



# DESCRIZIONE E TEORIA

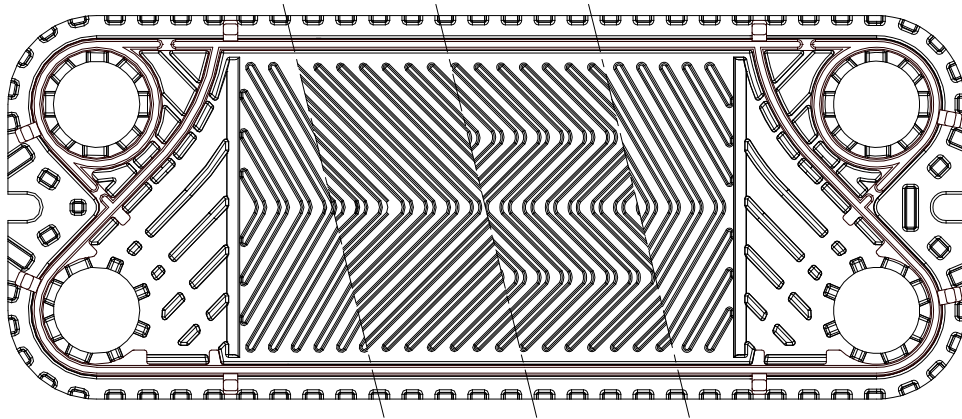
DESCRIPTION AND THEORY

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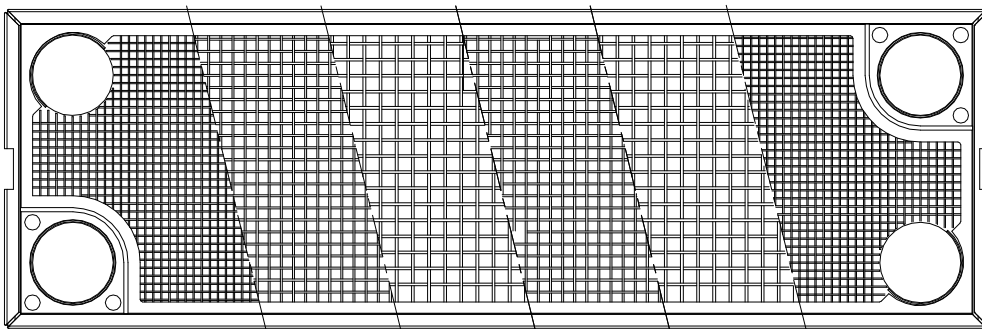
## GENERAL INFORMATION

With respect to other types of heat exchangers, the plate heat exchangers have unique characteristics. They differ from the shell and tube, spiral, coil, blade, etc. types above all because they are the only extensible exchangers. That is, they are so constructed as to permit increasing or decreasing the exchange power even after the system has been installed and for whatever reason, while guaranteeing continued perfect operation of the system. As is only logical, selection of the type of heat exchanger will depend on a great number of factors. The most important are undoubtedly the physical nature of the fluids, temperature and pressure, flow rates, pressure drops, tendency to fouling, construction materials in relation to required performance, ease of maintenance, and cost. Only naturally, the final assessment for selection will always be made by comparing the overall costs of the different types of exchangers that are suitable for resolving a given technical problem. Problems of selection can arise even among heat exchangers of the same type (we will deal with plate-type heat exchangers in particular). Clearly, the factors to be considered are those mentioned above, and the differences among the products of the various manufacturers are often considerable. In some cases, however, comparison points up only differences in price. Although all plate heat exchangers are manufactured and assembled in more or less the same manner, they do fall into two broad categories. One type has corrugated exchanger plates with various surface patterns, manufactured by pressing, and rubber gaskets, glued or clipped directly on the plates.



*Fig. 1 (Corrugated TECHNO SYSTEM plate)*

The other type, instead, features smooth plates, mechanically-secured and easy-to-replace rubber gaskets, and wire net turbulators laid over the plates and secured by housings on the gaskets (see Figure 4). This is the type of exchanger designed, perfected, and patented by TECHNO SYSTEM S.R.L.



*Fig. 2 (TECHNO SYSTEM's smooth plate with turbulator)*

The TECHNO SYSTEM offer therefore consists of heat exchangers with smooth plates and corrugated plates and thus can provide the ideal solution for any type of thermal exchange problem.

## FIELDS OF APPLICATION

Plate heat exchangers can be used in an enormous variety of applications, since they offer compactness, high efficiency, easy maintenance, the possibility to create complex circuit designs, and, last but not least, increasingly competitive costs. Therefore, this type of heat exchanger is increasingly used frequently in district heating, energy recovery, refrigeration, chemical, pharmaceutical, and food processing systems, and in civil engineering. The original construction solutions developed by TECHNO SYSTEM through years of experience in the sector have further expanded the field of application of plate heat exchangers by offering increased resistance to differential and absolute pressures - although there remains the limit determined by the admissible operating temperatures for the rubber gaskets (see Fig. 8 e Fig. 9).

## MATERIALS AND PED (2014/68/EU) NORMATIVE

Following the entry into force of the Pressure Equipment Directive (PED), TECHNO SYSTEM immediately decided, in line with a policy in act for some time, to certify the quality and compliance with the Directive of all the models of heat exchangers it produced.

For the company, this meant completing the procedure for obtaining certification of the internal Quality System and at the same time earning Module H PED certification.

Accurate revision of design and construction for all the heat exchangers involved redefinition and consequent improvement of all the relevant safety and quality parameters through use of only materials with excellent mechanical characteristics, such as P355 NH (EN 10028) for the large plates and A 193 B7 (ASTM) for the clamping bolts.

## THE PLATE HEAT EXCHANGER – OPERATION

The essential components of any plate heat exchanger (see Fig. 3) are the frame and the plates.

- A) The frame is made up of two large plates (one fixed and one movable) and a system of clamping bolts that holds the exchanger plates together in a single pack. Since it must withstand considerable weights and pressures, the frame is generally quite robust. Correct tightening of the clamping bolts compresses the gaskets and assures perfect seal in the exchanger.

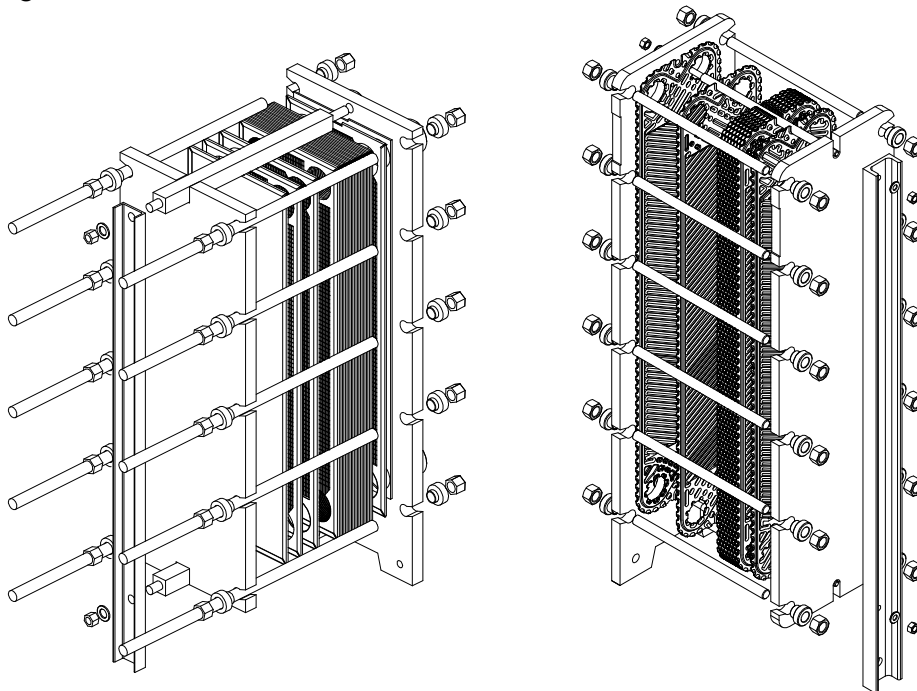


Fig. 3 (Assembling of a TECHNO SYSTEM plate heat exchanger)

