

# HEAT EXCHANGERS WITH THERMAL PIPES

## THE THERMAL PIPE

The **thermal pipe** is an insulated device (most often in the form of a pipe with two closed ends) containing a liquid in balance with its vapors, in total absence of the air or another gas.

According to the way in which the condense returns to the vaporizer, the thermal pipes can be with **capillary filling** (figure 1) or **gravitational** (no filling) (figure 2).

Fig. 1

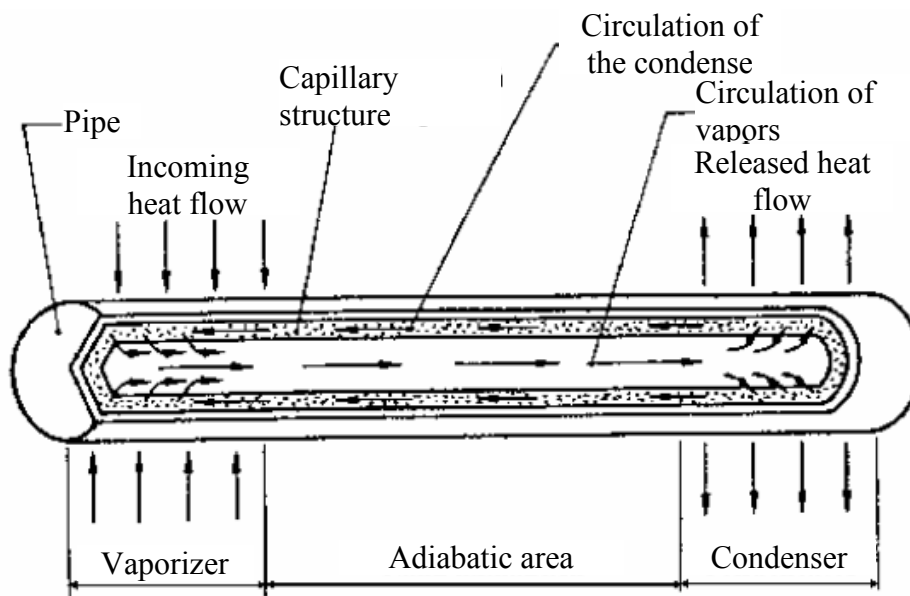
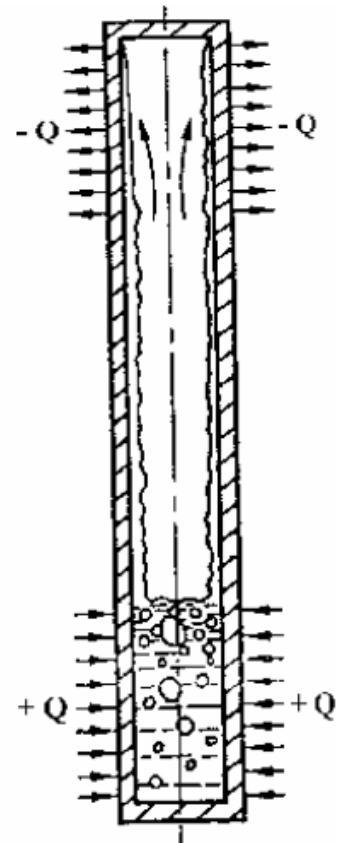


Fig. 2



In the first case the condense returns by means of the vaporizer, due to the capillary effect of the pore filling covering the inside walls of the pipe. In the second case, gravity ensures the circulation of condense (thermosiphon).

