Chapter 12
Introduction to Heat Exchangers

Heat exchangers are devices for transferring heat from a hot flowing stream to a cold flowing stream. There are three broad types of exchangers:

- The recuperator or the through-the-wall nonstoring exchanger
- The direct-contact nonstoring exchanger
- The regenerator, accumulator, or heat-storing exchanger

The type chosen in any situation depends in large part on the nature of the transferring phases, whether gas–gas, gas–liquid, gas–solid, liquid–liquid, liquid–solid, or solid–solid, and on the mutual solubility of the phases involved.

Let us present some examples of these three kinds of exchangers.

12.1 Recuperators (Through-the-Wall Nonstoring Exchangers)

In recuperators the two flowing streams are separated by a wall and heat has to pass through this wall. Many different contacting patterns are used for the two fluids and we will study a number of them in later chapters. The sketches of Fig. 12.1 indicate some of these many different contacting patterns.

Recuperators are certainly less effective than the direct-contact exchanger because the presence of the wall hinders the flow of heat. But this type of exchanger is used where the fluids are not allowed to contact each other, as with gas–gas systems, miscible liquids, dissolving solids, or reactive chemicals.

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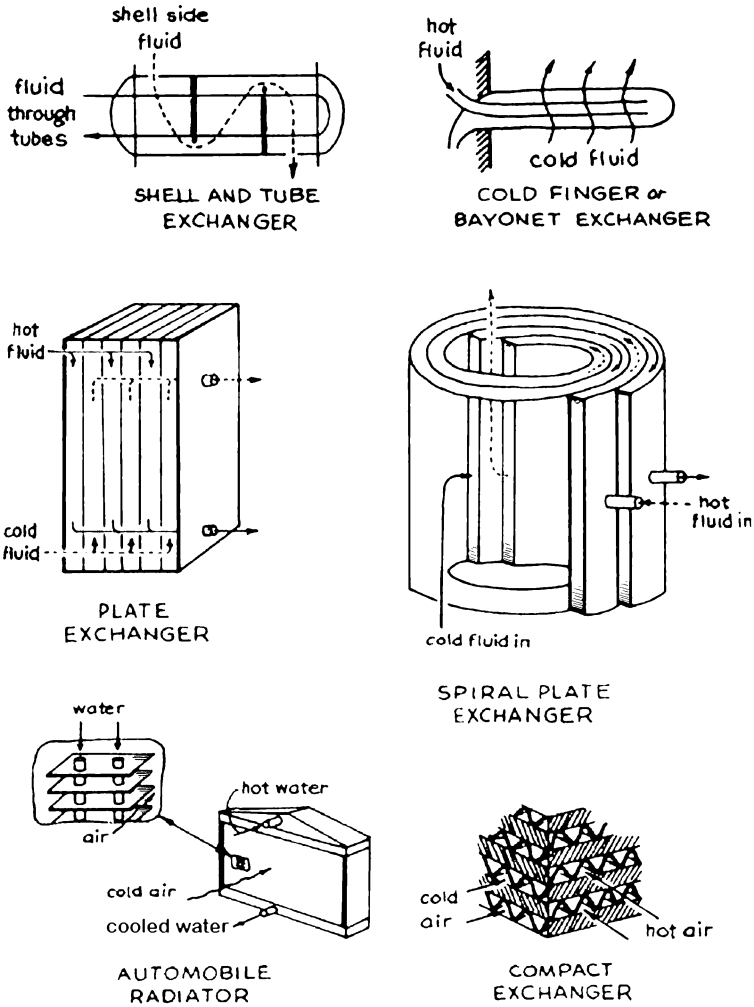

Fig. 12.1 Various kinds of recuperators or through-the-wall exchangers

12.2 Direct-Contact Nonstoring Exchangers

In direct-contact nonstoring exchangers, the streams contact each other intimately, the hotter stream giving up its heat directly to the colder stream.

Naturally this type of exchanger finds use when the two contacting phases are mutually insoluble and do not react with each other. Thus, it cannot be used with gas–gas systems.

