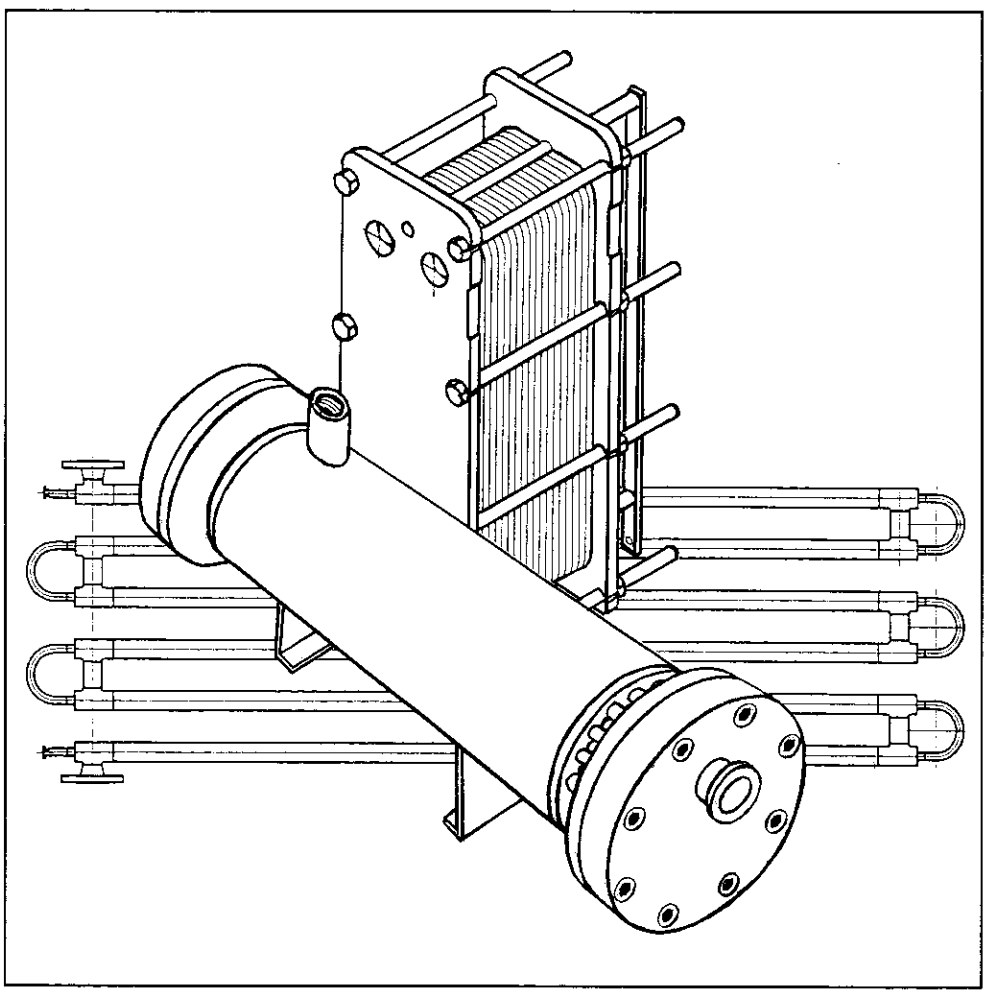
ECHANGEUR DE SÉCURITÉ
FAILSAFE HEAT EXCHANGER

"PHARM'ACM"



PHARMACIE - BIOLOGIE - COSMETOLOGIE

PHARMACEUTICAL - BIOTECHNOLOGY - COSMETICS

ACM

PHARMACEUTICAL - BIOTECHNOLOGY - COSMETICS

COMPONENTS FOR PURIFIED WATER & PURE STEAM SYSTEMS

SUMMARY

GENERAL INFORMATION

Heat exchangers installed on pure water distribution systems have to be designed with normal requirements of the end user : pressure, temperature, flow pressure drops but also have to meet specific requirements of the pharmaceutical industry for quality and safety.

Design requirements : Sealing between process and utility fluids has to be guaranteed.

Generally, shell and tube heat exchangers are designed with double tube sheets, plate and gasket heat exchangers have double plates and coaxial heat exchangers have no welds between the 2 circuits.

In addition, retention zones are not acceptable, process circuit has to be totally drainable and a minimum velocity is required for pure water.

Material requirements : Stainless steel - AISI 316L Type - is the normal choice for a pure water circuit with increasing use of "Mo Sup" Type (DIN 1.4435) for improvement of corrosion resistance.

Surface quality requirements : Required roughness is from Ra ≤ 0.8 µm to Ra ≤ 0.25µm. Electro-polishing may be required to improve cleaning and surface profile.

Working requirements : When the distribution system is sterilised with hot water circulation (125-130°C),heat exchangers have to be mecanically designed to satisfy transition situations during pre-sterilisation heating and post-sterilisation cooling.

Heat exchanger technology and dimensioning methods need to be adapted after considering all requirements.
This document explains the different designs and the possible choices.

THERMO-HYDRAULIC DIMENSIONING

Pure water flow and **velocity** requirements give the minimum circulating section inside the tubes. With this section **a first thermal calculation** is carried out assuming the heat exchanger is **a "one pass" type unit**, and determines the required surface and length for that type of construction (FMP TYPE).

