

When two worlds merge

A COMPACT AND EFFICIENT PLATE HEAT EXCHANGER COMBINED WITH A PRESSURE AND TEMPERATURE RESISTANT SHELL

Plate heat exchangers are widely used in the process industry. High efficiency and cost savings made them standard equipment in some areas. Shell and tube heat exchangers are used where demanding temperature and pressure conditions exist and often they are used in two phase applications. Plate & Shell heat exchangers from GESMEX GmbH, Germany are a fusion of these two types and accomplish new ways of plate heat exchanger applications. This report gives a survey of Plate & Shell technology, shows how to modernize already installed shell & tube heat exchangers and how the old Kettle-Type Evaporator principle is revived.

Heat exchangers with circular plates are manufactured since 1988. They consist of a stack of stainless steel plate pairs which form two separate flow channels. Between these flow channels heat is transferred through the plate. This is similar to plate & frame type heat exchangers. Plate heat exchangers manufactured by GESMEX GmbH are generally laser-welded. The laser-welding process ensures high quality weld seam. The molten area at the plate equals up to 3.5 times the plate thickness. Hence the plate stack is less sensitive to pressure and temperature changes. Additionally the geometric shape of the plate makes tensions spread homogenously in the plate material. This is an advantage compared to rectangular plates. Applications of plate & shell heat exchangers can cover temperatures of 550°C and up to 150 bar (see figure 1).

In plate & shell heat exchangers one fluid enters and leaves the plate stack through the shell that is why the plates have only two holes and not four like in plate & frame heat exchangers. A simple parallel flow arrangement is shown in figure 2. The flow channels are sealed against each other by welding. The circumferences of the plates and the edges of the holes are welded alternately.

The possibilities of flow arrangements in plate & shell heat exchangers are as manifold as in plate & frame heat exchangers. Several passes on the shell and plate side are implemented by certain baffle arrangements. Countercurrent, co-current and even cross flow can be achieved. Cross Flow is obtained by turning the stack by 90° relative to the flow direction of the shell side fluid. The plates are embossed with corrugations in a usual manner. The different corrugation patterns can be adjusted to different application modes.

Increasing efficiency and modernizing plants made easy

It is not straight forward to substitute shell & tube heat exchangers with plate & frame heat exchangers despite all the benefits like higher heat transfer efficiency and less fouling. Most of the time the piping has to be changed and the decreased volume of the devices lead to different dynamic behavior. Circular plates can be mounted directly inside existent shells (see figure 3). The advantages of the plate stacks remain and changeover-time is short. Additionally the changes of the piping are minimal. The shell is equipped with a lot more heat transfer area with increased heat transfer performance. This leads to higher heat recovery rates and the overall energy costs are diminished. Depending on the role of the heat exchanger in the plant and the cost structure of the plant 20% of operational costs can be saved.

If shell & tube heat exchangers are to be substituted completely it is possible to increase the compactness of the heat exchanger while maintaining all the usual process connections. Smaller shells with the same heat transfer area give faster dynamic behavior and reduce product hold up. This is also true for applications with phase change.

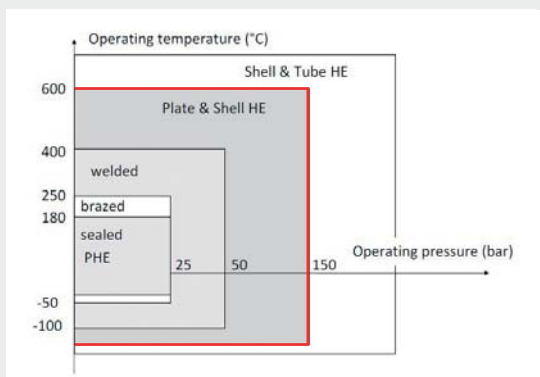


Figure 1: Pressure- and temperature range of plate & shell heat exchangers.

