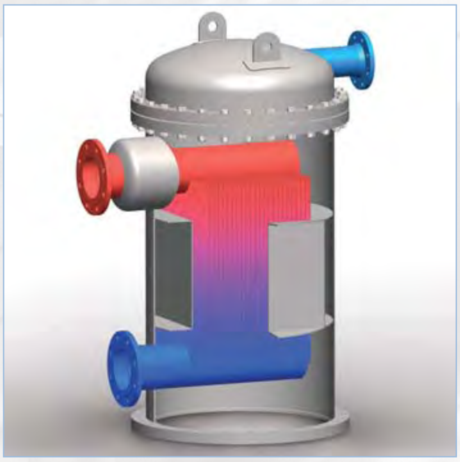
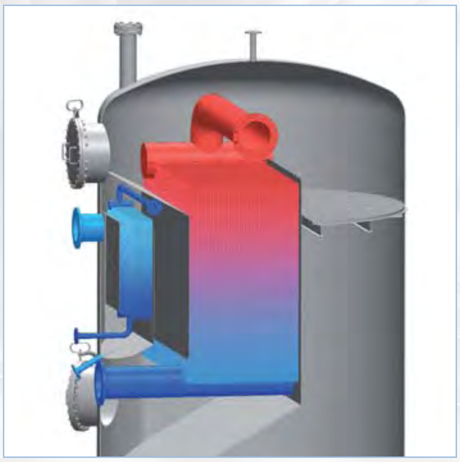
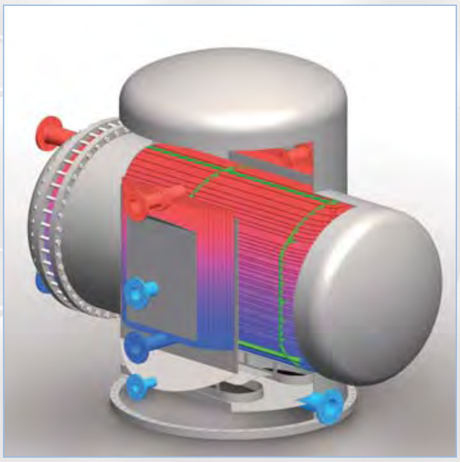






22 Years

WTP-System®

LOB

ENGINEERING & APPARATEBAU

Contents

22 Years of WTP-System®– Insights and Perspectives

LOB has been engineering and manufacturing equipment for the chemical industry for 90 years. 22 years ago, LOB started to focus on heat exchange by means of the **WTP-System® ("WärmeTauscherPlatten", German for heat exchange plates)** sWe and our customers quickly realized the advantages that this technology offers. A continuous dialogue produced a variety of ideas and applications. We started off producing WTP-Vessels, WTP-Clamping plates, WTP-Pipes and WTP-Baffles.

In hundreds of experiments we determined pressure resistance and flexibility of WTP-Systems. Afterwards, we investigated heat transfer and pressure loss properties. The data allowed us to calculate necessary heat exchange areas and welding patterns in order to design efficient systems. The result of this effort lead to our first patent titled, "WTP-Endlos", which enables us to combine high flow rates and high heat transmission coefficients at minimal pressure drop.

Furthermore, this data enabled us to pursue design, calculation and manufacturing of WTP-Head condensers. To facilitate research and development, the subdivision LOB-Engineering was founded, which focuses exclusively on process engineering and development of tools to aid design. This sparked numerous additional experiments, leading to the application of WTP-Head condensers as steam generators and cooling traps. Consequently, we added gaseous cross counter flow heat exchanger plates to our portfolio, which can be operated at high inner and outer pressures, while maintaining minimal pressure drop.

Concurrently, we developed "WTP-System innen“ (inner plate heat exchanger system), where heat exchange plates would be relocated from the outside to the inner volume of the vessel. This is advantageous in high pressure containments requiring thick outer shells, since the heat no longer has to pass through the thick vessel shell but only through the relatively thin top plate. In this way the operational time of batch processes can be as much as halved.

Another development is the WTP-Falling Film Evaporator (FFE). It has many advantages compared to regular tube bundle evaporators, for instance low weight and cost. Furthermore they can be cleaned easily. The WTP-Systems can be manufactured in a diverse set of materials, ranging from carbon steel to Titanium.

This brochure describes only a small part of the diverse applications of the WTP-System and aims to inspire new ideas and applications. We look forward to your challenge, because we love to develop.

Yours sincerely, the LOB Team

ENGINEERING & APPARATEBAU

LOB GmbH · Porzer Straße 1-5 · D-51107 Köln · Germany
Tel.: +49/221/82953-0 · Fax: +49/221/82953-40
E-Mail: info@lob-gmbh.de · www.lob-gmbh.de

March 2017



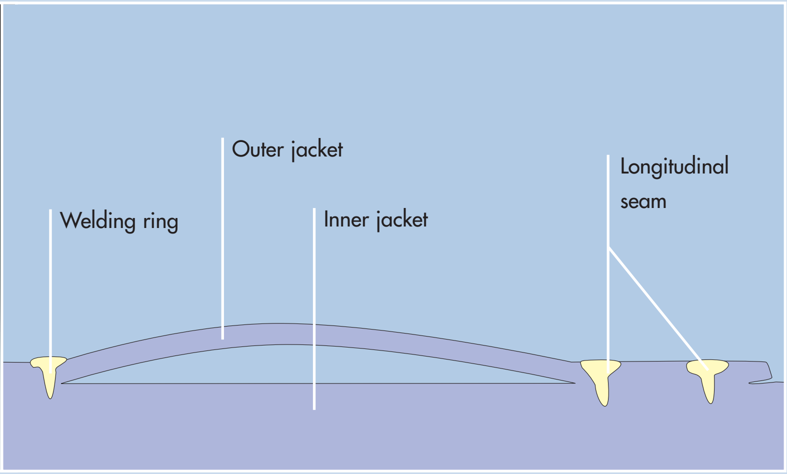
5.000 kg

1. The structure of WTP-Systems®

The WTP-System® is based on the following principle: Prior to forming, the pressure-bearing vessel jacket is coated with an outer jacket, which is between 1.5 mm and 3 mm thick. A laser beam welder fuses the sheet to the underlying vessel jacket, using circular welding patterns. After the vessel has been finished, the outer jacket is expanded by applying pressure to the interspace, creating evenly spaced pillows with a defined volume. Various fluids can be transported across the volumes, for instance heat carriers, refrigerant or gases. Additional seams can induce a tortuous path through the pillows. In this design, the weld seams serve as anchors, which allows for the application of high pressure to the thin welded outer sheet.

The circular welding patterns can be placed consecutively in a row or with an offset. The diameter as well as the expansion of the pillows can be altered, increasing the design space tremendously compared to pipes and tube bundles. This enables the WTP-System to be tailor-made for the specific application.

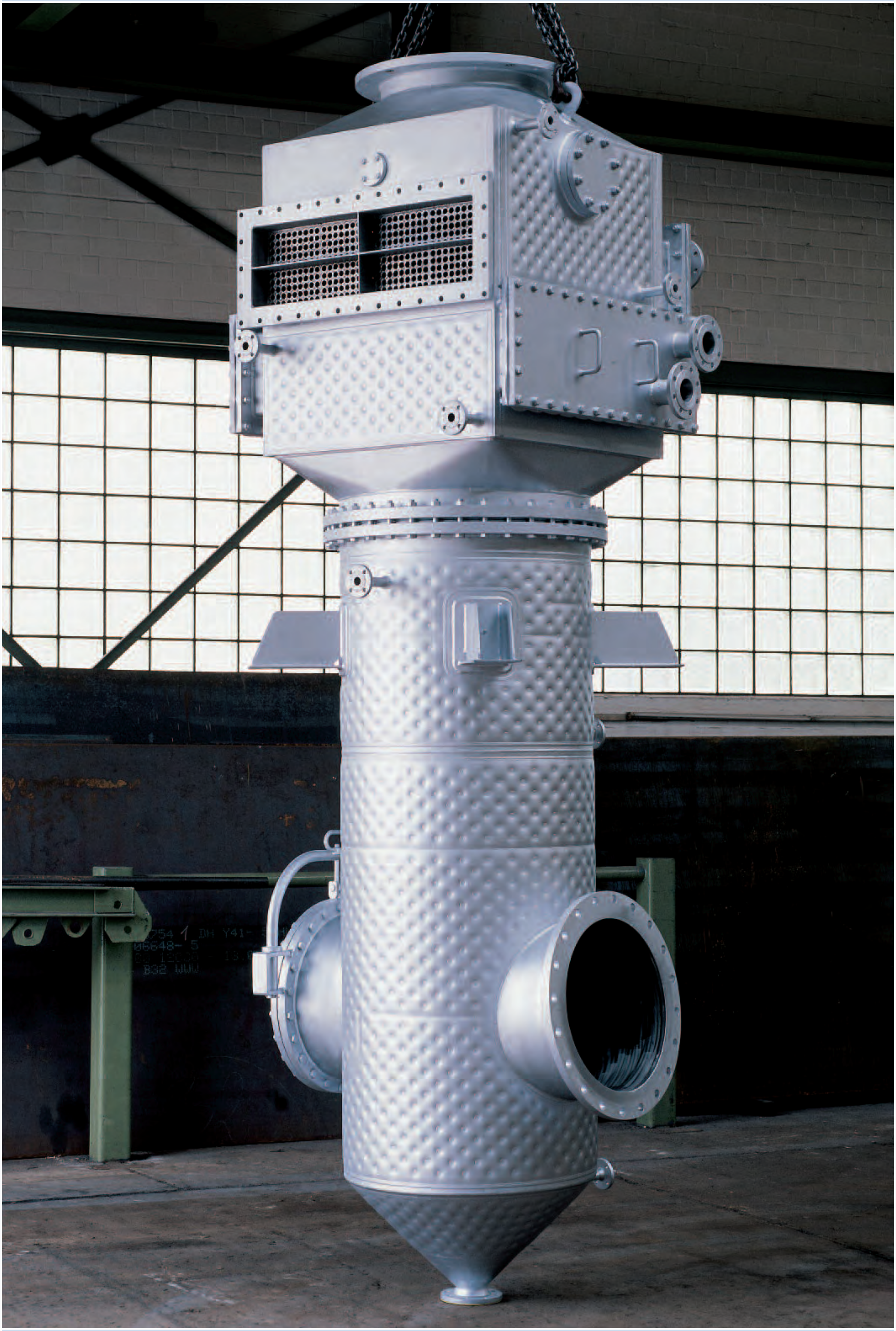
Cut through the system on the tube ø 144 mm



Welded connection

In the case of WTP-Plates, two equally thick sheets, of 1.5-2mm are fused together by circular seams. After the pressure expansion, the characteristic pillows will form on both sides. The pressure applied during the expansion will be a magnitude higher than the operating pressure, so that the manufacturing also poses a pressure test. Multiple plates can be stacked in a condenser package, by adding connecting pipes, fluid distributors and collectors as inlets or outlets of heat transfer medium.

The WTP-System can be designed and manufactured according to various standards, e.g. DIN EN 13445 or ASME Code, using austenitic steels or nickle-based materials.



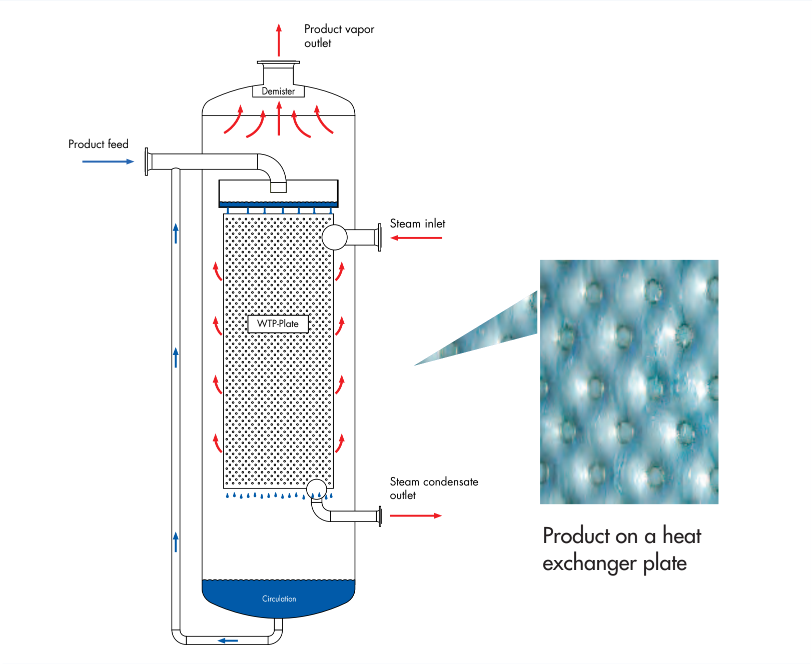
WTP-gas cooler with head condenser

2.1 Falling Film Evaporator (FFE) with WTP-Plates

Falling film evaporators comprised of WTP-Plates are operating in production scale plants today. However, due to the wide range of applicable operating conditions and ease of access to individual plates, they represent excellent experimental platforms to test the performance of the evaporation process.

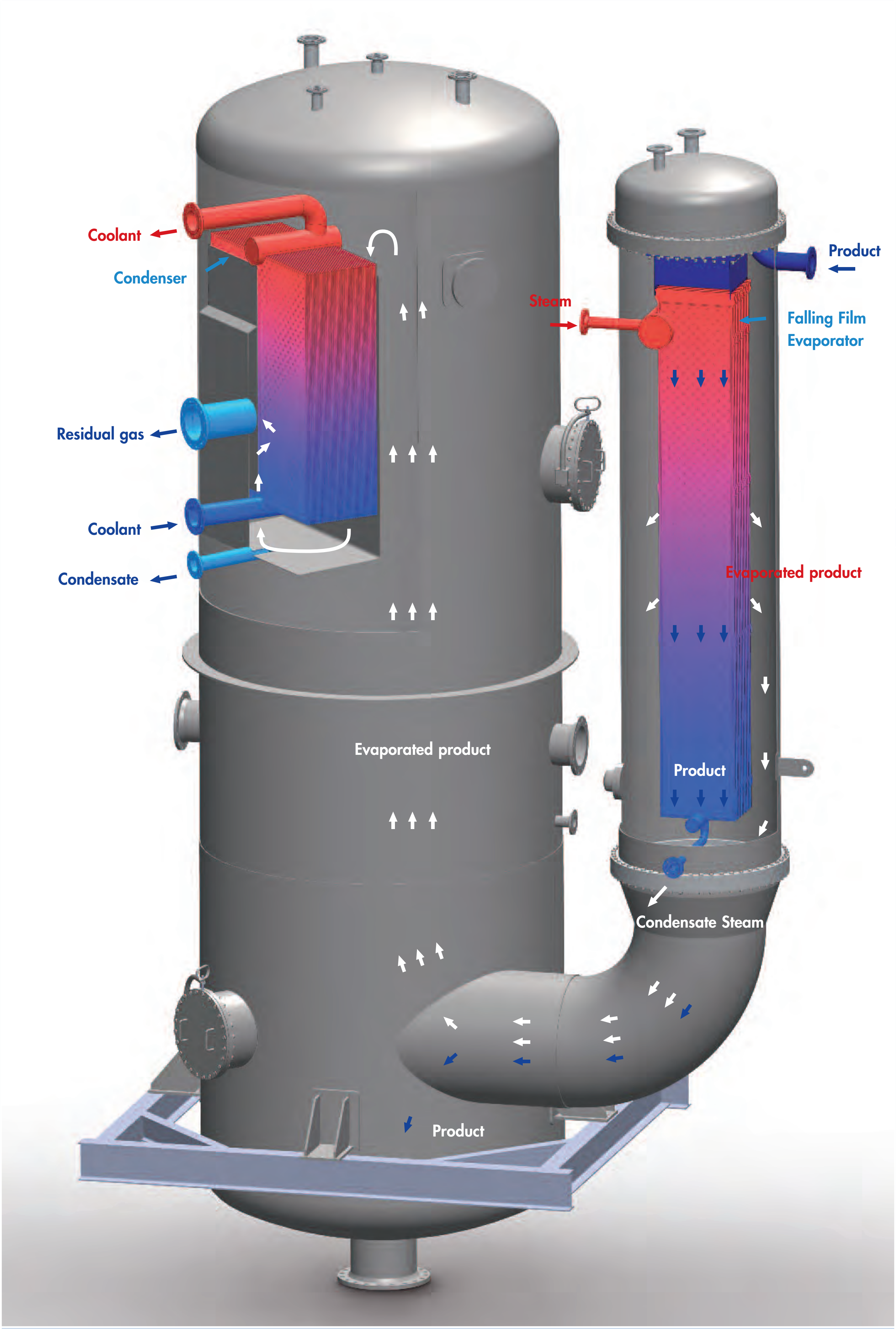
The used feed product for the shown falling film evaporator may tend to extreme thermal instability therefore large volume rates of fluid circulation above the regular rates are used to rinse off the forming crusts. The fluid distributor needs to be designed according to the fluctuation of the fluid circulation. The overall performance greatly depends on the feed conditions at the inflow to the plate package. LOB possesses an experimental setup, which can be used to design and test the fluid distributors for different products. The distribution system for the shown evaporator was built as a closed dispersing system, enabling a pressurized cleaning process. The evaporation temperature can be adjusted by applying different heating steam pressures and the performance can be tested. This can lead to different heat fluxes with different steam loads, which need to be accommodated by correct dimensioning of the WTP-System.

In contrast to a tube bundle evaporator, where the vaporized product is guided down the tubes along with the liquid product, evaporated product can exit towards the sides of the plate package. This means that smaller effective lengths, according to the half plate width, leads to low pressure losses. This is an advantage, especially, if the whole process operates at low pressures and pressure loss needs to be kept at a minimum. Both vapor and fluid product can leave the system at the lower outflow, or the vaporized fraction can be deducted at the top outflow, while the fluid remains to be deducted at the bottom outflow.



