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INDUSTRIAL PLANTS

Chapter twenty-five:

Piping – Assembly and protection of the pipelines

DOUBLE DEGREE MASTER IN

“PRODUCTION ENGINEERING AND MANAGEMENT”

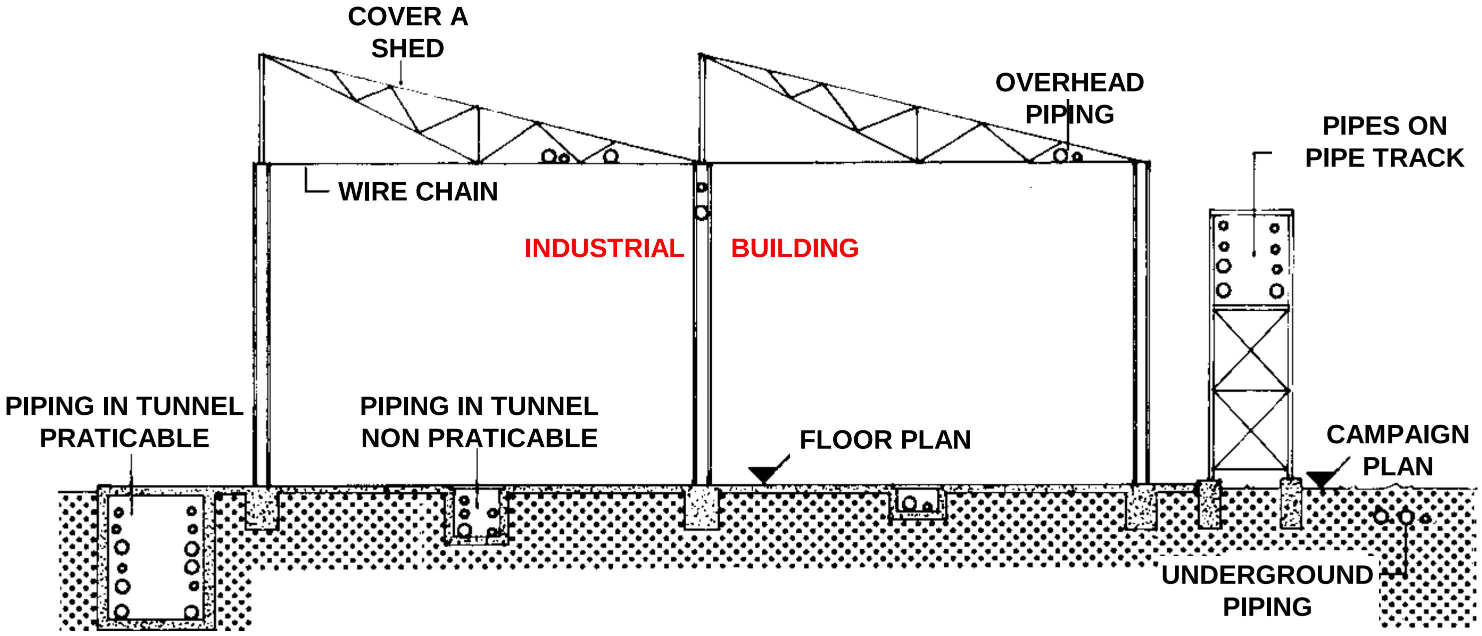
SEAT OF PORDENONE

UNIVERSITY OF TRIESTE

Assembly and protection of the pipelines

Within the industrial buildings, at one only floor, the pipes can be installed immediately above and below the chain wire (easy to do the inspections and any amendments), in the space left by the pillars, or in tunnels beneath the floor.

Outside the building, however, the pipes can be underground or mounted on special metal structures or in tunnels.



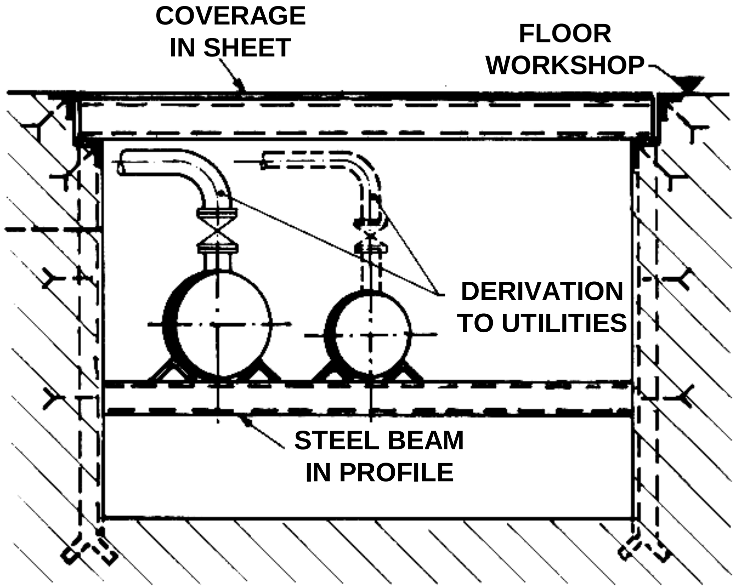
Assembly and protection of the pipelines

Within the industrial buildings, the arrangement of the pipes in tunnels made beneath the floor, is accepted only when the supply energy is prevented from or hampered by overhead cranes or other obstructions (reduction of ambient light).

The piping for the collection and recovery of fluids discharged by users with residual pressures near zero are placed in underground tunnels or under the floor plane.

In this case, must be arranged in correspondence with the appropriate wells of inspection of branches, or changes in direction of pipe portions very long (> 30-40 m).

Is typical of drainages or networks of recovery of the water technological use.