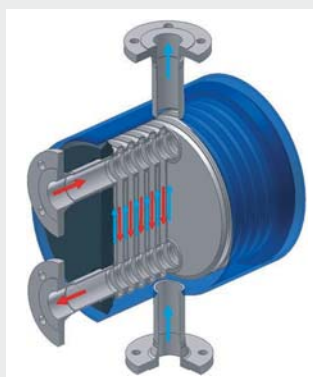


Figure 2: Construction of Plate & Shell heat exchangers (corrugations not drawn).



Figure 3: Illustration of tube bundle substitution by a stack of plate pairs.

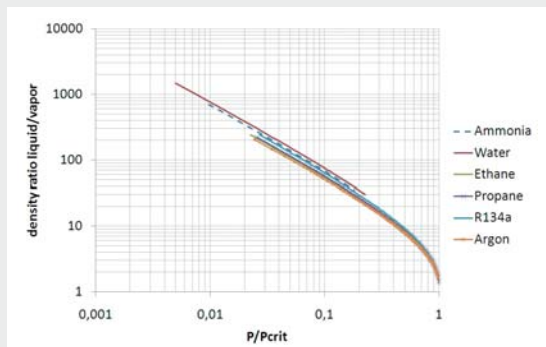


Figure 4: Ratio of liquid and vapor density of some fluids over ratio of operating pressure and critical pressure.



Figure 5: 2.3 Mega Watts Kettle-Type plate & shell evaporator for Gestra AG Bremen, Germany.



Figure 6: Plate & shell core: stack of corrugated stainless steel plates.

Applications with phase change

The most dominating effect during phase change in heat exchangers is the rapid change of volume flow rate. Steam has a much higher velocity than the corresponding liquid. If the cross-sectional area remains unchanged the increase of velocity equals the ratio of liquid and vapor density. Figure 4 shows this ratio as a function of reduced pressure. The figure shows that values of 10 to 1.000 can be reached. Data is depicted in the range of atmospheric pressure to 50 bars. The values will be high if the operating pressure is small compared to the critical pressure of the fluid.

High pressure drop is encountered when velocities are high. The increase in pressure drop often outbalances the increase of the heat transfer coefficient which is not desirable. Currently plate & frame evaporators are developed that have big sized steam outlet holes. This reduces the pressure drop at the outlet where a sharp direction change of the fluid takes place additionally. Most of the time the pressure drop dominates the sizing process and the heat exchanger must consist of more plates than necessary for heat exchange needs (oversized).

Inside Plate & shell heat exchangers the evaporation takes place on the shell side. The size of the outlet nozzle is chosen independently of the plate size and no sharp direction changes of the steam exist. The pressure drop is also reduced inside the channel between the plates by increasing the cross sectional area with respect to single phase applications. This leads to a minimized over sizing of the heat exchanger.

Kettle-type evaporator revived

A lot of engineers count on equipment they are familiar with and that is proven over years. On the other hand they know about the demand of efficiency increase. The concept of plate & shell heat exchangers revives old fashioned devices. Kettle-Type evaporators, for example, consist of flooded tubes which are heated mostly by steam condensation inside the tubes. Substituting the tubes by a stack of corrugated plate pairs this evaporator is turned into a plate & shell evaporator. The shell is the same in both devices. The plates are dimensioned that way that free convection and pool boiling are achieved. Figure 5 shows such an evaporator that was built as a secondary evaporator for GESTRA AG Bremen, the global leader in the design and production of valves and control systems for heat and process fluid control. The capacity was about 2.3 Mega Watts, mass flow rate 3.5 tons/hour at 12 bars. The diameter of the flange of the vessel is almost the same size as the diameter of the heat exchanger plates. Most part of the vessel is significantly larger. This extra volume is used to separate entrained droplets from the steam. Additional nozzles can be planned to remove inert-gases.

Shell & tube heat exchanger with tube-side evaporation are used as evaporators with natural or forced circulation. Plate & shell evaporators with natural or forced circulation can be used with shell-side or plate-side evaporation. Shell-side evaporation is mostly preferred because of the possibility of pressure drop optimization mentioned above.

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