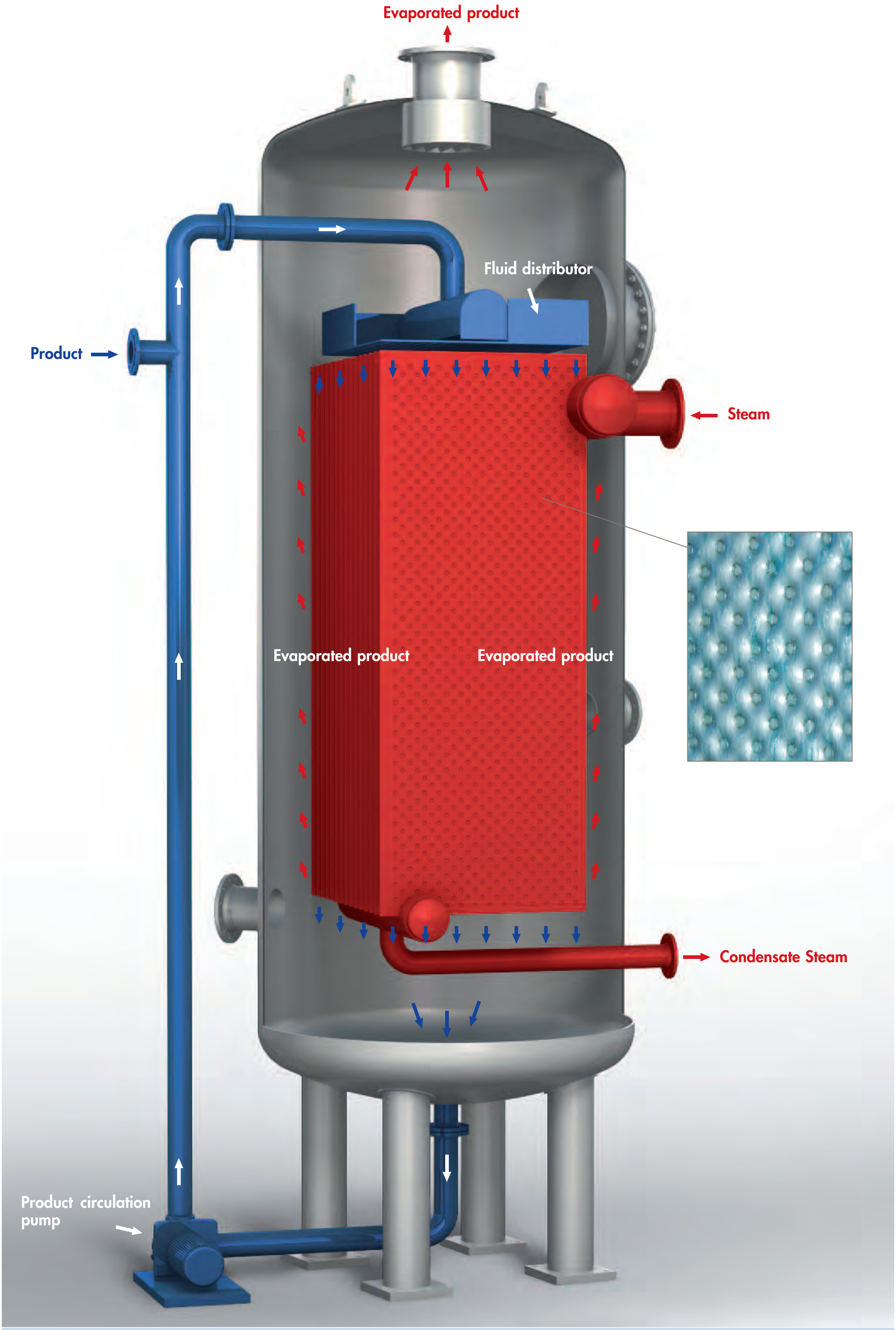
Theory of operation Falling Film Evaporator

Temperature compensators are not necessary for a falling film evaporator in WTP-Plate design, however, in some cases a compensator in the heating steam feed pipe is advisable. In comparison to a tube bundle evaporator a mechanism to completely exchange the plate package can be designed. Low procurement lead times and small external forces on the column complete the list of advantages of the WTP-Falling film evaporator. For a WTP-Plate falling film evaporator, the specific power density ranges from 5 - 7 kW/m² and the area-related liquid flow rate of 2 m³/(h*m) and more can be driven. The plate exchanger can be designed such that the plate package can be pulled out of the shell, allowing for fast and easy cleaning. Further, designing the fluid distributors accordingly can accommodate for highly viscous product.



Falling Film Evaporator with column and head condenser

WTP-Plate package of a Falling FIlm Evaporator (FFE)



Theory of operation Falling Film Evaporator

2.2 Falling Film Evaporator (FFE) Comparison

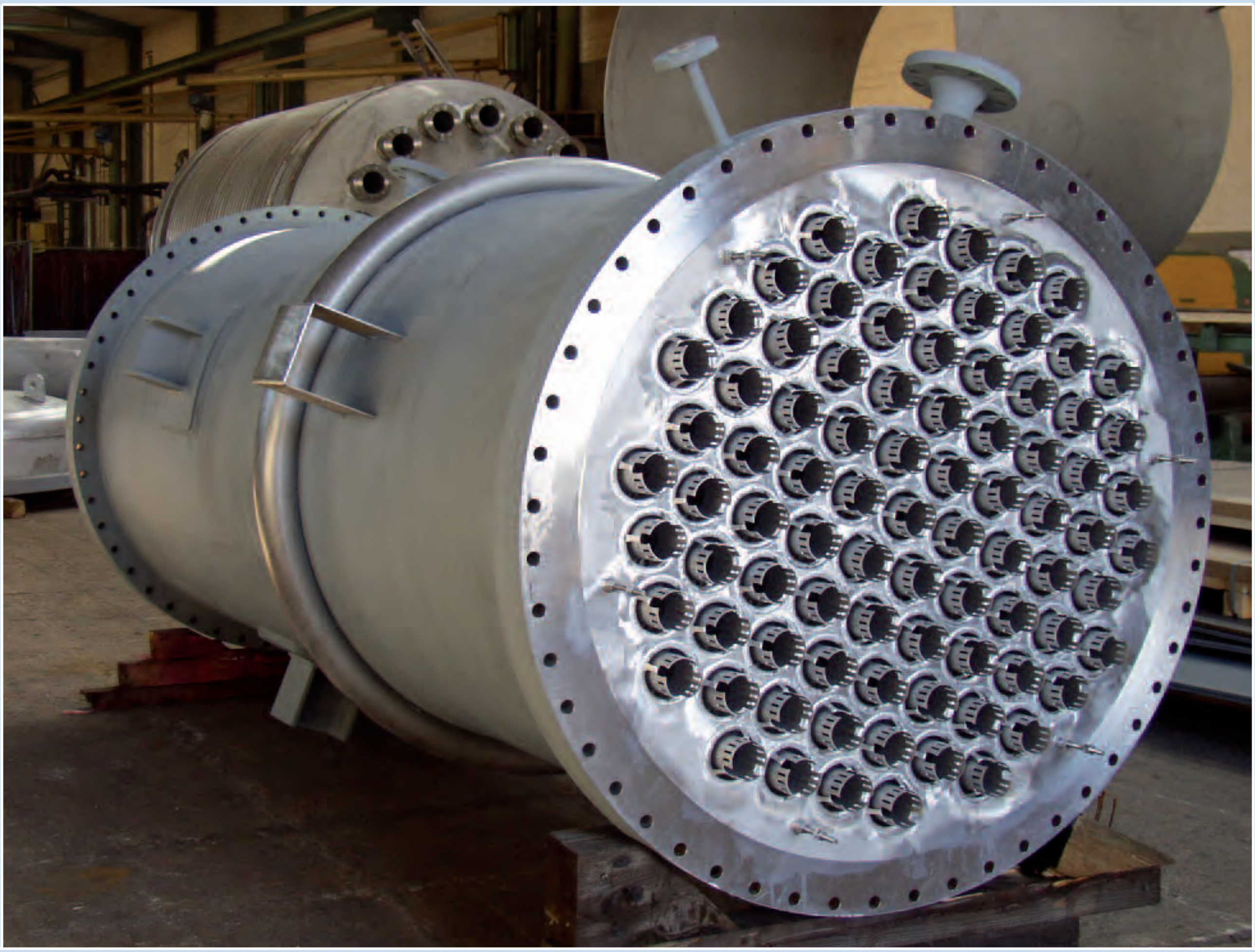
In a comparative study conducted by LOB, the falling film evaporator using WTP-Plate design showed a cost and weight advantage compared to the tube bundle version of the falling film evaporator. The cost advantage can be as much as 40 %, and the weight reduction as much as 70 %.

Falling Film Evaporator Using Tube Bundles

Conventional falling film evaporators are made up of a bundle of vertical 4 to 10 m long tubes. The commonly used heating medium is steam, which is guided around the tubes at high temperatures and pressure. Meanwhile, the product flows down inside of the tubes at low pressure. Both ends of the tube bundle are welded into the tubesheet and have to be strong enough to withstand the pressure difference between heating medium and product. A fluid distribution system at the top of the heat exchanger feeds the fluid into the individual tubes. Part of the liquid product vaporizes on the inner tube wall and leaves the falling film evaporator as vapor/liquid mixture at the lower tube ends.

Falling Film Evaporator Using WTP-Plates

In a falling film evaporator based on WTP-Plates, a plate package replaces the tube bundle as heating element. The heating medium flows through the inside of the plates while part of the product vaporizes on the outside between the individual plates on its way down together with the liquid phase. In tube bundles the vapor is forced downward with the fluid. By contrast, in a falling film evaporators using WTP-Plates, the vapor is guided in such a way that the nascent vapor can leave the WTP-Plate package sideways and leaving the evaporator upwards via an outlet nozzle with demister. This arrangement leads to a low pressure drop.



Falling Film Evaporator ø 1260 mm x 3000 mm

Comparison of Evaporators with WTP-Plates and with Tube Bundles

Due to the special design of falling film evaporators using WTP-Plates as heating elements and the process management considerable weight and cost reductions can be achieved based on the following facts:

In the tube bundle design, the heating steam is guided inside the jacket. By contrast, in the WTP design, the heating steam is guided inside the plates. In the plate design of a falling film evaporator, the product is inside the space surrounding the plates and inside the shell. The product exists in a condition with less pressure. Therefore, the shells of falling film evaporators using WTP-Plates can be designed with small wall thicknesses.

In tube bundle version of evaporators, strong tubesheets and thick wall thicknesses withstand the pressure difference between the space inside the shell and inside the tubes. On the other hand, the plate versions of falling film evaporators do not require tubesheets because the heated steam is guided inside the plates. To absorb the forces between the tubesheets the used tubes must have wall thicknesses about 4 mm. For the WTP-Plate design the used 1.5 to 2.0 mm thick sheets are sufficient to absorb the occurring internal pressure. The reason for this is the low buckling length caused by the small pattern of the welding circles.

Display of a Falling Film Evaporator
– the video can be found at YouTube:
www.youtube.com/watch?v=w_oFXt7WKtQ

Condenser ø 800 mm x 4000 mm, manufactured according to ASME-Code

2.3 Falling Film Evaporator (FFE) in Tube Bundle Design

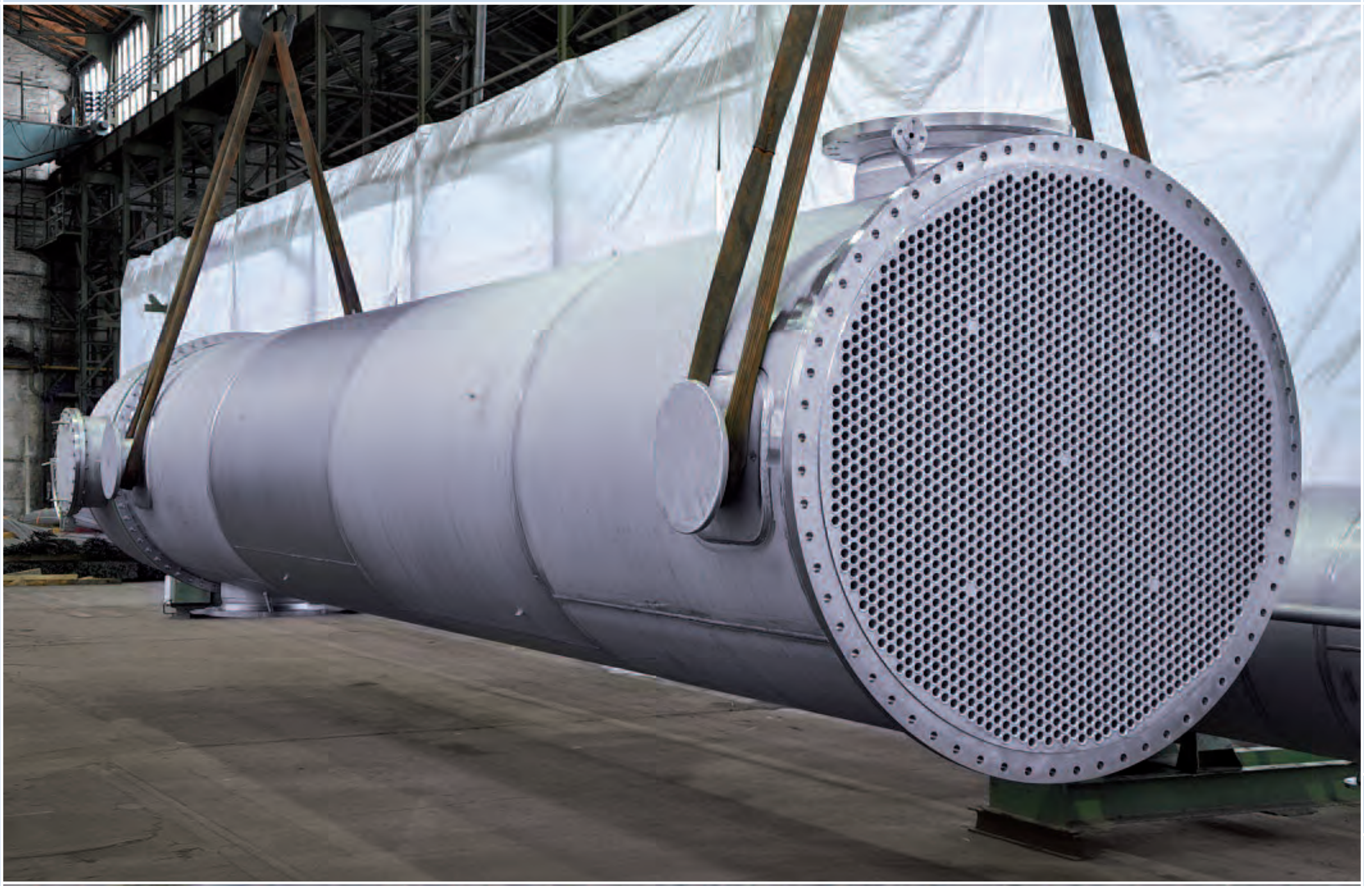
LOB built a tube bundle version of a falling film evaporator using about 2,000 tubes, each 8,000 mm long with a diameter of 1,550 mm. The weight of the 16-m long falling film evaporator was about 35 t. The heat output was around 3.3 MW with a heating area of 1,300 m². This is equivalent to a transfer capacity of 2.5 KW/m².

The even distribution of fluid across the vaporization tubes is crucial for a falling film evaporator operation. LOB designed a 3-hole version for the product distributor and tested it in a 5-times smaller model relative to the fluid amount.

LOB designs distributor systems and has built many fluid distributors for tube bundle falling film evaporators. The distributor is made up of a vertical stack of distributor plates. The top distributor has an overflow weir, which is designed to throttle the flow velocity and homogenize.

Falling Film Evaporator in tube bundle design with fluid distributor

Delivery of a Falling Film Evaporator ø 1550 mm x 17000 mm



Falling Film Evaporator and distributor bottom

3.1 WTP-Head Condenser

Process Engineering

During the condensation of fluids, a vapor mixture initially forms at the lower end of a several meters high column. The vapor mixture streams upwards against the fluid and becomes enriched. In a condenser, the vapormixture then returns to the liquid state. The condenser is located at the top end of the column, hence the name 'Head Condenser'.

Usually, the condensation takes place at low pressure while the cooling water is highly pressurized. Thick, heavy and costly tubesheets are necessary to withstand the pressure difference in tube bundle condensers. By comparison with tube bundle head condensers, WTP-Head condensers need a smaller installed area of only 25 to 35 % and have a lower weight by up to 50 %. Since the weight puts a strain on the column structure, high-capacity WTP-Head condensers increasingly prevail as head condensers.

In plate-type condensers, the product usually moves between the plates and the cooling medium moves inside the plates. The lower pressure on the product side determines the wall thickness dimensions of the vessel. WTP-Plates consist of 1.5 to 2.0 mm thick plates, which are connected with circular welding patterns. After expanding the sheets using pressure far above the operating pressure, the cooling water can be safely flow through the evenly spaced pillows.

The operating pressure varies between 5 bar and 5 mbar at a temperature from +300 to -25 degrees Celsius. At low operating pressure, the permissible pressure loss is less than 1 mbar. Under this aspect of low pressure only a plate condenser is applicable. This is achieved by adjusting the distance between the WTP-Plates. However, a high plate distances will go be at the expense of condensation. In such cases, a larger exchanger surface needs to be provided. The heat transfer coefficient (α-value) on the secondary side is adjustable by changing the inner plate bulging out sheet distance, less or higher expanding pressures, and the choice of the circular welding pattern. On the cooling water side, there also is a trade-off between high α-values and high pressure losses.

On the cooling water side, heat transfer coefficients (α-values) of 500 to 8,000 W/(m^2K) and higher are easily achieved. If the α-values on the product side are considerably lower, higher α-values on the coolant side will have no significant effect on the thermal transmittance coefficient k and will consequently not affect the heat exchange.

Column with WTP-Head Condenser


Coolant
Evaporated product
Residual gas
Coolant
Evaporated product
Condensate

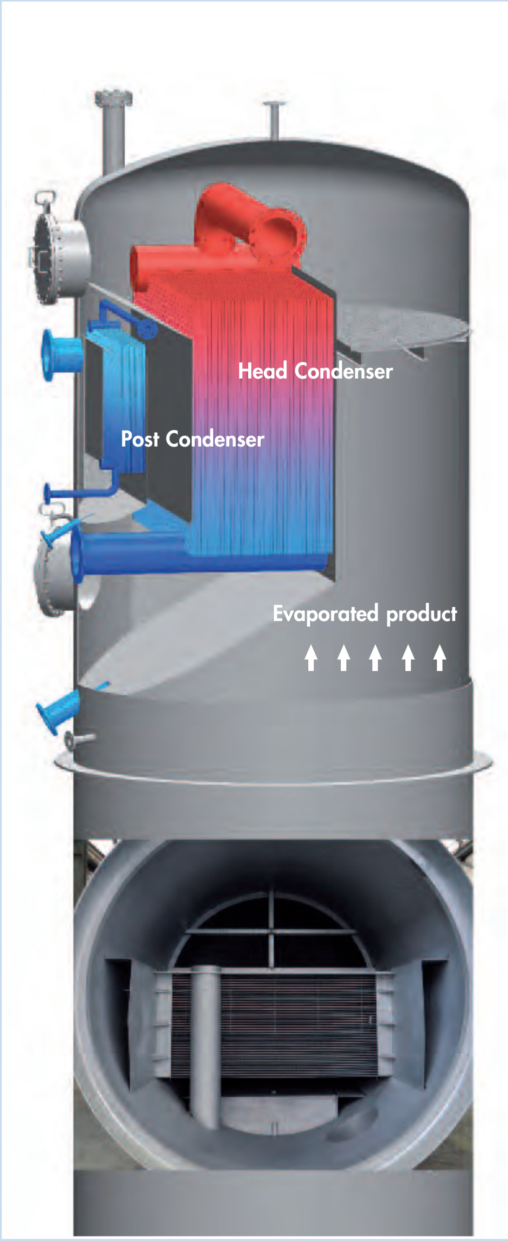
3.2 WTP-Head Condenser with Post Condenser

Head Condensers with Main and Post Condenser

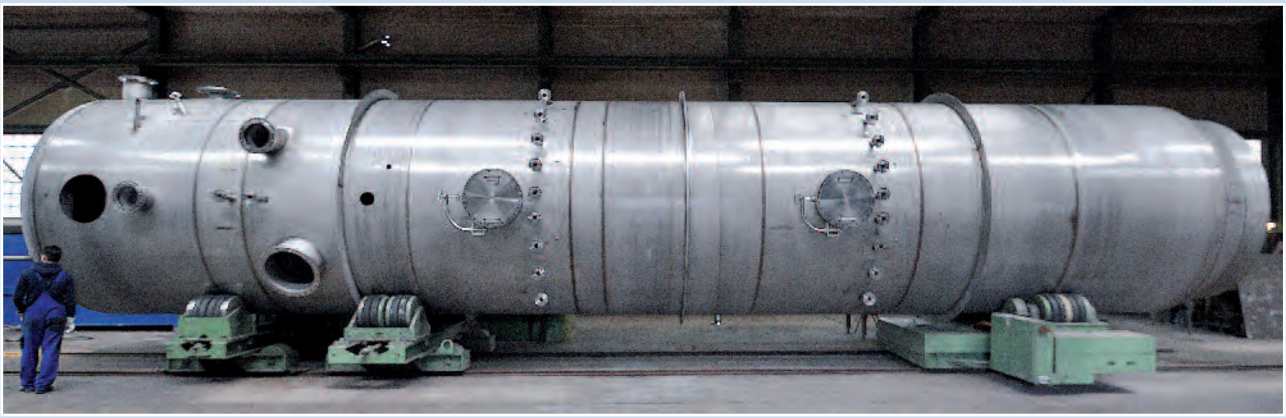
The process engineering parameters for the entire process determine how much product vapor will be turned into condensate. The corresponding condensation temperature can be determined using the heat curve. If the entire product gas has to be converted into condensate, the requirement for a main and post condenser has to be checked. The temperature step in the heat curve is selected in such a way that the main part of the condensate forms in the main condenser. The remaining small amount of residual gas is then condensed in the smaller post condenser at lower temperature. In many cases, the post condenser merely provides reserve capacity.