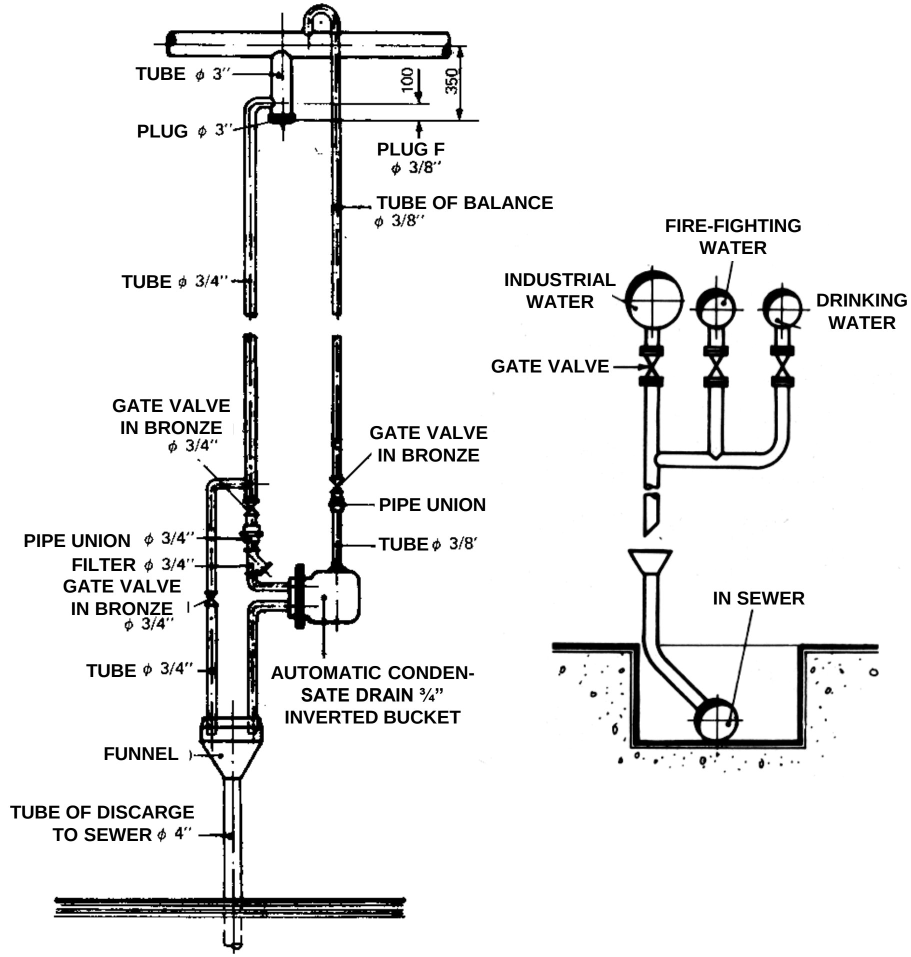
Assembly and protection of the pipelines

The tunnels are covered by slabs of reinforced concrete, steel sheets striatum or ashlars or gratings.

These covers must be designed to withstand the loads rovers working in the workshop without warping or sagging.

The tunnels must be equipped with manhole exhaust for the water to drain; the same floors must be sloped to facilitate the natural flow of water toward the manholes.

It is not uncommon for the adoption of mixed accommodation of overhead piping or in the tunnel in a single industrial building.



Assembly and protection of the pipelines

The pipelines must always be equipped with an adequate slope to allow them to drain if necessary (0,2-0,5%).

If the fluid conveyed in the tubes is a liquid, it must facilitate the collection, in the upper parts of the network, of the air which is liberated.

Often, if the characteristics of the ground permit, the building and its roof is constructed with a certain slope (up to 0.3% if there are overhead cranes and 1% if there aren't, and there are no difficulties of accommodation of machinery.

When the building is plane and the space available to make the gradient of the piping network is limited, alternate with uphill, downhill.

If the fluid is gaseous and drag condensate or other liquids, the slope of the piping allows the fluid to collect in low spots, where it can be evacuated with the condensate drains.

The vertical exhaust pipes are installed at the columns or walls. The collection of waste pipes are buried under the floor or installed in a tunnel.

Assembly and protection of the pipelines

The tubes before being placed in work, must be cleaned internally to avoid the presence of foreign bodies, fouling or surface oxides.

The networks of pipes are generally tested at pressure; may be used the compressed air (spreading soapy water on them after cleaning) or water (filling the network and pressing it by means of a pump at the pressure test - 1.5-2 times the maximum pressure working fluid conveyed in the network).

Both the overhead piping, that those in tunnel, must be supported by appropriate supports. The pipes must therefore rely on brackets, which have the authority to limit the deflection of the arrow, preventing the formation of pockets in which the fluid may stagnate, and limit the stress on the pipes and attacks on the machines and equipment.

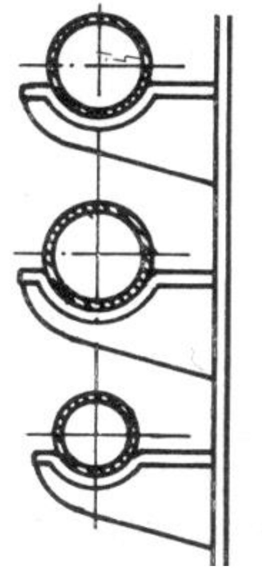
If the temperature of the fluid in the pipes is variable in time, the choice of the type of brackets and the relative positioning must take account of thermal expansion induced.

Assembly and protection of the pipelines

The types of **brackets** are divided into:

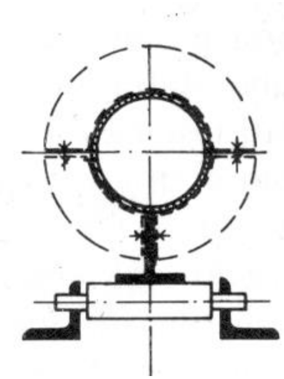
Normal support

Unloads the weight of the pipe and the fluid contained in it on a bearing structure (integral part of the building or structure specific)



Support with a guide

Same as the normal support, prevents any transverse movement of the pipe. It's used to reduce the buckling length of the pipe cross, to limit the frequency of vibration of a horizontal pipe, and to guide the pipe during the thermal expansion.

