PLATULAR ALL-WELDED PLATE HEAT EXCHANGERS

By D. MARTIN

Barriquand Echangeurs SNC, Soumagne, Belgium

Abstract

Technological evolution in welding processes, together with an increasing demand for compact heat exchangers combining efficiency and flexibility, has led to the development over 25 years of all-welded plate heat exchangers called platular heaters. This paper gives the background to the introduction of the all-welded plate heat exchangers into sugar factories in recent years.

Introduction

The heat exchange coefficients of a plate and gasket heat exchanger are among the highest, the pressure and temperature limits are rather low. Tubular heat exchangers are particularly adapted for high pressure and temperature but give lower thermal performance. The platular heat exchanger was therefore designed to combine the most important advantages of traditional heat exchangers, to increase scope and solve specific problems occurring in the following applications: liquid/liquid, liquid/gas and gas/gas exchanges, condensation and evaporation.

Construction of platular heat exchangers

Construction has been aimed at developing a 'custom-built' solution, based on a wide set of totally independent parameters:

Type of channels (with their own thermal, hydraulic and geometrical properties)

Channels with contact points

The basic plate pack is built up with rectangular channels, therefore one side of the heat exchange area must be able to withstand full pressure without support from the adjacent plate, i.e. it should be 'self-pressure resistant' to achieve the mechanical strength of each unit.

Four channels have been developed as shown in Figure 1.

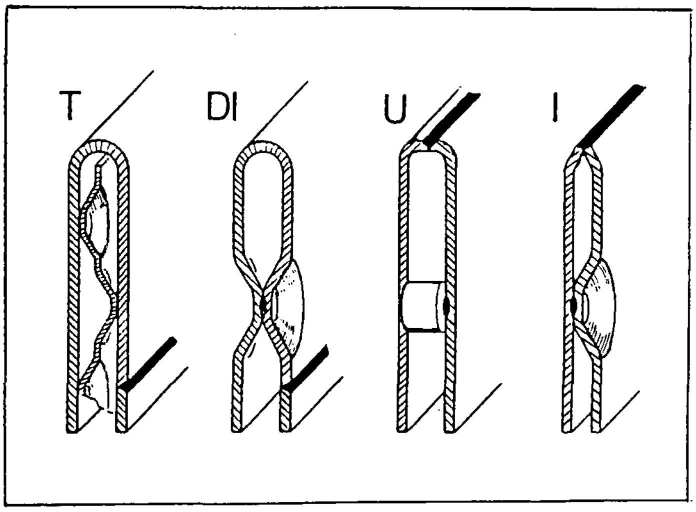

FIGURE 1 Channels T, DI, U, I with contact points.

Rectangular channel with turbulator (type T). This consists of a folded plate, longitudinally welded, through which is inserted a turbulator having the two basic functions of ensuring mechanical resistance and creating considerable turbulence-generating exchange coefficients similar to those found in the plate exchangers. Use of the channel for exchange with gas, viscous fluids or air proves to be advantageous.

Rectangular channel (type I). This consists of a flat plate and a stamped plate being assembled by spot welding. The channel thus formed is perfectly self-pressure resistant.

Rectangular channel (type DI). This consists of an assembly of two plates stamped together by spot welding. Spacing of the resulting channel amounts to twice that of channel type I.

Rectangular channel (type U). This consists of two flat plates assembled by the use of studs welded on both sides to form a pressure resistant channel. The spacing can be larger, making cleaning operations easier.

Channels B without contact points

These are completely clear channels as shown in Figure 2.