Condensation with co-current flow has the advantage of low pressure drop because the product vapor first streams upward along the column and then parallel to the nascent condensate downward by gravitational force. The disadvantage is that the construction requires baffle plates, which guide the product gas from the main condenser into the post condenser. Operating the post condenser in the counter flow direction, simplifies the flow.

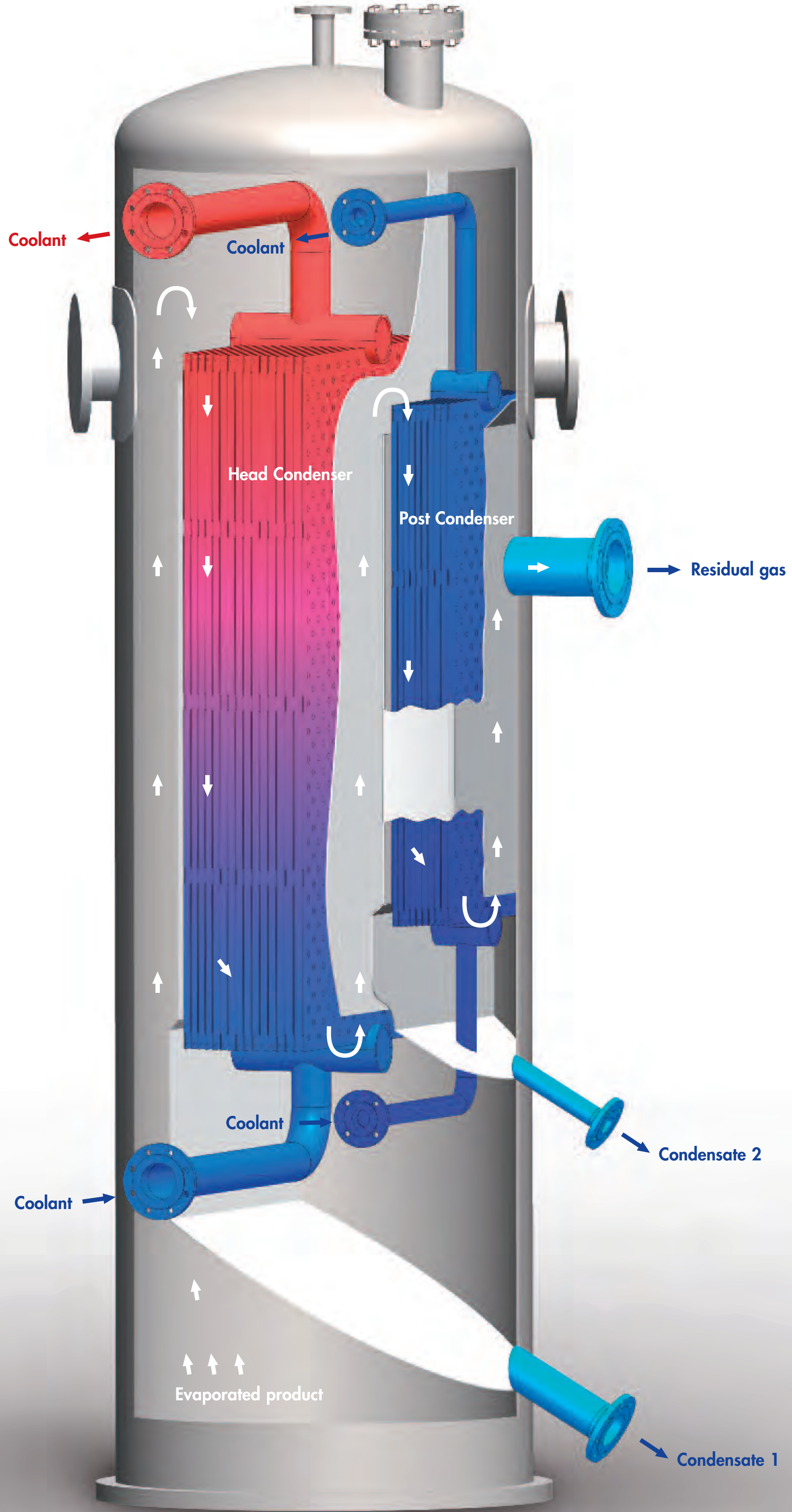
Dependent on the existing local cooling facilities, the main condenser will run with large amounts of cooling water at moderate temperatures (e.g. 25 to 45 degrees Celsius). Frequently, the post condenser circulates coolant (brine or water plus antifreeze) at a temperature of 3 to 5 degrees Celsius or even at sub-zero temperatures. Providing coolant at a low temperature is expensive. However, the required amounts for the post condenser are significantly lower than for the main condenser.



WTP-Head Condenser with post condenser



Column with WTP-Head Condenser, 28 tons



WTP-Head Condenser with post condenser

3.3 WTP-Condensers with Integrated Steam Generation

Head Condensers with Integrated Steam Generation

During condensation, the initially provided latent heat is released. Recovering the released heat as steam improves the energy balance of the entire process. The latent heat can be used for the generation of saturated steam above 3 bar, provided the temperature level in the heat curve is above about 135 degrees Celsius.

Thermosiphon vaporizers are an often welcome choice of vaporizers because their operation is stable, and they are energy efficient. The natural circulation takes place by itself and is based on the density difference between water and the steam/water mixture. Merely the replacement feed-water flow must be brought to the respective pressure. By contrast, forced circulation vaporizers consume electrical pump energy for the entire amount of circulated medium. This reduces the amount of recaptured energy during the heat recovery.

For this type of energy recapturing WTP-Plate condensers are an obvious choice. In these condensers the steam is generated inside the plates and the product condenses outside between the plates. Experiments at LOB showed that blistering during the steam generation does not result in vibrations inside the plates.

By comparison with tube bundle heat exchanger, WTP-Plate condensers have the advantage that the required condensation surface can be reduced by up to 25 % due to the better heat transmission coefficient. The steam can be directed through the 1.5-mm thick intrinsically safe plates at a saturated steam pressure of 37 bar by selecting the circular welding pattern and the expansion of the plates accordingly.

LOB successfully designed and built many condensers with integrated steam generation and adapted them to the specific customer's applications. For example, LOB manufactured condensers with 2 MW heat output and heat recovery of more than 95 %. This design has proven itself many times for different companies.

Column, ø 1600/2500 mm, length 19650 mm, 17000 kg, material 1.4571

WTP-Condenser with integrated steam generation

3.4 WTP-Countercurrent Condensers (Reflux)

Reflux Condensers

In reflux condensers, the vapor streams up from the column or the vaporizer between the condenser plates where the process vapor condenses. While the process vapor rises up, gravitation causes the condensed product to run down in a countercurrent flow.

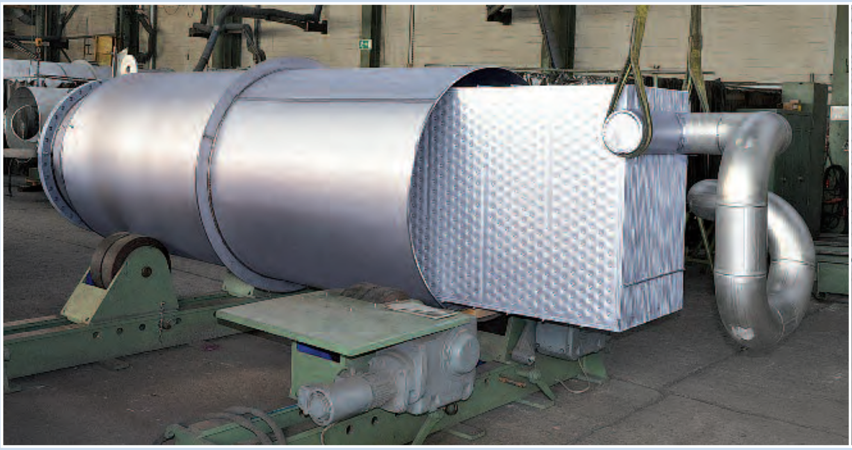
However, the velocity of the rising process vapor must not be so high that it prevents the flowing down of the condensate (Flooding). In the process design, the plate distance is adjusted in correlation with the permissible vapor velocity to meet this requirement. In reflux countercurrent condensers, the plates can not be arranged as close to each other as in a co-current flow condenser.

The simplicity of its construction is the most important advantage of a reflux condenser as no deflector plates for the product vapor are required. The diameter of the vessel can almost be entirely filled with plates to save space.

Pure substances such as water steam with few inert gases are most suitable for reflux condensers. Inert gases cannot be condensed and put a strain on condensation, these gases leave the condensation zone at the top of the condenser. By contrast, pure substances condense instantly reaching the condensation temperature. This makes it possible to keep the plate length of reflux condensers short.

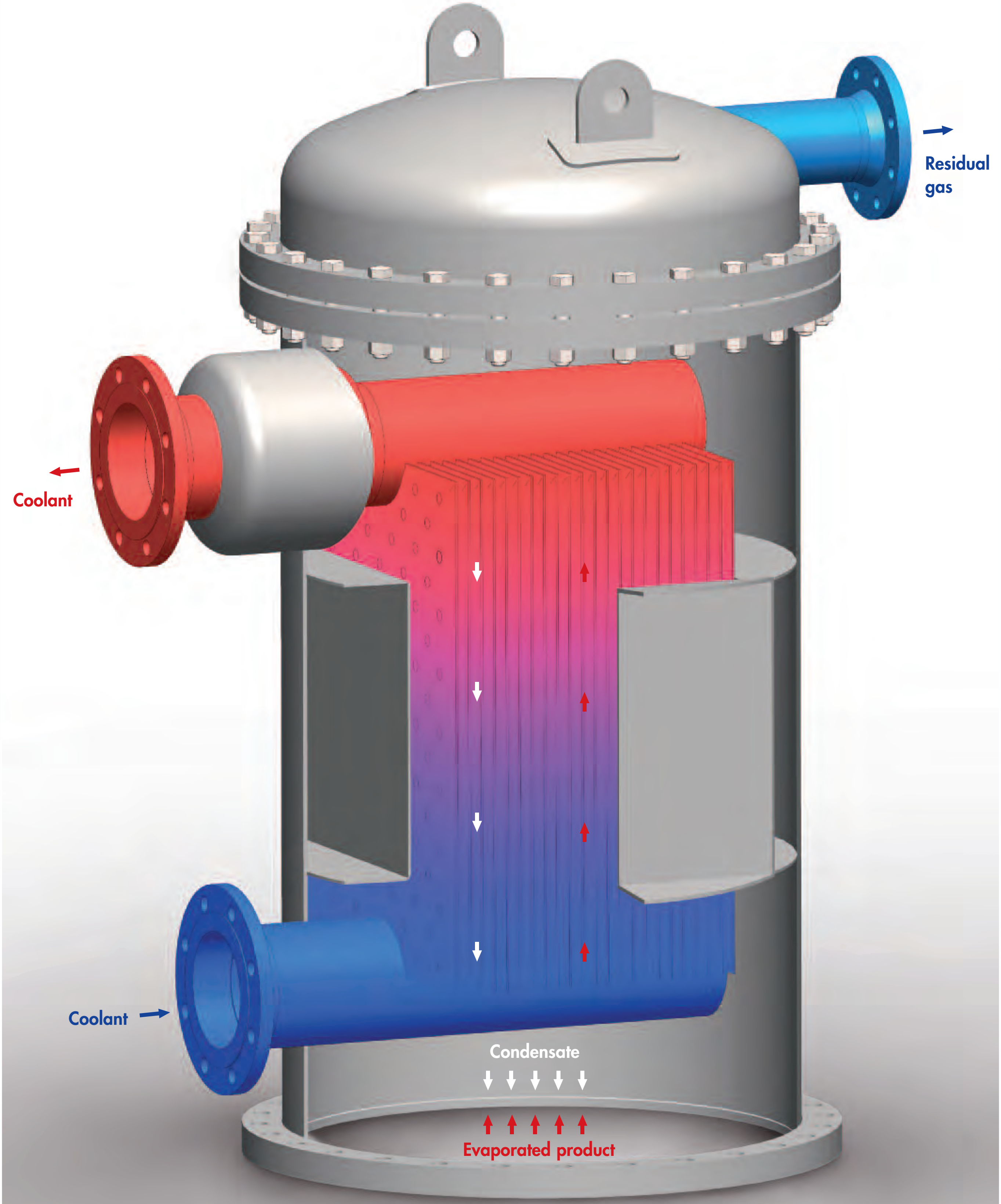
The plates in a reflux condenser are continuously rinsed with the dripping condensate. This is particularly advantageous when the product vapor is corrosive while the liquid phase causes only little metal corrosion. This effect can happen during the condensation of waste water.

Reflux WTP-Plate package



Assembling a Relux-plate package and the plate housing

Reflux condenser



WTP-Countercurrent condenser (Reflux)

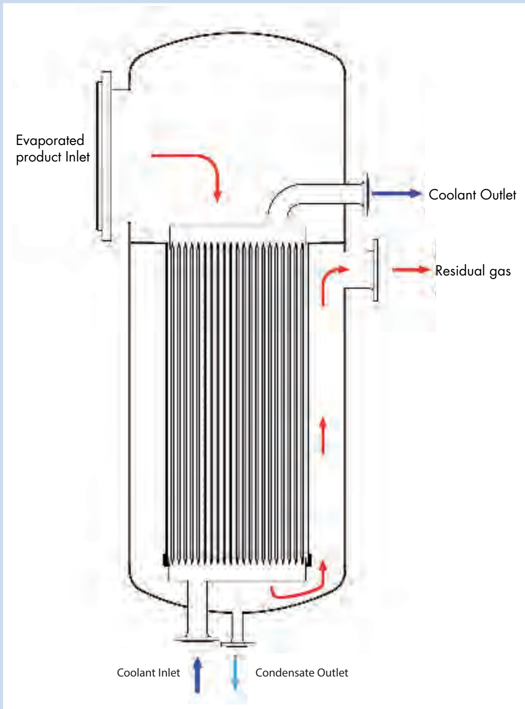
3.5 WTP-Condensers in Separate Vessels

Pressure Drop Using Condensers in Separate Vessels

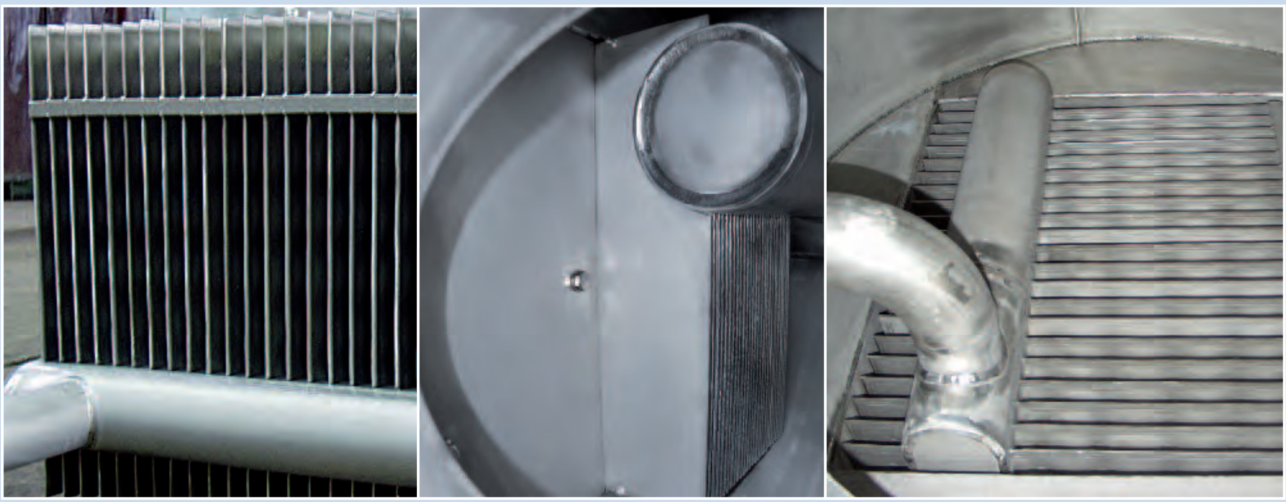
The pressure drop of a condenser depends on the type of flow, co-current or countercurrent flow, laminar or turbulent along every part of the product vapor path. Installations such as pipe bends, baffles and fittings have to be considered as much as extended or narrowed flow channels. For head condensers the entire vapor path must be considered from exiting the column, between the plates and the path to the condensate outlet nozzle and residual gas nozzle.

A plate condenser operates with a lower pressure drop than a tube bundle condenser because in a tube bundle the vapor hits the tubesheet vertically, then has to constrict upon entering the tubes and then expands inside the tubes.

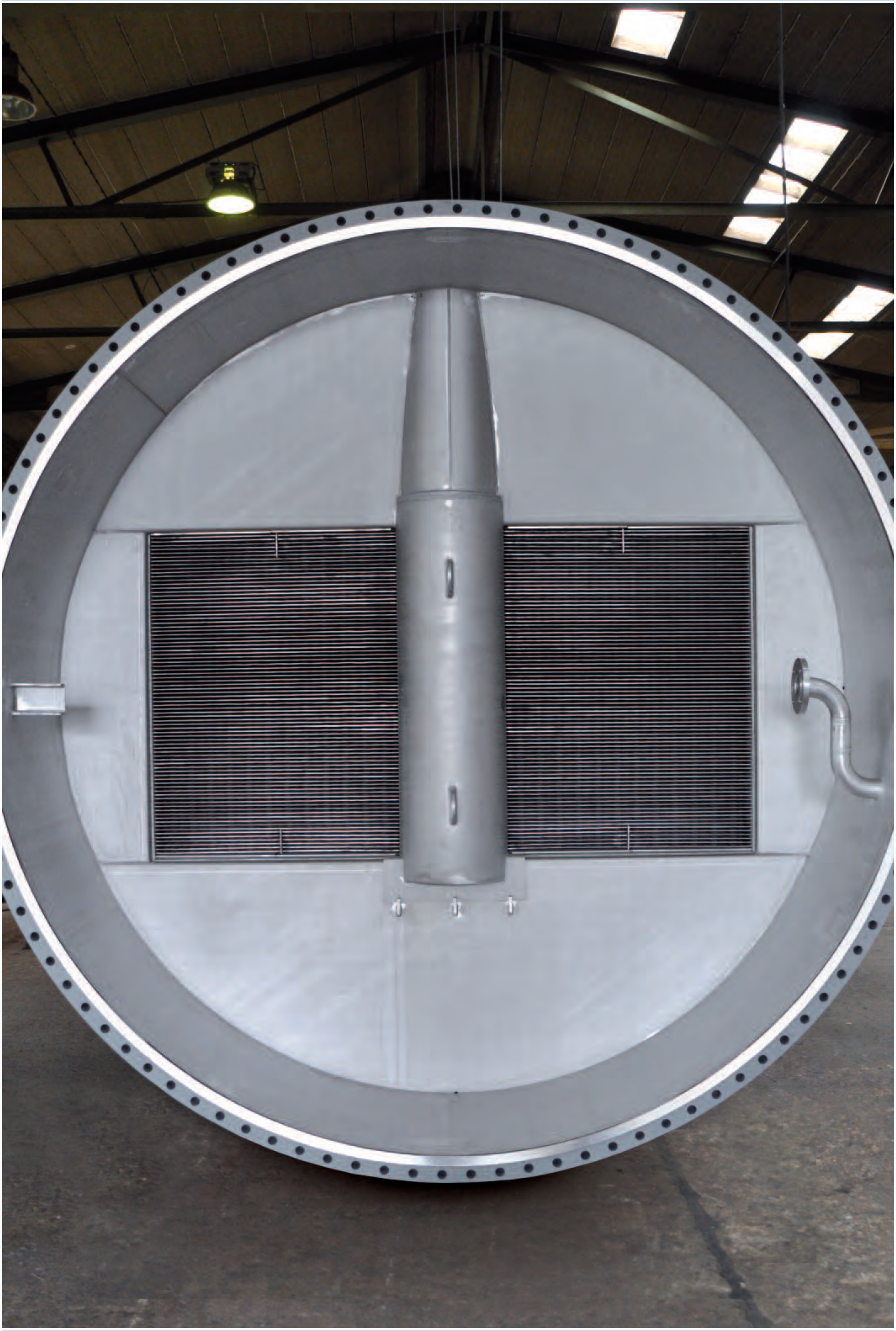
The installation of a WTP-Condenser in its own vessel can significantly reduce the pressure loss in comparison to a WTP-Head condenser, in which the vapor must pass past the plate package. Almost the entire inner area of the vessel can be used space with the plates' efficiency. In this design, the product vapor is fed via a large inlet nozzle into the plate package with one or no change of the flow direction. This design is used when only little pressure drops can be tolerated, when no column is available or when the column diameter and/or height is limiting. In such a case, the separate vessel is installed in the structural steelwork next to the column.