Insofar as possible, the exchanger connection nozzles (which may be of various types) are located on the fixed plate in order to facilitate maintenance operations, but as we will see, this is not always feasible. The two plate alignment (or guide) rods, other essential components of the heat exchanger, often also act as supports for the plates.

- B) It is understood that the plates are the most important parts of a heat exchanger. As we have already mentioned, they can be manufactured in a variety of different geometries and incorporate different construction features (see Fig. 1, Fig. 2 and Fig. 5). Drawing on its years of experience in resolving thermal exchange problems, TECHNO SYSTEM produces three types of plates, two of them incorporating innovations with respect to other plates available on the market. The first case makes use of plates in smooth steel sheet, rubber gaskets secured under a U-profiled border, and wire net turbulators each inserted in a housing on the gaskets (see Fig. 4).

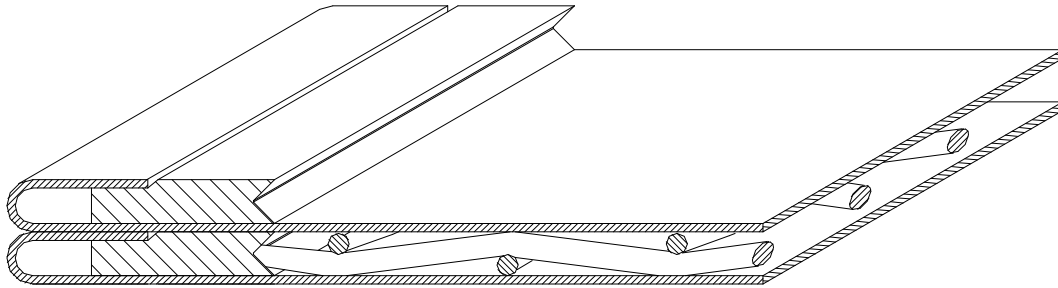


Fig. 4 (Particular of the gasket anchorage – smooth plate with turbulator)

This configuration is recommended for use with “clean” fluids, for high-pressure applications, and in all cases in which optimization of the heat exchanger is a priority concern because of great differences in the flow rates and/or fluids in the two circuits.

In the second case, the plates are made of pressed corrugated sheet steel; the gaskets are not glued and secured mechanically.

The play in the gaskets permits the two circuits in the pack of plates to reciprocate (counterflow) in such a manner that the fluid in any one channel exchanges with that in the two contiguous channels.

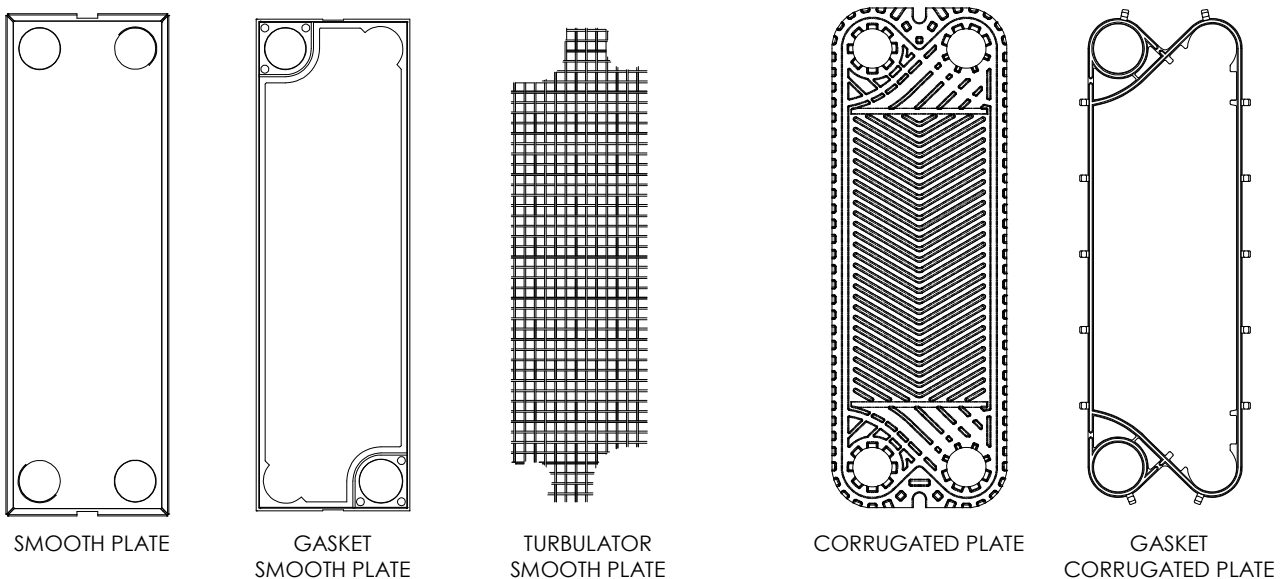


Fig. 5 (Components of TECHNO SYSTEM's plates)

The flow patterns (see Fig. 6 and Fig. 7) are normally symmetrical with parallel channels, but it is a simple matter to arrange flows with channels in series and mixed parallel/series flows. Selection of one or another configuration will depend on the thermal program and on the "thermal length" (geometrical characteristics) of the plates.

The exchangers with smooth plates and turbulators have crossed connections, while the exchangers with corrugated plates have parallel non-crossed connections (see Fig. 6 and Fig. 7).