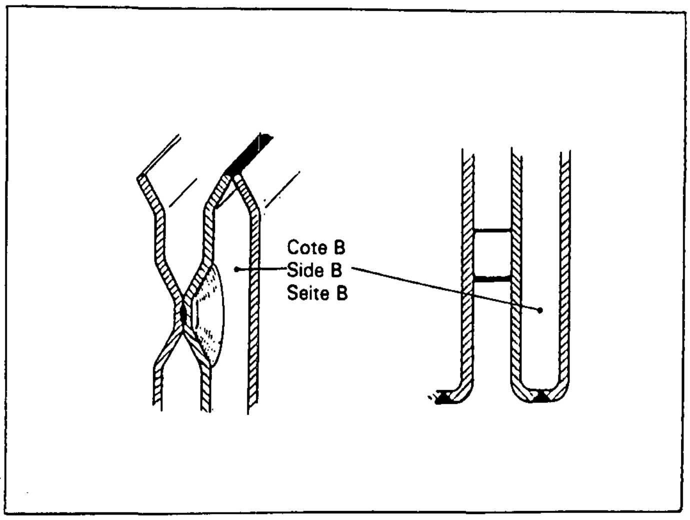

FIGURE 2 Channels B, without contact points.

The circuit of the exchanger for the other medium is achieved by folding and longitudinal welding, permitting a channel design without any contact points (free flowing channel). In consequence, dirty or fibrous media can be handled under low pressure drop, but with a high heat transfer coefficient, owing to high media velocities. The spacing of this channel is completely independent from that making up the first circuit of the exchanger, and offers an optimal solution from a hydraulic point of view, even when there is a considerable difference in flow rate.

Configuration of fluid flow in the unit

Counter-current, co-current, cross-flow, multipass on both circuits with an asymmetrical number of channels for each fluid, or a mixture of all these types are possible.

Thermally, the heat exchange ratios necessary for designing platular exchangers are similar to those used for tubular exchangers. However, a simple geometrical comparison between rectangular channel and pipe will show the advantages of rectangular channel. In a pipe, flow must be turbulent enough to create radial migration of the fluid particles, whereas in a rectangular channel all the particles of fluid take part in the exchange of heat.

Mathematically, a comparison of channels of different geometrical shape better shows the importance of the geometry compared with the hydraulic diameter (d_h).

$$d_h = \frac{4S}{P_m} = \frac{4(H.e)}{2(H+e)}$$

$$\approx 2e \text{ (if H is >>e)}$$

Here S is the cross-sectional area, and P_m the wetted perimeter. H and e are defined in Figure 3.

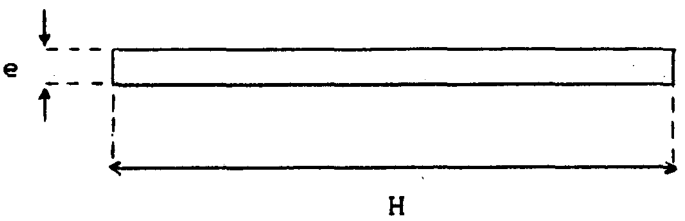

FIGURE 3 Cross-section of a platular channel.

Comparison between some geometrical shapes of heat exchange channels

The hydraulic diameter of the flow channel depends on its geometry.

Table 1

Values of hydraulic diameter, d_h, for some geometrical shapes

Channel section, mm		S (mm^2)	P_m (mm)	d_h (mm)
Tube of diameter	20	314	62,8	20
Square	17,7 × 17,7	314	70,8	17,7
Rectangular	31,4 × 10	314	82,8	15,2
Rectangular	157 × 2	314	318	3,95

The aim of rectangular channels is to decrease the hydraulic diameter as much as possible compared with a shell and tube heat exchanger with an identical cross section. In order to increase heat exchange coefficients, the designer can vary only hydraulic diameter and/or velocity. Velocity cannot be increased too much because of the resulting pressure drop. Heat transfer coefficient (h) on the juice side is derived from the Sieder and Tate equation:

$$h = \frac{k}{d_n} Nu$$

$$Nu = 0{,}028 \, Re^{0,8} \, Pr^{0,33} \, \frac{(Nu)^{0,14}}{(Nu_w)}$$

Therefore h = function $[v^{0,8}, d_h^{-0,2}]$

where e = thermal conductivity of the juice
v = velocity
Re = Reynolds No.
Nu = Nusselt No.
Pr = Prandtl No.