Schematic of WTP-Condenser in separate vessel



Condenser package in detail



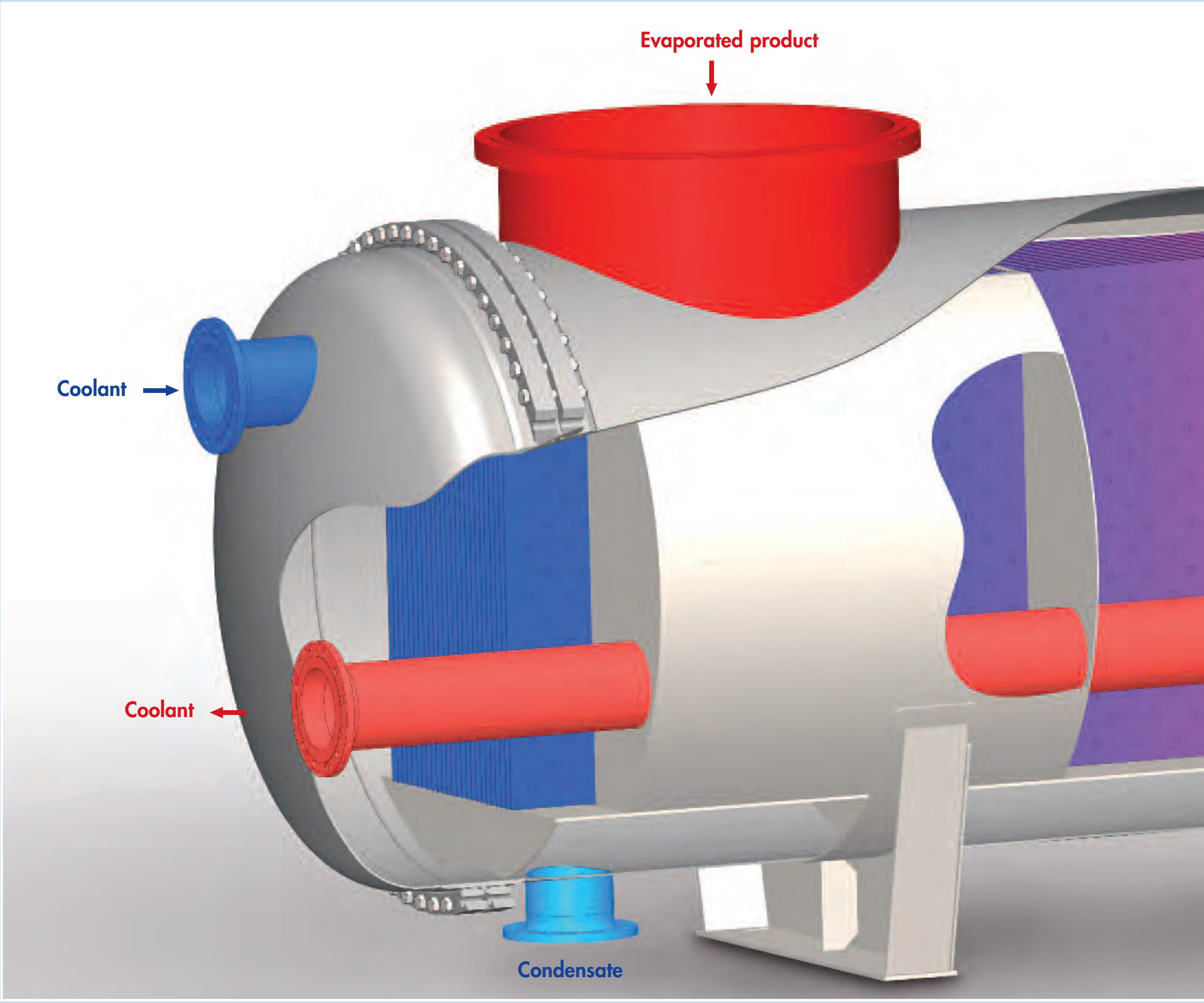
WTP-Condenser in separate vessel

3.6 Horizontal WTP-Condensers

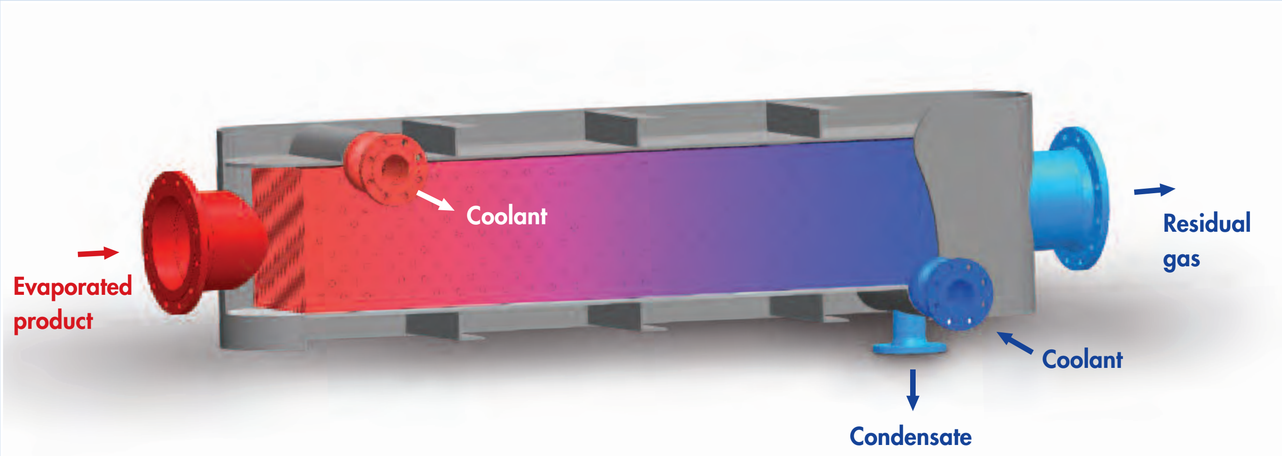
Capacity Increase of an Existing Condenser

This is a special construction that can replace an existing tube bundle condenser without change in geometry and size ratio. The replacement increases the heat transfer area and doubles the heat transmission capacity. The design can include drawable plate packages, which can be cleaned. The pipework in the plant does not have to be modified in any significant way.

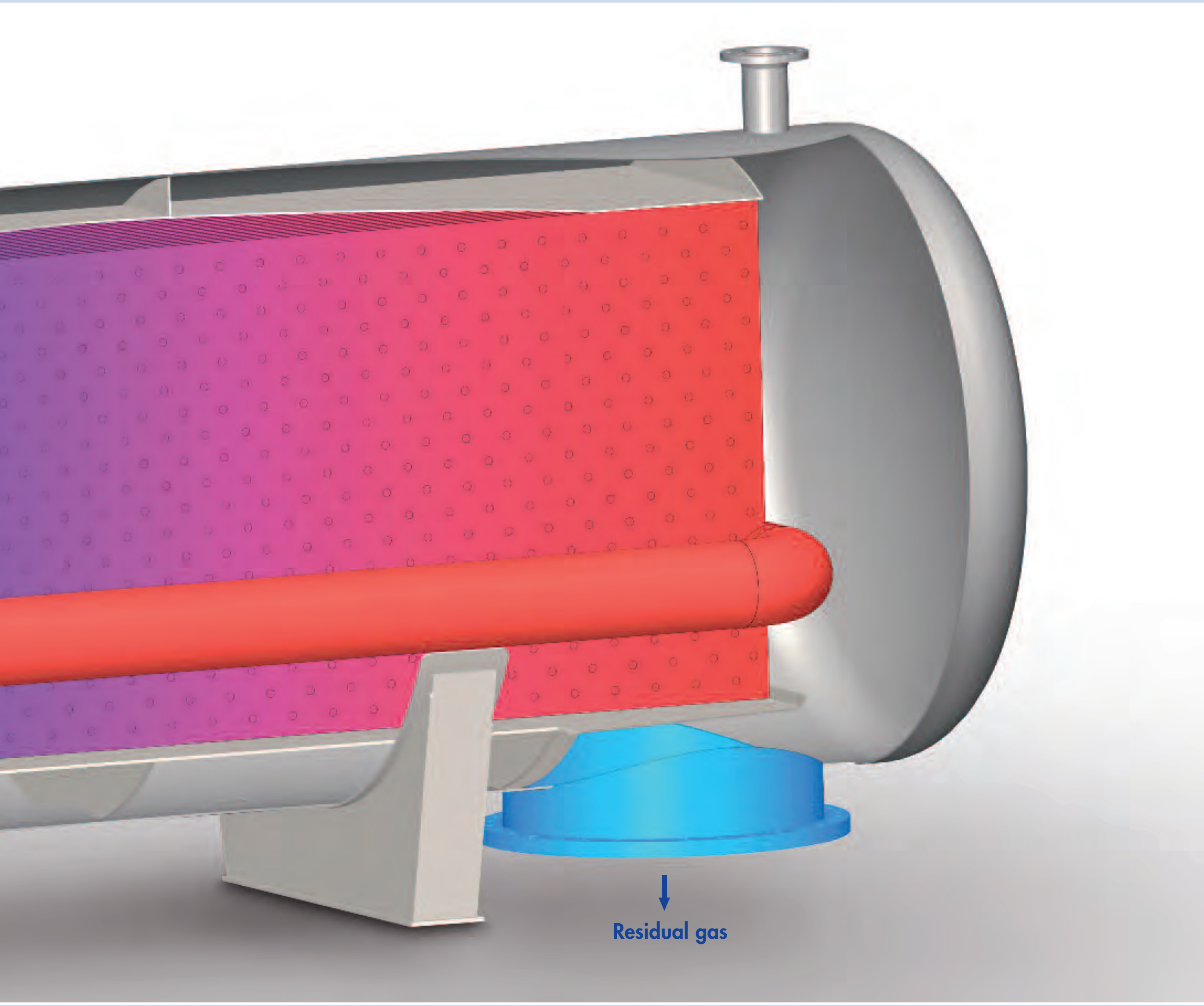
The product vapor enters through the top nozzle and then streams outside between the plates. The residual gas leaves the condenser through the lower nozzle. After entering the outside of the plate package, the condensate flows downward and is collected with a slope at the condensate outlet. With the inlet and outlet pipes the plates are attached to the torispherical head and can be pulled out.



Horizontal WTP-Condenser



Horizontal WTP-Condenser



3.7 Horizontal WTP-Cooling Traps

Cooling Traps with WTP-System®

Cooling traps are used to condense moisture or solvents in gas flows. They are used to protect vacuum pumps from damaging water hammers. If valuable condensable components are present in low concentrations in the gas stream, such as solvents, they can be recovered and reused. Cooling traps are also used to rid exhaust gases from toxic substances and prevent damage to the environment.

Usually, industrially sized cooling traps are built using tubes with or without fins made of stainless steel or better conducting materials such as copper. However, using different materials requires special attention to the construction process. This applies in particular to tube installations using gland packing or other connectors that could cause problems. In cooling traps with WTP-Thermo plates, the medium flows longitudinally to the plates in a more effective way than through installed finned tubes.

In an application, organic components containing about 800 ppm of nitrogen must be condensed before entering a vacuum blower. During the operation, the pressure is reduced from 1 bar to 10 mbar while maintaining the same flow rate. To ensure the condensation of the organic components, the vapor temperature must be reduced to -30 degrees Celsius.

The construction allows the loaded crude gas to enter through the inlet tube at the top right. The gas is then channelled downward between the outside of the plates and redirected by 180 degrees at the lower end of the plate package. The plate package consists of WTP-Plates. The stream of cooled gas streams vertical upwards before leaving the vessel through the exhaust gas nozzle on the upper left side. From there, the stream of gas enters the vacuum blower. The condensed organic components flow downward along the plates, are collected and then carried away through the liquid outlet nozzle. The insides of the plates are cooled with common coolants to about -55 degrees Celsius. During the stepwise evacuation, the product gas cools down from +60 to -50 degrees Celsius.

According to AD Rules and standards, stainless steel 1.4571 can be used without any problems for temperatures down to -200 degrees, other materials, for example Hastelloy, can also be used.

The vessel of the cooling trap is also equipped with the LOB WTP-System. The WTP-System on the shell is connected to the cooling circulation and also cooled during operations. The temperature of the WTP-Vessel can be adjusted as a heater if the cooling trap has to be thawed out.

The coolant nozzles run through the upper torispherical head, and are welded to it. The body flange is located underneath the vessel support. This design allows disassembly of the shell downward without removing the coolant feed pipes. The plate package remains in the structural steelwork and can be cleaned if necessary. It is therefore unnecessary to pass the cooling pipes through gland packings and other connectors.

LOB designs the cooling traps specifically for customers and develops suitable solutions.

WTP-Cooling Trap

3.8 WTP-Hybrid Condensers

WTP-Condensers in Combination with a Tube Bundle

LOB revamped a cross-flowed U-tube head condenser in such a way that 85 % of the condensation heat could be used for the purpose of preheating the cold product flow before vaporization. The remaining residual gases can be condensed completely in a post condenser.

The entire condenser consisting of U-tube bundle and WTP-Plate condenser can be disassembled and may be taken down for cleaning. The new design does not significantly change the outer shape of the vessel. The WTP-Plates are dimensioned so that the entire condensation heat can be diverted in case the product inside the tubes stops flowing and no heat is decoupled inside the U-tube heat exchanger.

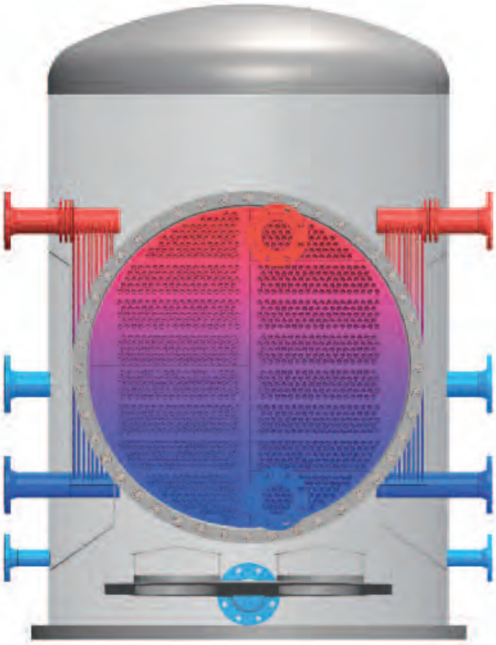
This construction is used when a complete modification of the existing head condenser to a WTP-Plate condenser is not an option because the product to be heated has a tendency to "fouling" and it is not possible to clean the expanded space inside the WTP-Plates. This is a compelling reason for using the tube bundle design in which the outer surface of the tube bundle is used to condense the product and the pre heating of the product takes place inside the U-tube bundle. The inner surfaces of the U- tubes are easy to clean. If these tubes are completely blocked, they can be closed and taken out of service with a stopper at the tubesheet.

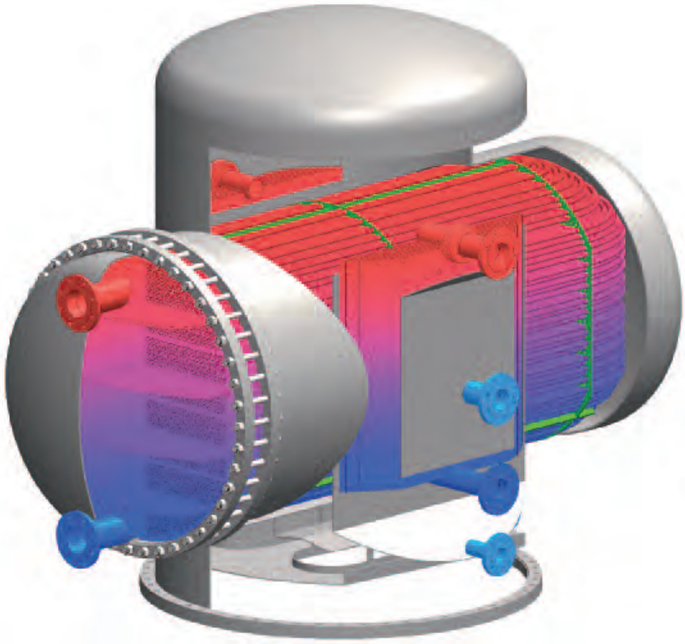
The construction consists of a combination of a cross-flowed U-tube bundle and a WTP-Plate condenser. The tube bundle serves as a reflux condenser and for the preheating of the liquid product stream inside the tubes. The WTP-Plates function as a post condenser in a co-current flow at a cold temperature. This is advantageous as the WTP-Plates have a high condensation rate while also requiring little space.

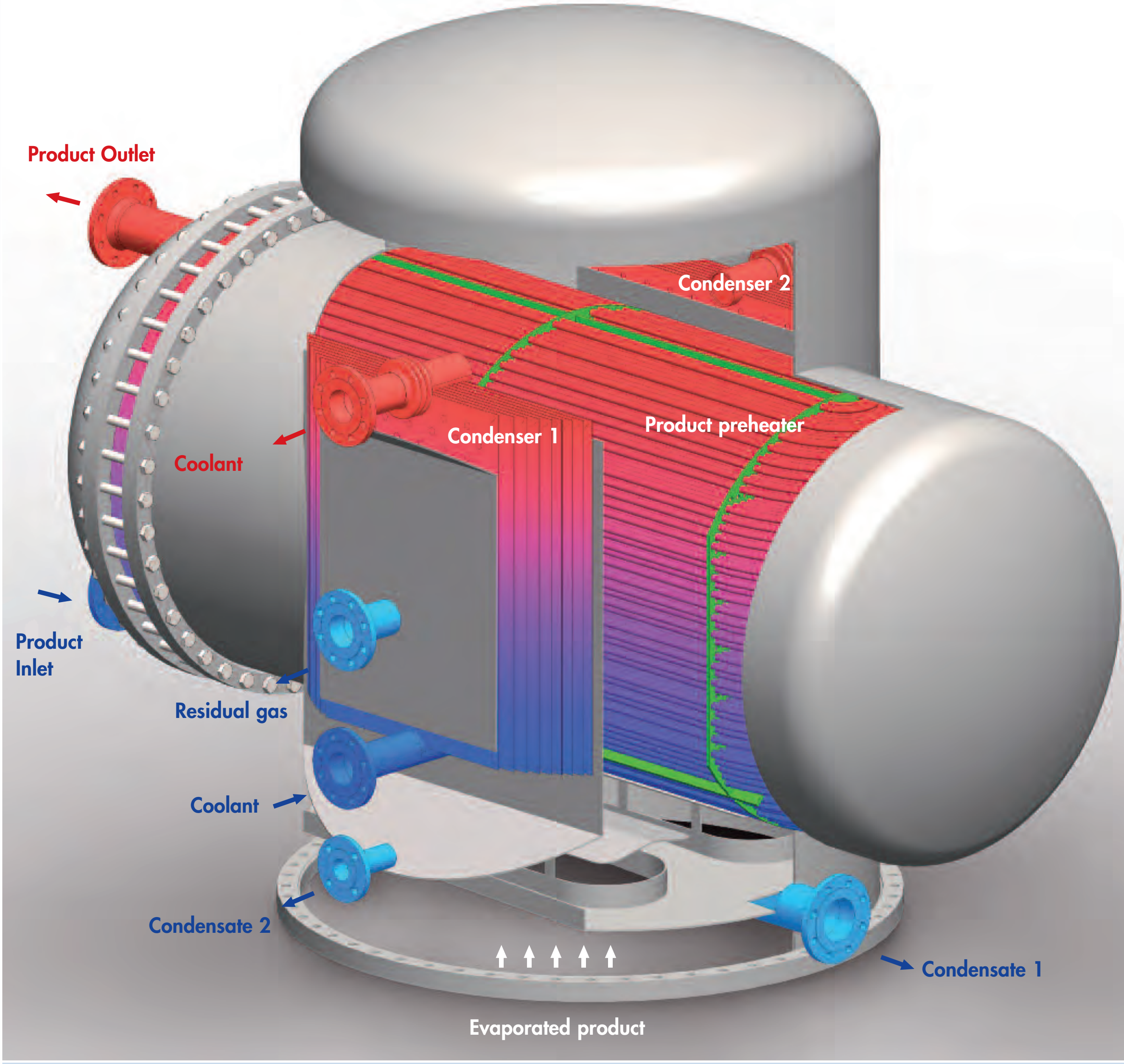
Parts of the tube bundle have to be removed on the right and left side to provide enough space for the installation of the WTP-Plate package including the cooling water inlet with compensators.