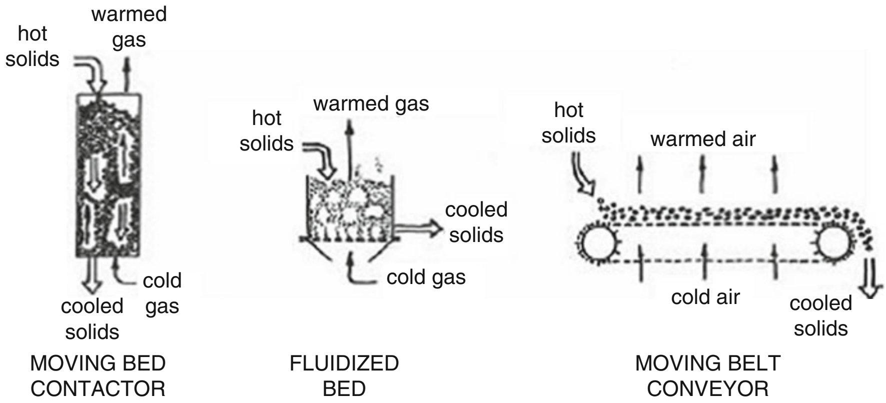

Fig. 12.2 Gas–solid direct-contact nonstoring exchangers

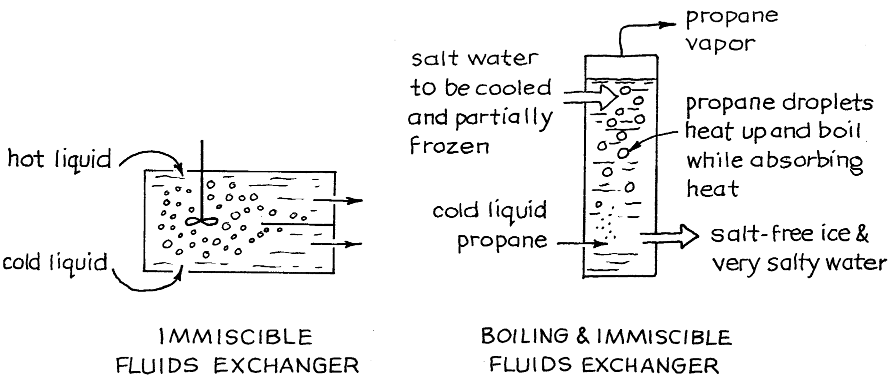

Fig. 12.3 Fluid–fluid direct-contact nonstoring exchangers

Direct-contact exchangers are of three broad types. First, there are the gas–solid exchangers, various forms of which are shown in Fig. 12.2.

Then, there are the fluid–fluid exchangers where the two contacting fluids are mutually immiscible. These are shown in Fig. 12.3.

Finally, it is not always necessary that the two contacting fluids be mutually insoluble, and Fig. 12.4 shows exchangers where one of the flowing fluids does dissolve in the other. In particular, in air–water systems the direct-contact exchanger is of prime importance just because one of the phases (water) does dissolve, or evaporate, in the other phase (air). The water cooling tower, shown in Fig. 12.4, is such an example and, in fact, represents the most widely used type of heat exchanger in industry.

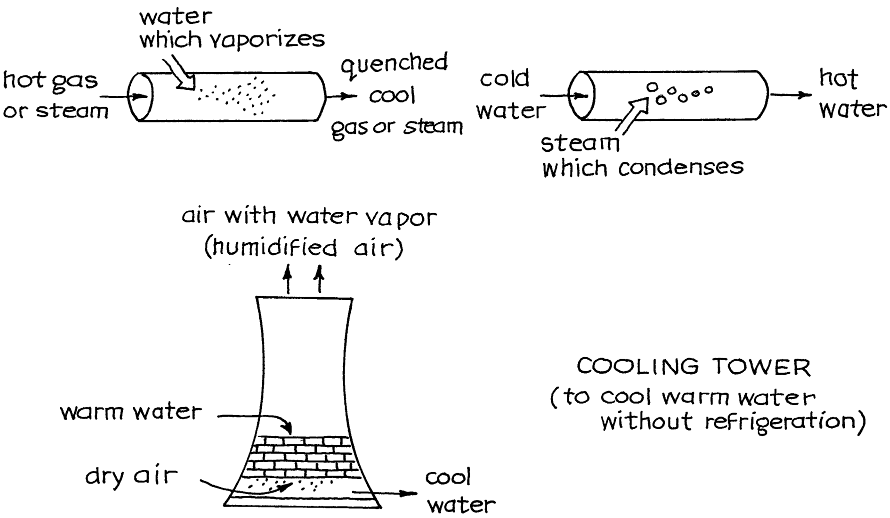

Fig. 12.4 Fluid–fluid direct-contact exchangers where one phase can dissolve in the other

The proper treatment of this type of exchanger requires using the methods of simultaneous heat and mass transfer and is beyond the scope of this volume. The interested reader is referred to Fair (1972a, b) and to the many standard books on unit operations and mass transfer for such a presentation.