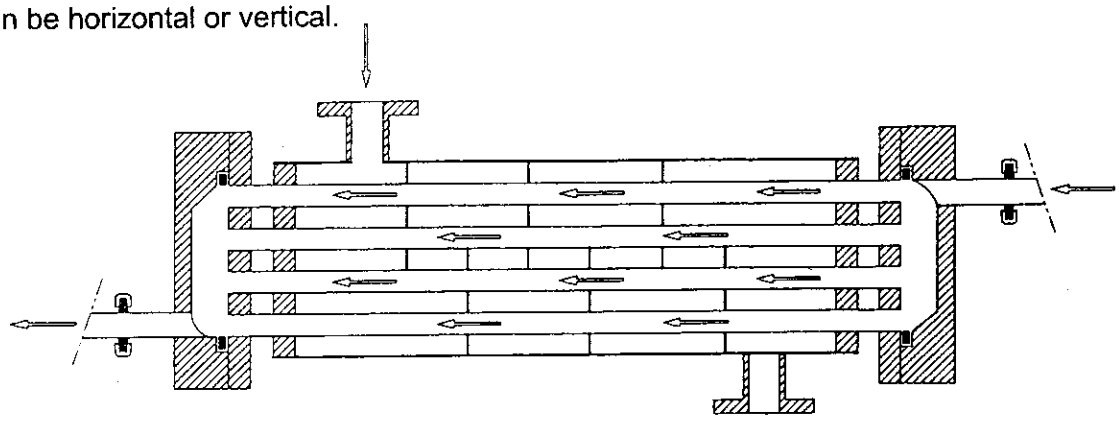
If this length is smaller than an acceptable length, the velocity can be in creased to give a longer heat exchanger, which is more economical.

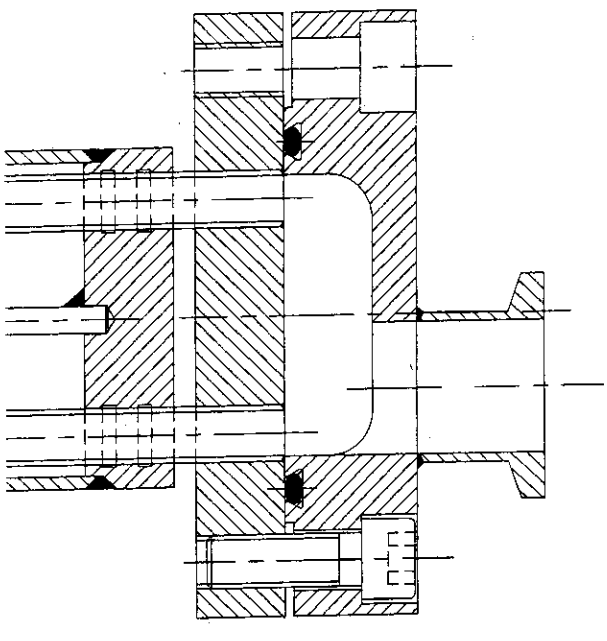
If this length is larger than an acceptable length the following calculations are made for the heat exchanger as : multi-shell, multi-passes types (FXP, FMC, UDC, USC or FMI).

This procedure is also used for coaxial heat exchangers, but not for plate & gasket heat exchangers - For these apparatus, dimensioning is based on turbulence obtained with plate corrugations and not on a required minimum velocity.

PHARM'ACM - ONE PASS - HEAT EXCHANGER : FMP TYPE

This is a "double tube sheet" fixed heat exchanger. Internal flow is monopass, extra-tubular also.
A bellows is installed on shell, if required.
Installation can be horizontal or vertical.





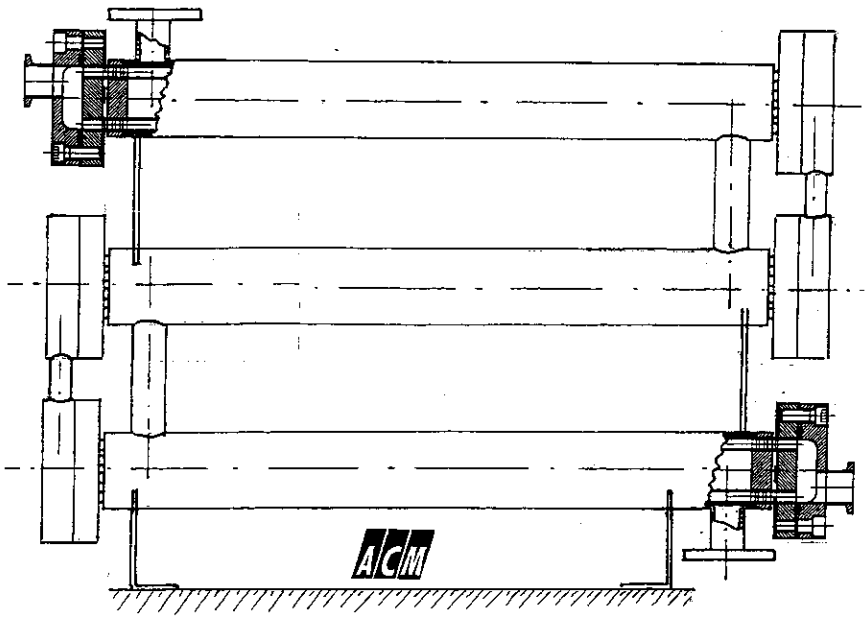
⇒ **THIS IS THE BEST TYPE**, being perfectly adapted to pharmaceutical requirements

- Heads designed for **total draining**
- Inclined installation is of no consequence.
- No pass partition in heads and use of "O" Rings is a guaranty **for extremely limited retention**.
- Tube rolling and welding of tubes are limited to the minimum, **which is a guaranty of quality**.

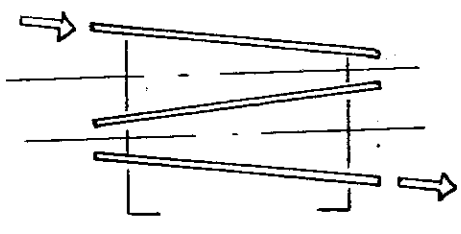
⇒ When space is limited, length may be slightly too long, when duty is high, flow is low or temperatures differences low.