The U-tube bundle can be drawn after the torispherical head is removed. After pulling out the tube bundle, the WTP-Plate condensers on the right and left are also accessible and can be cleaned.

The plate condenser requires only marginal modification for its installation in the shell. The construction is simple, and the separation of product and cooling water circulation guarantees a safe operation. Both condensers are cleanable. The retrofitted condenser meets all requirements for heat recovery operations.







WTP-Hybrid Condenser as product preheater with utility model protection

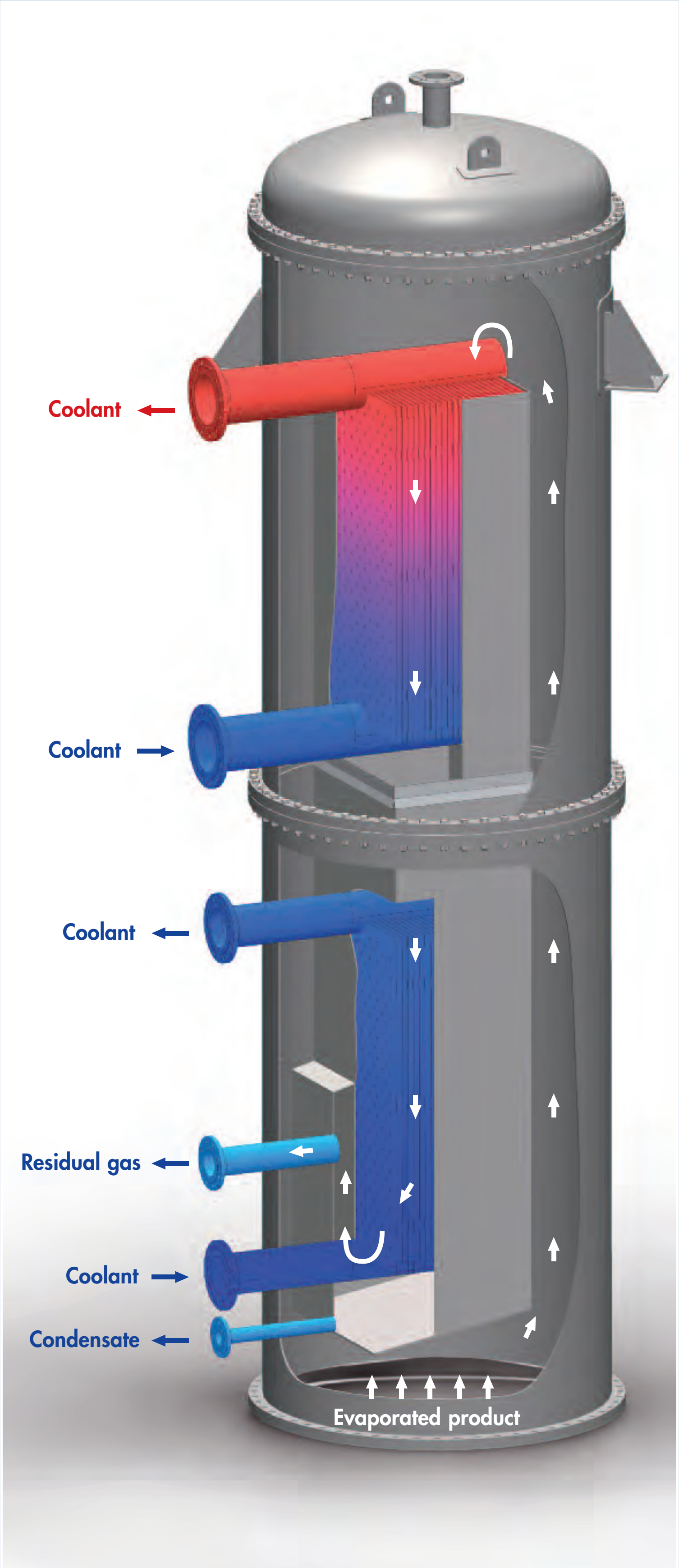
3.9 WTP-Stacked Condensers

Stacked Arrangement of Main and Post Condensers

If it is essential to keep the pressure drop at a minimum, a stacked arrangement of the main and post condenser is a solution. This has the advantage that the vapor from the main condenser does not have to be redirected to reach the post condenser. Another advantage is that the product gas is accelerated downward as a result of the gravitational force down the entire length of the fluid column, which is the length of the main and post condenser combined. This minimizes the pressure drop of the main flow.

If the temperature profile is split between main and post condenser according to the condensation curve and the temperature level is sufficiently high, the main condenser can be used for the generation of steam inside the plates.

However, it is a disadvantage that the condensate formed in the top main condenser flows as liquid into the lower post condenser together with possibly present residual gas. The liquid phase can block the condensation in the post condenser considerably. Further disadvantage may be that Supercooling of the condensate to a lower cooling temperature takes place in the post-condenser. Excessive supercooling is often energetically undesired if another processing step may require a higher temperature where the condensate has to be heated again.



WTP-Stacked Condenser

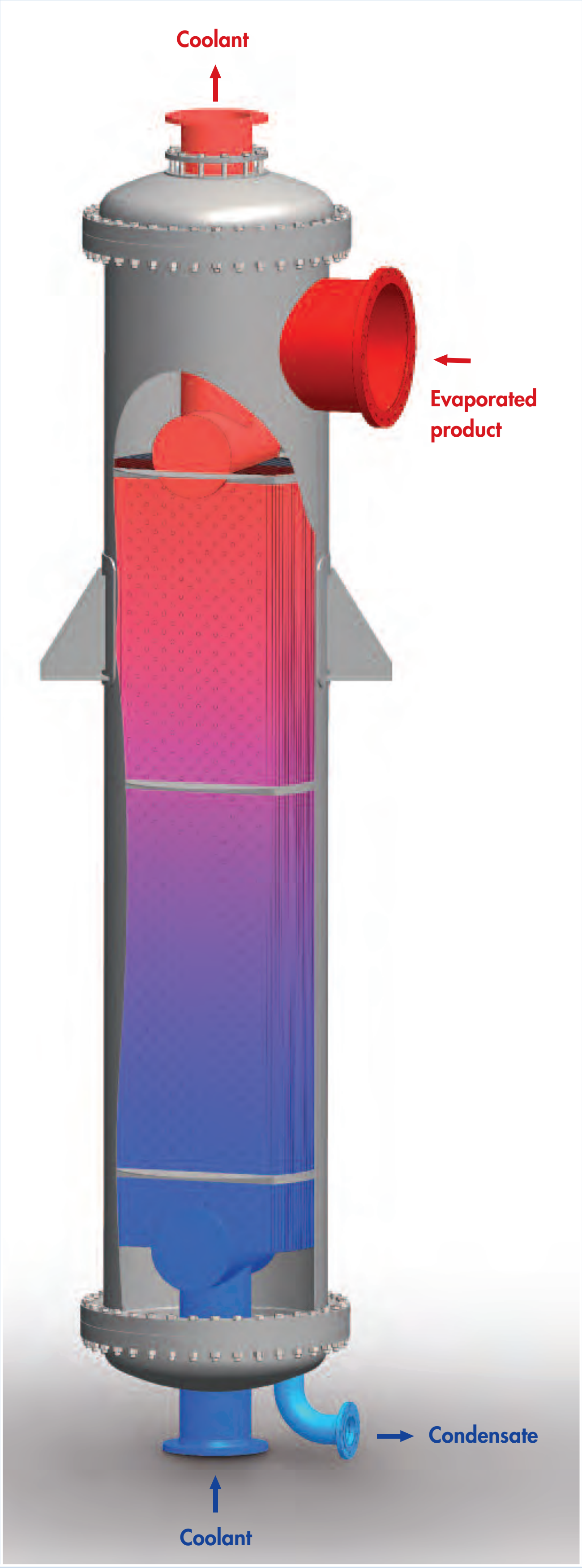
3.10 WTP-Condensers for Highly Liquid Portion

Condensation of a Two-Phase System

LOB specializes in developing customized WTP-System solutions. In this case, LOB designed a condenser for the purpose of condensing a product vapor with a high content of liquid phase completely. The plates had to be able to be removed annually for cleaning. Only little space in a shell with a diameter of 900 mm was available. At the inlet at 90 degrees Celsius, the portion of liquid condensate to vapor was about 50 %. The product vapor had to be cooled to about 38 degrees Celsius and condensed completely at this temperature.

Due to the high portion of liquid, the process calculation was heavily limited in terms of condensation. This resulted in a required condensation surface of 350 m^2 with a condenser length of more than 6 m and a narrow plate width of 750 mm with a removable plate package. Based on the vertical design and by making use of the gravitational force, the calculations showed only a small pressure drop of less than 1 mbar.

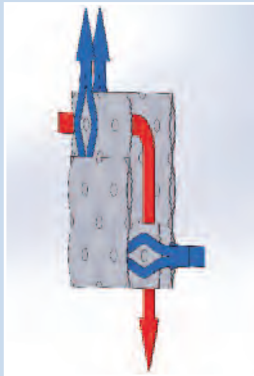
The following illustration shows the resulting construction.



WTP-Condenser with highly liquid portion

4. Gas-Gas Cross Counterflow WTP-Heat Exchanger

Chemical processes proceed often under high pressure and high temperatures. In some processes wasted heat is released (exotherm) others need energy delivered from outside (endotherm). The chemical processes are especially economical if an internal heat transfer occurs between them, in which the operating pressure will be held without greater pressure drop. Waste heat from one reaction can be used to preheat feed for another process. For this purpose usually heat exchangers were used under well-defined conditions particularly relating to the process. The heat transfer design is difficult if the heat transfer mediums on the primary and secondary side are not liquid but in a gaseous phase. Small heat transfer coefficient is the consequence. The heat flow can be raised with higher gas velocities, but results in pressure drop on both sides. Additional energy is necessary due to the use of compressors. The operational pressure may cause constructive problems if it is very high. Ordinary plate heat exchangers cannot be used.



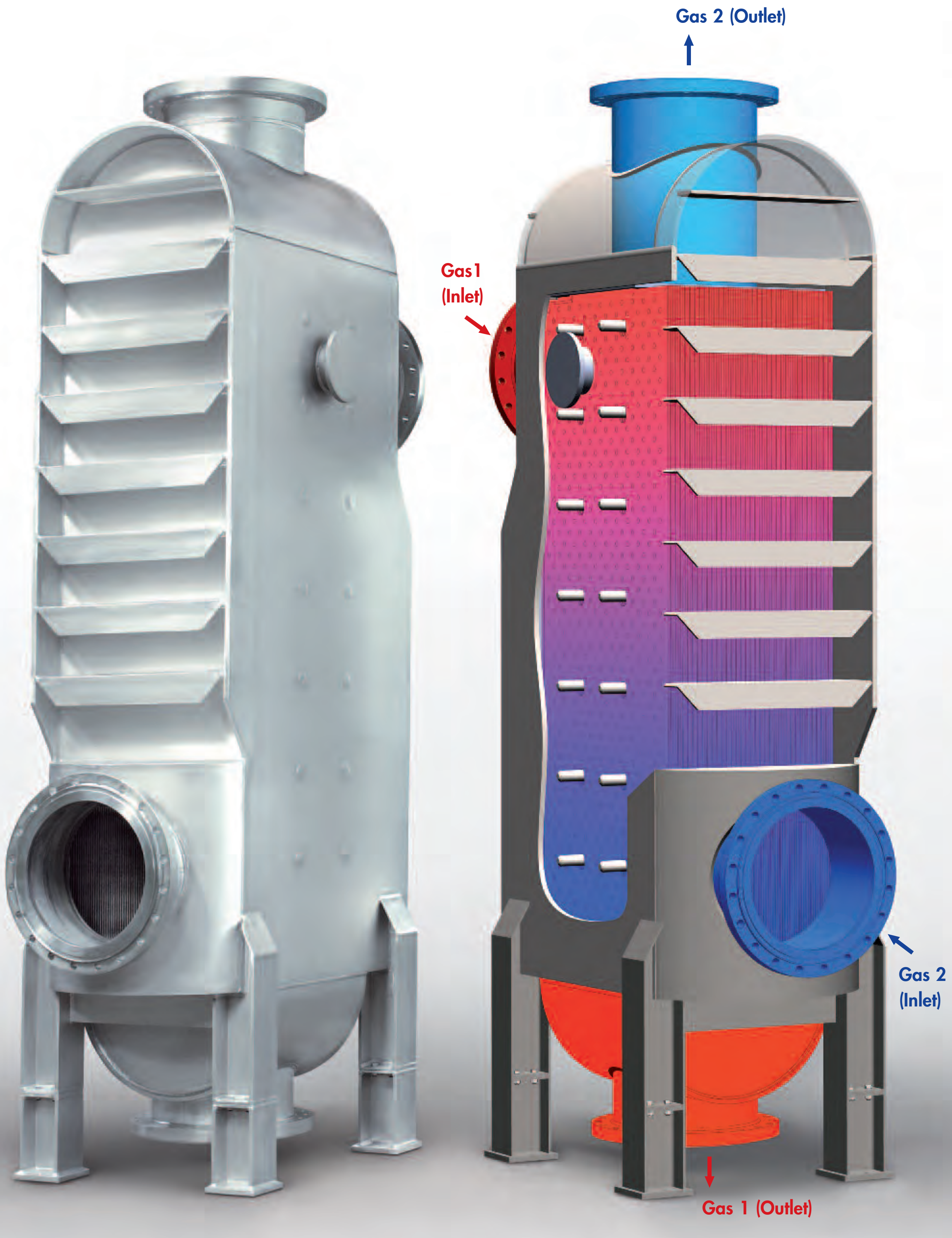
The WTP-System® based Gas-Gas Cross Counterflow Heat Exchanger developed by LOB meets all the requirements for such processes. The LOB-Gas-Gas heat exchanger was so designed that the operating pressure in the housing and the side of the WTP-Plate package can be higher than 10 bar, while keeping the wall thickness moderate. The circular welding pattern of the WTP-Plates is chosen in such a way that it can absorb the pressure inside. The pressure surrounding the WTP-Plates and on the vessel wall is absorbed by connecting anchors, which run through the plates and are welded to the other vessel wall. The light spacing between the expanded plates and the small pillow heights of the laser welded heat exchanger plates allows for a very compact design.This explains the very low weight and small dimensions.

The volume rates on the primary and secondary side are different because of the temperatures. The colder flue gas streams inside the exchanger the WTP-Plates, while the hotter gas streams between the plates. The distance between the plates and the expanded volume inside the plates is adjusted to create a balanced on the gas velocities on cold and warm sides. A specific design of gas inlet into the WTP-Plates leads to a significantly lower pressure drop than there is on a comparable tube bundle heat exchanger.

Upon start-up, or recommissioning after standstill of the heat exchanger, the entering hot gas will lead to a jump in temperature. Therefore, LOB designed the gas-gas cross counter flow heat exchanger to compensate for the heat-related stretching. This avoids the heat stresses caused by the stretching of the initially still cold housing and rapidly heated plate packages.

Nominated for the Achema Innovation Award

At the 2015 Achema, the design of the WTP gas-gas heat exchanger developed by LOB was nominated for the Achema Innovation Award. During the trade show, the LOB booth was also a destination in the official Achema Innovation tour.



Gas-Gas cross counterflow WTP-Heat Exchanger

5. Liquid-Liquid Heat Exchanger with WTP-Plates

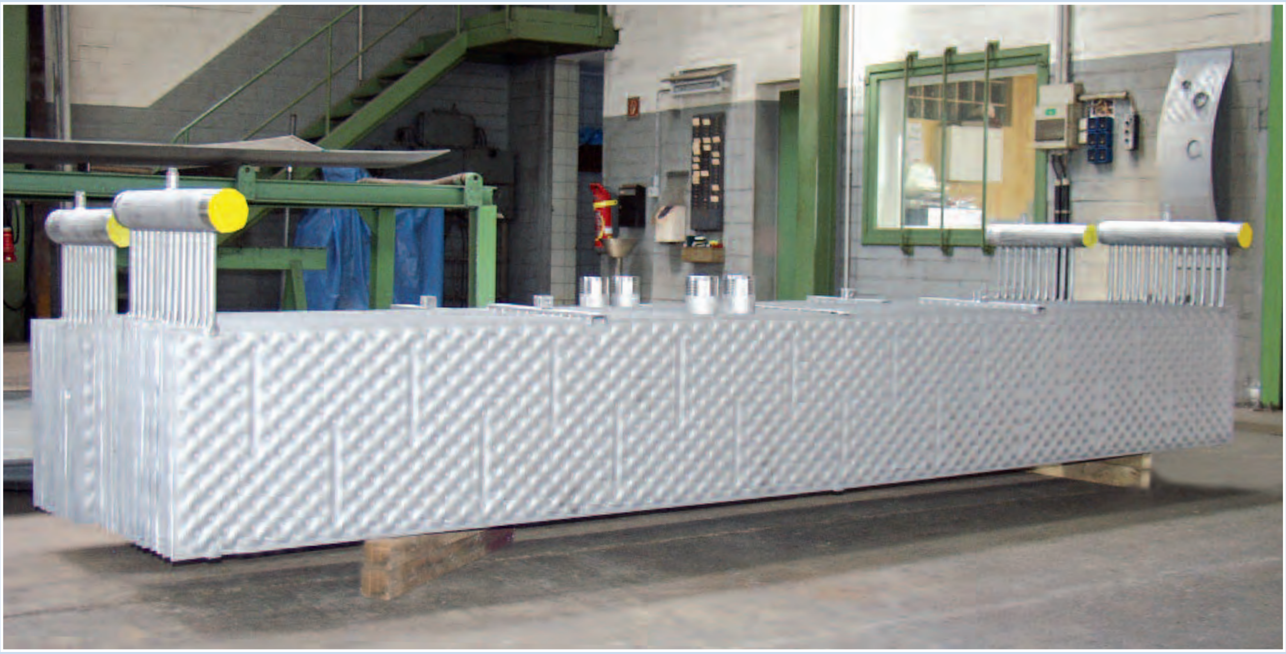
WTP-Plates are particularly suited for the heat exchange from processing water with standing or flowing water. In this process, conditioned processed water is flowing inside the expanded plates for heating or cooling purposes. The waste or river water is flowing on the outside of the plate package to prevent "fouling" inside the WTP-Plates. The movement of the flowing water over the smooth outer WTP-Plates prevents fouling. The outer shell of the plates is also accessible for cleaning with a steam blaster.