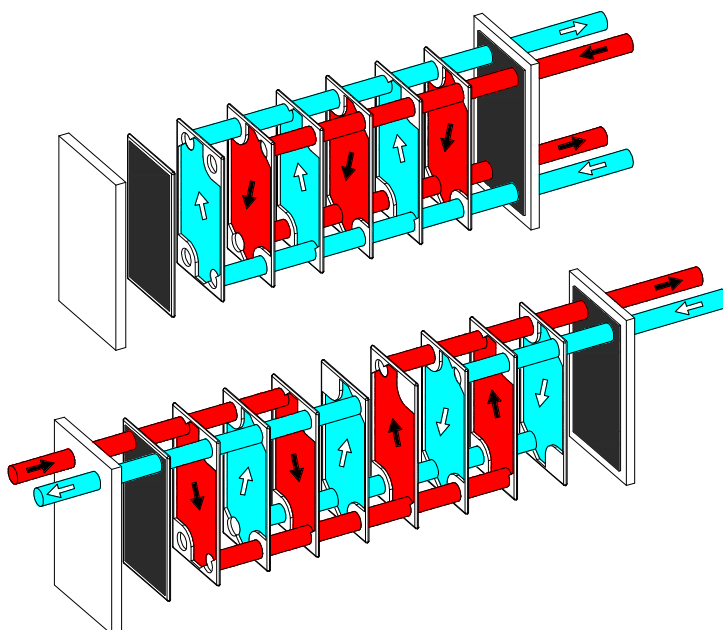


Fig. 6 (Example of exchanger flow in a smooth-plate exchanger)

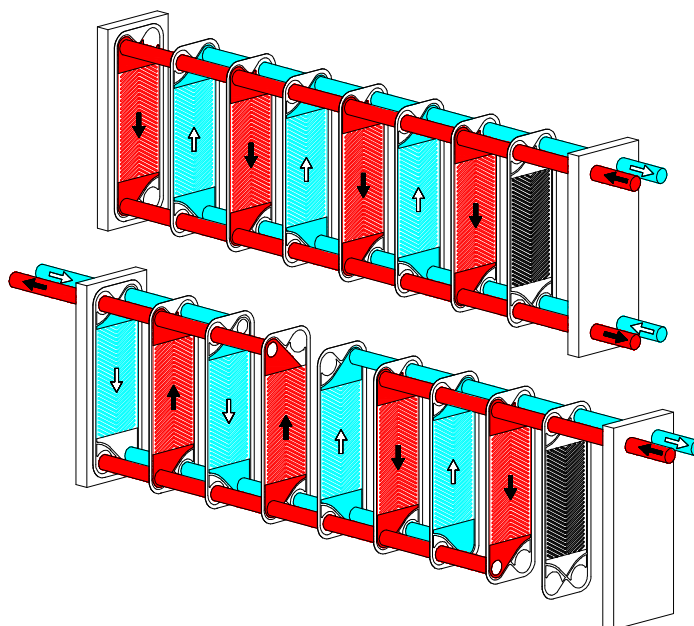


Fig. 7 (Example of exchanger flow in a corrugated-plate exchanger)

# CONSTRUCTION MATERIALS

## A) PLATES

Corrugated exchange plates (and therefore plates manufactured by drawing) can be made of any material suitable for pressing. However, there exist severe limits on use of very ductile and malleable materials (for example, copper) since in this case the plates risk alteration of their original form when they are assembled on the exchangers and tightened down. This will result in irreparable alteration of the cavities and the channels, with easily imaginable consequences.

The smooth plate with turbulator can be made also with these materials. In any case, the materials commonly used for the plates are:

AISI 304 stainless steel, AISI 316 stainless steel, titan, monel, incoloy, hastelloy, copper (only smooth plate) etc. Choice of material will depend mainly on its compatibility and chemical inertness in contact with the various fluids; that is, on the degree of its resistance to corrosion. Final selection will of course also take into account cost factors in relation to system type.

## B) GASKETS

The materials used for manufacturing the gaskets are generally special rubbers of the nitril, butyl, ethylene-propylene (EPDM, EPM), silicon, fluoridated (Viton), and other types.

When chemical compatibility is assured, the maximum operating temperatures for the various types of rubber gaskets are the following:

|             |        |                          |
|-------------|--------|--------------------------|
| Nitril      | 130 °C | (Standard Techno System) |
| Butyl       | 110 °C |                          |
| EPDM        | 155 °C | (Standard Techno System) |
| EPM         | 165 °C |                          |
| Silicon     | 210 °C |                          |
| FKM (Viton) | 210 °C | (Standard Techno System) |

These values refer to operating pressures not exceeding 25 Atm, with TECHNO SYSTEM heat exchangers with smooth plates and turbulators. With exchangers with corrugated plates the maximum operating temperatures are much lower (see Fig. 8).

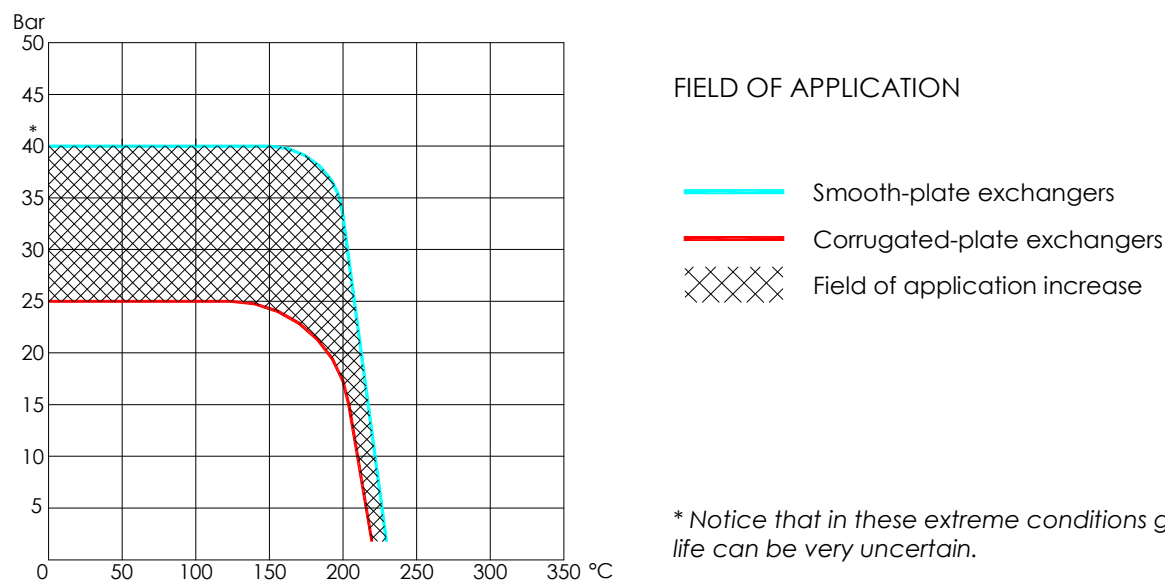


Fig. 8

The construction design of TECHNO SYSTEM's smooth plate with turbulator assures that, once the exchangers is tightened, the gaskets are contained inside the plate pack and completely protected against aging agents for rubber materials like UV-rays, Ozon, etc. This makes gasket's mean life very longer.

### C) FRAME

Suitably-painted carbon steels with excellent mechanical characteristics are usually used for the frame (for example P355NH). For special applications (e.g. food industry), stainless steel, finished in various manners, can be used.

### D) CLAMPING BOLTS

High tensile carbon steel or alloy steel is used for bolts, nuts and clamping bolts (for example A193B7). For special and not particularly demanding applications, stainless steel can also be used for the clamping bolts.

### E) COMPARISON WITH SHELL AND TUBE HEAT EXCHANGERS

Generally, and above all when dealing with costly materials, the final choice between a shell and tube heat exchanger and a plate heat exchanger will favor the latter type, which can guarantee a higher overall heat transfer coefficient and therefore a reduction in surface area. Plate exchangers also require vastly inferior thicknesses, which in no way compromise the life or the safety of the devices. The shell and tube heat exchangers are generally welded at many points; the welds can trigger corrosion and lead to perforation of even the thickest materials. In comparison with the corrugated plate exchangers, the TECHNO SYSTEM smooth-plate heat exchangers also offer advantages as regards corrosion. In the former type the roughness of the material and the stress to which it is subjected during manufacture (both of which factors are due to the pressing process), can trigger corrosion phenomena. The smooth plate, which is neither pressed nor drawn, clearly offers the best guarantees against corrosion.