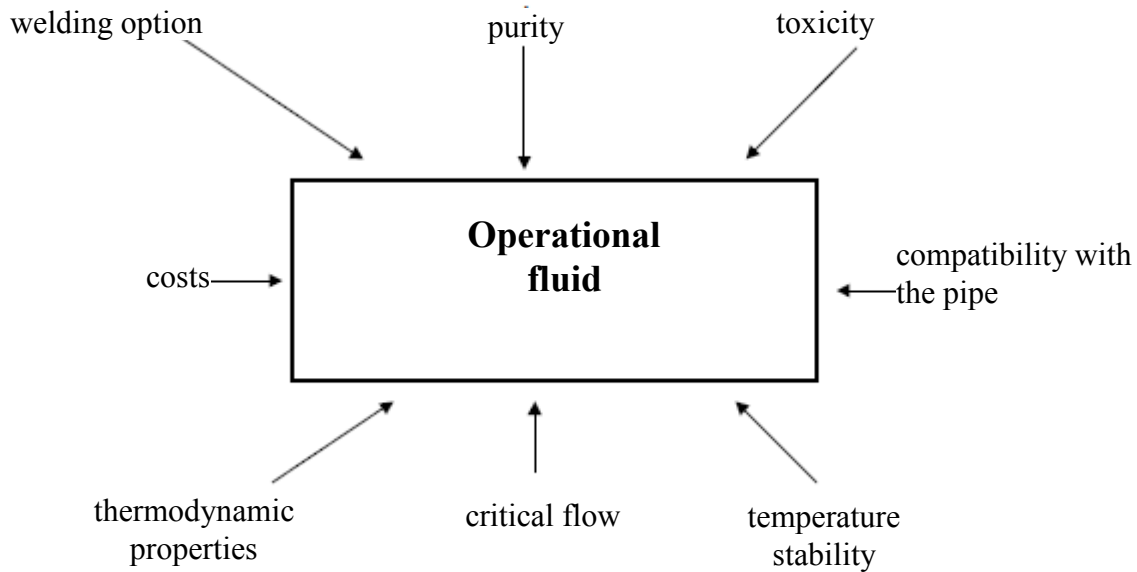
Main problems to be considered in the construction of the thermal pipe are:

- ☞ Selection of the interior fluid;
- ☞ Selection of the material of the pipe and the type of filling.

## THE SELECTION OF THE INTERIOR FLUID

The operating temperature dictates the interior pressure; the liquid on the inside of the pipe is saturated. From this point of view we will try to prevent pressure from falling below 0.1 bar and from exceeding 30 - 40 bars.

### Criteria for the selection of the operational fluid:



## SELECTION OF THE MATERIAL OF THE PIPE

Between the material of the pipe and the interior fluid absolutely no chemical reaction or corrosive action must occur because these could have negative effects, up to the blocking of the circulation inside the pipe.