The WTP-Plate package can be directly placed in a river, a separate channel or a waste water pond. By comparison with tube bundles, vertically arranged WTP-Plates are less costly to install and to operate while the performance is equal.

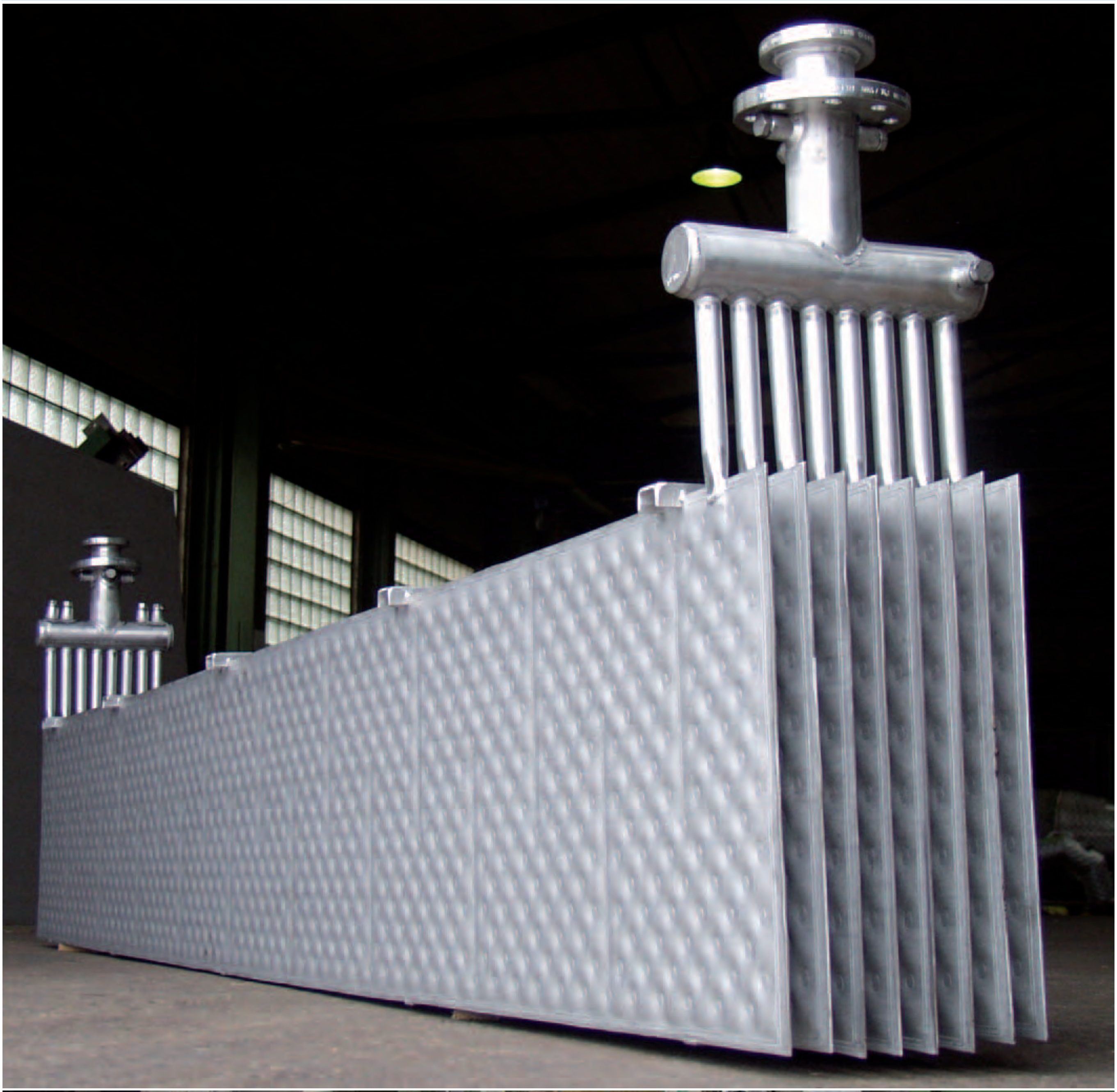
The pressure drop on the process side can be adjusted by the choice of the circular welding pattern and the high expansion of the WTP-Sheets. In comprehensive experiments, LOB studied and stored in calculation models the pressure drop inside the plates dependent on the inlet channels, the expansion distance of the plates and the amount of flowing process water. Usually, the velocity of the streaming water ranges from 0 m/s (standing water) to 1.2 m/s (moving water). In the second case, forced streaming overlies the natural convection. This created mixed convection results in higher thermal transition.

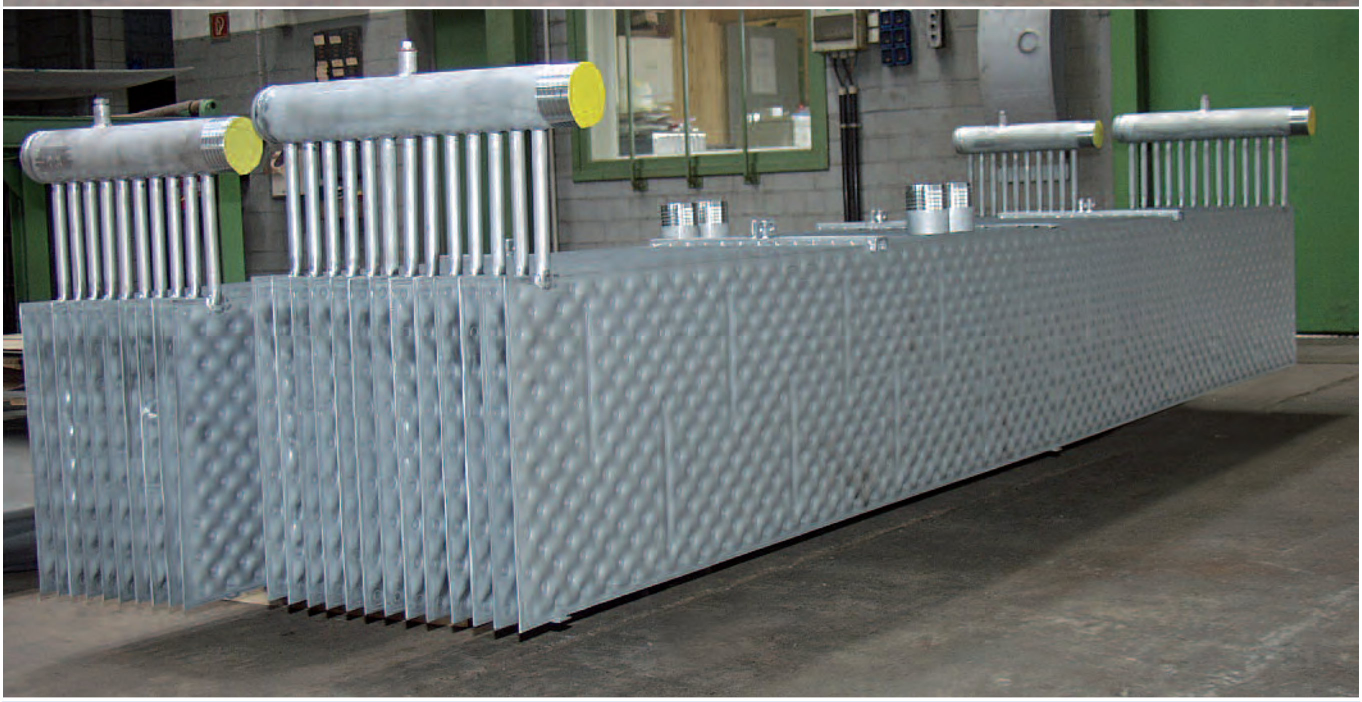
In the example used, the calculated heat output was approximately 700 kW using a streaming surface of about 35 m^2 and natural convection on the outside of the plate package. The heat transition coefficient ranges between 600 and 800 W/(m^{2}K).

Dependent on the application, the output capacity can be increased by changing the number of plates and their running length and arranging multiple plate packages in series. A distributor manifold in the form of an entire pipe, compared to the shown version, with several individual pipes, may be used for the cooling water feed. The pressure drop inside the WTP-Plates can be adjusted by changing the distance between the WTP-Plates.



Liquid-liquid heat exchanger





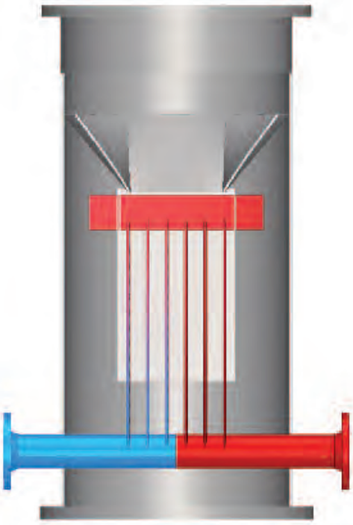
Liquid-liquid heat exchanger

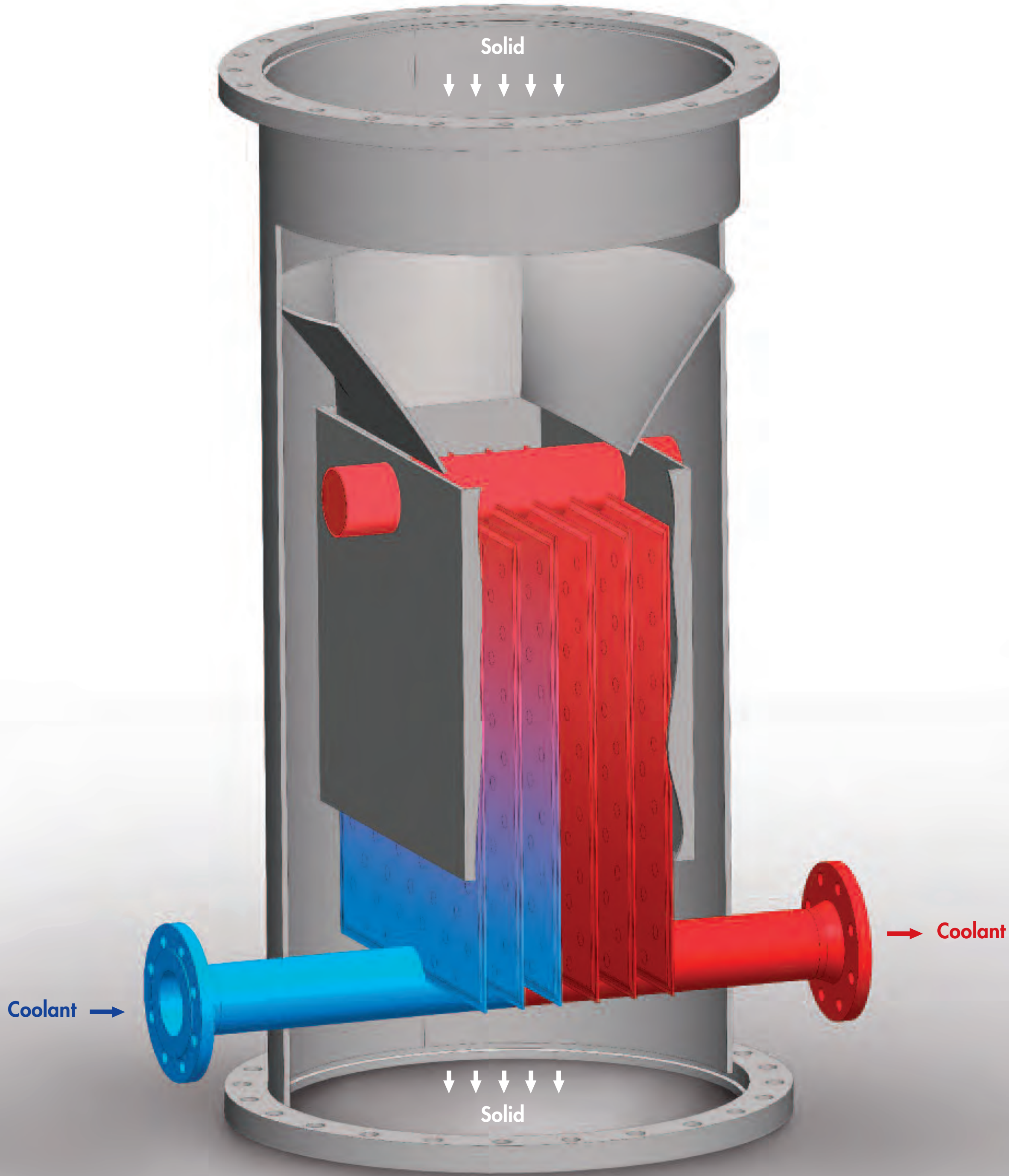
6. Cooling Solid Materials with WTP-System

We tackled the task of cooling solid matter from a temperature of 450 degrees Celsius at a pressure of 6 bar. The solid material is guided downwards between a WTP plate package. The solid material then moves down into a flange mounted vessel. The coolant is fed into a split inlet pipe, streams inside one half of the plate package upward, it is redirected and leaves the vessel through the second half. The advantages of this construction are a compact design and the installation above a collection vessel for solid materials.

The heat transfer on the solid material side depends on the characteristics of the solid material and the geometry. Assuming that the material is sphere shaped, the α-value of the solid material depends on the density, thermal conductivity and heat capacity. On the solid material side we assume an α-value of 9 W/(m²K). On the cooling water side, the heat transfer coefficient (α-value) should only be high enough to increase the thermal transition coefficient (k-value) significantly.

Solid cooler





Solid cooler

7.1 Agitator Vessel with WTP-Jacket

The LOB WTP-System® is an alternative to traditional systems such as the half-pipe coil or double jacket for use on agitator vessels. The advantages are the more effective heat transfer as well as lower cost of manufacturing.

The heat transition of agitator vessels and with it the energy efficiency depends on the heat transfer inside the vessel and on the outer wall as well as the vessels wall thickness. The heat transfer on the inside of an agitator vessel depends mostly on the type of agitator (e.g. spiral mixers or blade agitators), the revolutions per minute, vessel and agitator size as well as the data on the chemical media of the vessel content.

Usually, the heat transfer coefficient (α-value) of the inner vessel wall is within the same range as the heat transfer coefficient (α-value) inside the WTP-Shell. For the determination of the inner heat transfer coefficient we refer to the agitator manufacturers and operators of agitator vessels.

High α-values inside the WTP-System result in high pressure drops and are only of advantage if the increased heat transfer in the shell significantly increases the heat transition from the inside to the outside. This is the case when the heat transfer coefficients inside the vessel and in the WTP-System are within the same range.

In case of thermal balance, the pressure drop in the outer shell will be crucial for the efficient heating or cooling of the agitator vessel. The pressure drop in the WTP depends on the choice of the circular welding pattern and high expansion of the WTP-Sheets. The design of the inlet and outlet to the inside of the WTP and the connections of the various WTP spaces is crucial. LOB tested many designs, which resulted in patented solutions such as the ring header and 'Endless WTP'.

Traditional agitator vessels and pipe connections of complex geometries, such as support bearings or support rings and pipe inlets, are costly both in terms of design and money. By comparison, even complicated vessels geometry can be efficiently heated using the LOB WTP-System®.

WTP-Jacket

7.2 Agitator Vessel with WTP-Chilled or Heated-baffles

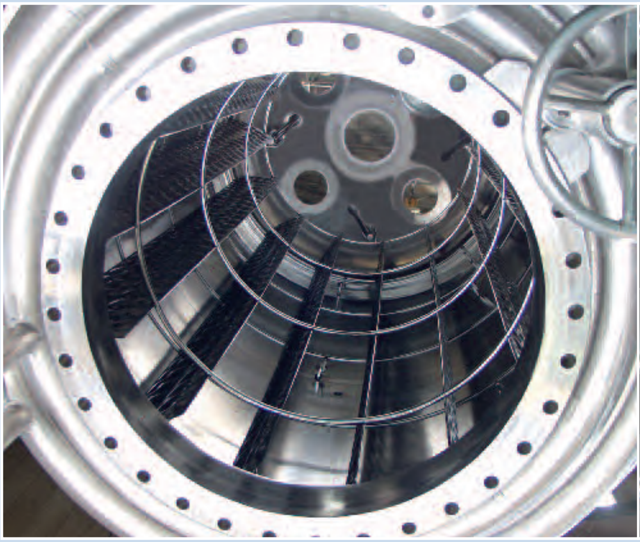
Heated and Chilled Baffles

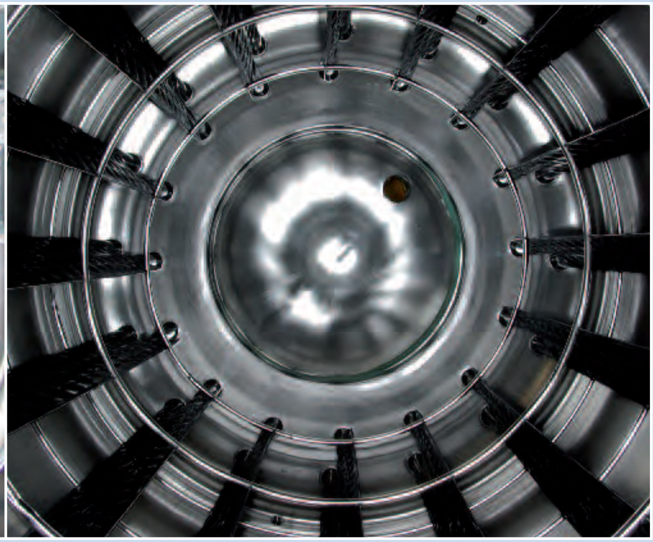
Usually, baffles are installed on the inner walls of agitator vessels to achieve homogeneous mixing. Traditionally, they consist of thick plates, which absorb the torque value of the agitator as they are sturdily attached to the inside of the vessel wall. Conventionally, coils are installed in case the agitator vessel requires heating or cooling.

WTP-Baffles meet the requirement of both the mechanical mixing and the additional heating of the product. In an agitator vessel, LOB installed 16 WTP-Baffles with an additional heating area of about 20 m^2. Via two ring pipes, these baffles are fed with coolant. Tilting the baffles in relation to the agitator rotation optimizes the heat transfer and mixing. This is a way to apply additional heat to the product. The surfaces are polished to avoid sticking of the agitated material. Round metal bars serve as distance holders for the offset mounted WTP-Baffles and also absorb the agitator torque.

Another benefit of using WTP-Baffles rather than pipe coils inside the vessel is the capability of quickly changing between heating and cooling due to the low amount of needed heat transfer media. Large amounts of coolants must be used to cool down tube coils after steam-heating to achieve nearly the same heat transfers

As a flow pattern in an agitator vessel, it is known that product rolls are formed horizontally and lengthwise to the baffles. For the heat transfer this means that the material moves in lengthwise parallel and in vertical direction when it comes into contact with the WTP-Baffles. Tube bundles expose less heat exchange surface than WTP-Baffles as there are gaps between the pipes which are not effectively passed through by the horizontal product roll.