## MAXIMUM OPERATING PRESSURES AND TEMPERATURES

A) Diagram in Fig. 9 illustrates the temperature/pressure ranges in which plate heat exchangers can be safely used with different types of gaskets. It is clear that the performance of the TECHNO SYSTEM smooth-plate exchangers with turbulators is vastly superior to that of the corrugated-plate exchangers.

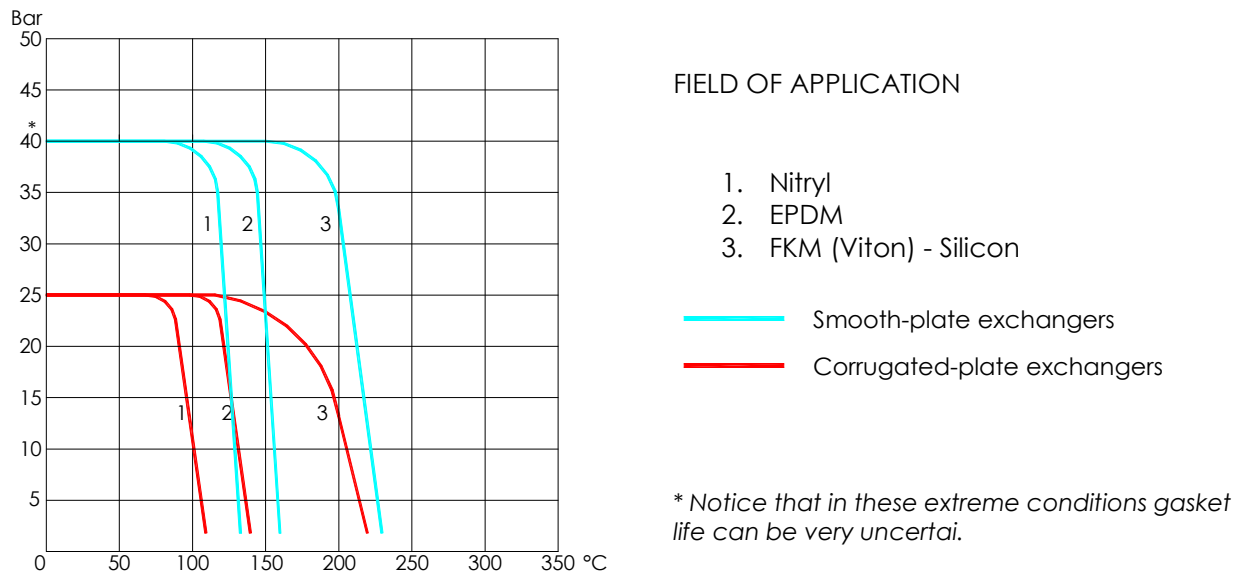


Fig. 9

B) Comparison with shell and tube heat exchangers.

The operating temperature and pressure ranges for the shell and tube type of heat exchanger are obviously much broader than the ranges of the plate heat exchangers, since the former are not limited by reduced thicknesses and rubber gaskets. Paradoxically, however, the limits for this type of exchanger are dictated by the excessive thicknesses and the welds, which, at high temperatures and pressures, due precisely to the excessive thickness and non-uniformity, always produce fatigue phenomena with concentration of fatigue phenomena resulting from vibrations and thermal stress. These problems obviously do not exist in the case of plate heat exchangers, thanks to the uniformity of the thicknesses and the absence of welds.

## PERFORMANCE AND EFFICIENCY

The performance of a heat exchanger is normally measured with reference to a certain number of parameters that characterize the type of duty. The most common of such parameters are thermal length, flow rates, pressure drops, fouling coefficients, seal efficiency, maintenance needs, etc. In the paragraphs that follow we will discuss the above-listed parameters in detail in order to clarify certain concepts that are of fundamental importance for understanding the problems involved in thermal exchange.

### A) THERMAL LENGTH

The thermal length of a heat exchanger (also called number of transfer units or NTU) is calculated according to the dimensionless ratio:

$$NTUs = \frac{K \cdot S}{G \cdot c}$$

where: K = Overall transfer coeff. (Kcal/m<sup>2</sup>h°C)  
S = transfer surface (m<sup>2</sup>)  
G = Mass flowrate (kg/h)  
c = Specific heat (Kcal/Kg°C)

For any given type of duty, this number must be equal to or greater than:

$$NTUp = \frac{T_i - T_o}{\Delta T_{ml}}$$

where: T<sub>i</sub> = Inlet temperature (°C)  
T<sub>o</sub> = Outlet temperature (°C)  
ΔT<sub>ml</sub> = Mean logarithmic temperature diff. (°C)

The inlet and outlet temperature parameters are referred to one of the two circuits (usually the primary circuit). With low-pressure drops, and in a water/water exchange single-channel system, TECHNO SYSTEM heat exchangers can attain NTU values equal to or even greater than five per passage.

Once the fluids, temperatures, and flow rates have been defined, the thermal length of a heat exchanger will depend on the exchange surface and the overall transfer coefficient; that is, in the last analysis, exclusively on the geometry of the plates.

TECHNO SYSTEM smooth-plate heat exchangers make it extremely easy to optimize thermal length, since the geometry of the plates can be altered by simply inserting turbulators with suitable characteristics - and there are a great number of types of wire nets on the market. Contrariwise, in the case of corrugated plates, once the geometry of the plates is set the thermal length cannot be altered. The only modification possible is to insert types of plates with different patterns into the same exchanger. This operation can only yield intermediate thermal lengths and in any case cannot optimize, independently the two circuits one from the other. In the conditions described above, the shell and tube exchanger can attain maximum NTU values of 0,6 per passage. From the point of view of thermal length, the plate heat exchanger (and the TECHNO SYSTEM exchanger in particular) is clearly superior to the shell and tube type. It is so superior, in fact, that it is possible to design devices that operate with logarithmic mean temperature differences of just 1°C.

### B) FLOWRATES

Obviously, the maximum flow rates of the plate heat exchangers are determined by the diameter of the nozzles. In general, in this type of exchanger and for liquids with low viscosity (e.g., water), pressure drops of up to 2 mWG (corresponding to a flow rate of about 6 m/sec) are admissible. Instead, for high-viscosity fluids, the factor limiting maximum flow rate is normally not the pressure drop in the nozzles but rather the pressure drop in the channels. The only plate heat exchangers that permit optimizing the pressure drops and the heat transfer coefficients in the case of very different flow rates in the two circuits (or in the case of fluids with different physical characteristics) are the TECHNO SYSTEM smooth plate exchangers with turbulators. As we have already mentioned, these heat exchangers can incorporate plates with completely different geometries, by making use of turbulators with coarser or finer meshes and/or different wire diameters (see Fig. 10). In the TECHNO SYSTEM heat exchangers, the ratio between the flow rates in the two circuits can be as high as 1:4; only the finned heat exchangers can perhaps obtain a similar value.