For example, water is incompatible with stainless steel because in case of temperatures above 100°C reactions with release of hydrogen can occur, which, even if in very small amounts, will block the operation of the thermal pipe, by disturbing the condensation process, due to the presence of a non-condensable gas.

## Materials for thermal pipes

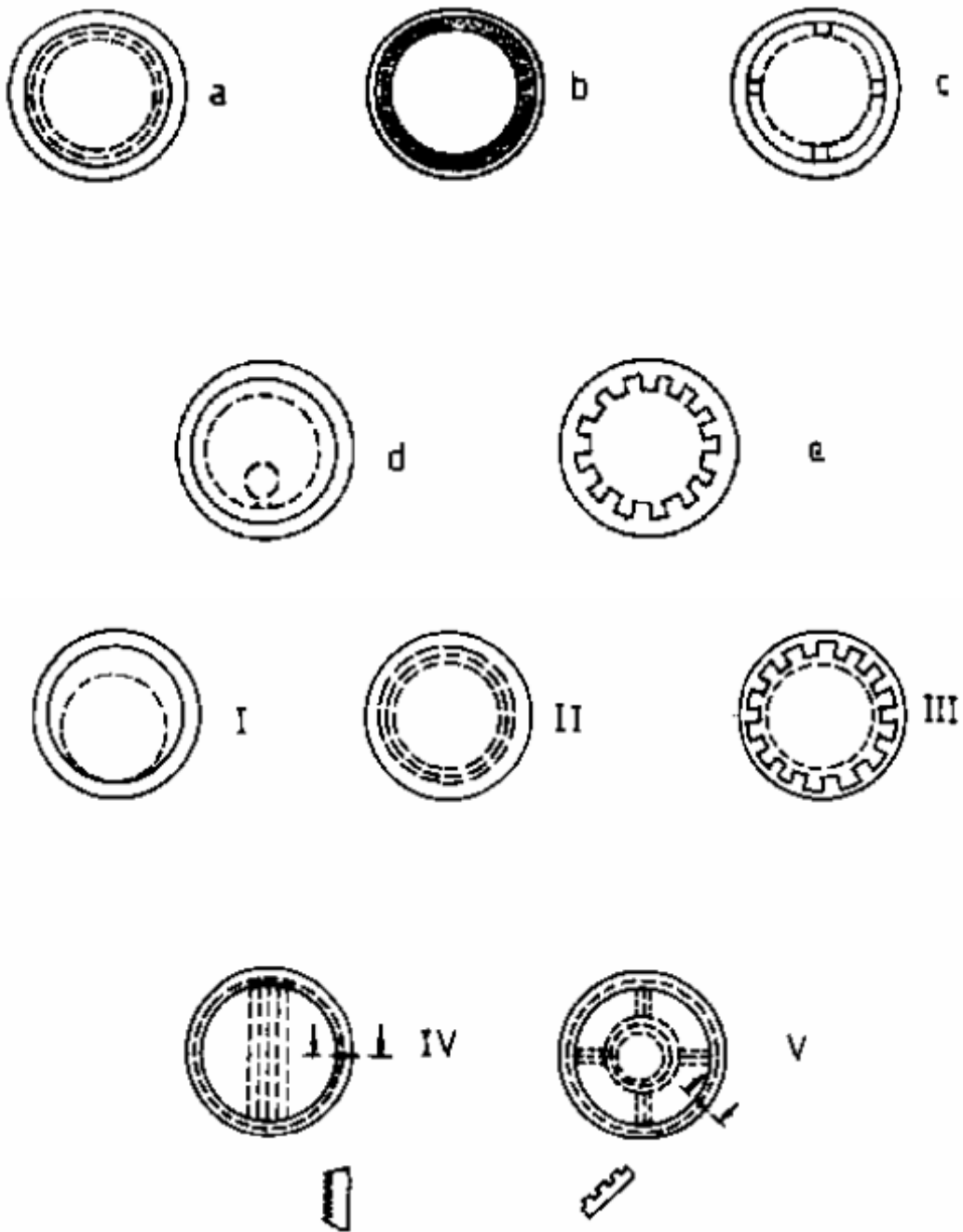
<b>Operational fluid</b>	<b>Compatible material</b>
Ammonia	Aluminum, stainless steel
Freon	Aluminum, copper
Acetone	Copper
Methanol, Ethanol	Copper
Water	Copper
Toluene	Steel, stainless steel
Gilotherm DO	Steel, stainless steel
Mercury	Steel with reduced carbon content, stainless steel
Potassium	Stainless steel AISI 316, Nickel
Sodium	Stainless steel AISI 316, Nickel, Molybdenum
Lithium	Tungsten, Molybdenum