PHARM'ACM - MULTI SHELL EXCHANGER : FXC TYPE

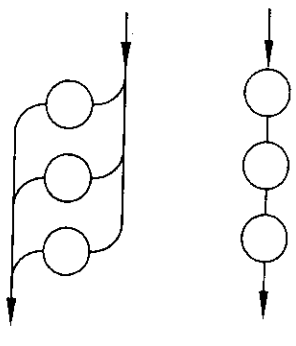
- This type is the **assembly of several monopass heat exchangers** : **in series for pure water flow,** in **series or in parallel for shells.**
  Assembly is envisaged when **the length is greater than the required length for the heat exchanger** in question.
- Bellows are installed on shell if required.
- Assembly is horizontal or inclined (low slope).



Assembly shell side



Inclined assembly



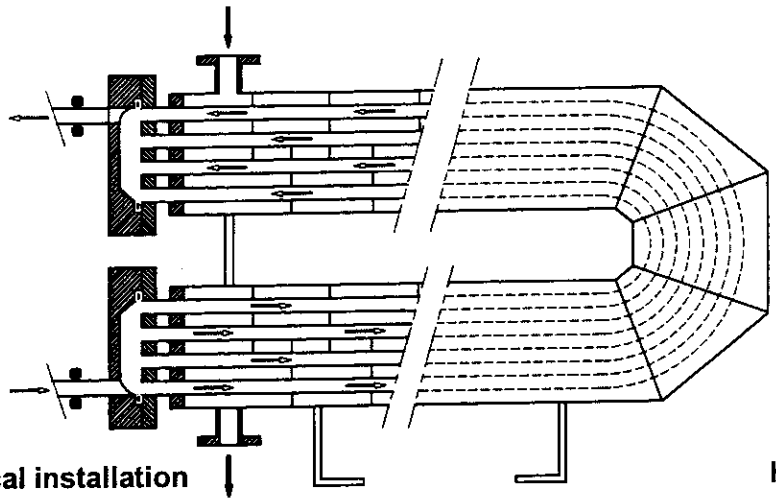
Parallel Serial

⇒ **Qualities : drainability and limited retention are approximatly those of a mono pass exchanger.**
⇒ Width is low and wall mounting is possible.
⇒ **When space is limited, length can be reduced by increasing the number of shells.**
⇒ Inclined assembly is possible.

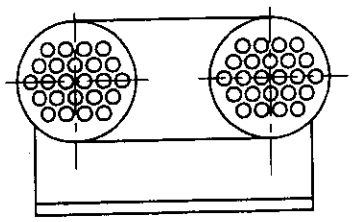
⇒ **The number of tube rolling and welds are multiplied** by the number of shells.
⇒ Head room may be incompatible with the assembly required.

PHARM'ACM - U BUNDLE EXCHANGERS : UDC & USC TYPE

UDC TYPE - DOUBLE SHELL
Tubes are **bent** and installed in 2 **U type shells**, offering a **free expansion of tubes inside the shell**.
The axial plane of the shell can be horizontal or vertical and each half of the shell can be inclined for better draining.

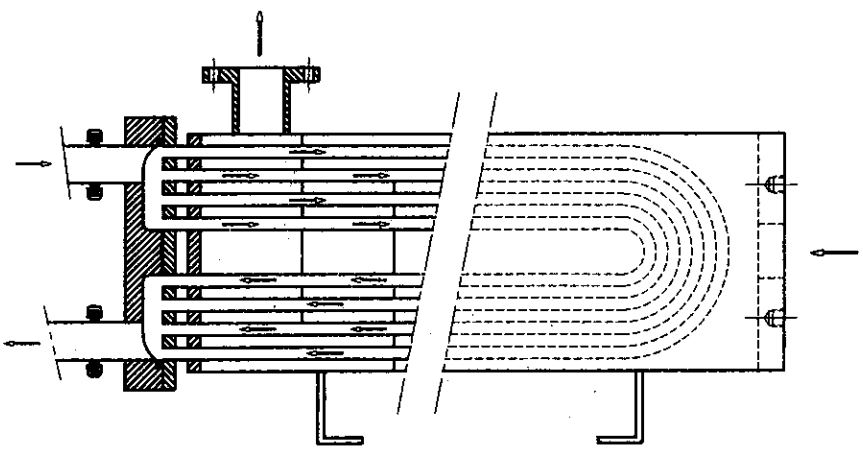


Vertical installation



Horizontal installation

USC TYPE - SINGLE SHELL
Tubes are installed in a single shell and bent with a large radius - This type of unit can only be used when cooling or heating fluid **flow is important** or when the **heating fluid is steam**.