WTP-Chilled or Heated-baffles

Chilled WTP-Baffles for agitator vessels

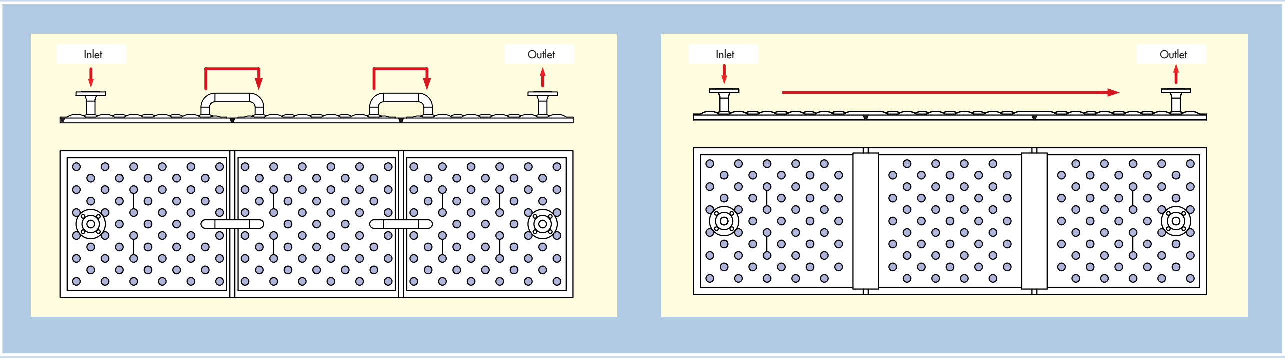
7.3 Connecting WTP-Chambers with circular pipeline and Endless WTP

Connecting WTP-Areas with nozzles or circular header

Each WTP section has an inlet and outlet nozzle for cooling water to feed the inner area. To avoid several separate feed pipelines to each WTP section normally the outlet nozzle of one WTP area is connected with the inlet nozzle of the next WTP section by tubes with several elbow pipes. So the cooling water is looped through all sections. But a lot of elbows and short tubes with small cross-sectional areas are needed, which causes high pressure drop in the WTP cooling water supply.

In some applications a very low pressure drop in the secondary cooling circuit is required. LOB developed for this purpose a so called "endless construction" after many steps of development work, flow simulation and testing, which resulted in a LOB patent.

At the upper and lower rim of a vessel with WTP-Jacket there is a circular pipe arranged as a header. For the header a slotted tube is used. The slotted inlet and outlet surface has the same contour as the inner WTP-Surface. The open sides of the WTP-Plates are welded in the circumference of the upper and lower header.



Schematic of Endless WTP

With this principle it is possible to connect WTP-Plates at the open length side/circumference so that the coolant enters and leaves the inner space via the entire cross-sectional area. The enlargements of the inlet and outlet area minimize the pressure drop significantly. Another advantage is that only two pipes are needed in order to feed and drain cooling water to and from each header.

With this technique it is also possible to connect several WTP-Plates in series as flat sheets or round shape like a WTP-Jacket. Very long WTP-Containments can be built.

Reactors for a mixing plant with Endless WTP

8. Up to 300% faster heating-up times of reactors through the WTP-System on the inside area

Some chemical processes (e.g. watery Polymeresystems) take place batchwise in agitator vessels under high pressure and multiple temperature cycling. During such reactions the temperatures need quick and exact adjustment from cooling to heating and reverse. High pressure vessels need thick shell walls. When heating or cooling from outside of the vessels heat must be conducted through these thick walls. The heat transfer can be achieved by fitting a double-shell, a half-pipe coil or a WTP-System® on the outside area of the vessel. But this is in conflict with a good heat transition.

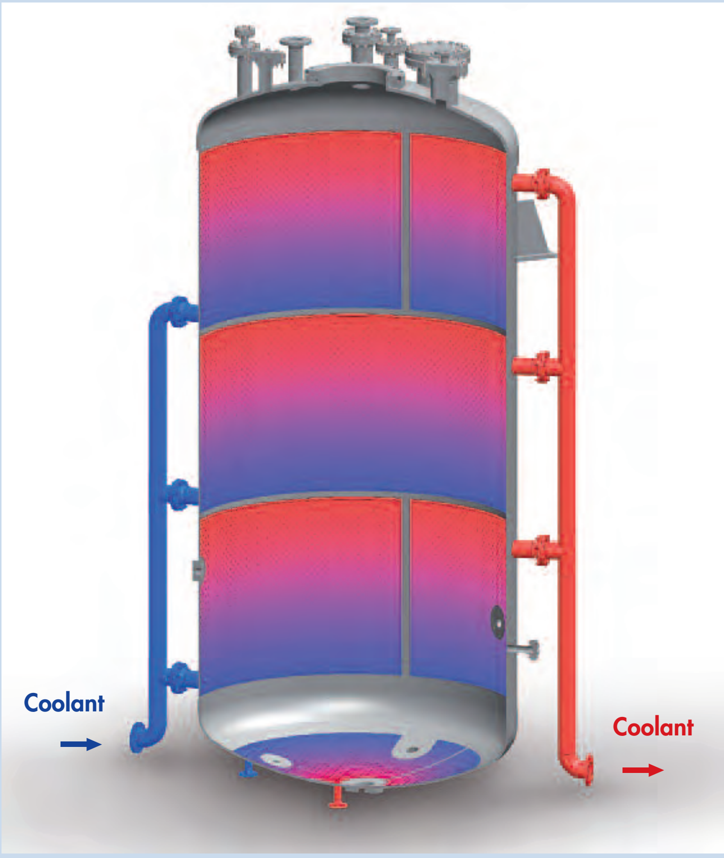
Using the WTP-System® on the inside area of the vessel the heat resistance can significantly be reduced. The heat must only be conducted through the thin WTP sheet of 1.5 to 3 mm. This improved heat conduction and the high heat transfer coefficients on the cooling side inside the WTP-System enable, in comparison to carbon steel vessels with thick walls the double amount of heat flow and to stainless steel, almost triple amount of heat flow with significant resultant reduction of the batch processing time.

Using the WTP-System® a smaller flowing volume of heat transfer medium is needed in comparison to a double jacket or half coil. This ensures that the energy for heating and cooling medium can be reduced and the pressure drop is not so high. This also influences the number of inlet and outlet nozzles required.

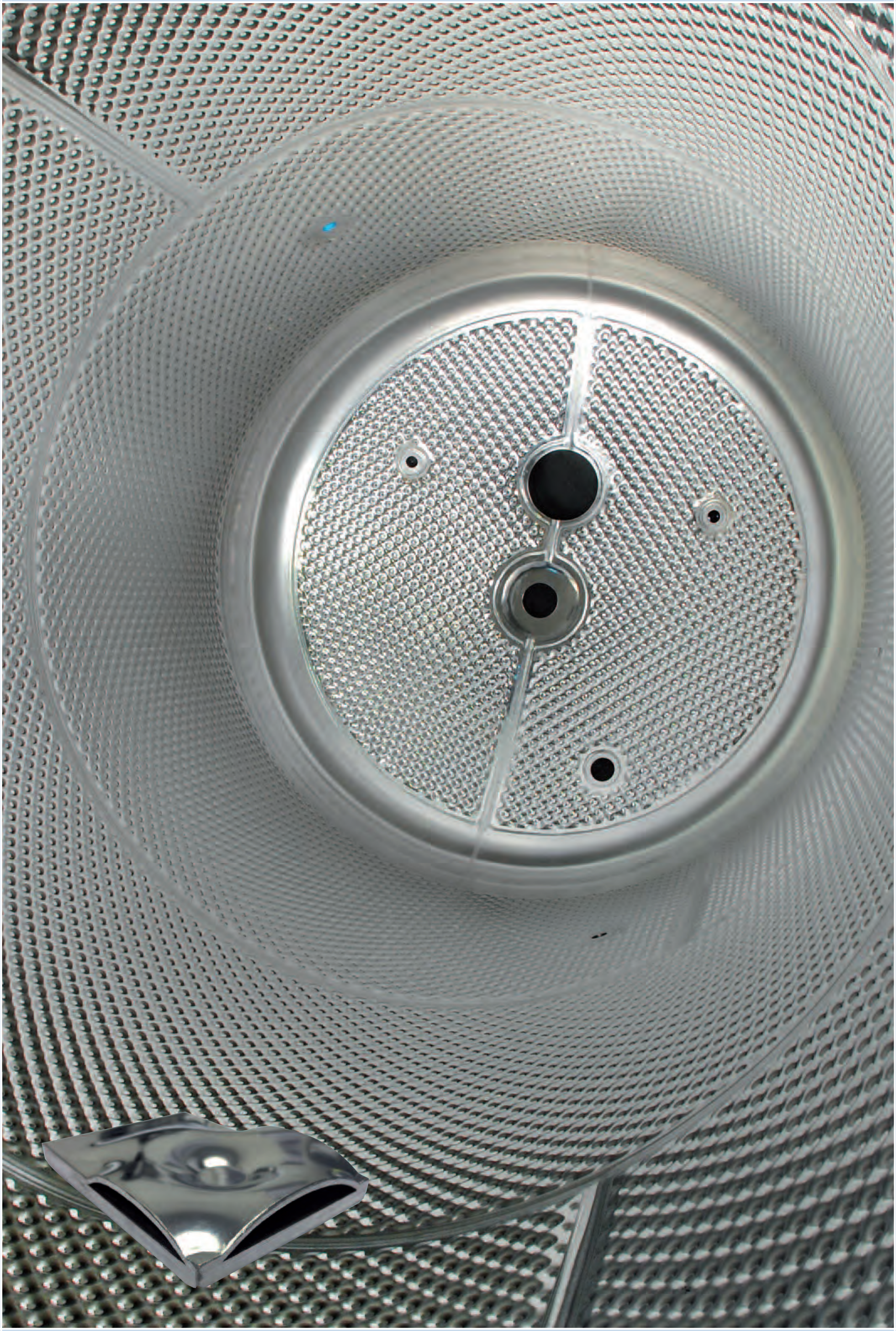
A smaller mass of the vessel with WTP-Inside (by comparison with a double shell less than 50 %) requires less energy to heat or cool the vessel itself. The temperature control characteristics are accurate and much better because the cooling/heating area is in close contact with the product.

The WTP surface can also be polished and then electropolished so that the shell can be cleaned without leaving residues during product changes.

The WTP on the inside area is extremely resilient. In case of mechanical damage, partial repairs of the inner shell are possible. With suitable circular welding patterns the pressure inside the vessel can easily be more than 10 bar. Load change experiments have shown that the WTP-System effortlessly tolerates 500.000 load changes at a pressure difference of 6 bar. Therefore, the WTP-System® is ideally suited for batch reactors with a large number of load cycles and changing pressures. Still, just as in all other systems, it is important to avoid abrupt temperature changes between cooling and heating processes.



Agitator vessel with WTP-System on the inside area



WTP-System on the inside area

9. Clamping Plates with WTP-System

Offering a solution to make existing containers more efficient

WTP-Clamping plates have the purpose of retrofitting existing vessels and storage vessels. They are also used as a heating system for fittings and pipes. Clamping plates consist of a 3 to 5 mm strong lower sheet and a 1.5 mm upper sheet. Depending on the outer shape of the existing vessel or tanks, the WTP-Clamping plates are equipped with cutouts for nozzles and brackets. With the help of connecting links the individual segments are then installed as half-shells at the outside of the existing vessel. WTP-Clamping plates for small equipment are available for hazardous 'Ex' zones providing hot water is available.

Clamping plates are particularly suitable for storage tanks when heat is dissipated through convection from their outer wall. This heat depends on the velocity of the air blowing on the tank and the temperature difference between the tank content and the outside. For example, the heat transfer is 3 to 10 W/(m²K). Clamping plates can balance the heat radiation. Inside the tank it is possible to assume the heat transfer coefficient about 100 W/(m²K) or constant wall temperature providing the containments content does not move. Generally, heat transition coefficient values between 80 and 180 W/(m²K) can be achieved between tank content and the WTP-Clamping plates. In most cases, this is sufficient to keep the tanks content warm or for slow heating.

WTP-Mounting part heating DN 80

WTP-Clamping plates

WTP-Clamping plates

WTP-Cone heating

WTP-Heating of a vessel bottom

Heat conducting cement can be filled into the gap between outer vessel jacket and the clamping plates. This leads to an improved heat transfer as the poor heat-conducting air gap is removed. This heat conducting cement has a heat conductivity of about 100 W/(m²K). Using clamping plates with steam heating is not sensible because the heat conducting cement breaks down at high temperature.

WTP-Clamping plates
WTP-Pipeline, ø 300 mm, for cooling gases from 1,500 °C

10.1 WTP-System® vs. Double Jacket

A Technology Comparison Based on Comprehensive Experiments

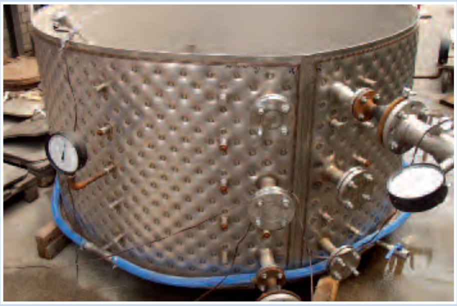
20 years ago, LOB started testing pressure drop and the heat transfer for a test vessel and a plate. Here is a simple summary of the result:

The heat transfer in the WTP-System is by far better than in the classic double-jacket and requires less coolant circulation with less energy consumption.

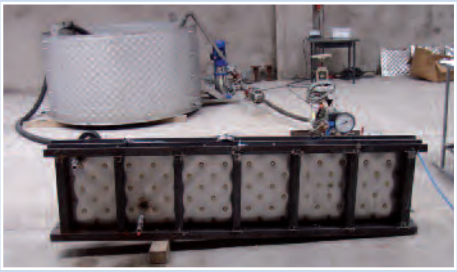
The test object was a vessel with a diameter of 1,900 mm and a height of 1,000 mm. The circular welding pattern was 95 mm x 85 mm, and the inner expansion had 3.4 mm. Using this vessel, the pressure drops dependent on the flow volume was measured. The results allowed for the development of generalized models, which enables LOB to calculate the pressure drops and heat transfer in WTP-Plates.

However, an analogy to the fluid mechanics and heat transfer in tube bundles is difficult because a WTP-Plate has more degrees of freedom than a tube or tube bundle. For WTP-Plates the circular welding pattern and the inner expansion distance can be adjusted while only the diameter of the pipes can be changed. In addition, the WTP-Plates characteristics can be adjusted to individual requirements.

The first step of the experiments was to determine the inner WTP-Plates volume. This was necessary to be able to calculate the different volumes at different inner expansion distances and circular welding patterns. A series of pressure drop measurements with and without flow redirection resulted in generally applicable pressure drop coefficients. The vessel was then used to perform agitation experiments to determine the heat transfer coefficients and the heating times. This provided the data to compare the flows, heat transfers and heating times for the double wall, the WTP-Vessel heating and the half-pipe coil.



Test vessel for pressure drop and heat transfer measurements



Experimental set-up of the WTP-Plate for pressure drop measurement

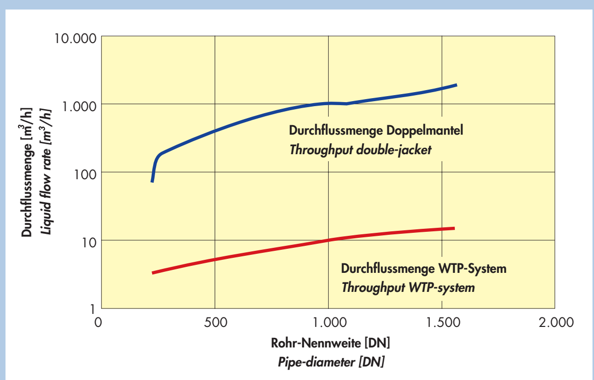
Results of an Experiment Series

In an experiment, we compared the required circulation rates for the double jacket and the WTP-System in order to achieve identical heat transfer coefficients. For various different nominal sizes, a constant flow speed of 1.2 m/s in the double shell was used.

The Result: To achieve the same heat transfer coefficients as in a double-shell, the flow speed in the WTP -System is reduced from 0.84 m/s at DN 250 mm to 0.52 m/s at DN 1500 mm. Furthermore the required energy of the pump was compared at a pressure of 2.5 bar and 8,000 operating hours. This gave us the following values:

- Double jacket (DN 250) 431.600 kWh
- Double jacket (DN 1500) 13.873.000 kWh

- WTP-System (DN 250) 27.800 kWh
- WTP-System (DN 1500) 98.650 kWh

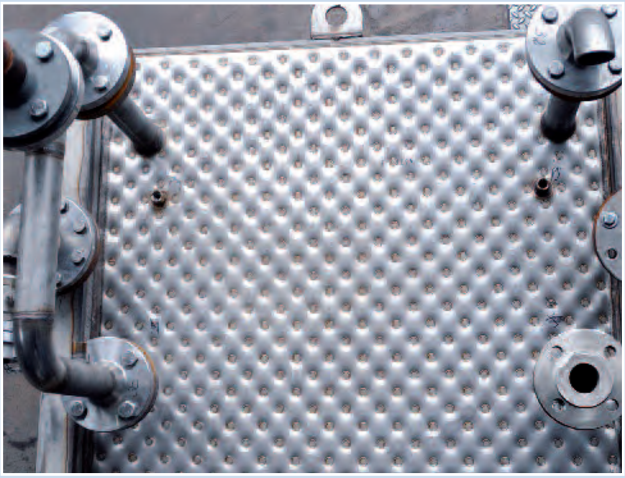


Compare flow rates Double Jacket versus WTP-System

The experiments showed that at the same flow speed the WTP-System achieved a more than 30 % higher heat transfer coefficient. This means, at the same flow speed, the user is able to reduce the amount of heating or cooling medium by 91 %. If the user wants to achieve the same heat transfer coefficients, he is able to use 93.5 % less heating or cooling medium. The user needs only 6.5 % of the original amount of medium. Since the pump performance is directly proportional to the amount of circulated medium, this will increase the energy efficiency of the process significantly.

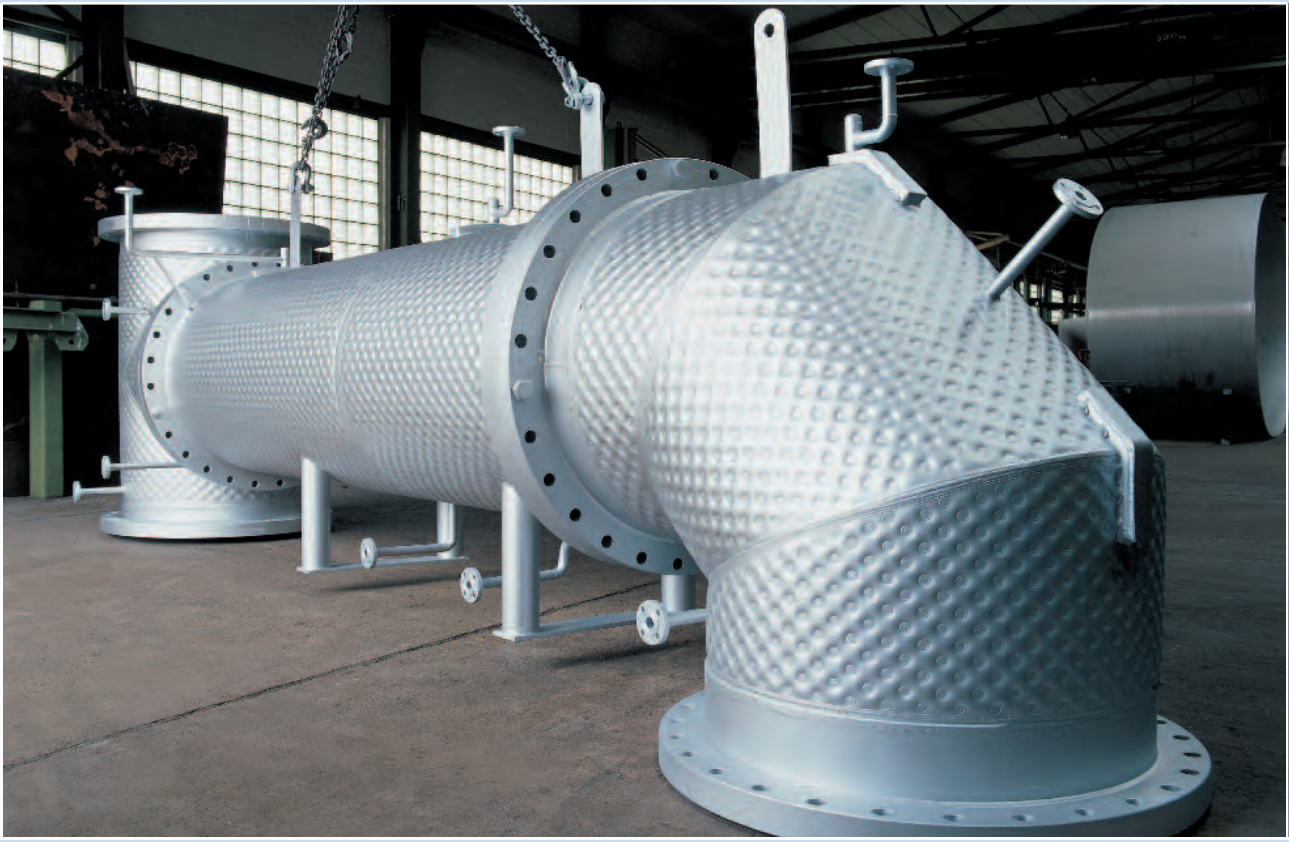
LOB performs measurements to characterize a WTP-Plate with a distributor and two inlet and outlet nozzles. With a constant circular welding pattern, LOB measured the pressure at the inlet and outlet nozzles in dependent on the amount of water. These measurements are carried out with changing inner expanding space from 2 to 4 mm with 0.5 mm distances.

