HEAT EXCHANGER WORLD

Volume 3, Issue 4, July 2021

UNITING THE HEAT EXCHANGER SUPPLY CHAIN

Cover story:

Bronswerk Heat Transfer: Solutions for the energy future

Hybrid tubular plate heat exchangers for heat condensation: an efficient and cost-effective alternative to shell & tube?

In this technical article, plate heat exchanger specialist VAU Thermotech explains the benefits of hybrid tubular heat exchangers over the traditional shell & tube option. A question of design flexibility, robustness and cost, the hybrid offers a promising alternative, especially for modern power plants.

True-to-scale comparison of a shell & tube heat exchanger (left) with a hybrid tubular plate heat exchanger (right).

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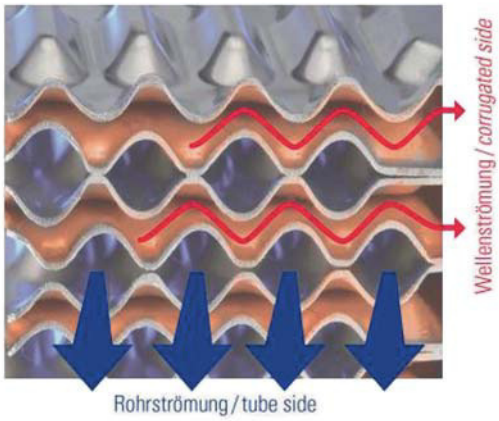
An exemplary shell & tube heat exchanger installed as a heat condenser weighs 26 tons, is 10m long, measures 1.6m in diameter and consists of 1,804 pipes. It transmits a heat output of 51 megawatts through its heating surface of 800m².
Whereas a fully welded VAU Thermotech hybrid tubular plate heat exchanger used for generating district-heated hot water has a heat output of 52 megawatts, but its heating surface measures 382m² and weighs 7.8 tons. Why is a hybrid tubular heat exchanger more efficient, requiring only 48% of the transfer area and 70% less material?

Tube and plate heat exchanger in one

The answer is the sandwich structure of the hybrid tubular heat exchanger's fully welded and shaped sheet-metal elements. The plate pairs stacked on each other creates a tubular and a corrugated flow shape. This special plate geometry creates an optimal flow cross-section area for the condensing steam on one side (tube side) and a turbulent water flow cross section area on the other side (corrugated side). Compared to a shell & tube heat exchanger, the hybrid heat exchanger offers about three times higher specific heating surface density per m³ of space.
By varying the length, width and height of the stainless-steel heating surface plate-pack, different modular sizes of the hybrid tubular plate heat exchanger can be achieved. As a result, the heat transfer area can be varied between 50 and 10,000 m² and the unit can be customized considering the actual space limitations and the existing piping arrangements.
Based on design parameters, the flow cross-sections of the hybrid tubular heat exchanger can be modified using the flexibly adjustable shaping depth of the shaping tools. The shaping depth has a direct influence on the pressure loss, the heat transfer and the geometry of the heat transfer surface. A choice of diameters between five and ten millimeters on the tube side and gap widths between 2.5 and 5 millimeters on the corrugated side is available. Although greater shaping depths reduce the heating surface density and specific heat transfer, they have a beneficial effect on both cleaning and service life of the device. This is because with a sufficiently dimensioned cross-section, the tube side can be easily rinsed with cleaning solutions without dismantling the apparatus. The corrugated structure on the other hand creates turbulences that make it difficult for water constituents to settle. However, the hybrid tubular plate heat exchanger realizes higher performance and a more compact design, needs less material, reduces weight and manufacturing costs.

Shell & Tube vs. Hybrid				advantages of hybrid tubular heat exchangers
capacity	MW	51	52	1.9% more capacity
surface	m²	800	382	only 50% required heating area of a tube and shell heat exchanger with comparable capacity
weight	t	26	7.8	weight savings of up to 75%
length	m	10	2.3	approx. 1/5 of installation area
width	m		1.3	
height	m		3.57	
diameter	m	1.6		
Footprint	m²	16	2.99	
Installation space	m³	25.6	10.67	more than 50% space savings
Positioning	-	horizontal	vertical	more compact boiler or machine house



How the hybrid works as a heat condenser

Hot water generation in a hybrid tubular plate heat exchanger occurs in cross flow: Steam enters the inlet header from above, flows horizontally through the tube side, heats the water pumped over the corrugated side and condenses in the process.

On the tube side, condensate collecting at the bottom of the vessel is forcibly guided by baffle plates to the condensate outlet nozzle via several passes. In this way, the condensate can be subcooled to a specific temperature. The number of flow paths (passes) can be freely selected in the sub-cooling zone. Process condensate inlet at a higher level of pressure is likewise possible at this point.

