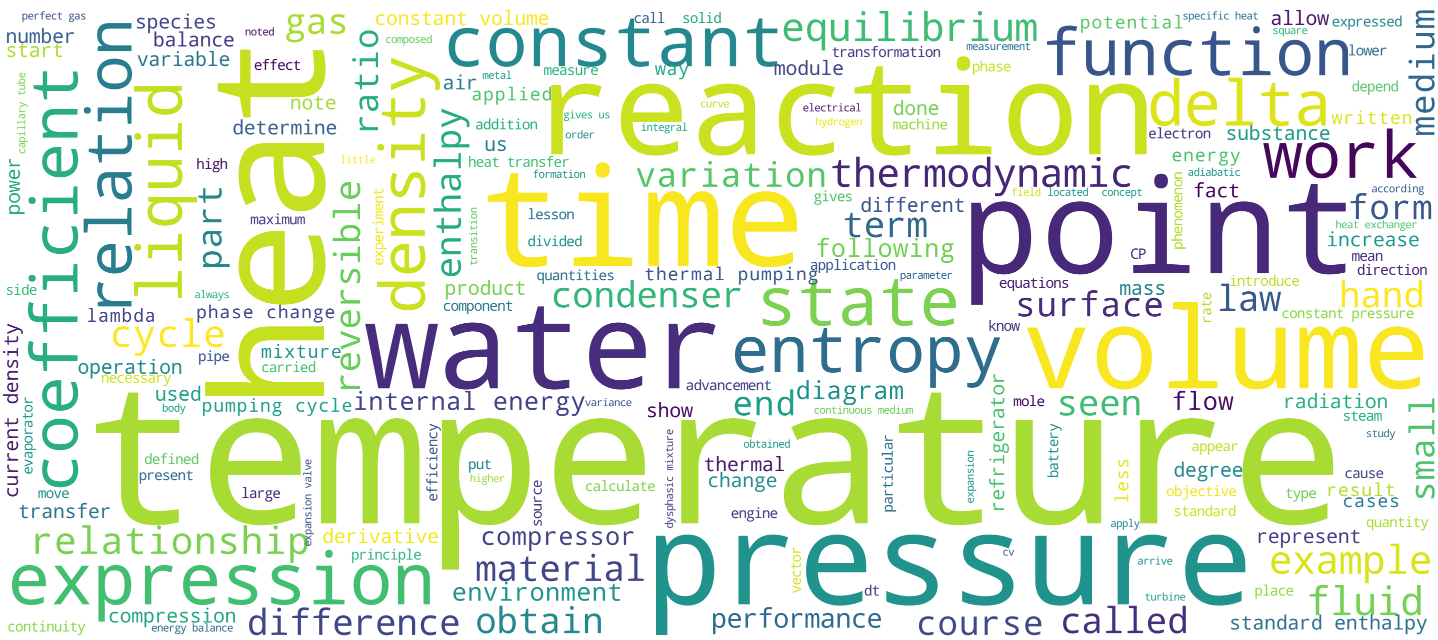
Thermodynamique

Cycles de pompe thermique

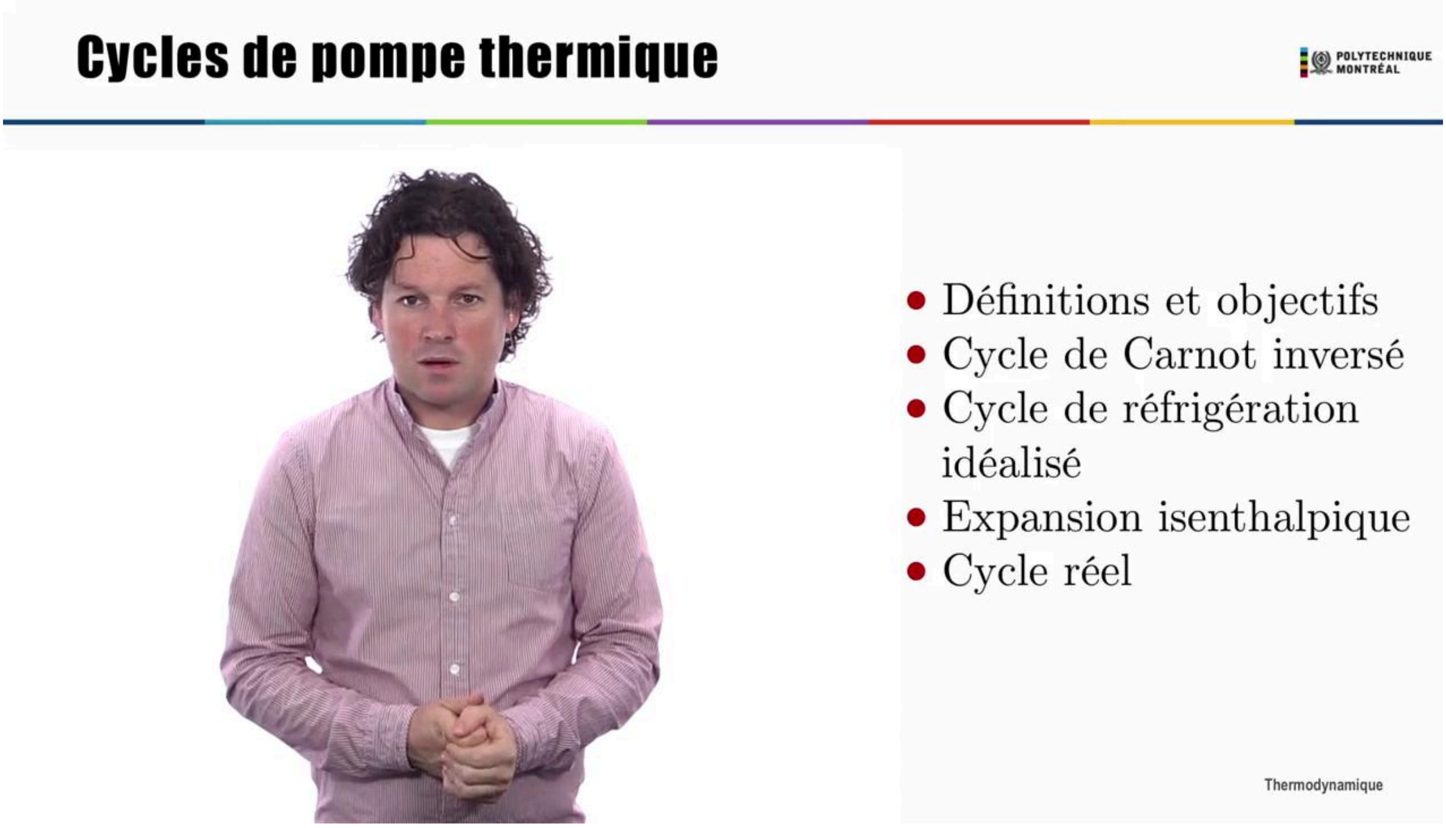
Prof. Etienne Robert

Nicolas Léonard Sadi Carnot, 1796-1832



Video

EPFL



Hello, my name is Etienne Robert and I am now going to present you a brief module on thermodynamic analysis of thermal pumping cycles. As mentioned in the introduction to the lesson on cycles thermodynamics, the thermal pumping cycles aim at transferring a heat, the transfer of a quantity of heat against a guard of temperature, using a work input external to the cycle. Of course, these cycles have applications in the field of refrigeration, but also for residential heating. This module will cover the following. First, I will introduce some definitions and objectives of the different thermal pumping cycles and then I will explain why the cycle inverted cardan shaft cannot be used to perform these tasks. I then presented a cycle idealized refrigeration system that lends itself well to thermodynamic analysis and raised two important points in relation to these idealized cycles. Firstly, the differences between the real cycle and then the identical nature of the pressure loss that is carried out in the cycle.

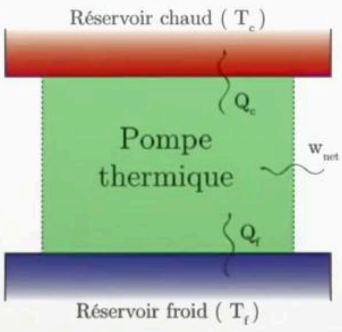
Notes

Summary

0m 04s

Cycles de pompe thermique

POLYTECHNIQUE MONTRÉAL



- Définition et objectif
  « Cycle pour transférer de la chaleur d'un réservoir froid vers un réservoir chaud. »
- Utilise du travail
- Objectifs: deux types
  - Réfrigération: garder T_f constant, maximiser Q_f

$$COP_R = \frac{Q_F}{W_{entrée}} = \frac{Q_F}{Q_C - Q_F} = \frac{1}{\frac{Q_C}{Q_F} - 1}$$