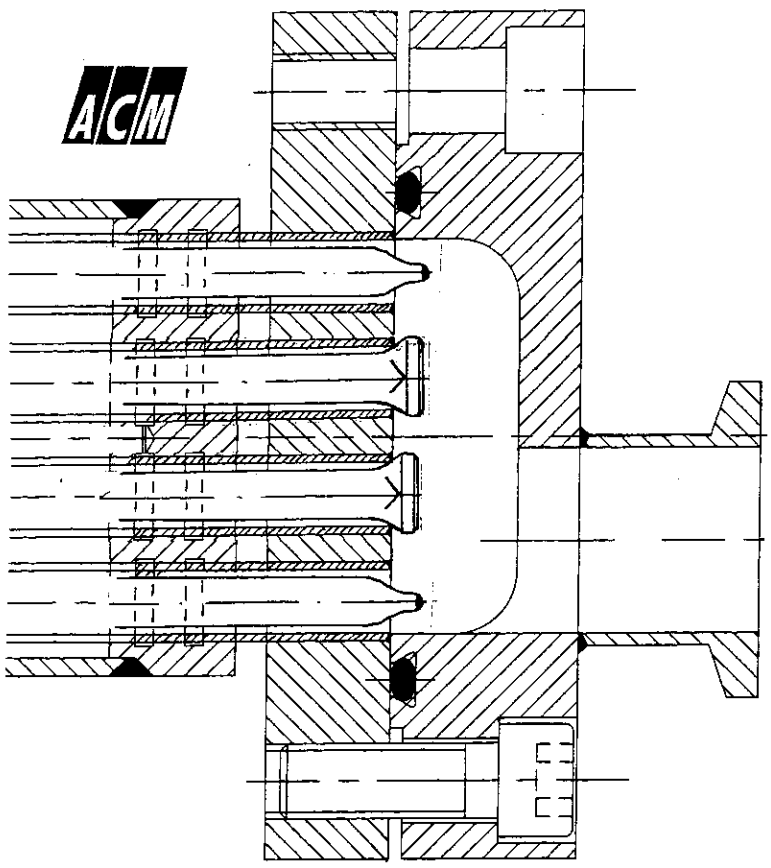
⇒ For UDC Type : Qualities : **Drainability and limited retention are those of a mono-pass heat exchanger.**
⇒ Considering **free expansion of the bundle**, this type of heat exchanger is well adapted to **great and/or fast differential expansion,** such as water re-heating **inside tube circuit,** after total purging.

⇒ For UDC Type : Height or length restrictions pay be incompatible with the assembly envisaged.
⇒ For USC Type : This type has difficulties in meeting all pharmaceutical requirements (retention, draining ...) Low value for Ra is limited due to tube bending.

PHARM'ACM - ONE PASS WITH INSERT - HEAT EXCHANGER : FMI TYPE

To reduce length of a mono-pass heat exchanger, it is possible to install **"inserts"** inside the tubes to **increase velocity** and to increase the heat exchange coefficient or to **achieve the minimum velocity required.**

These "inserts" have to meet **the surface roughness required** for the unit **They are concentric with the tubes**.
Slightly inclined installation is possible.



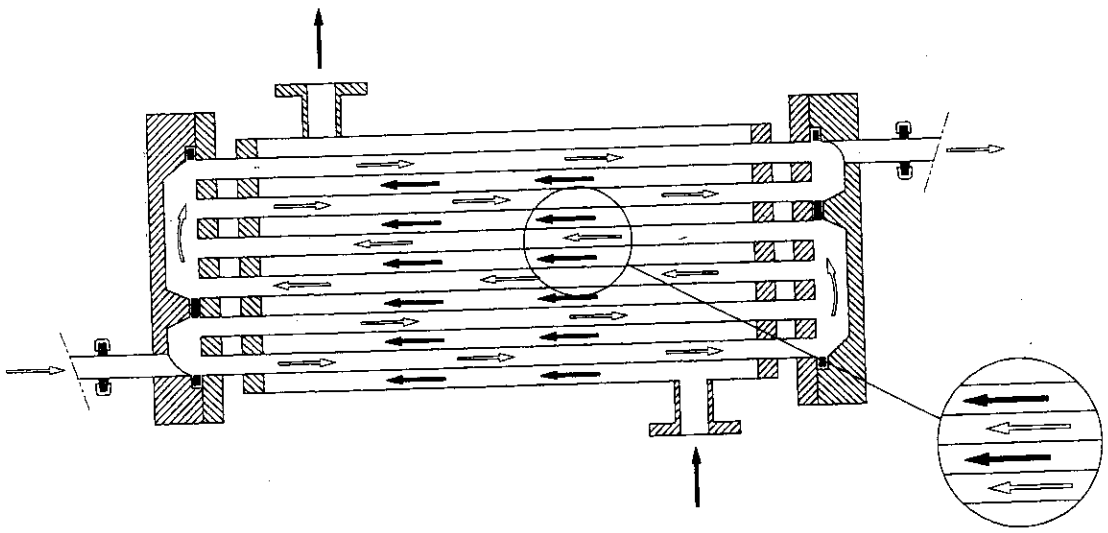
⇒ Qualities : **Draining** and limited retention are those of a **mono-pass heat exchanger**.

⇒ In spite of improvement in heat exchange performance, length reduction is not sufficient for difficult thermal programs.

Remark : Use of **"corrugated" tubes** (helicoïdal corrugations) improves heat transfer but **corrugation manufacturing is not compatible with surface roughness** requirements and draining requires **vertical installation**.

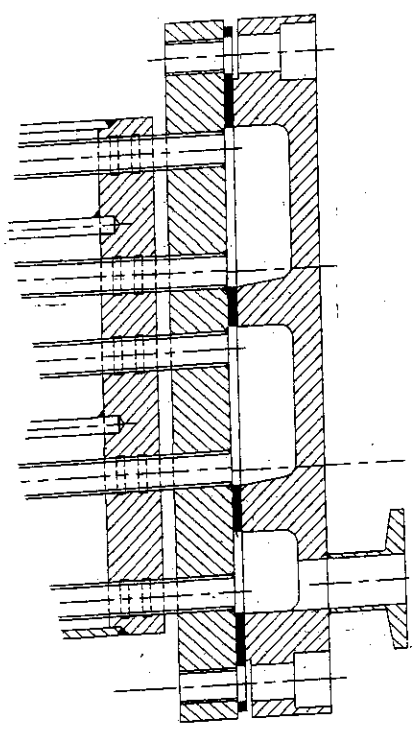
PHARM'ACM - MULTI PASS HEAT EXCHANGER : FXP TYPE

This type is a **multi-pass - internal tube - heat exchanger**.
For circulation internal tube, **pass partitions are installed in heads**. The number of tubes calculated is in accordance with the velocity required and the number of passes depends on **length compatible with space available**.
Slightly inclined installation is possible for many inconvenient sites, but generaly vertical installation is not possible.