Therefore, h increases if velocity increases and/or d_h decreases.

Constructionally, the spacing for each channel is completely independent and can be individually optimised. In consequence, duties subject to large flow rate differences can be easily solved by independently optimising the flow velocity on each circuit according to the permissible pressure drop. The dimensions, height and length of the channel can also be chosen according to thermal programme flow rates and possible maintenance requirements.

Type of shells — access to the circuits

Much work has gone into providing quick and complete access to the heat transfer channels. Four general solutions are available, each offering a large number of dimensional possibilities.

Construction completely welded on both circuits: This type of apparatus is used when the fluids are of high temperature, when they are clean, when they can chemically attack the gaskets or when cleaning in place is possible. The construction is cheapest and is particularly suited to chemical applications.

Construction mechanically cleanable on Side B — completely welded on Side A: Access to the exchange channels (without contact points, i.e. free flowing channels) is immediate after opening the hinged doors located at each end of the unit. To reduce the maintenance operations for cleaning as much as possible, hinged doors should be mounted free from piping and flanges. Maintenance is easy and timesaving.

The use of self-pressure resistant rectangular channels with contact points on the completely welded side allows the presence of different fluids in separate circuits and under different temperatures and pressures. This means several media (three, four or five) can be accommodated in one unit, achieving different duties in different steps, such as cooling and pre-cooling for example. If requested, partial access can also be provided on side A by the use of flanges on collectors instead of completely welded partition boxes. Applications in sugar factories are numerous; for example, condensation of vapour (from multi-effect evaporation systems): several vapours are condensed together in one unit but in totally separated circuits, by heating juice before evaporation.

Construction mechanically cleanable on both sides: This design, with a maximum of four cheap flat gaskets, offers very important advantages for maintenance and avoids stocking of costly spare parts. Furthermore, a really effective mechanical cleaning can be carried out on both sides of the heat exchange area without excessive dismantling operations.

Special constructions: Platular flexibility also permits the design of equipment with special geometrical shapes; for example, column-head condensers located directly on a distillation column which eliminates the need for large vapour piping and make it possible to extract the plate pack from the whole body.

Examples of platular exchangers in sugar factories

Pan vapour/raw juice heater

The unit shown in Figure 4 has replaced a barometric condenser. Performance details are given in Table 2. The very large quantity of steam (28 ton/h) required a large steam inlet diameter (1 100 mm). Pressure drop restrictions on the steam side were severe and, due to the presence of a large volume of incondensibles, an appropriate outlet pipe was installed in order to extract the incondensibles from the unit.

Table 2

Details of pan vapour/raw juice heater

Platular heat exchanger — **Type: UXASP**
Material: AISI 304L — **Surface: 738 m²**

Duty: 18 280 kW	Hot side	Cold side
Fluid	Pan vapour	Raw juice
Flowrate (m³/h)	27 952 kg/h	896,29
Temperature inlet/outlet (°C)	62,5/62,5	34/52
Service pressure (kPa) (Abs)	23	500
Pressure drop (kPa)	0,15	80
Spacing (mm)	7	10
Juice velocity (m/s)	—	1,6

Heat exchange co-efficient of the duty: 1 400 W/m²°C

Table 3

Details of condensate/raw juice heater

Platular heat exchanger — **Type: DIXASP**
Material: AISI 304L — **Surface: 362 m²**

Duty: 2 424 kW	Hot side	Cold side
Fluid	Condensate	Raw juice
Flowrate (m³/h)	294,4	708,9
Temperature inlet/outlet (°C)	62/54,8	52/55
Service pressure (kPa) (Abs)	800	800
Pressure drop (kPa)	50	60
Spacing (mm)	8	10
Juice velocity (m/s)	—	1,4