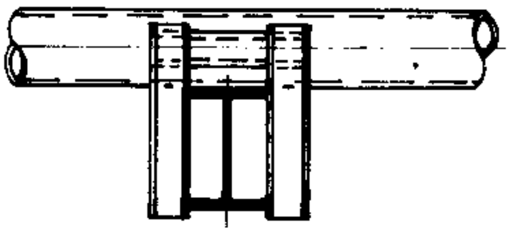


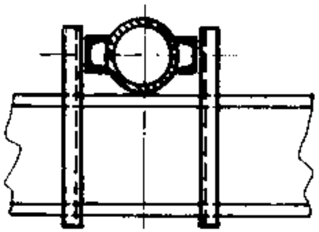
Assembly and protection of the pipelines

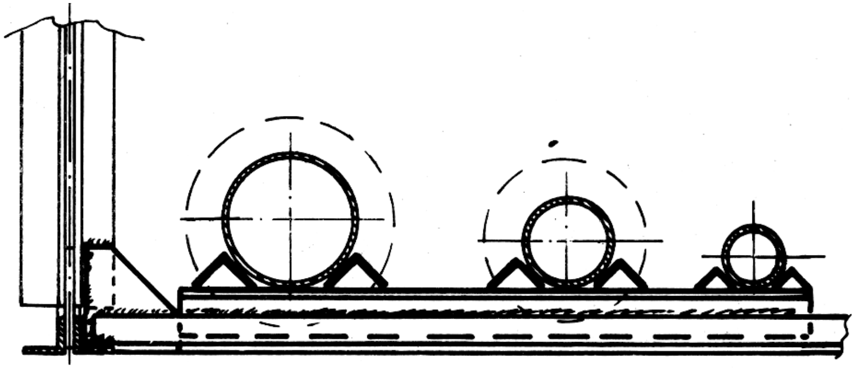
The types of **brackets** are divided into:

Support at a fixed point

Realizes a fixed anchorage, at which the pipe does not have translations or rotations (for example the points of attachment of machines, plants etc.). The fixed points are made by welding a metal section between the tubes and a rigid structure, or by bolting on suitable media drowned profiles with walls of the clamps in the mural parts.







Assembly and protection of the pipelines

The distance between two consecutive supports depend on the diameter, thickness and material of the tube, and the specific weight of the conveyed fluid and possible thermal insulation of the pipe and the valves, fittings, elbows, etc.

Whereas the piping as semi-jammed beam, subject to uniformly distributed load, the arrow of inflection f holds:

$$f \approx 0{,}01 \cdot q \cdot l^4 / (E \cdot J) \qquad \text{(cm)}$$

where:

q = uniformly distributed load (kg/cm)

l = length of piping between two consecutive supports (cm)

E = modulus of elasticity of the material of the piping (kg/cm^2)

J = module of inertia of the piping (cm^4)

It requires that the arrow does not exceed usually a few millimeters in diameter of the pipe up to 200 mm, while for larger diameters can be accepted arrows of 10-20 mm.

Assembly and protection of the pipelines

In any case, the distances between two consecutive brackets should not exceed the following values:

Nominal diameter DN	Distance between two brackets (m)
25	2,5
40	3,0
50	3,5
75	4,0
100	4,5
150	5,5
200	6,2
250	7,2
300	7,5

Protection of buried pipes

The metal pipes underground are subject to aggressive phenomena which can cause corrosion. These phenomena are due to electrochemical action between metal and salt solutions in the soil.

The humidity of the soil may constitute the electrolyte and, in certain areas of the outer surface of the tubes, can be formed of the electrodes, while the electric circuit closes through the tubes. The electric current starts from the positive electrodes and, through the electrolyte, returns to the negative electrodes. In correspondence of the first, occur corrosion, while on the latter is formed a thin layer of hydrogen, which is produced following the decomposition of the water. The oxygen that is released contributes to oxidize the iron ions, detached from the tube.

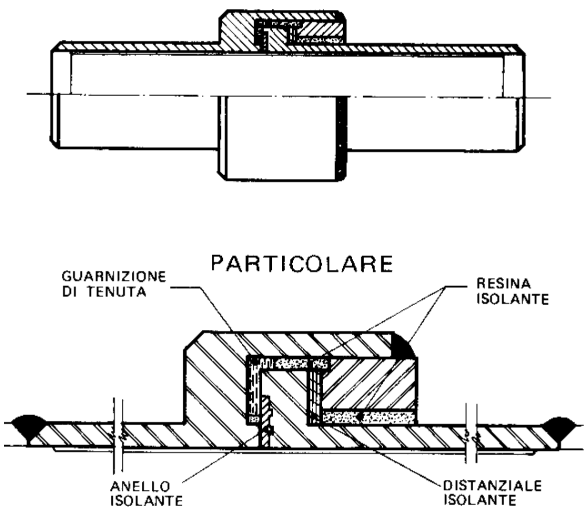
The electrolytic process is enhanced by the presence of stray currents electrolytic dispersed from the rails of rail or other electrically powered equipment, changes in soil characteristics, action of microorganisms and the insertion of new pipes in an underground pipe for a long time.

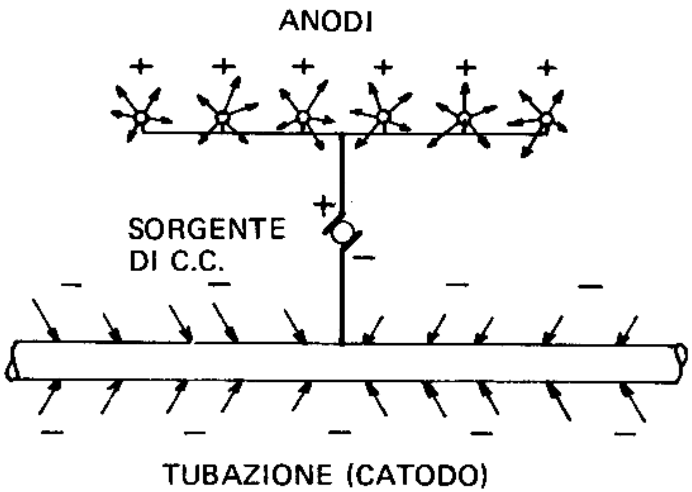
Assembly and protection of the pipelines

Protection of buried pipes

The phenomena aggressive of the ground can be mitigated or eliminated by the following protection devices:

- installation, along the buried pipes, of joints of electrical insulation (dielectric joints) that interrupt the electrical continuity of the same piping;
- cathodic protection, obtained by connecting the negative pole of a direct current source with the pipe and the positive pole of the same to the anodes underground. The potential difference is negative, which comes to have between the pipe and ground that it functions as a cathode preventing the detachment and migration of ions of the metal piping;





Assembly and protection of the pipelines

Protection of buried pipes

The phenomena aggressive of the ground can be mitigated or eliminated by the following protection devices:

- coating of the tubes with materials impervious to water (liquid layers of hot bitumen, bituminous mixture after cooling the first layer, helical bandage with a double layer of glass wool impregnated with bitumen and a layer of white lime hydrate in order to make white the outer surface);
- coating with adhesive tape of polyvinyl, obtained by winding in a spiral on the pipes the self-adhesive tapes of polyvinyl chloride after brushing and antioxidant coating of the piping.