Hybrid benefits

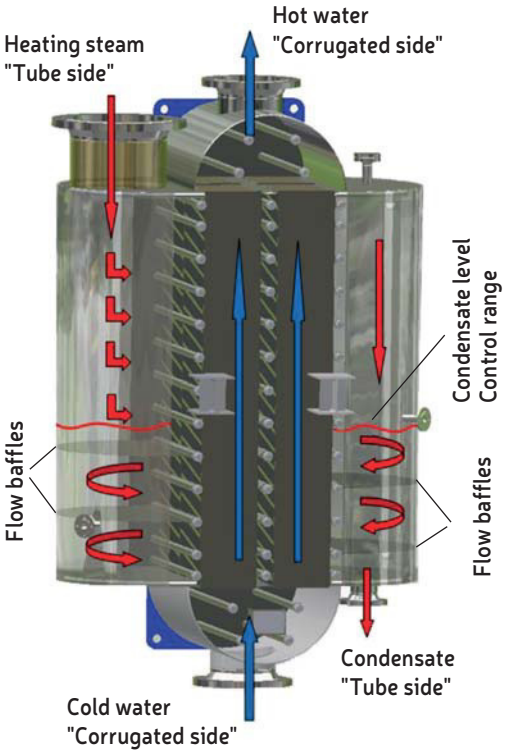
In contrast to classic plate heat exchangers where connections are attached directly to the plate, the connections of the hybrid are located at the welded-on inlet and outlet headers. This results in several advantages: depending on the geometric size of the plate packs, any nominal connection width can be attached, for example diameters up to DN 1,500 at the steam inlet. Special operating modes and functions also require additional connections which can be provided in accordance with the customer requirements. For example, in order to provide an optimal solution for condensation under vacuum conditions, connections for extracting non-condensable gases can be easily attached. In conjuction with the tube side flow shape which provides low pressure drop values, a high efficient heat transfer will be achieved. Level indicator tubes and displays, measuring nozzles, vents, degassing or draining devices can also be flexibly installed to the vessel.

Since the hybrid tubular plate heat exchanger can be adapted to all operating requirements (as well as the shell and tube heat exchanger), the vessel design is much more similar to a shell & tube heat exchanger than to the usual plate heat exchanger.

Heat capacity is available as needed

Hot water supply temperatures are weather-dependent. For this reason, the capacity has to be adapted to the actual requirements. The heating surface usage in a hybrid tubular heat exchanger can conveniently be controlled by minimizing or maximizing the area of the plate pack through which the steam flows. This is achieved using the "condensate level control" principle.

As the term suggests, the heating capacity is controlled via the condensate drain valve. This valve regulates the amount of condensate drained. A reduction in the valve cross-section increases the condensate level on the tube side. This reduces the available condensation area and the transferred heat flow. If, on the other hand, a larger heating surface is required again, the condensate drain valve can be opened to in order to release a higher heat transfer capacity. If the condenser has to be shut down, the steam side needs to be completely flooded with condensate. A positive side effect: the condensate protects the device against corrosion known as wet preservation. Incidentally, the capacity - as with all other steam-heated devices - can also be regulated via steam pressure. A corresponding steam pressure control valve carries out this function.



By the special condensate level control of VAU hybrid tubular heat exchanger it is possible to adjust the heating capacity almost continuously between 0 and 100%. The sensitive and responsive controlling mechanism comes along with optimum heat transfer and high heat surface density opposite to a shell & tube heat exchanger.

Steam is not just steam

A steam-heated hybrid tubular plate heat exchanger can have plate wall thicknesses starting from 0.8 mm. At first glance, the slightly higher material input when compared to a classic plate heat exchanger with a wall thickness of 0.4 mm, may appear too high. The same 0.8 mm thickness may appear too small when compared to a shell & tube heat exchanger's wall thickness of 1.2 mm.
Due to its thicker stainless-steel sheet the hybrid tubular plate heat exchanger is more protected against abrasion caused by high velocity water drops - which arise when using moist steam under two-phase physical-state conditions - as a regular plate heat exchanger would be. This is crucial in power plants that have to be highly fail-safe. A hybrid can guarantee a longer service life by less wear and tear.
The hybrid tubular plate heat exchanger's fully welded plate pack is completely welded to its pressure retaining housing. The result: no gaskets are required, as gaskets become brittle and have to be replaced regularly.
Steam condition and steam quality must always be considered during thermal and mechanical design of a heat condenser. Non-condensable gases reduce condensation pressure. They should therefore be extracted during operation to prevent blockage and disfunction of the heating surface.
Both superheating of incoming steam and moist steam influence the amount of steam available as well as the mechanical stress of the processed materials. Designing a heating condenser requires a careful calculation of the different load cases under consideration of the applicable design values as such are e.g. pressures and temperatures. Thus, mechanical loads on all components are predictable, which occur as a result of flow velocities, pressure conditions, steam conditions, and thermal stresses.

Conclusion for modern power plants

For nearly 30 years fully welded hybrid tubular heat exchangers have actively been working without malfunction as heat condensers. They are to be found in power plants, heat and power plants as well as waste incineration facilities. Fully welded hybrid tubular plate heat exchangers have achieved a service life the same as the classic shell & tube heat exchanger.
These heat exchangers are economic, flexible in design, have low weight and offer high heat capacity at less space. They are characterized in operation by their ease of maintenance, fatigue resistance, efficiency, and flexible adaptation to different requirements.
Thanks to their long service life, they ensure safe and continuous availability in district-heated hot water generation. A power plant expansion or re-planning using a hybrid tubular plate heat exchanger could increase overall efficiency, economy and variable utilization of the entire facility.