Heat exchange co-efficient of the duty: 1 460 W/m²°C

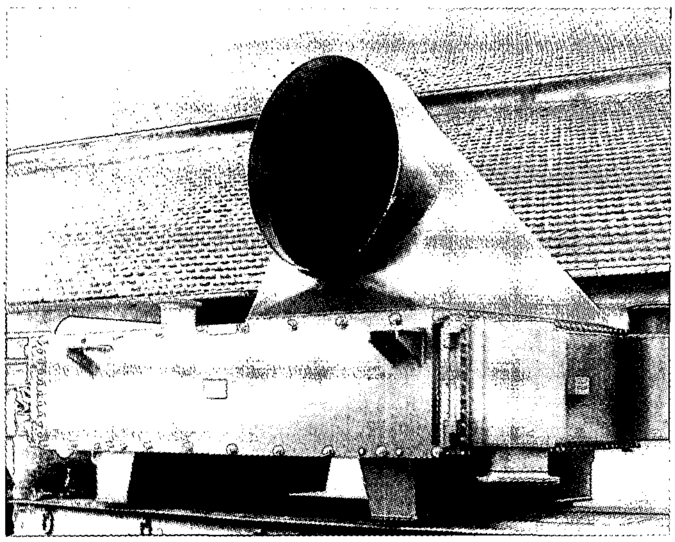

FIGURE 4 Raw juice heating by condensing pan vapour.

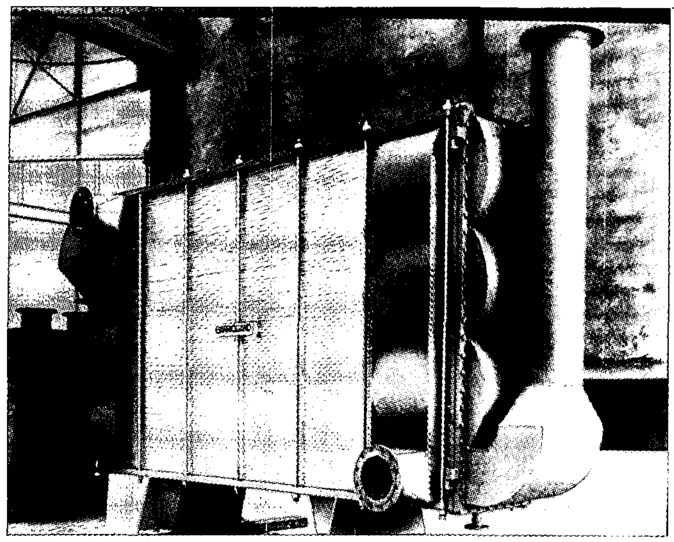

FIGURE 5 Raw juice heating with condensate.

This last pipe was connected to a vacuum pump. The area installed (738 m²) gives an excellent area/volume ratio. For this duty, the only alternative was a shell and tube unit. Decisive advantages of the platular exchanger were:

- high heat exchange co-efficients even with incondensibles
- very low volume on the juice side reducing the time needed for chemical cleaning
- longer operation time due to high velocity on the juice side
- ready access to the channels, allowing easy mechanical cleaning after the campaign
- excellent relationship between juice velocity and pressure drop.

The length of the channels is approximately 4 000 mm. This gives minimum direction changes and consequently reduces the pressure drop, allowing a general design under high velocity and minimum pressure drop. For this unit, six passes of 21 channels each were necessary. This means a total length of 24 metres and a resulting pressure drop of 80 kPa.

Condensates/raw juice heater

Performance details of this heater are given in Table 3, and an illustration is provided in Figure 5. Competitors in this case are exclusively shell and tube, due to expected fouling on the raw juice side. Because of unequal flow rates and very low log mean temperature differences (LMTD), a shell and tube design was very difficult to optimise. Independent spacing values for each medium in the platular design allow an optimised calculation and consequently the high coefficient generated permits an economical design under very low LMTD.

Two step juice heaters

These condensers are heating 836 m³/h clear juice from 90 to 128,5°C, by condensing four vapour streams in only two units. Details are given in Table 4, and Figure 6 shows a view of the unit.

The competitors in this case were shell and tube or plate and gasket heat exchangers.