12.3 Regenerators (Direct-Contact Heat Storing Exchangers)

With regenerators a hot stream of gas transfers its heat to an intermediary, usually a solid, which later gives up this stored heat to a second stream of cold gas. There are a number of different ways of doing this, as shown in Fig. 12.5.

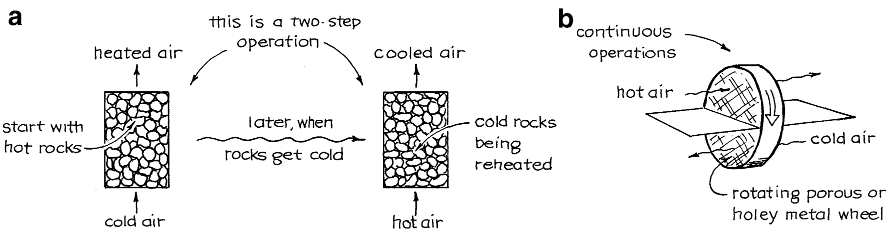

Fig. 12.5 Heat regenerators or heat storing exchangers: (**a**) Heat storing solids are stationary; (**b**) heat storing solids continuously circulate between hot and cold streams

12.4 Exchangers Using a Go-Between Stream

In a number of difficult situations or when the two heat exchanging locations are far apart, a third stream may be used as go-between, to take up heat from the hot stream and then deliver it to the cold stream. This go-between stream may consist of solid particles or it may be a fluid.

Consider a few processes which use this idea.

12.4.1 The Heat Pipe for Heat Exchange at a Distance

The heat pipe (see discussion after Problem 3.24) very effectively transports heat from one location to another, and since the primary resistance to heat transfer is at the two ends of the pipe, where heat is taken up and released, finned tubes are normally used in these sections, as shown in Fig. 12.6. The fluid in the pipe which boils at one end and condenses at the other acts as the go-between in the transfer of heat.

Examples of the use of heat pipes are in the recovery of stored heat in solar home heating (see Problem 3.27), in space capsules as a means of transferring heat from the hot side (facing the sun) to the cold side of the capsule, and in microelectronic and hi-fi equipment to draw off heat from critical components and dissipate it into the air, thereby avoiding overheating. Finally, close to 100,000 heat pipes were built into the Alaska pipeline supports to keep heat away from the support footings which had to be imbedded in permafrost soil.

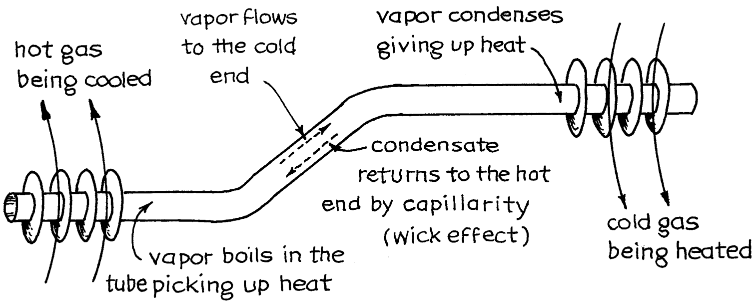

Fig. 12.6 The heat pipe transfers heat from one place to another, often far apart

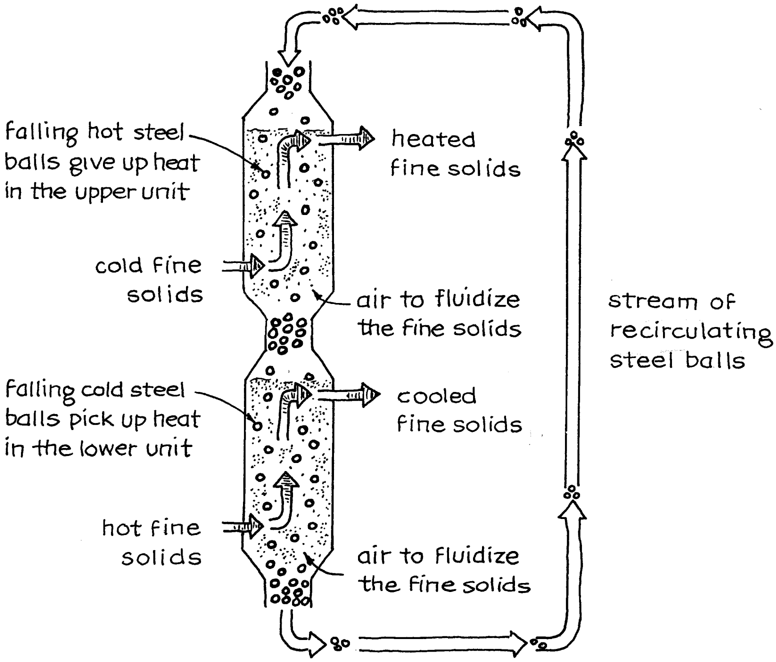

Fig. 12.7 The SPHER process [J. E. Gwyn et al., *Chem. Eng. News*, p. 42 (Sept. 15, 1980)] for the recovery of heat from spent shale and its transfer to cold fresh shale. This is a counterflow solid–solid heat exchanger which uses a third stream of solids as go-between