  The application temperature should be between 0 and 70°C, but preferably 18-20°C.

These two protections allow to call these pipelines "coated externally“.

Assembly and protection of the pipelines

Internal protection of piping

The pipes must often be protected by internal agents containing the fluid conveyed. The chemicals can cause corrosion, against which they take the following measures:

- use of pipes with internal coating bituminous, obtained by immersing the tubes in baths of hot liquid bitumen;
- ebonite on the inner surface of the pipes, obtained by applying a coating (several mm) consisting of mixtures of natural or synthetic elastomers with a high content of sulfur;
- adoption of tubes made of special materials, such as stainless steel and plastics, and used for fluids weakly acidic or basic and having low temperatures and concentrations;
- preliminary treatment of the fluid to be pumped, through the use of chemical reagents (inhibitors of the anodic corrosion - sodium chromate, oxygen etc. - and cathode - zinc sulfate, calcium bicarbonate), adapted to prevent corrosion by the formation of films protection on the metal.

Assembly and protection of the pipelines

External protection of overhead piping

The steel tubes installed outside or inside of the industrial plant are usually protected by the destructive processes due to atmospheric agents (ad example moist air).

To avoid or minimize the impact caused by these agents, are used for protective coatings. The cycle of treatment of these is:

- polishing and brushing (or sandblasting) of the surfaces to remove the oxide layer powdery;
- applying a coat of protective paint (antirust);
- application of one or two layers of enamel chlorine--synthetic in such a way that the layer of paint is at least a minimum thickness of 90 μm.

Assembly and protection of the pipelines

Coating of pipes conveying fluids hot or cold

In this case we are faced with the following requirements:

- protect from frost liquids contained in the pipes;
- reduce the heat losses towards the outside;
- prevent condensation of moisture contained in the environment along the outer surfaces of the pipes.

It then uses the **insulating coatings** (thermal) and coatings anti-dripping, to avoid condensation of water vapor on the pipes.

The insulating materials are realized by means of fibrous or cellular type having a low coefficient of conductivity (kW/m °C), which increases with the increase of the temperature.

The insulating materials are suitable for:

- *fluids having temperatures below the ambient temperature* (polyurethane, cork, foam, mineral wool or glass etc.);
- *fluids having temperatures above the ambient temperature* (rock wool or glass).

Assembly and protection of the pipelines

Coating of pipes conveying fluids hot or cold

The insulation of the pipes are made in the form of cups, mats etc. They are held in place by wire mesh or galvanized steel wire galvanized.

The final exterior coating for aesthetic purposes and protection against impact, consists of galvanized sheet steel or aluminum, cement plaster or gypsum, reinforced with galvanized steel mesh.

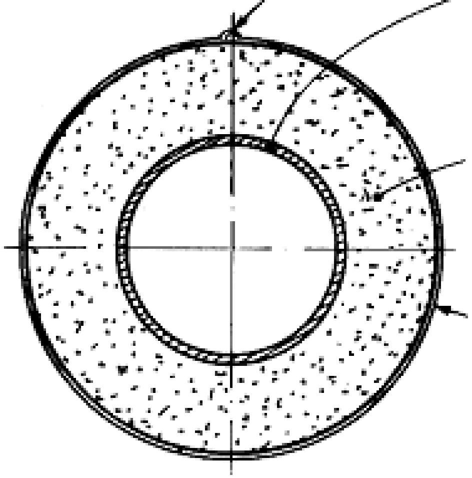
The coatings anti-dripping, for fluids at temperatures below the dew point temperature of atmospheric air, are protected by an impermeable layer of steam (vapor barrier) to avoid that the steam passes from atmospheric air to the insulating material.

If is formed in the cavities of the insulator of the water instead of air, then this last loses its insulating power, and then the characteristics for which it was used.

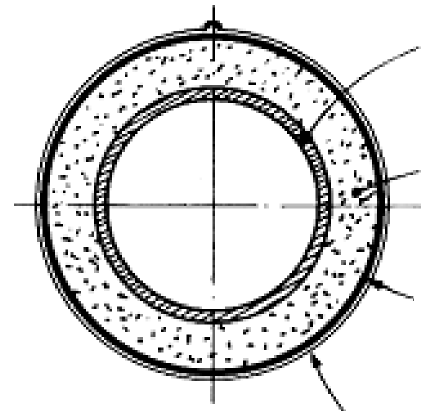
Assembly and protection of the pipelines

Coating of pipes conveying fluids hot or cold

Pipe with hot fluid (t > temperature environment)



Pipe with cold fluid (t < temperature environment)



Note: In the case of fixing with self-tapping screws it is appropriate to wrap the vapor barrier with a mat of mineral wool or glass, thickness 10 mm, in order to avoid piercing the barrier by the screws

Choice of coating of the piping

For this choice it is based on a criterion technical-economic. In the case of a pipe that conveys a hot fluid, are:

r_i, r_e = inner and outer radius

t_i = temperature of the fluid within

t_e = external surface temperature

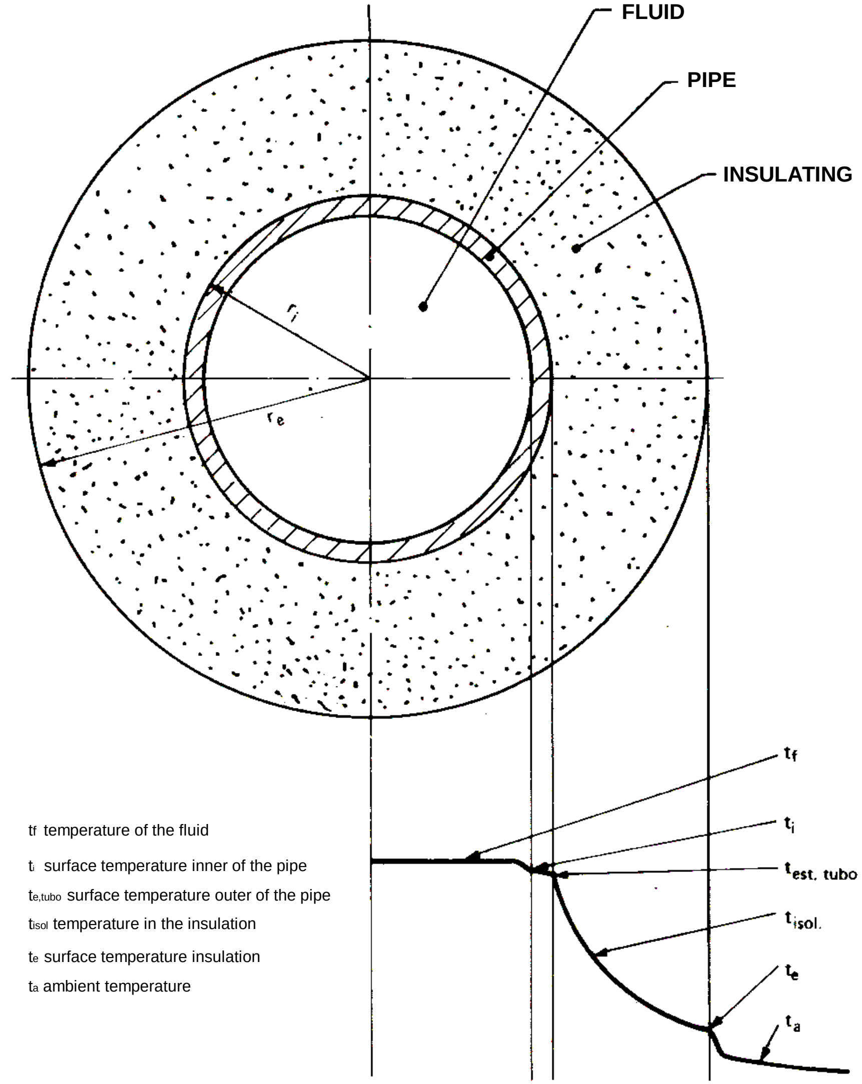
t_a = environment air temperature

L = length of the piping

λ = conductivity coefficient

h_i, h_e = coefficient of adduction of the surfaces i and e, taking into account the propagation coefficient liminal and that of irradiation

Is permissible suppose that the temperatures are considered constant and t_e = t_a e t_i = temperature on the inner surface of the insulating coating



Choice of the pipe coating

The amount of heat that per unit of time that passes of the interior at the outside of the pipe is given by the relation:

$$Q = \frac{t_i - t_a}{R} \cdot L$$

where:
R = total resistance expressed by the relation:

$$R = \frac{1}{2 \cdot \pi} \left(\frac{1}{h_i \cdot r_i} + \frac{1}{\lambda} \cdot \ln \frac{r_e}{r_i} + \frac{1}{h_e \cdot r_e} \right)$$

The report was not taken into account the pipe metal since it is of small thickness and has a high coefficient of conductivity of the steel.

Choice of the pipe coating

a) *Insulating coatings antifreeze*

We consider the case of pipes placed in environments at temperatures below 0°C and conveying fluids which must not freeze. Considering a section of pipe infinitesimal dl, the amount transmitted dQ must be equal to the amount of heat lost by the fluid that flows through pipeline:

$$dQ = \frac{t_i - t_e}{R} \cdot dl = -G \cdot c_p \cdot dt_i$$

where:

G = fluid flow rate (kg/h)

c_p = specific heat of the fluid (kJ/kg °C)

dt_i = cooling of the fluid in the stretch dl

Since t_a is constant and c_p = 4,18 kJ/kg °C, is transformed:

$$\frac{t_i - t_e}{R} \cdot dl = -G \cdot d(t_i - t_a) \cdot 4{,}18$$

Choice of the pipe coating

a) *Insulating coatings antifreeze*

Integrating along a length of tubing of length L and simplifying, we obtain:

$$\frac{L}{G \cdot R \cdot 4{,}18} = \ln \frac{t_i^{'} - t_a}{t_i - t_a}$$

where:

$t_i^{'}$ = inlet temperature in the stretch of pipe considered;

t_i = outlet temperature in the stretch of pipe considered;

In this way one can determine:

- the minimum temperature t_i that you can reach the fluid conveyed;
- obtain R and therefore the thickness of insulation required;
- evaluate the minimum flow rate G because the fluid in the pipe does not freeze.

In case of firefighting networks, where the water is stopped, the danger of frost is more serious: in this case especially if the networks are underground pipes pass outside of the building or in unheated rooms

Choice of the pipe coating

b) *Insulating coatings properly said*

We consider the case of piping, which should limit the exchanges of heat between a fluid at a temperature different from that environment and the environment itself. The thickness of insulation must be such that the sum of the annual costs for the waste heat and for the execution of the coating is minimized. The cost of the waste heat is:

$$C_Q = Q \cdot n \cdot c$$

where:

Q = heat lost through a long line of insulation L (kW) expressed by the relation:

$$Q = (t_i - t_a) \cdot L / R$$

n = number of hours of operation per year (h/year)

c = unit cost of waste heat (€/kWh)

Choice of the pipe coating

b) *Insulating coatings properly said*

Since we can neglect the external supply of heat (pipes installed in virtually calm atmosphere), the cost of the insulation in place (€/year) is:

$$C_i^{'} = \pi \cdot \left(r_e^2 - r_i^2\right) \cdot L \cdot c_i \cdot \frac{1}{a_{n|}}$$

where:

r_e = outer radius of the coating (m)

r_i = inner radius of the coating (m)

L = length of the piping (m)

c_i = unit cost of the coating in work (€/m^3)

$1/a_{n|}$ = unitary term of depreciation in n years at interest rate i

Choice of the pipe coating

b) *Insulating coatings properly said*

At value of the cost of the insulation in work you must add the cost of the outer sheet (€/year) expressed by the relation:

$$C_i^{''} = 2 \cdot \pi \cdot r_e \cdot L \cdot c_r \cdot \frac{1}{a_{n|}}$$

where:

c_r = unit cost of the coating in work (€/m²)