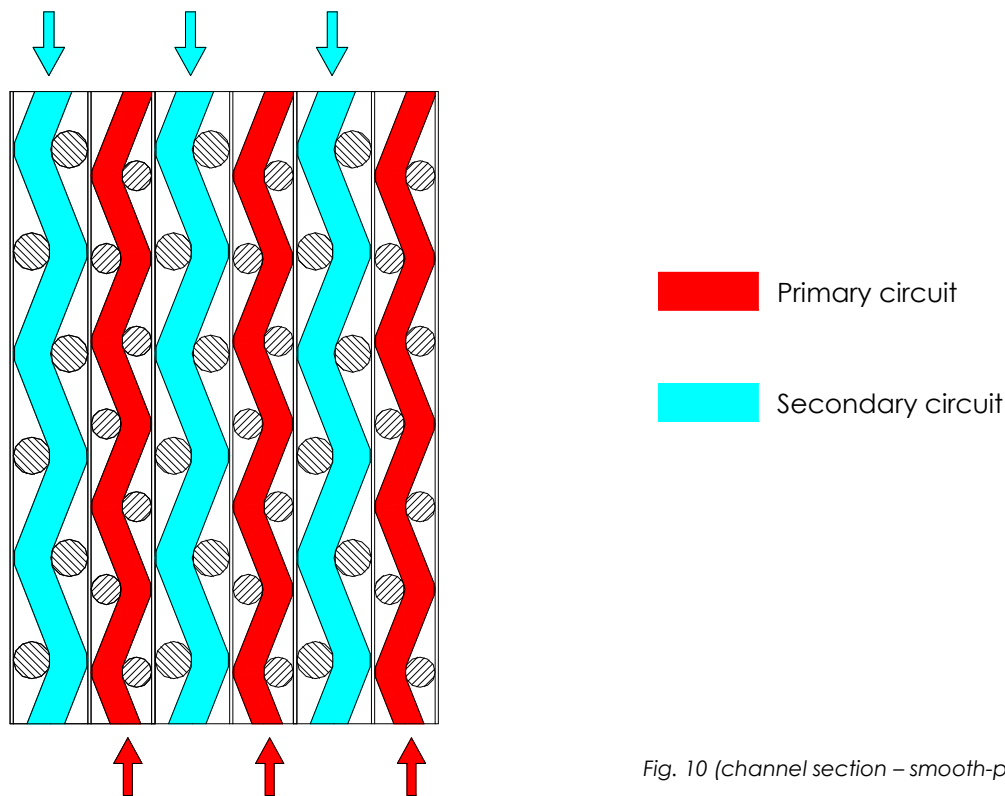


Fig. 10 (channel section – smooth-plate exchangers)

### C) PRESSURE DROPS

The loss of pressure in the heat exchanger between inlet and outlet (also called pressure drop) is simply the result of the resistance encountered by the fluid as it flows through the device. To overcome high resistance it will be necessary to institute pumping, an operation that will be more costly the higher the pressure drop for a given flow rate. This explains why, when dimensioning a heat exchanger, it is extremely important to determine the maximum tolerated pressure drops. Obviously, the higher the admissible pressure drop, the smaller and more economical the exchanger - but this saving will be offset by higher pumping cost. The determination of reasonable pressure drop values takes into account the process, the cost of materials, and pumping costs. The usual approach when designing a heat exchanger is to keep pressure drops to a minimum without unduly sacrificing the heat transfer coefficients; that is, to seek to obtain the highest possible efficiency in heat transfer. In the case of inexpensive materials, this approach is certainly justified. The TECHNO SYSTEM plate heat exchangers, as we have already mentioned, offer the possibility of selecting from among a vast range of geometries (surface patterns). This permits approximating the ideal solution very closely and exploiting to the maximum the permissible pressure drops in both circuits even when dealing with very different flow rates and/or fluids - and doing so better than any other type of plate heat exchanger. In light of the above, one useful parameter for correct dimensioning of a heat exchanger is the Jensen number (Je), which indicates the specific pressure drop:

$$Je = \frac{\Delta P}{NTUp} \quad (\text{mWG}) \quad (\text{bar}) \quad (\text{kPa})$$

For water/water heat transfer, the optimal values for this parameter (from the point of view of total device and operating costs) fall in a range of 2 to 10 mWG, according to construction material. For example, with stainless steel, the Je should be about 2 mWG. Higher values will result with more costly materials. For fluids different from water, the optimal Jensen number values are generally considerably higher.

## D) FOULING

One very important factor, to be attentively evaluated, is the tendency of any fluid (with rare exceptions) to deposit on the exchange surfaces films of dirt and incrustations that eventually cause obstruction. The quality factors that most influence the speed at which fouling occurs in an exchanger are the velocity of the fluids and the condition and geometry of the heat transfer surfaces. The velocity inside any heat exchanger varies continually as to direction and magnitude from point to point and even at the same point, due to the uneven flow path the fluid is forced to follow. This greatly influences the tendency to fouling since it is directly responsible for the turbulence and the erosive force of the current and determines how long the fluid will remain in contact with the surface and the laminar layer thickness.

In light of the above, we may say that in relation to fouling the critical areas of an exchanger are those in which the velocity is lowest; in certain areas, we may even have "stagnant" areas in which the velocity is practically nil.

This does not normally occur in the plate heat exchangers, since the flow distribution conditions are always optimal. (see Fig. 11). Good flow distribution must be assured inside the single channels but also between parallel channels. In many applications, the TECHNO SYSTEM heat exchangers have proved to possess optimal qualities from this point of view. In practical application with fluids of all types, the TECHNO SYSTEM heat exchangers have yielded excellent results as regards fouling and scaling. The perfectly smooth surfaces of the plates, with no recesses or projecting parts to which impurities may attach, impede formation of the film of dirt or scale. What is more, the wire net turbulators, which are in continual movement due to thermal dilatation and contraction, have a marked tendency to disgregate hard scale and thus may be said to be "self-cleaning" in this respect. On the other hand, plate exchangers are not suitable for use with excessively dirty liquids or better, with liquids containing large particles (on the order of 1 mm) in suspension. In this regard, the only plate exchangers that have yielded satisfactory results are the TECHNO SYSTEM corrugated plates, thanks to their unique surface pattern. Liquids containing fibers are in any case much more damaging and almost always cause obstructions. In this case it is advisable to use spiral exchangers or exchangers with very wide passages and, if possible, featuring easy maintenance, since obstruction is practically inevitable.