3 pass heat exchanger

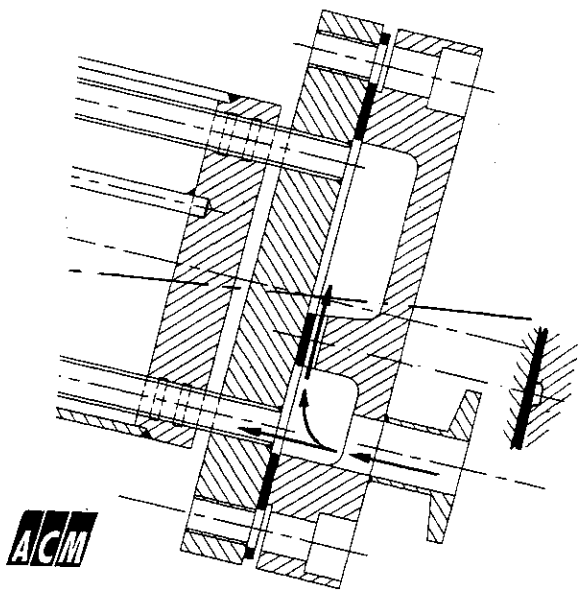
co-courant circulation for passes



Heat exchanger
head for 5 passes

When heat exchangers are installed inclined, to guarantee total draining, all box baffles have to be designed with **by-pass for draining of corresponding passes**.
These by-passes have to be designed and calculated carefully since mixing, leads to **an increase** of **the exchange surface**.

Nb of passes	Extra surface required
2	25%
3	20%
4	35%
5	30%

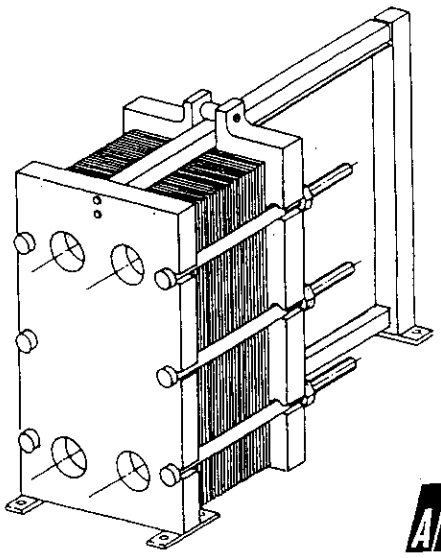


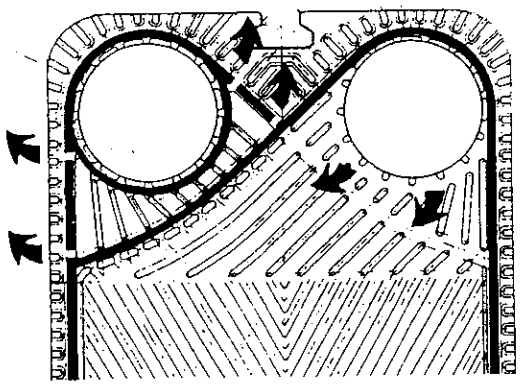
⇒ This type of heat exchanger enables the design, **with only one shell**, for a heat exchanger adapted to the avalaible space to be made.

⇒ The number of **tube rolling** and **tube welding** are multiplied per number of passes.
⇒ Size of gaskets is increased by the number of passes and by the type of gasket to be used - and they are an **increasing retention risk** (**surface, bad position**)
⇒ Some passes are **co-courant circulation passes**, i.e **decrease of temperature difference** and an **increase of the surface is required**.
⇒ When the heat exchanger is installed **inclined**, by-passing installed in heads, **significantly increase the heat exchange surface**.
⇒ Vertical installation is (generally) impossible.
⇒ ALL THESE INCONVENIENCES MAKE THIS TYPE OF HEAT EXCHANGER THE ONE WITH MOST DIFFICULTIES TO MEET ALL PHARMACEUTICAL REQUIREMENTS.

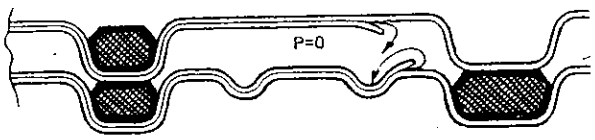
PLATE AND GASKET PHARM'ACM HEAT EXCHANGERS : SPP & DPP TYPES

Manufacturing of these heat exchangers derives from our standard production. Generally they are equipped with **"Double-plates" (type DPP) - to be fail safe heat exchangers.**
Occasionaly, they are equipped with **"single-plates" (type SPP)** when used as **energy economisers** (pure water both sides).
Port connections on the pure water side are **"clamp" type and are excentric to reduce water retention** when the unit is drained.
With "double-plates" DPP type, if one plate leaks, the leak is drained outside, and in this way detected. (draining trough safety zones)

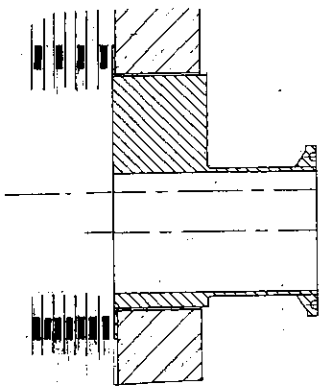




Safety zone between 2 fluids



Double-plates



Excentric clamps connections

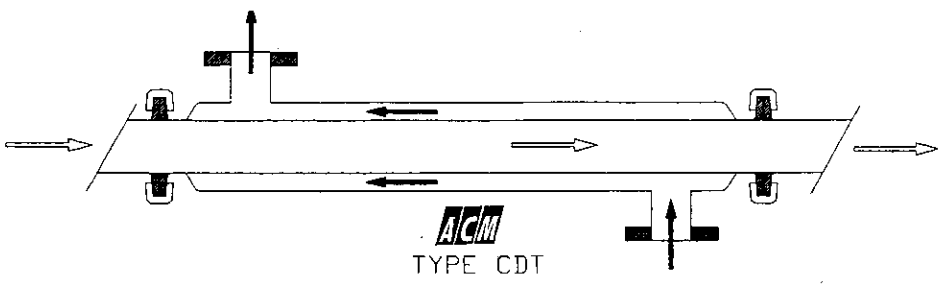
⇒ These heat exchangers have **excellent thermal performances**
⇒ They are **good fail safe heat exchangers**