12.4.2 Solid–Solid Heat Transfer

To achieve counterflow heat exchange of gases and liquids is no problem, but for two streams of solids, this is not an easy matter. Figure 12.7 shows one proposal which uses a recirculating carrier solid which falls countercurrent to the two primary solids in their separate fluidized beds. This is a complex operation, and the vigorous backmixing of solids in the fluidized beds results in severe deviations from the desired ideal of countercurrent plug flow of solids.

Another much simpler way for approaching countercurrent heat exchange of two streams of solids is to use a liquid stream as go-between, as shown in Fig. 12.8.

Still another approach uses the highly efficient heat pipes in a crisscross arrangement to yield countercurrent heat transfer. This is shown in Fig. 12.9.

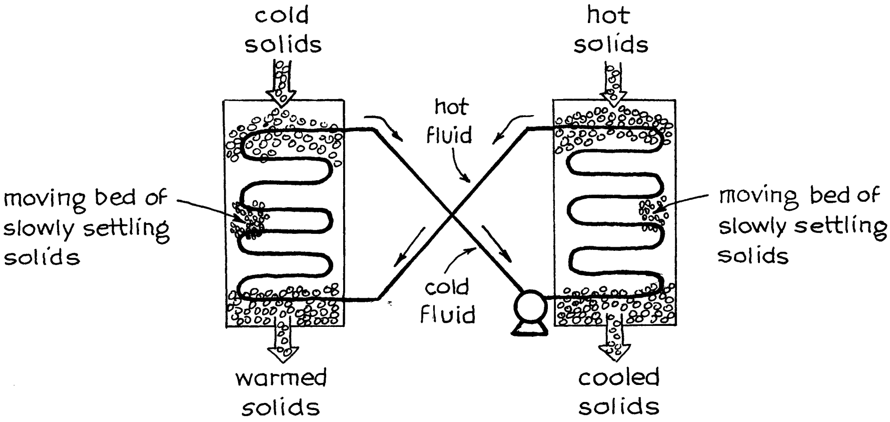

Fig. 12.8 Counterflow solid–solid heat exchanger using a liquid go-between

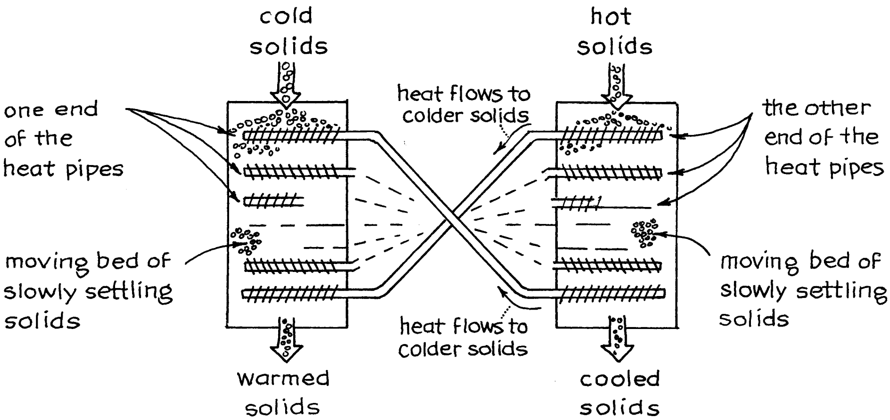

Fig. 12.9 Counterflow solid–solid heat exchanger using properly arranged heat pipes as go-between [O. Levenspiel and R. T. Chan, U.S. Pat. No. 4,408,656]

12.4.3 Comments

What these designs show is that there are many different ways of transferring heat from one flowing stream to another, and the important first decision is to choose the right type of exchanger. Often this is a clean-cut decision, but sometimes one has to compare the economics of quite different kinds of exchangers.

In the following chapters we consider in turn the various kinds of exchangers and their important design parameters and simple design methods.

References

J.R. Fair, Process heat transfer by direct fluid phase contact. AIChE Symp. Ser. **68**(118), 1 (1972a)
J.R. Fair, Designing direct-contact cooler/condensers, Chem. Eng. 91 (June 12, 1972b)