conditions and economic aspects, it is also necessary to mention the following regarding the general utility of this work. In addition to the thermal design, mechanical design of heat exchangers is also a part of it. The mechanical design is done under the ASME Section VIII, which is entitled “Pressure Vessel Design” Although the subject of this work is the design of heat exchangers, which, as noted was achieved successfully, the utility of it is wider and there are several methods for the design of heat exchangers.

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