  - Pompe thermique: garder T_c constant, maximiser Q_c

$$COP_{PT} = \frac{Q_C}{W_{entrée}} = \frac{Q_C}{Q_C - Q_F} = \frac{1}{1 - \frac{Q_F}{Q_C}}$$

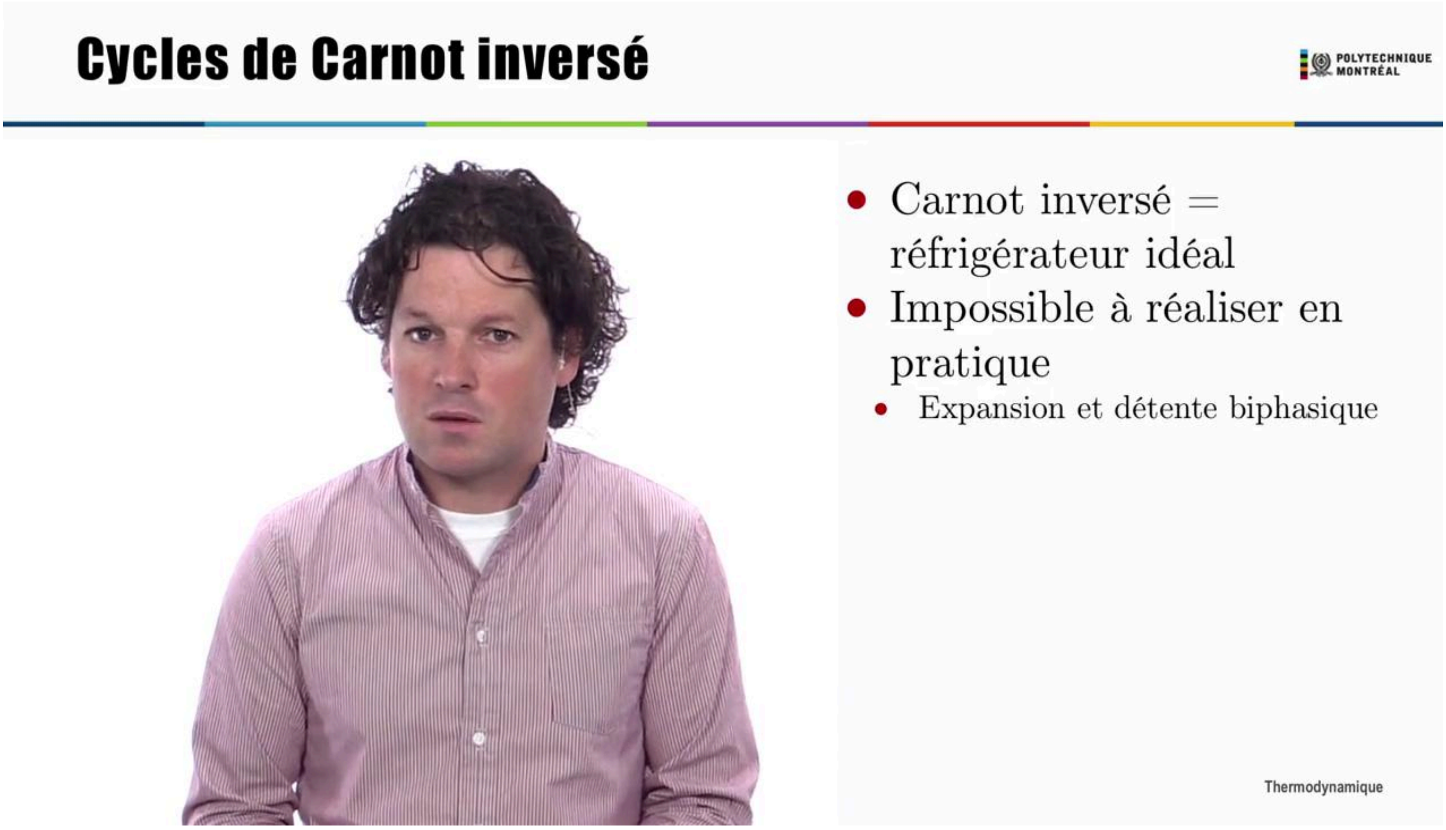
Thermodynamique

The objective of a thermal pumping cycle is to transfer heat from a cold tank to a warm tank, therefore against the temperature gradient. To do this, the cycle uses work and what we want to obtain from of this work will depend on the targeted application. If it is a refrigerator, we try to remove a maximum of heat from the cold tank, thus to maximize QF. If, on the other hand, we are dealing with a thermal pump, we try to maximize QC, for example, to carry out domestic heating. We must therefore consider two distinct equations to quantify the performance of these systems depending on whether it is a refrigerator or a thermal pump. In both cases, this coefficient of performance is a ratio between what we want to achieve and what we have provided to the system. And in both cases, we can ultimately express the coefficient of performance as a function of of the ratio of heat exchanged at the two sources.