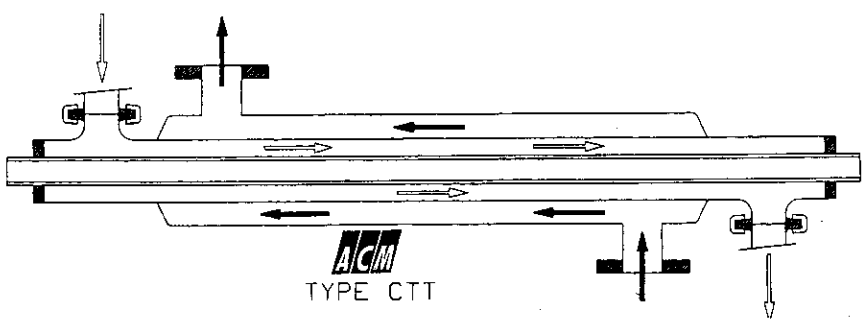
⇒ **Draining caracteristics are poor** at port level
⇒ **There are retention risks** all along the gaskets, even when the profile of these gaskets is adapted
⇒ Surface quality (Ra) obtained after plate pressing is lower than **0.8µm - Electropolishing for improvement is difficult.**
⇒ **Use of these heat exchangers is often limited to water, sometimes accepted for pure water, but rarely used for WFI.**

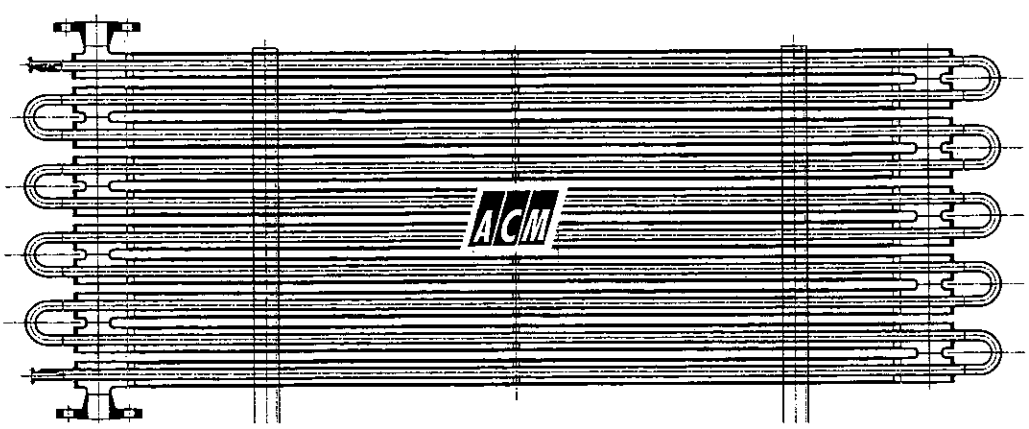
Remark : **Welded plate heat exchangers**, even without gaskets on one circuit, are not used, **on water loops**. Geometric designs are complex with possible retention. Surface quality (Ra) is poor - and welding quality is less sure (ferrite content) when compared to orbital automatic welding for shell and tube heat exchangers.

COAXIAL PHARM'ACM HEAT EXCHANGERS : CDT & CTT TYPES

These heat exchangers are quite simple and easily meet the specific requirements of the pharmaceutical industry - They are built using **2 or 3 concentric tubes** - They are fail safe as there is **no welding betwen fluids**.
They are used for the heating and cooling of **low water flow**.
CDT type is designed with **2 tubes.** An increase in velocity to improve performance and reduce length is obtained by mounting a third tube - This is a CTT type exchanger.







⇒ **The perfect heat exchanger to answer specific pharmaceutical requirements**, mainly for low water flow.

⇒ For multi-shell type, height may be important for installation.