## SELECTION OF THE FILLING

For the thermal pipes the constructors and researchers tested a large number of fillings. From the simplest ones, in the form of metallic nets, up to the most complex ones combining internal ribs with a filling of metallic net.

Most thermal pipes used in heat exchangers use a thermosiphon and have only low triangular ribs on the interior, in order to intensify the heat transfer during boiling and condensation and less for favoring condense circulation.

## Types of capillary nets for thermal pipes



- a) Simple metallic plate
- b) Sintered metallic powder
- c) Metallic plate in the form of a ring
- d) Metallic plate with an artery
- e) Axial ribs

- I. De-centered metallic plate
- II. Compound metallic plate
- III. Axial ribs with a protective plate
- IV. Ring-type ribs with an axial element
- V. Ring-type ribs with a tunnel

## MAIN TYPES OF THERMAL PIPES USED IN HEAT EXCHANGERS

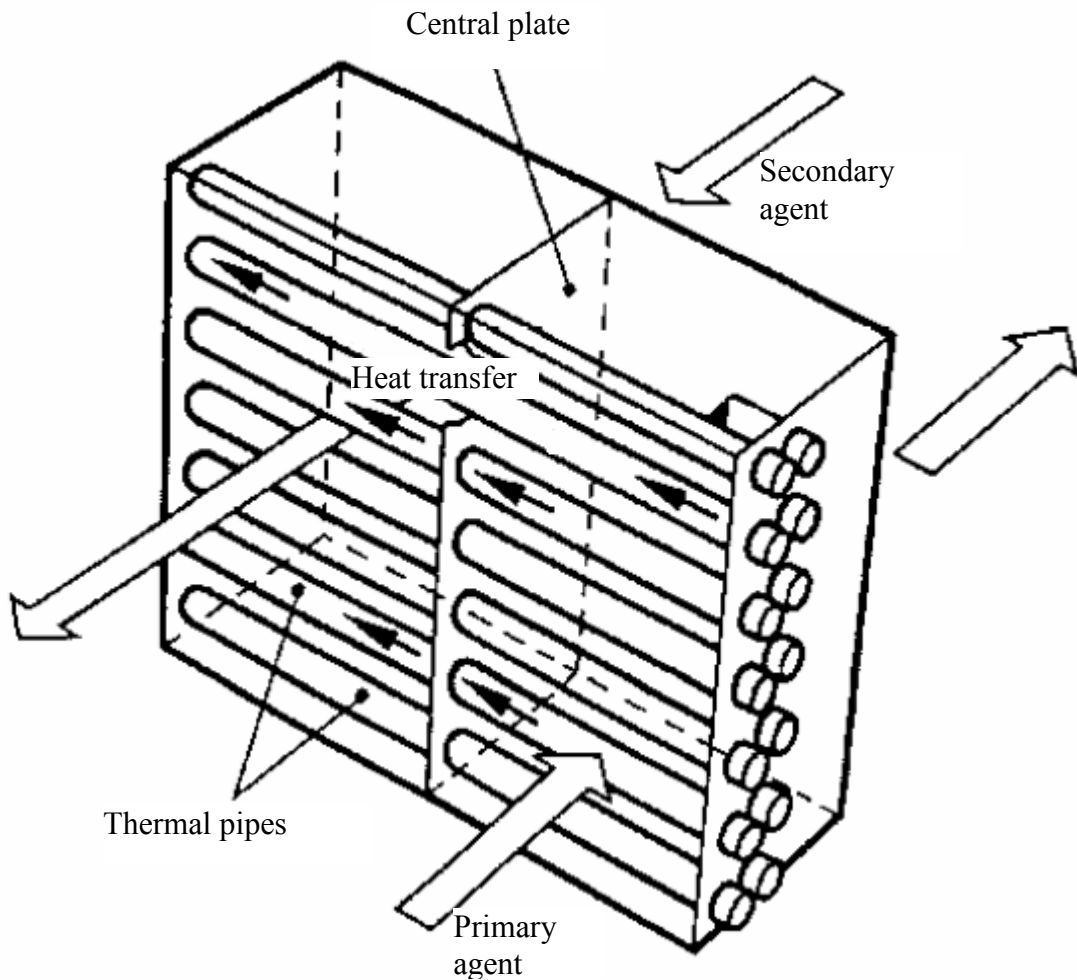
<b>Type of thermal pipe</b>	<b>Temperature range</b>	<b>Interior fluid</b>	<b>Pipe material</b>
<b>Thermal pipes for low temperatures</b>	- 20 ÷ 60 °C	Cooling agents Methanol Ethanol	Aluminum Copper
<b>Thermal pipes for average temperatures</b>	60 ÷ 250 °C	Water Organic liquids (Toluene)	Copper
<b>Thermal pipes for high temperatures</b>	250 ÷ 400 °C	Mercury	Stainless steel
<b>Thermal pipes for very high temperatures</b>	> 400 °C	Liquid metals (HG, Na, K, Li)	Stainless steel Special compounds rich in Ni, Molybdenum, Tungsten

### THERMAL CALCULATION OF THE HEAT EXCHANGERS WITH THERMAL PIPES

In a heat exchanger there are thermal pipes positioned together in a bundle, connected in the middle by a central plate, separating the device into two areas, one for the flow of the primary agent releasing heat by vaporizing the operational agent and another in which the secondary agent receives heat from a condensing operational agent.

If the thermal agent is gas, the exterior surface of the thermal pipes is usually increased by ribbing.