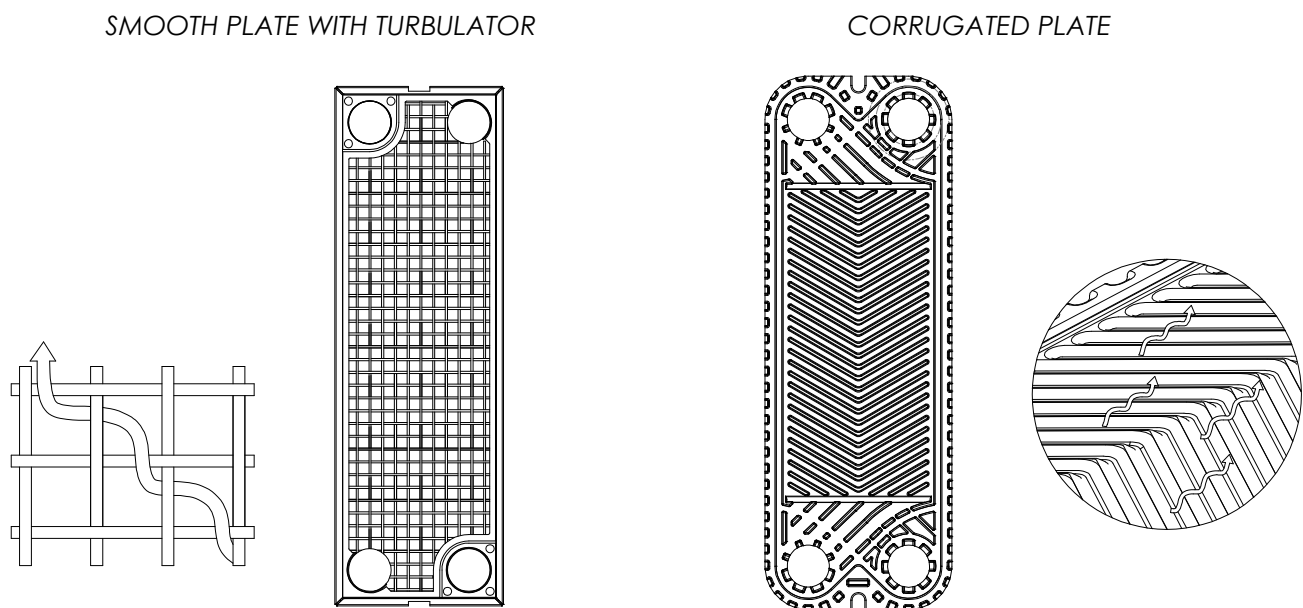


Fig. 11 (Flow distribution and turbulence)

When dimensioning a heat exchanger, special attention must be paid to careful evaluation of the tendency to fouling of the liquids to be used, and to correspondingly increasing the heat transfer surfaces. This is necessary in order to offset the considerable increase in resistance to heat transmission in the case of dirty liquids, which leave deposits of dirt and/or cause scaling. In shell and tube heat exchangers, there is real difficulty as regards obtaining good flow distribution and there are also stagnant areas (or in any case, areas of low velocity). Consequently, fouling factors of up to ten times those commonly adopted for plate exchangers must be used in calculation (see table below) of the requirements for the same duty.

Fouling factors (indicative values):

| FLUID               | PHE     | THE     |
|---------------------|---------|---------|
| Pure water          | 0.00001 | 0.00005 |
| Hard water          | 0.00003 | 0.00015 |
| Cooling tower water | 0.00005 | 0.00025 |
| Industrial water    | 0.00006 | 0.00030 |
| Dirty water         | 0.00010 | 0.00050 |

(m<sup>2</sup>h°C/Kcal)

PHE = Plate heat exchangers

THE = Shell and tube heat exchangers.

## E) SEALS

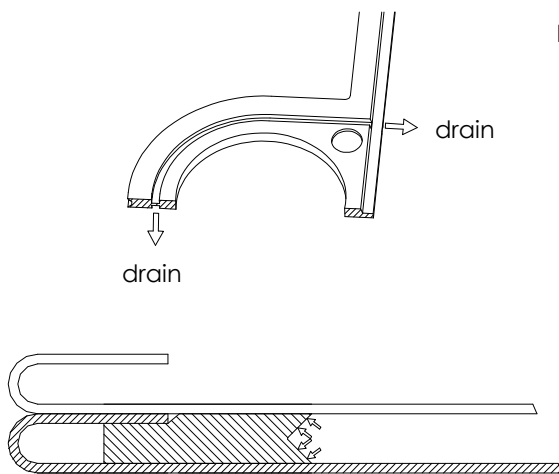
Each plate is provided with a gasket, which defines the exchange channel, alternating the sealing rings around the left and right holes.

The gaskets of the corrugated plates are not gloed, but mechanically sealed to the plates.

Moreover, thanks to their special assembly system (see Fig. 4), the seal gaskets of the TECHNO SYSTEM smooth-plate heat exchangers permit achieving considerably high pressures, since expulsion of the gaskets is practically impossible. Fig. 12 shows how the V-section of the turbulator housing ensures a further seal increment.

For all types of plates the dual seal ring around the holes impedes mixing of the two fluids; if anything, they may drip to the outside.

SMOOTH PLATE WITH TURBULATOR



CORRUGATED PLATE

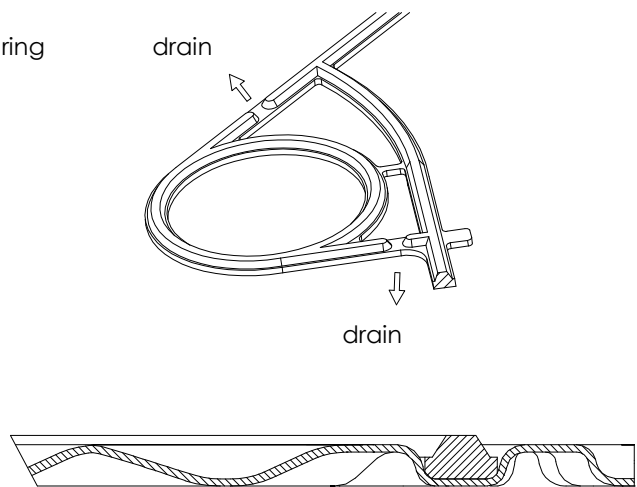


Fig. 12 (Sealing particulars)

## F) INSPECTION – CLEANING – EXTENSIBILITY - REPAIRS

From these points of view, the plate heat exchanger is undoubtedly the best solution, since it can be, easily and completely, disassembled for cleaning, inspection, and on-the-spot repairs. With other types of exchangers, these operations are generally difficult to perform or even impossible. In particular and as already mentioned, the gaskets of all the versions of the TECHNO SYSTEM heat exchangers can be replaced easily and rapidly, since they are not glued but rather held in place by a housing. Finally, extensibility is a feature unique to plate heat exchangers.

# CRITERIA AND SUGGESTIONS FOR CHOOSING A HEAT EXCHANGER

Compatibly with the temperature and pressure ranges (see graph, Fig. 8), the TECHNO SYSTEM plate heat exchangers are suitable for use, and can offer singular advantages, in the majority of the applications examined below.