Notes

Summary

0m 57s



As mentioned in the introductory module. The reverse Carnot cycle would represent an ideal refrigeration cycle since it is composed of four reversible evolutions. Unfortunately, this one is impossible to implement in practice, in large part because in the systems of refrigeration, the fluid used changes phase. Indeed, the phase change undesirable because the large amount of energy stored in the heat of the fluid allows the transfer of large quantities of of energy between a condenser, for example, and an evaporator. This high energy density allows to have smaller installations, thus the use of a Carnot cycle is extremely difficult because it would require compression and expansion of a dysphasic mixture, and unfortunately no machine The existing system allows to do this task with a high reliability, in large part because in a phase mixture we have both steam and the liquid which both have very different densities. And this difference in density there causes very high mechanical stress on moving parts. We therefore seek to avoid having a dysphasic mix for all years. Operations that require the use of a machine with moving parts, among others. All operations that involve a change in pressure.

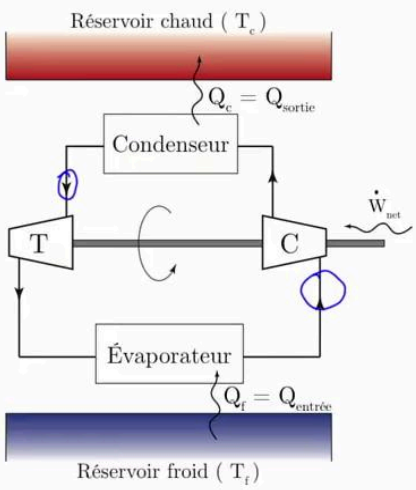
Notes

Summary

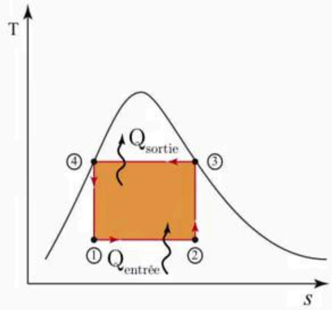
1m 47s

Cycles de Carnot inversé

POLYTECHNIQUE MONTRÉAL



- Carnot inversé = réfrigérateur idéal
- Impossible à réaliser en pratique
  - Expansion et détente biphasique



Thermodynamique

This danger zone in the TS diagram is located below the saturation standard. One of the objectives of the design of a system or a thermodynamic cycle is to find a way to move the operations of the refrigeration system that involve a change in pressure outside the zone dangerous in the saturated mixing zone. Therefore, when designing these cycles, it is essential to properly size the heat exchangers to ensure that the fluid entering the compressor for example, or possibly in a turbine either single-phase and thus allow a reliable and dry refrigeration cycle.

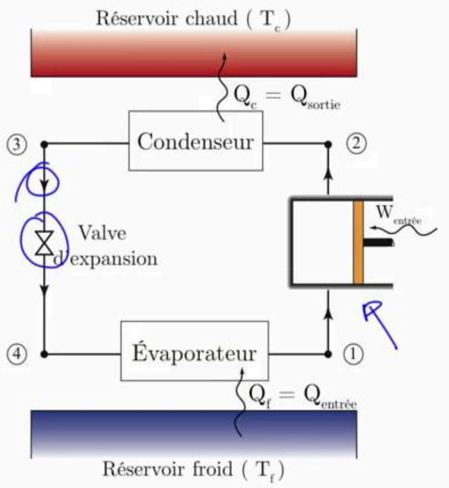
Notes

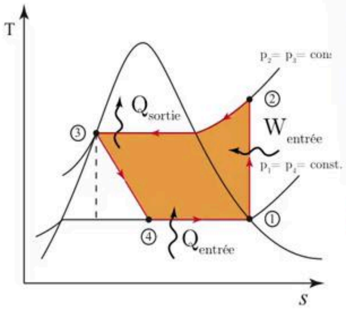
Summary

3m 01s

Cycle de réfrigération idéalisé

POLYTECHNIQUE MONTRÉAL





- 4 évolutions

Évolution	
1 - 2	Compression isentropique
2 - 3	Rejet de chaleur (P=cste)
3 - 4	Expansion non-isentropique
4 - 1	Absorption de chaleur (P=cste)