SPECIAL APPLICATIONS

1/ BATCH OPERATION

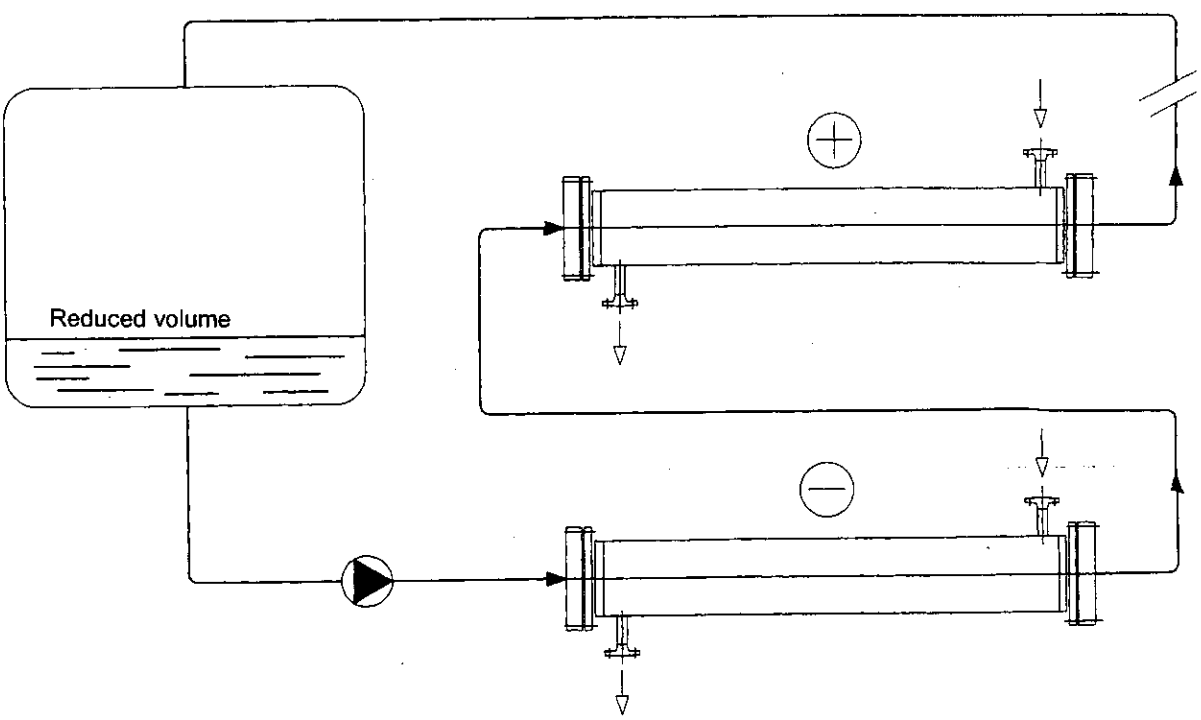
Exchangers do not always operate continuously to maintain the right temperature - Heating or cooling - of a water loop.
Sometimes they are designed for **batch operation**, ie to obtain - within a certain time :

- warming for start up
- pre - sterilization warm up
- cooling down post-sterilization, **of the whole loop** (tank + piping)

For this design, it is necessary to specify the **real capacity of the loop**, and in particular to take into account **the reduction** (preferable) **of the volume of water** enclosed in the tank **during the sterilization operation**.
It is very important not to impose **too short operating periods** (unless mandatory) knowing that the duty required can be very important when starting the cycle (Duty changes during the full cycle)

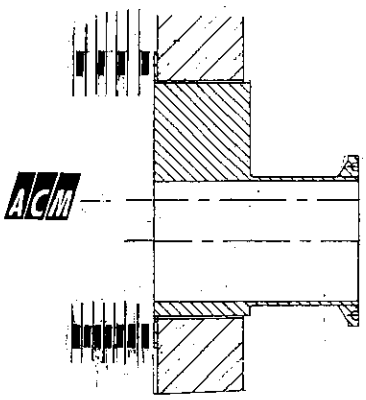
Example
Loop of 3000 liters
heat during 3 hrs
from 85°C to 125°C
with steam 3b/143°C

Time (hrs)	Duty
0.5	172%
1	151%
1.5	100%average
2	76%
2.5	64%
3	52%

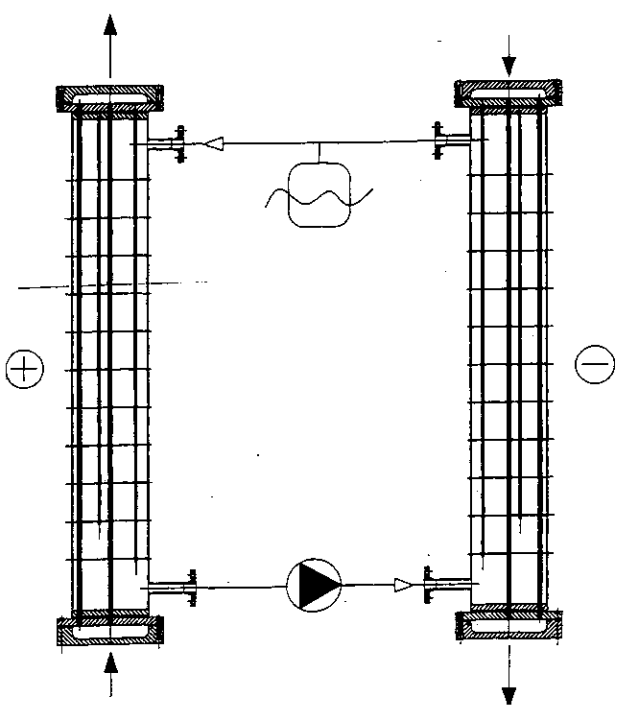


2/ ECONOMIZERS

They **recover energy** and are installed when cooling and heating are required at the same time when one loop is cold, the other warm.
The best performance and most cost saving heat exchangers are the **plate & gasket type heat exchangers**. For this application "**single plates**" are used, the exchange between 2 pure water circuits not being fail safe - In spite of the presence of gaskets, this type of exchanger is a very good compromise - with them, **efficiency of about 80% and more** is obtained (note : the efficiency of an exchanger is the ratio between recovered duty and possible duty corresponding to an exchanger with infinite surface) - **the 4 connection ports** are equiped **with excentric clamps.**