- A) Liquid-to-liquid heat transfer in all viscosity ranges. Given the high heat transfer coefficients and optimal flow distribution, the TECHNO SYSTEM plate exchangers always require a lesser surface area for the same duty. This is due to the possibility to optimize the geometry of the plates in relation to the viscosity of the fluid and the flow rates. For extremely high viscosity liquids, we recommend using the special corrugated plates type "L".
- B) Vapor condensation. Within the limits mentioned above, the TECHNO SYSTEM plate heat exchangers offer excellent results since they permit, once again, to optimize the essential parameters. One limitation to use of plate heat exchangers is represented by the very high flow rates at low pressures, a situation requiring large-diameter nozzles. The dual inlet, with an additional nozzle on the mobile plate, can represent a feasible solution to this problem since it permits dividing the total flow by two. Unfortunately, this is not always practical. Remember that in any case, the embossed plates can help solve the problem, since pressure drops must often be limited.
- C) Gas and compressed air. Since they offer excellent seal and great flexibility, the TECHNO SYSTEM heat exchangers can be used successfully in these applications.
- D) Dirty fluids without fiber content. The only TECHNO SYSTEM plate exchangers suitable for these applications is the corrugated type.
- E) Fluids at high pressures and temperatures. The only devices employed in these cases are specially designed and constructed shell and tube exchangers.
- F) Highly corrosive fluids. Special graphite heat exchangers are used in these cases.

\*\*\*      \*\*\*      \*\*\*

To sum up, we may say that the TECHNO SYSTEM plate heat exchangers are suitable for use in a vast range of applications. With respect to other solutions, they always offer great technical and economic advantages. In addition, all this is possible within a very wide range of temperatures and pressures.

The versatility of the various types of TECHNO SYSTEM heat exchangers makes them your first choice for almost any application.

For applications in which the fluids in the two circuits have very different physical characteristics (above all, different viscosity values) or simply very different flow rates, the TECHNO SYSTEM heat exchangers, as explained at length above, are undoubtedly the best choice for solving the technical problems involved. The admissible pressures and temperatures for the TECHNO SYSTEM plate exchangers are the highest available anywhere. This is made possible by the specially designed gaskets and the system used to secure them to the plates (see Fig. 4). Thus, the TECHNO SYSTEM plate exchangers offer a much wider range of application with respect to other plate exchangers.

# FORMULAS AND METHODS FOR THERMAL CALCULATION

The basic formulas for dimensioning plate heat exchangers are:

$$(1) \quad Q = K S \Delta T_{ml}$$

$$(2) \quad Q = c G \Delta t$$

$$(*) \quad \Delta T_{ml} = \frac{(T_i - t_o) - (T_o - t_i)}{\ln \frac{(T_i - t_o)}{(T_o - t_i)}}$$

where:  $\Delta T_{ml}$  = Logarithmic mean temperature difference  
 $\Delta t$  = Circuit's temperature difference  
 $K$  = Overall heat transfer coefficient  
 $S$  = Heating surface  
 $c$  = Specific heat  
 $G$  = Mass flow rate  
 $T_i, T_o$  = Primary input and output temperature  
 $t_i, t_o$  = Secondary input and output temperature

Obviously, the quantities of heat (1) and (2) must be equal, where (1) expresses the calories transferred through the heat transfer surface and (2) the calories given up or absorbed by one of the fluids.

From  $KS\Delta T_{ml} = cG\Delta t$

comes

(3)

$$\frac{KS}{cG} = \frac{\Delta t}{\Delta T_{ml}}$$

The first term of expression (3) is the thermal length of the exchanger or of the plate ( $S$  and  $G$  may express, respectively, the total surface area and flow rate or only the surface area and flow rate for one channel); the second is the process thermal length. In practice, however, the first term will always be greater than the second, since a certain degree of over-dimensioning is the norm in these cases. To calculate the heat transfer surface using expression (1) or (3) we need to know  $K$ , which is given by:

$$(4) \quad K = \frac{1}{\frac{1}{\alpha_1} + \frac{1}{\alpha_2} + \frac{s}{\lambda} + f}$$

where:  $\alpha_1$  = Film coefficient of heat transfer 1  
 $\alpha_2$  = Film coefficient of heat transfer 2  
 $s$  = Plate thickness  
 $\lambda$  = Plate conductivity  
 $f$  = Fouling factor

In order to calculate  $K$  with (4), we need to know  $\alpha_1$  and  $\alpha_2$ . The other terms are already known. The coefficients  $\alpha_1$  and  $\alpha_2$  are normally calculated by formulas like:

$$(5) \quad \alpha = \frac{Nu \lambda_f}{De}$$

where:  $Nu$  = Nusselt's number  
 $\lambda_f$  = Fluid conductivity  
 $De$  = Hydraulic diameter (\*\*)

Nusselt's dimensionless number is calculated according to the formula:

$$(6) \quad Nu = A Re^a Pr^b Vi^c$$

where :  
 $A, a, b, c$  = Experimental constants  
 $Re$  = Reynolds' number  
 $Pr$  = Prandtl's number  
 $Vi$  = Ratio between mass and film viscosity

The Reynolds' and Prandtl's numbers are given by:

$$(7) \quad Re = \frac{\rho V De}{\mu}$$

$$(8) \quad Pr = \frac{\mu c}{\lambda_f}$$

Dove:  $\rho$  = density  
 $V$  = velocity  
 $\mu$  = Dynamic viscosity  
 $c$  = Specific heat

Since we know the experimental constants  $A$ ,  $a$ ,  $b$ , and  $c$ , we can calculate the Nusselt number and with it  $\alpha_1$ ,  $\alpha_2$ , and then  $K$ . Although all these calculations, while simple in theory, they are iterative calculations and require some time; they are normally performed by a computer. Nevertheless, in the most common cases and with known fluids (using suitable correction coefficients when conditions deviate from standard) it is possible to formulate preliminary dimensions using the graph calculation method. The experimental constants  $A$ ,  $a$ ,  $b$ , and  $c$  for the TECHNO SYSTEM exchangers, with different turbulator and plate geometries, have the values:

$$\begin{aligned} A &= 0.15 \div 0.45 \\ a &= 0.63 \div 0.90 \\ b &= 0.30 \div 0.45 \\ c &= 0.06 \div 0.21 \end{aligned}$$

Formula (6) is only valid for turbulent flow. As we know, the passage from turbulent flow to laminar flow occurs due to movement in pipes or channels with the Reynolds' number value is about 2100, while, for example, in the TECHNO SYSTEM plate heat exchangers we may have turbulent flow at  $Re$  values of 10 or less. With laminar flow, the Nusselt's number is expressed as:

$$(9) \quad Nu = A \cdot Re^a \cdot Pr^b \left( \frac{De}{L} \right)^c \cdot Vi^c$$

with:  $A = 1.80 - 4.50$   
 $a = 0.24 - 0.39$  (in media 0.33)  
 $c = 0.10 - 0.18$

## PRESSURE DROPS

The pressure drops in a plate heat exchanger may be calculated according to the formula:

$$(10) \quad \Delta P = 4f \frac{\rho V^2 L}{2 De}$$

$L$  = plate length

$$(11) \quad f = \frac{M}{Re^n}$$

$M$  and  $n$  = experimental constants

The symbols used in (10) and (11) are all known to the exception of  $f$ , which is the so-called coefficient of friction.