Ultimately, the total cost of the coating is:

$$C_i = C_i^{'} + C_i^{''}$$

It's about finding the value of r_e and the thickness of insulation (r_e - r_i) that minimizes the sum:

$$C = C_Q + C_i.$$

Choice of the pipe coating

b) *Insulating coatings properly said*

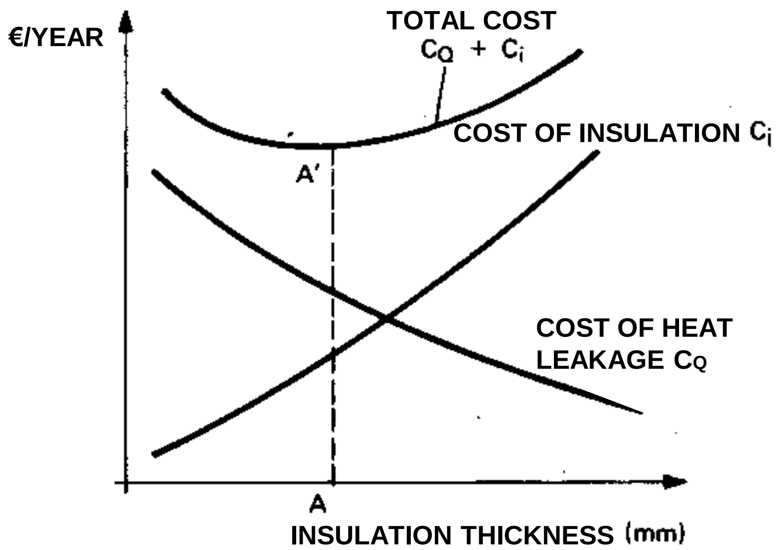
From a theoretical point of view, one can determine the value of the outer radius of the coating r_e that minimizes the total cost C (the first derivative is nothing). In practice, the cost in heat loss C_Q depends on certain elements can not be expressed in function of r_e:

- depreciation of plant;
- cost of fuel consumed;
- labor costs for the operation of the plant generators-distributors;
- cost of electrical energy consumed by the operation of the plants;
- cost of the treated water consumed for the operation of plants;
- cost of plant maintenance.

Choice of the pipe coating

b) *Insulating coatings properly said*

The solution is found from a point of view graph that allows to determine the lowest total cost, which corresponds to the thickness of the coating insulating considered more economical.



A = insulation thickness which corresponds to the total annual cost minimum (AA'), that is the thickness more economical

You then choose the diameter nearest shopping, because standardization is more convenient than creating a diameter resulting from the calculation.

Choice of the pipe coating

c) *Coatings anti-dripping*

Serves to prevent condensation of atmospheric water vapor on the outer surfaces of the pipes, by means of the thermal insulation which increases the surface temperature of the external surfaces in contact with atmospheric air. The atmospheric air clear (without mist) is a mixture of dry air and water vapor (moist air). The steam contained in the humid air is overheated (partial pressure lower than that of saturated steam having the same temperature).

Adding steam to moist air, the partial pressure of the steam increases until it reaches the pressure corresponding to that of saturated steam, in which case the moist air is saturated with steam (not may contain more and more doses of moisture remain in the air as a mist.

The temperature at which the humid air becomes saturated it is said **dew temperature** or **dew point**.

Choice of the pipe coating

c) *Coatings anti-dripping*

Cooling further the air below the dew point temperature, is obtained the condensation of the steam.

The fundamental sizes of humid air are:

- dry bulb temperature (temperature marked by a thermometer placed in ambient air);
- wet bulb temperature (temperature marked by a thermometer bulb wrapped in moist gauze placed in ambient air;
- dew point temperature (temperature at which there is the condensation of the steam);
- specific humidity or absolute (amount of steam contained in the dry air – $kg_{vapore}/kg_{aria\ secca}$);
- relative humidity (relationship between specific humidity and relative humidity of moist considered specifies that the moist air would have if it were saturated -%);

Choice of the pipe coating

c) *Coatings anti-dripping*

The fundamental sizes of humid air are:

- enthalpy or heat total (sum of the heat required to carry 1 kg of dry air from 0°C and 760 mm Hg at the temperature t of humid air, heat required to vaporize the absolute humidity x contained in the humid air supposed to 0°C and heat required to superheat the moisture x from 0°C to the temperature of the moist air t:

$$J = 4{,}18 \cdot (0{,}24 \cdot t + 595 \cdot x + 0{,}46 \cdot t \cdot x) \qquad (kJl/kg_{aria\ secca})$$

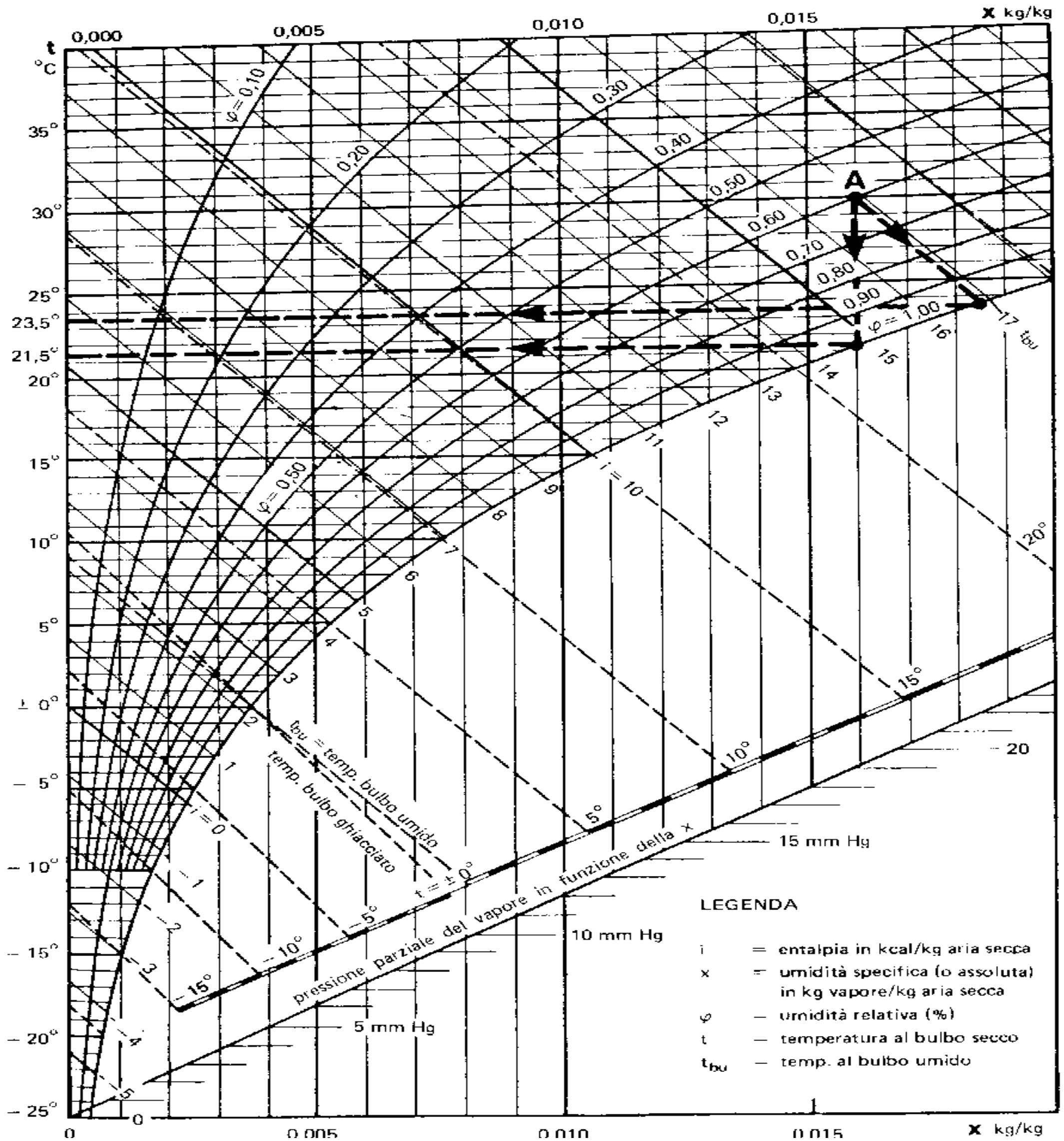
- specific volume (volume of moist air containing 1 kg of dry air and x kg of steam).