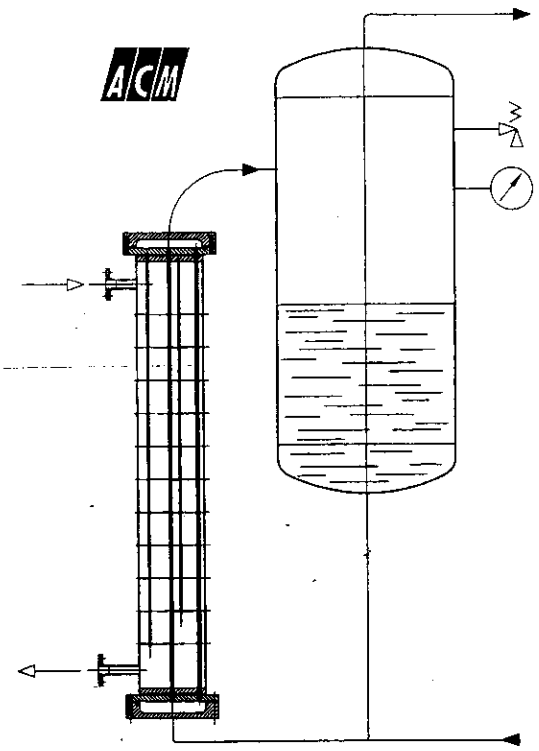


If surface quality and no retention requirements are fully imposed, it is possible to use **co-axial or shell & tube economizers** (shell and tube heat exchangers are designed with no baffles in shell side) but for both types they are **less compact and a lot more expensive**, even with reduced efficiency (50% and less).
It is also possible to design recovery systems with **2 shell and tube heat exchangers**.

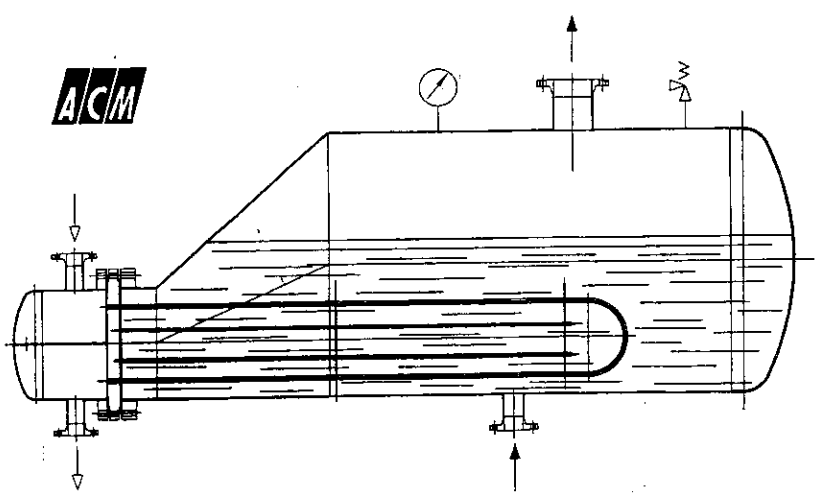


3/ PURE STEAM GENERATORS

These produce **pure steam** (or clean steam) from pure water (or soft water) - heating fluid is high pressure waters thermal fluid or steam at high pressure.
The most usual type is **"thermo-syphon" type**, that associates a vertical shell & tube heat exchanger and a separation tank designed to guarantee the absence of water.The heat exchanger is **a "PHARM'ACM" type** with double tube-sheets identical to those used for monophasic applications. The heat exchanger has to be as small as possible in order to have an **acceptable height** for installation. Knowledge of **this acceptable height is essential information for dimensionning.**

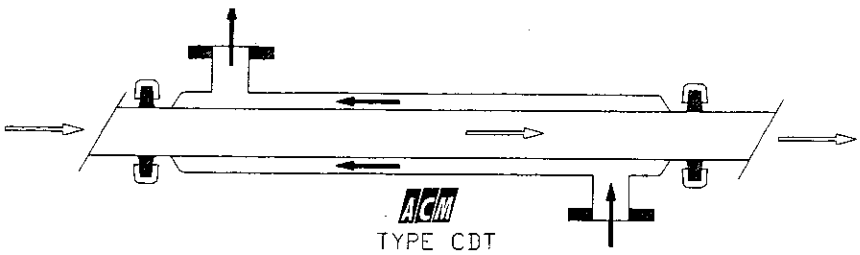


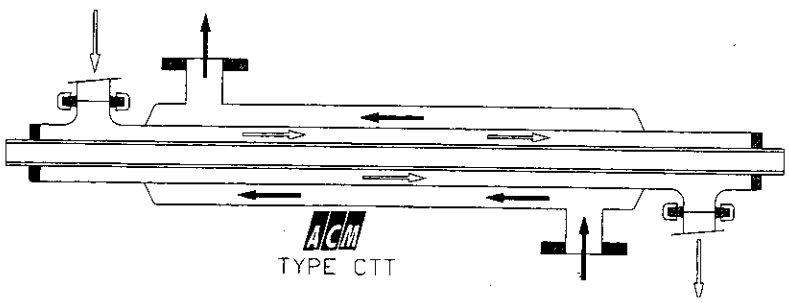
Heat exchangers can also be **"kettle" type**, but in this case, "clean steam" is required.
Steam is produced outside the tube bundle, built with U tubes and equipped with baffles.

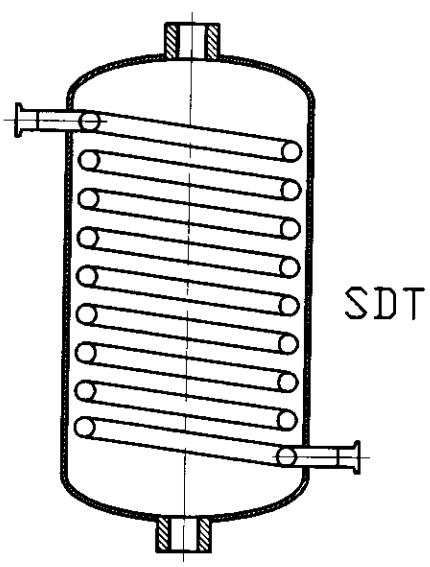


4/ SAMPLING COOLERS / CLEAN STEAM CONDENSERS

These are heat exchangers designed to cool pure water at the **user tap**, for sampling - or to condense, and sub cool, samples - of pure steam.
In all cases, **flow is very low**, and the most adapted heat exchangers are either **coaxial types (CDT or CTT)** or **coil type (SDT).**







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