To obtain the total loss in the exchanger, we must add to these losses the pressure drops in the nozzles, which are given by:

$$(12) \quad \Delta P = m \frac{\rho V^2}{2} \quad \text{normally } m=1$$

Depending on the geometries of the plates, the experimental values for  $M$  and  $n$  for the TECHNO SYSTEM exchangers are:

$$\begin{aligned} M &= 0.90 \div 4.80 \\ n &= 0.12 \div 0.39 \end{aligned}$$

In laminar conditions, (11) becomes

$$(13) \quad f = \frac{M}{Re} \quad \text{with } M = 38$$

$$(**) \quad De = \frac{4S}{P} \quad \text{Dove: } \begin{aligned} S &= \text{Channel section} \\ P &= \text{Wet perimeter} \end{aligned}$$

We may conclude, leaving graphs and examples for the annexes, by reporting some indicative values of the overall heat transfer coefficients obtainable with TECHNO SYSTEM exchangers. The values in the table below refer to cases with pressure drops of between 3 and 6 mWG and fouling coefficients in a normal range. With different fouling factors,  $K$  may be considerably lower.

| FLUIDS                   |           | K<br>(Kcal/m <sup>2</sup> h°C) |
|--------------------------|-----------|--------------------------------|
| Primary                  | Secondary |                                |
| water                    | water     | 3000 - 6300                    |
| Et. alcool               | water     | 1000 - 3000                    |
| sae 10 oil               | water     | 450 - 1200                     |
| solvents                 | water     | 1000 - 3000                    |
| solution                 | water     | 900 - 2400                     |
| brine                    | water     | 1800 - 3900                    |
| compr. air               | water     | 150 - 600                      |
| steam                    | water     | 2700 - 6300                    |
| steam                    | oil       | 450 - 1200                     |
| steam                    | solvents  | 900 - 3000                     |
| steam                    | solutions | 750 - 2400                     |
| condens. NH <sub>3</sub> | water     | 2500 - 5400                    |
| freon                    | water     | 1500 - 3000                    |

## STEAM AND OTHER CONDENSING VAPOURS

A rough graphic calculation is not advisable in the presence of steam and condensing vapours as they imply a phase change. It is impossible to display clearly in a graph all variables. In these cases the computer is indispensable, and we therefore advise you to contact our technical department.

### COMPARISON BETWEEN TECHNO SYSTEM SMOOTH PLATE HEAT EXCHANGERS AND CORRUGATED PLATE HEAT EXCHANGERS

|                         |                                                                                                                                                                             |                                                                                                                                                                                                 |
|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PLATES                  | Smooth with turbulator<br>(corrugated for special applications).                                                                                                            | Corrugated.                                                                                                                                                                                     |
| GASKETS                 | Not glued: mechanically secured under the entire plate perimeter.                                                                                                           | Glued or spot-fixed.                                                                                                                                                                            |
| GASKET AGING            | Very slow. The edge of the plate holding the gasket protects it from agents that can cause deterioration; e.g. ultraviolet rays, ozone, etc.                                | Quite rapid, especially when the gaskets are not glued and therefore essentially unprotected.                                                                                                   |
| AVERAGE GASKET LIFE     | More than five years, even after many maintenance operations.                                                                                                               | Generally less.                                                                                                                                                                                 |
| GASKET REPLACEMENT      | Since the gaskets are not glued, on-site replacement creates no particular problems.                                                                                        | Unglued gaskets are very easy to replace.                                                                                                                                                       |
| THERMAL LENGTH          | Either of the circuits can be built to the desired length by inserting a turbulator of the correct geometry; it is thus possible to optimize efficiency and pressure drops. | The corrugation of the plates excludes the possibility of having different geometries (surface patterns) on the two circuits; independent optimization of the circuits is therefore impossible. |
| PRESSURE CONSIDERATIONS | The TS heat exchanger guarantees seal even with absolute and differential pressures of up to 40 bar.                                                                        | The maximum non-differential pressure obtainable is 25 bar.                                                                                                                                     |
| MAINTENANCE             | To be done with particular shrewdness. Follow strictly the instructions given in the instruction and maintenance manual.                                                    | Ordinary maintenance for corrugated plates is generally easier than for smooth-plate exchangers.                                                                                                |
| HANDLING                | Delicate, especially for big-sized models.                                                                                                                                  | Generally easy.                                                                                                                                                                                 |

| <b>NECESSARY DATA FOR THERMAL CALCULATION</b>                          | <b>1</b>                 | <b>2</b>                 | <b>3</b>                 | <b>4</b>                 |
|------------------------------------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Nature of the fluids (density, viscosity, conductivity, specific heat) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Maximum operating temperature                                          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Maximum operating pressure                                             | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Fouling factors                                                        | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Allowable pressure drop in the primary circuit                         | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Allowable pressure drop in the secondary circuit                       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Input temperature of the primary circuit                               | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Output temperature of the primary circuit                              | <input type="checkbox"/> |                          | <input type="checkbox"/> |                          |
| Flow rate of primary circuit                                           | <input type="checkbox"/> | <input type="checkbox"/> |                          | <input type="checkbox"/> |
| Input temperature of the secondary circuit                             | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Output temperature of the secondary circuit                            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Flow rate of secondary circuit                                         |                          | <input type="checkbox"/> |                          | <input type="checkbox"/> |
| Heat load                                                              |                          |                          | <input type="checkbox"/> | <input type="checkbox"/> |

N.B. Data of one column are enough for calculation.

## CONVERSION TABLE

|                           |       |                               |                      |
|---------------------------|-------|-------------------------------|----------------------|
| 1 kcal                    | _____ | 4.185 kJ                      | Heat quantity        |
| 1 kJ                      | _____ | 0.239 kcal                    |                      |
| 1 kcal/h                  | _____ | 1.163 W                       | Capacity             |
| 1 W                       | _____ | 0.860 kcal/h                  |                      |
| 1 CV                      | _____ | 633 kcal/h                    |                      |
| 1 mca                     | _____ | 9.81 kPa                      | Pressure drops       |
| 1 kPa                     | _____ | 0.102 mWG                     |                      |
| 1 bar                     | _____ | 100 kPa                       |                      |
| 1 kPa                     | _____ | 0.01 bar                      |                      |
| 1 kcal/Kg°C               | _____ | 4.185 kJ/kg°C                 | Specific heat        |
| 1 kJ/kg°C                 | _____ | 0.239 kcal/kg°C               |                      |
| 1 kcal/mh°C               | _____ | 1.163 W/m°C                   | Conducitivity        |
| 1 W/m°C                   | _____ | 0.860 kcal/hm°C               |                      |
| 1 cP                      | _____ | 0.001 Ns/ m <sup>2</sup>      | Viscosity            |
| 1 Ns/m <sup>2</sup>       | _____ | 1000 cP                       |                      |
| 1 mPa s                   | _____ | 0.001 Ns/m <sup>2</sup>       |                      |
| 1 kg/m <sup>3</sup>       | _____ | 0.001 gr/cm <sup>3</sup>      | Specific weight      |
| 1 gr/cm <sup>3</sup>      | _____ | 1000 kg/m <sup>3</sup>        |                      |
| 1 kcal/m <sup>2</sup> h°C | _____ | 1.163 W/ m <sup>2</sup> °C    | Transfer coefficient |
| 1 W/ m <sup>2</sup> °C    | _____ | 0.860 kcal/m <sup>2</sup> h°C |                      |
| 1 m <sup>2</sup> h°C/Kcal | _____ | 0.860 m <sup>2</sup> °C/W     | Fouling factor       |
| 1 m <sup>2</sup> °C/W     | _____ | 1.163 m <sup>2</sup> h°C/kcal |                      |

NOTES:

[illegible]

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[illegible]

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