The corresponding values can be detected by the Mollier diagram for moist air at atmospheric pressure of 760 mm Hg.

Assembly and protection of the pipelines

Choice of the pipe coating

c) *Coatings anti-dripping*



Choice of the pipe coating

c) *Coatings anti-dripping*

The formation of dew on the outer surface of a bare pipe, traveled by a cold fluid, can be avoided thermally isolating the pipe, so as to raise the surface temperature of the pipe isolated above the dew point of atmospheric air in which is the same pipe.

Indicating with:

r_e = outer radius of the coating (m);

r_i = inner radius of the coating = outer radius of the tube (m);

L = length of the piping (m);

t_i = temperature of the fluid to the internal

t_e = external surface temperature

t_a = temperature of the ambient air

λ = conductivity coefficient

h_i, h_e = coefficient of adduction of the surfaces i and e, taking into account of the propagation coefficient liminal and that of irradiation

Choice of the pipe coating

c) *Coatings anti-dripping*

The heat coming into a pipe of length L, in the case where $t_i < t_e$:

$$Q = \frac{2 \cdot \pi \cdot (t_a - t_i)}{\frac{1}{h_i \cdot r_i} + \frac{1}{\lambda} \cdot \ln \frac{r_e}{r_i} + \frac{1}{h_e \cdot r_e}} \cdot L$$

In the case of water flowing in the pipe, h_i = 8.000-12.000 kJ/h m^2 °C, for which the term $1/(h_i \cdot r_i)$ is negligible.

The heat entering the tubing can be calculated from the relationship:

$$Q = h_e \cdot 2 \cdot \pi \cdot r_e \cdot L \cdot (t_a - t_e)$$

The coefficient of adduction of the outer surface for pipes in still air is given by the relation:

$$h_e = 4{,}18 \cdot (8{,}2 + 0{,}0073 \cdot t \cdot \sqrt[3]{t})$$

where t is the external surface temperature of the insulated pipe.

Choice of the pipe coating

c) *Coatings anti-dripping*

Ultimately, equaling the two reports is obtained:

$$\frac{(t_a - t_i)}{\frac{1}{\lambda} \cdot \ln \frac{r_e}{r_i} + \frac{1}{h_e \cdot r_e}} = h_e \cdot r_e (t_a - t_e)$$

The unknowns are t_e e r_e. Fixed t_e, which must be greater than the dew point temperature of the air surrounding the pipe, is obtained r_e and therefore the thickness of the insulating coating:

$$s = r_e - r_i$$

This thickness is able to guarantee a surface temperature on the coating itself greater than the dew point.

Assembly and protection of the pipelines

Thermal expansions of the pipes

In the transport of hot fluids, the pipes are subjected to temperature changes that cause elongation and contraction of the same. These expansions depend on the coefficient of linear expansion of the material forming the tubes, their length and the temperature jump.

The thermal expansion of a straight pipe ΔL free at one end and a long L is given by: $\Delta L = \alpha \cdot L \cdot \Delta t$

where:

α= thermal expansion coefficient that depends on the nature of the material,

Δt = temperature jump.

The effort of compression to which a pipe is subject rigidly anchored to the two extremes is:

$$\sigma_c = \alpha \cdot E \cdot \Delta t = F/S$$

where:

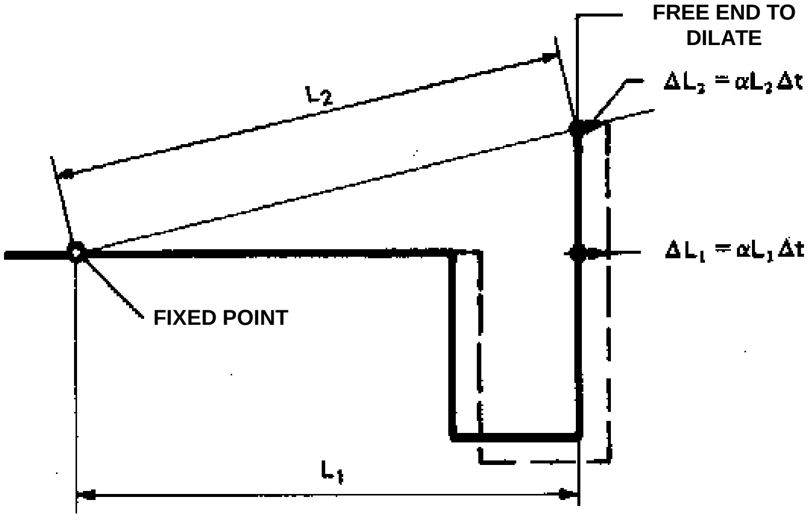
F = force exerted by the pipe;

S = section of the pipe.