Heat exchange coefficients are very high (2 900 W/m²°C) due to the non-fouling state of clear juice, which flows through the unit at a velocity of 1,8 m/s.

Advantages of the platular design are:

- **Compactness:** Four units are required under shell and tube design, with rather low coefficients, and thus a larger heat exchange area. Due to the high flow rate, parallel design was requested for plate and gasket heat exchangers, which meant more connection pipes and more units.
- **Easy cleaning operations:** Cleaning operations with a plate and gasket are very difficult due to the large number of plates to be handled. Prices of spare parts (gaskets) are also prohibitive.
- **Approach temperatures:** A very close temperature approach can be achieved due to high heat exchange coefficients generated by the platular design.

Table 4

Details of two stage juice heaters

Duty: condensing four vapours from a multiple effect evaporation system to heat juice before evaporation

First unit

Duty: 15 776 kW : 7 416 kW	Fluid 1		Fluid 2
	3rd effect	4th effect	
	Steam	Steam	Juice
Flowrate (m³/h)	25,475 kg/h	12,104 kg/h	836
Temperature inlet/outlet (°C)	111,6	120	90/115
Service pressure (kPa) (Abs)	250	300	700
Pressure drop (kPa)	3,5	2,8	80
Spacing (mm)	8	8	7

Second unit

Duty: 6 496 kW : 6 051 kW	Fluid 1		Fluid 2
	2nd effect	1st effect	
	Steam	Steam	Juice
Flowrate (m³/h)	10,693 kg/h	10,052 kg/h	890
Temperature inlet/outlet (°C)	126,4	133	115/128.5
Service pressure (kPa) (Abs)	34,0	400	700
Pressure drop (kPa)	3,5	2,8	80
Spacing (mm)	8	8	6

For similar reasons, the platular design is used for duties such as heating of limed juice, with steam or condensates. The main advantage is in simplification of cleaning operations, which are not necessary during the compaign.

Conclusions

During the past decade, shell and tube heat exchangers have been progressively replaced with all-welded plate heat exchangers or plate and gasket exchangers.

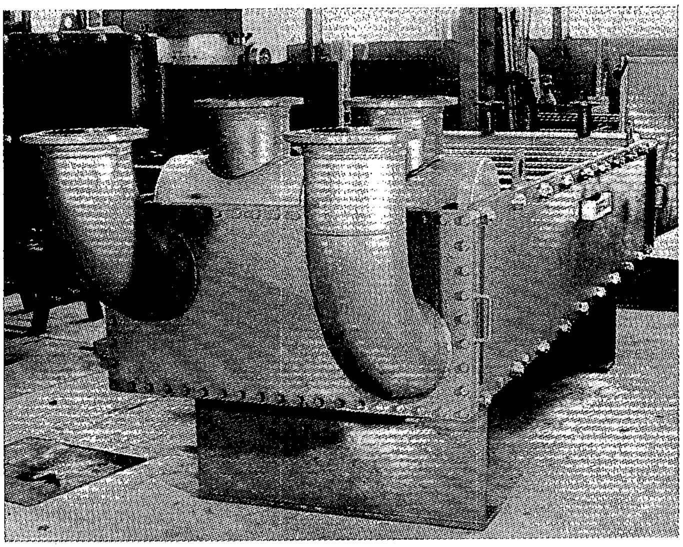

FIGURE 6 Heating of clear juice using 2 vapour steams from multiple effect evaporator.

Plate and gasket exchangers should be reserved for duties handling low fouling fluids where their choice is appropriate, provided the stocks of spare parts can be reduced.

All-welded plate heat exchangers have been used in beet sugar factories for traditional applications handling fouling fluids such as: raw juice/condensates, raw juice/pan vapour, raw juice/steam, limed juice/condensates, limed juice/steam, steam/juice before evaporation (multiple fluids application) and press water/condensates. Some special applications include water/vapour from carbonations system, limed juice/raw juice, and prelimed juice/pan vapour.

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