## Principle plan of a heat exchanger with thermal pipes



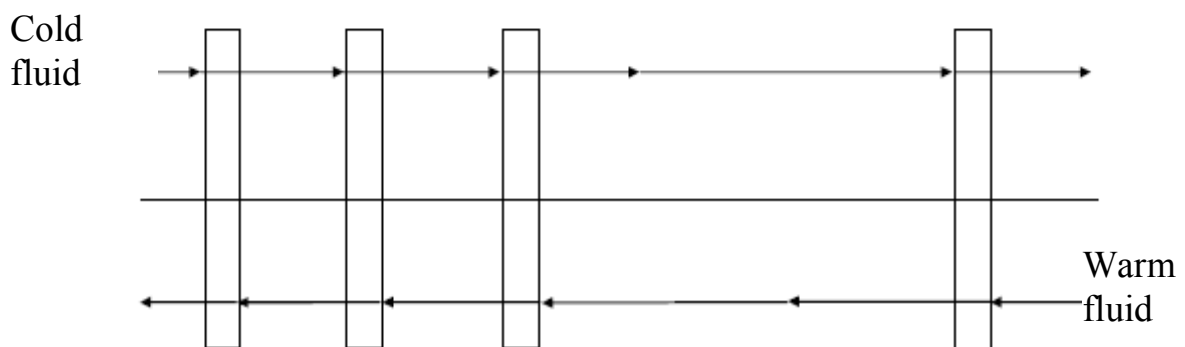
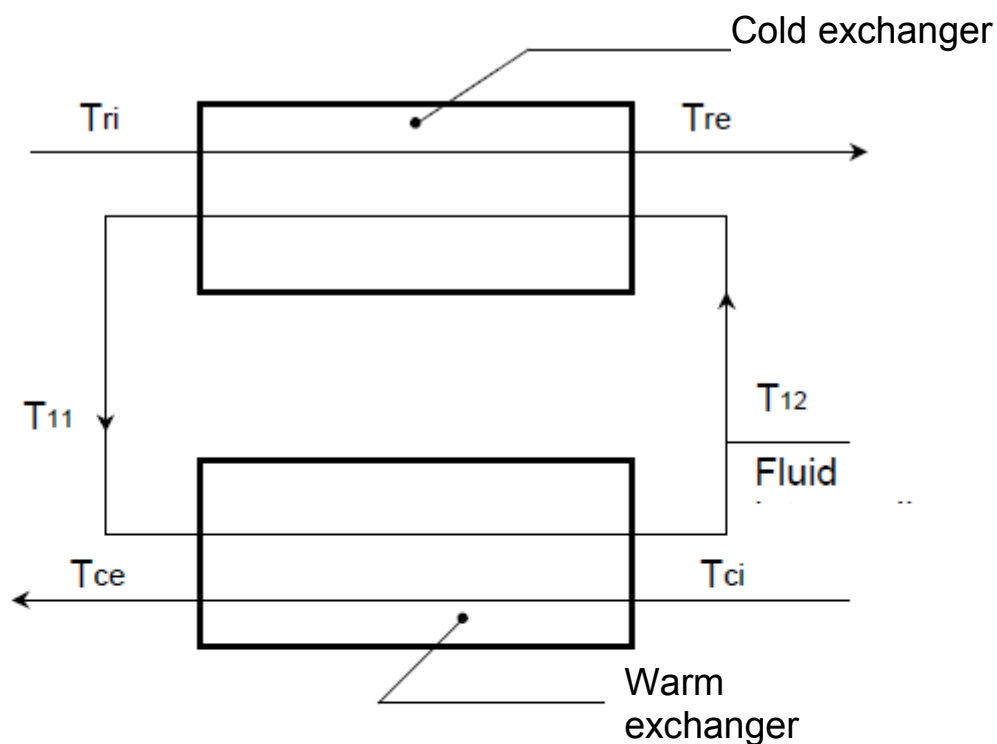
For the calculation of the heat exchangers using thermal pipes, the device is disassembled in its elementary exchangers.

Every thermal pipe is seen as an assembly of two coupled heat exchangers (one vaporizer and one condenser), where the vapors phase has the same temperature. It is also considered that the thermal pipes on the same row (on the same vertical flow line) have the same temperature, whereas for one row a single thermal pipe is taken into consideration with a heat exchange surface equal to the surface of the pipes in one row.

The method implies the following subsequent calculation steps:

- ☞ The determination of the global heat exchange coefficient for the vaporizer and the condenser of each “cell”;
- ☞ The determination of the temperatures of the two thermal agents exiting every cell by means of the  $\epsilon$  NTC procedure;
- ☞ The determination of the temperatures of the thermal agents when exiting the heat exchangers (calculation by means of the matrix method);
- ☞ The verification of the temperature field in each thermal pipe and the determination of the thermal flows transferred by every “cell” and the whole heat exchanger.

Model of a row of thermal pipes



## USE OF THE HEAT EXCHANGERS WITH THERMAL PIPES

### ADVANTAGES

- **Very good sealing** between the two fluids, there is only one wall between them, very easy to seal by welding
- **High reliability** of the device containing a large number of pipes; the failure of one pipe affects the operation of the device only by a very small percentage and does not endanger operation in any case.
- **Very good expansion characteristics**, thermal pipes are free at both ends,
- **Versatility** because the pipes are independent (not connected among each other), any geometry of composition can be used.
- **High efficiency** due to the high inner heat transfer coefficients (boiling and condensing) and the possibility of extension of the transfer surface by ribbing.
- **Reduced pressure losses** because the thermal agent flowing over the pipe bundle generates smaller pressure losses than in the case of the flow through the inside of the pipes.

The versatility and the possibility of ribbing on the outside have led to the use of the thermal pipes as **heat recovery devices** for pre-heating of the combustion air in industrial ovens.

Another area of application for these devices is **the air conditioning** technology, where cheap thermal pipes filled with cooling agent are used, with plane ribbing made of aluminum on the outside.

Due to the possibility of perfect sealing, the heat exchangers with thermal pipes are used in some applications in the **chemical and nuclear industry**.