Thermal expansions of the pipes

The lines must be subject to verification calculations, in order to determine whether the efforts that are generated during the expansion can deform with the dangers of broken pipes or determine the unacceptable pressures on plants to which the pipes are connected.

In practice, installing compensators that have the function to absorb the expansion of the pipes.

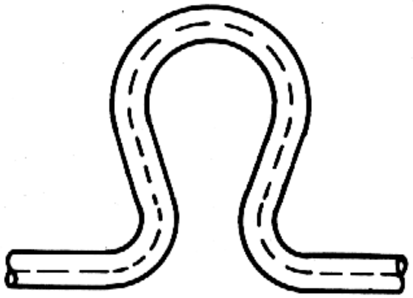


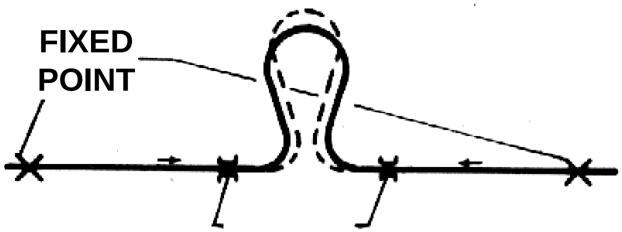
Graphical determination of the expansion of a non straight pipe

Thermal expansions of the pipes

Types of compensators:

a) compensators to omega or to lyre





Absorb axial expansion of straight pipes. They can be installed on small and large diameter tubes and high internal pressures. Require maintenance, but show the overall dimensions than other compensating and cause pressure losses are not negligible

The overall height H is given by the relation:

$$H = k \cdot (f \cdot D)^{1/2}$$

k = costant

f = arrow or axial strain that can absorb the compensator

D = diameter of the tube

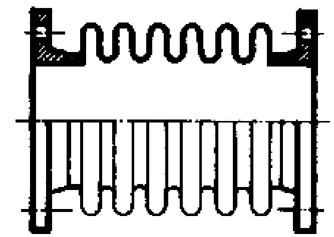
Thermal expansions of the pipes

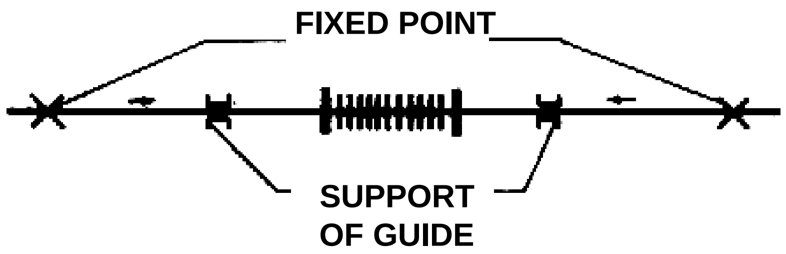
Types of compensators:

b) axial compensators to bellows

They are made of logs or stainless steel tubing having parts rolling.

Are able to absorb only the dilations that take place along the longitudinal axis. They are installed along the straight sections of pipe between two fixed points and guides at the attacks, to prevent the transverse displacements





They are suitable for internal fluid pressures of a few atmospheres for small-and medium sizes. Are more expensive than a lyre, but do not require maintenance and their overall dimensions and the pressure drop induced in the fluid are minor. The ends are flanged or weld smooth. To avoid fatigue, it is important to know the number of cycles provided.

Thermal expansions of the pipes

Types of compensators:

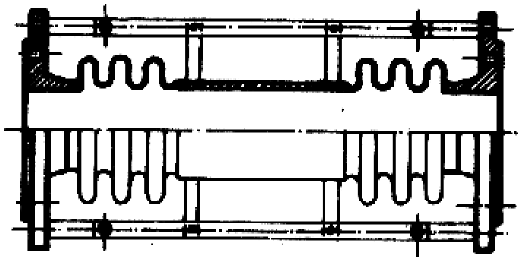
c) compensating at articulation at bellows

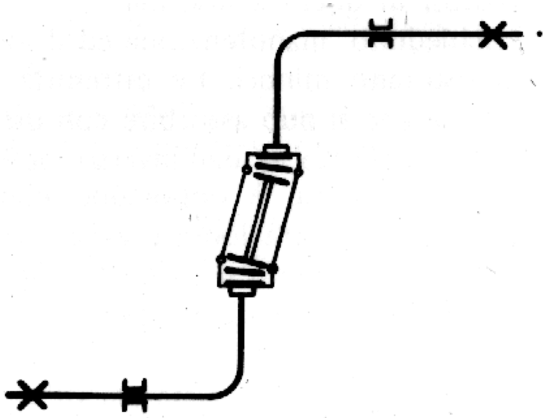
They are made of logs or stainless steel pipes to corrugated walls.

Deform only transversely to their longitudinal axis, thanks to the presence of articulated levers which prevent the axial deformations.

The angles of rotation of the levers to junction vary depending on the number of waves of the bellows compensators.

The forces induced on any fixed points are negligible





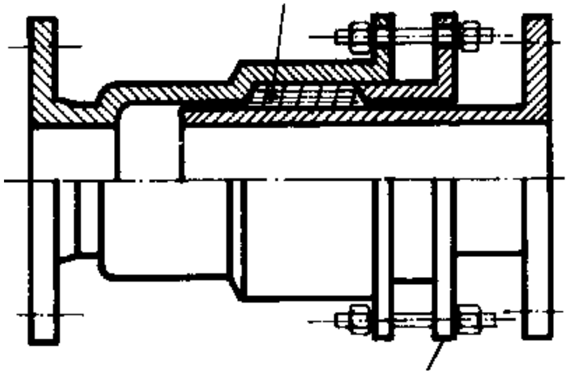
Thermal expansions of the pipes

Types of compensators:

d) compensators at telescope

Are constituted by two coaxial parts, sliding one inside the other and seal gland. Are not subject to fatigue phenomena.

Of lower cost than the previous ones, have the drawback of requiring periodic maintenance (substitution of the stuffing box).



The compensators at omega, axial and junction are fitted with pretensions to exploit their performance.

Each compensator must be installed with a deformation contrary to that which will have to undergo dilation durations (for example, if the total expansion to be absorbed is T, the compensator must be mounted with a prestrain D/2.