The improved methods allow it to calculate the pressure losses in WTP-Plates and vessels with different weld patterns, running length as well as inlet and outlet nozzle. The measurements were done in collaboration with the Fachhochschule Köln (University of Applied Sciences, Cologne, Germany).



Test plate for pressure drop measurement with different inlet and outlet nozzles

LOB also offers the service of measuring the pressure drop in the manufactured WTP-Plates or vessels before delivery in order to determine the actual pressure drop during operations. If necessary, the pressure drop may be adjusted by expanding the WTP-Sheets farther apart.



WTP-Pipeline, ø 1,000 mm, steam 18 bar

10.2 Condenser with Integrated Steam Generation inside the Plate

Results of a Comprehensive Test Series

During condensation the prior induced vaporization energy will be re-released. The energy balance of a process will be more efficient when this vaporization energy is used at a high heating steam level for other steps in the process rather than simply removing this energy at low temperatures with the cooling water. Steam generation is a viable option if the condensation temperature of the product used is above the boiling temperature for water.

The heat recovery is particularly cost-effective using a thermosiphon vaporizer, which is integrated in the WTP-Head Condenser, does not use any pump and is located in the same housing as the head condenser. In a thermosiphon vaporizer, the water circulates without pump by natural convection based on nucleation.

Incoming heat from condensation overheats the water on the inner side of the vaporizer or in case of plate-based vaporizers the inside of the WTP-Plates, which leads to the formation of boiling bubbles. These bubbles rise up and create buoyancy in the mixture of water and steam, which is crucial for the natural circulation. The steam is separated from the still liquid water in the steam collector at the top of the plates. The water is returned to the vaporizer at the lower end of the vaporizer.

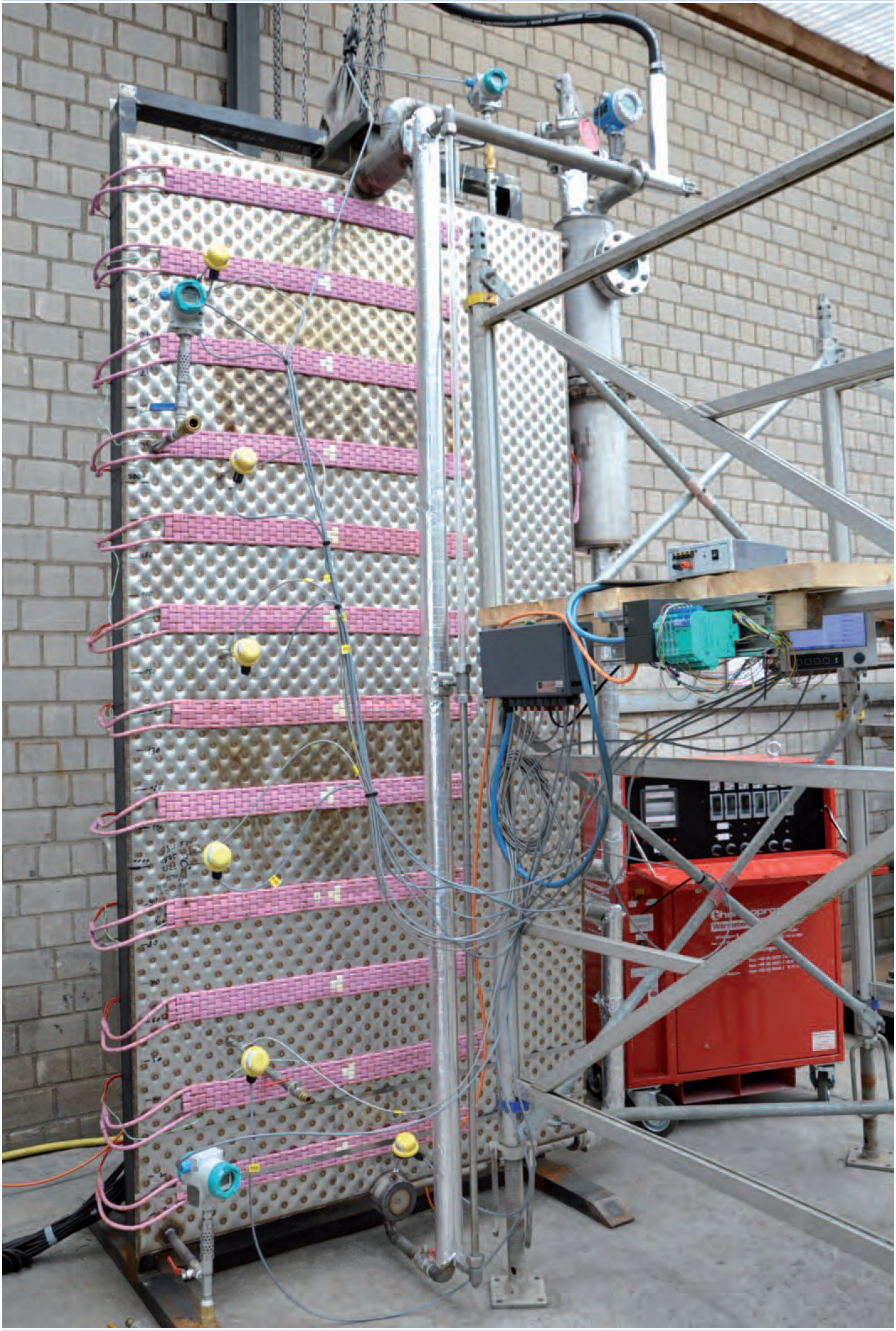
The Test System

For the existence of a density difference on the steam generation side a minimal temperature difference between the condensation temperature and the saturated steam temperature must exist. In collaboration with the Fachhochschule Köln (University of Applied Sciences, Cologne, Germany) LOB examined the operating behavior and design data of a WTP-Plate type condenser with natural circulation vaporizer and measured the circulation rate as well as the amount of steam dependent on the operating pressure and temperature. One of the objectives was to show whether the steam generation would cause vibrations in the plates.

LOB attached heating elements to the outside of a 1.5 m x 3.0 m WTP-Plate to simulate condensation heat. This plate size allows the simulation of operating conditions as they occur in large chemical industrial operations. The return flow from the natural circulation is returned to the plate via a distributor pipe from the bottom. At the top end of the plate, the generated steam-water mixture is passed through a steam collector into a separator. The generated steam is released into the open air and the separated water is returned to the plate via the bottom. If the condensation temperature ranges between 7 and 10 degrees C above the planned steam generation temperature, then the condensation process is suitable for the residual heat recovery using a thermosiphon vaporizer.

The experiments confirm that the thermosiphon vaporizer can be run stably with a minimal temperature difference. No vibrations occur in the plate as a result of the bubble formation. The circulation rate is within the desired range. The test system provides valuable information for the construction and operations. The gained information goes into the planning and cannot be obtained during operations on-site by the customer.

The experimental results are reflected in the LOB construction and design programs. As a result, LOB has manufactured and delivered various condensers with integrated steam generators in the main condenser. The condensation surfaces ranged between 80 m^2 and 300 m^2. All condensers passed the customers performance tests.



Experimental set-up of a WTP-Plate in cooperation with the Cologne University of Applied Sciences

10.3 WTP-Plate Condenser compared to Tube Bundle

A Comprehensive Test Series as InnovA² Research Project

The flow pattern and heat transfer around tubes or tube bundles are well known. The relevant commercial computer programs are state-of-the-art. Tuble bundle condensers need heavy and costly tubesheets between cooling water and product. By comparison, in WTP-Condensers, the cooling medium is safely run inside the plates.

In the course of the InnovA² research project, LOB and Bayer-Technologie-Services compared the efficiencies of WTP-Plate condensers and tube bundle condensers. At the Technikum Leverkusen (Germany) a WTP-Condenser consisting of six plates and a comparable tube bundle with a surface area of 10 m² was installed into an existing column with a diameter of 0.6 m and a height of about 2 m in such a way, that the condensers could be run mutually.

Due to the possibility for mutual operation, it was possible to measure and compare the output for both operating modes side-by-side. One other objective was to find out how well the experimental results overlapped with those of the LOB calculation program for WTP-Plates.

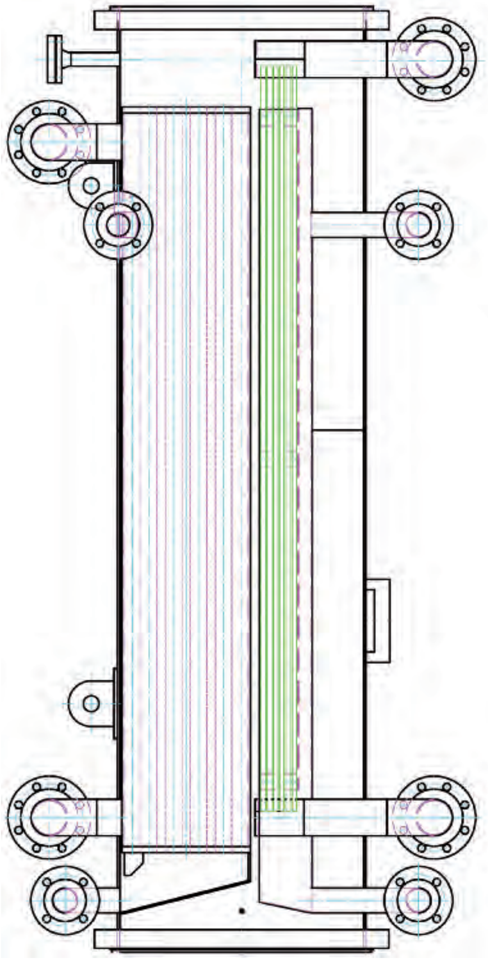
Test Procedure

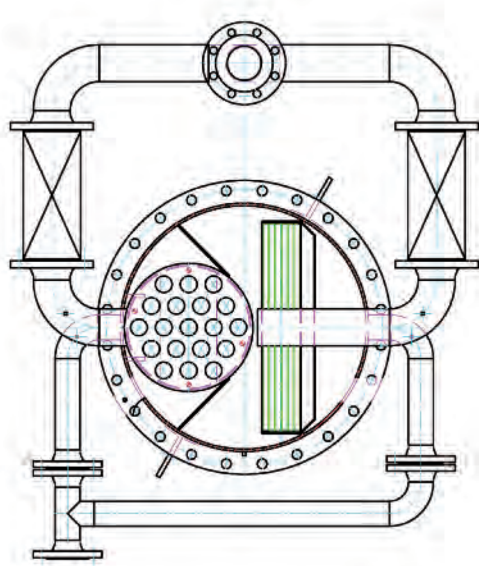
The product condenses outside between the plates or inside the pipes. In both cases, vapor and condensate streams in co-current flow from top to bottom. Technical chlorobenzene was used at 800 and 200 mbar with and without nitrogen as inert gas additive. Nitrogen gas up to 8.9 kg/h was added. The system was operated at a heat transfer rate of up to 320 kW. Scaling up from this value is suitable for big equipment. Thanks to new fiber optics technology, it was possible to measure the temperature profile over the condensation length of the product space of both the plate and the tubes.

The following results were recorded: Compared to the tube bundle condenser the WTP-Plate condenser outperforms by about 25 to 35 % under these specific conditions. Compact plate design condensers may weigh 50 % less than tube design condensers. The Results from the condensation experiments for the comparison between plate and tube bundle condensers confirm the accuracy of the calculation model developed by LOB and show that this model is also well suited for other applications.

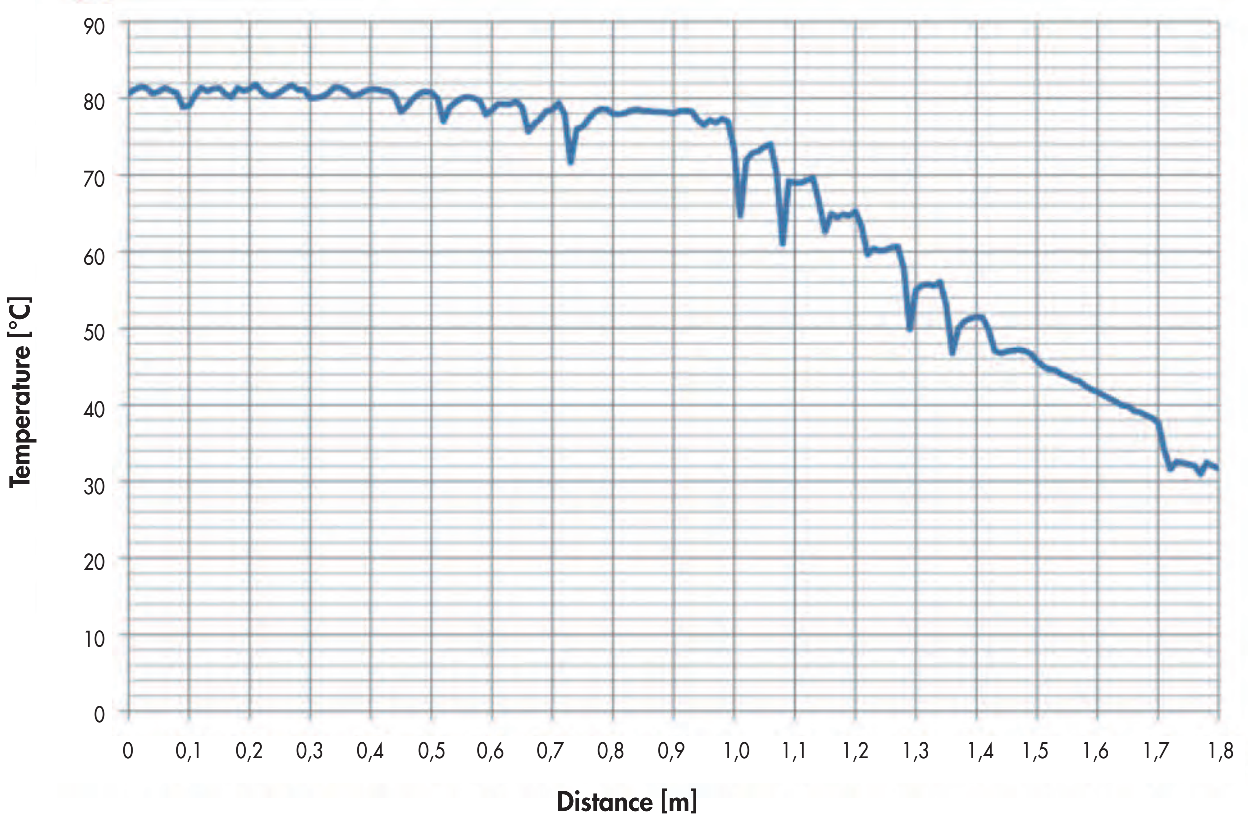
Column head with integrated plate and tube bundle condenser

Top view of the plate and tube bundle condenser





Design of the column head with integrated plate and tube bundle condenser and its piping



Typical temperature profile of chlorobenzene measured over the plate length at 200 mbar(a)

11. LOB Design Programs

Computer Programs for the Process Engineering of WTP-Plates

LOB developed the following computer programs for the process engineering of WTP-Plates and confirmed their accuracy in the actual operation of equipment. Process engineering for the following applications can be done:

1. **Condensers**
   - Includes the design of the plate geometry, the heat transfer, the pressure loss between plates, the cooling water range, installation in the column, the design of reflux condensers with flooding limit
2. **Thermosiphon Vaporizer in Condenser Plates**
   - Designing of condensers with natural circulation steam generation inside the WTP-Plates
3. **Falling Film Evaporator**
   - Plate geometry design with irrigation density and vaporizer capacity; includes a fluid distributor
4. **Heat Exchanger**
   - Designing of gas-gas, liquid-liquid and liquid-gas heat exchangers in WTP-Plate design; includes heat transfer and pressure drop calculations
5. **Waste Water Cooler**
   - Design of waste water coolers with natural convection and flow pattern at the WTP-Plates
6. **Cooling Trap**
   - Design and calculation of cooling traps with WTP-Plates
7. **Pressure Drop Calculation**
   - Calculation of pressure drops in WTP-Systems with various expanding space widths and different inlet nozzles
8. **Comparison of Half-Pipe coils and WTP-Plates on the Outside of Vessels**
   - Comparison of the heat transfer and pressure drops in systems with half-pipe coils and WTP-Plates
9. **Heat Transfer for Agitator Vessels**
   - Calculation of the heat transfer and pressure drop for agitator vessels
10. **High-Pressure Vessels with WTP-Inside**
    - Design of high-pressure vessels with inside WTP-System and heat transfer
11. **Solid Material Cooler, Heat Transfer**
    - Calculation of the heat transfer data and design of solid material coolers
12. **Vapor Pressure Calculation for Storage Tanks**
    - Vapor design of storage tanks with various liquid content
13. **Heat Recovery from Flares (Thermal Conduction, Convection)**
    - Heat recovery from flares including thermal radiation and convection
14. **Radiation Losses at Storage Tanks**
    - Radiation losses from storage tanks during summer and winter operations; compensation through use of clamping plates
15. **Tube Bundle Heat Exchangers**
    - Design of conventional tube bundle heat exchangers
16. **Additional Services**
    - Pressure drop measurements of the cooling system performed on manufactured equipment; possibility to adapt existing systems by changing the distances between expanded space inside the WTP-Plates (condensers, agitator vessels, gearbox housings and plates)

ENGINEERING & APPARATEBAU

WTP-Pipeline

Certificates and approvals

- HP0 certification
- License according to AD 2000
- License according to DIN EN 13445
- Welding license according to DIN EN ISO 3834-2
- DIN EN 1090 EXC2
- ASME U certification
- License according to TRBF 181
- Specialised business in accordance wit WHG
- Test mark for double floors in storage containers
- QM-system according to DIN EN ISO 9001
- Pressure vessel regulation 2014/68/EU: Modul A2
- National Board certification

DIN EN ISO 9001:2000	TÜV CERT **HP0**	**EN 1090**	**ASME U-Stamp**

Material overview

LOB processes all popular steel qualities according to DIN EN 10025/10028 as well as anti-rust and non-ferritic austenitic steel qualities. One of our focuses is the processing of nickel-based materials or titanium.

For a complete overview of the materials used please refer to our website **www.lob-gmbh.de**. Here you find lists sorted by material number, DIN identifier or AISI-, ASTM- and UNS-Types.

LOB

ENGINEERING & APPARATEBAU

LOB GmbH

Porzer Straße 1-5 · D-51107 Köln, Germany

Tel.: +49/221/82953-0 · Fax: +49/221/82953-40

E-Mail: info@lob-gmbh.de · www.lob-gmbh.de