- Coefficients de performance

Thermodynamique

Also composed of four revolutions, starting with a compression and entropy, therefore irreversible adiabatic in vapor phase, This is usually done by a positive displacement compressor such as a cylinder piston system, because the size of the installations the use of turbo machines, which are used for the production of a wide range of products, is rarely justified. much more complex and much more expensive. The heat is then removed to the hot tank with phase change at constant pressure to achieve to a liquid saturated or close to saturation at the condenser outlet. In this state, the high pressure fluid contains a potential to do work. On the other hand, the extraction of this potential would be complex because it should be done in a dysphasic environment. The primary objective at this stage is to obtain a saturated mixture at low pressure and low temperature to absorb heat in the evaporator. It is usually sufficient to lower the pressure in an expansion valve or a capillary tube. These are devices without parts mobile who can therefore survive an operation in a dysphasic mixture. Therefore, there is no attempt to exploit or extract the potential of the work generation of the fluid at point three.

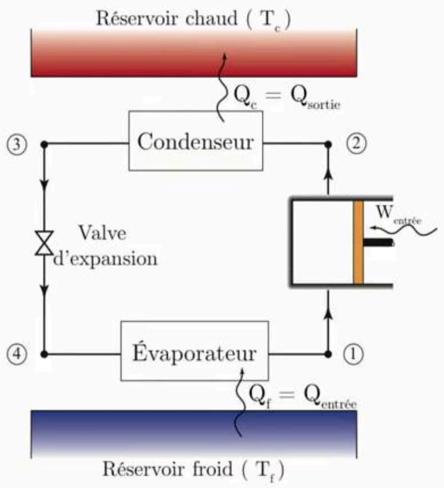
Notes

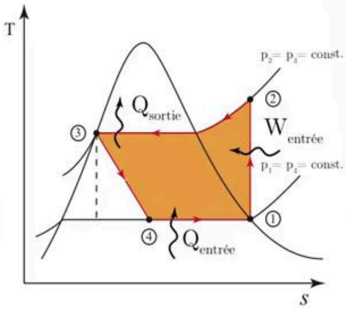
Summary

3m 37s

Cycle de réfrigération idéalisé

POLYTECHNIQUE MONTRÉAL





- 4 évolutions

	Évolution
1 - 2	Compression isentropique
2 - 3	Rejet de chaleur (P=cste)
3 - 4	Expansion non-isentropique
4 - 1	Absorption de chaleur (P=cste)

- Coefficients de performance

$$COP_r = \frac{Q_f}{W_{net,\ entrée}} = \frac{h_1 - h_4}{h_2 - h_1}$$

$$COP_{pt} = \frac{Q_c}{W_{net,\ entrée}} = \frac{h_2 - h_3}{h_2 - h_1}$$

Thermodynamique

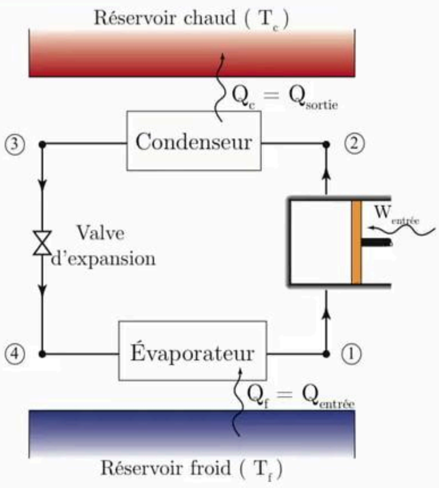
An energy balance on expansion components, such as expansion valves and capillary tubes, reveal that this operation is carried out in an isolated way, i.e. with constant enthalpy. Definitions of coefficients of performance can therefore be expressed in terms of the ratio of the difference between PI, between the evaporator and the condenser for the refrigerator and between the condenser and the compressor for the heat pump.

Notes

Summary

4m 44s

Considérations pratiques



- Valves et tubes capillaires
  - Échangent ni travail ni chaleur
  - Non-isentropiques – isenthalpiques
- Fluides utilisés
  - Propriétés
    - Température critique élevée
    - Point de fusion bas
    - Chaleur latente élevée
  - Fluides frigorigènes: Rxxx
  - HydroCluoroCarbones (HFC)
  - R-134a: 1,1,1,2-Tetrafluoroethane (CH_2FCF_3)

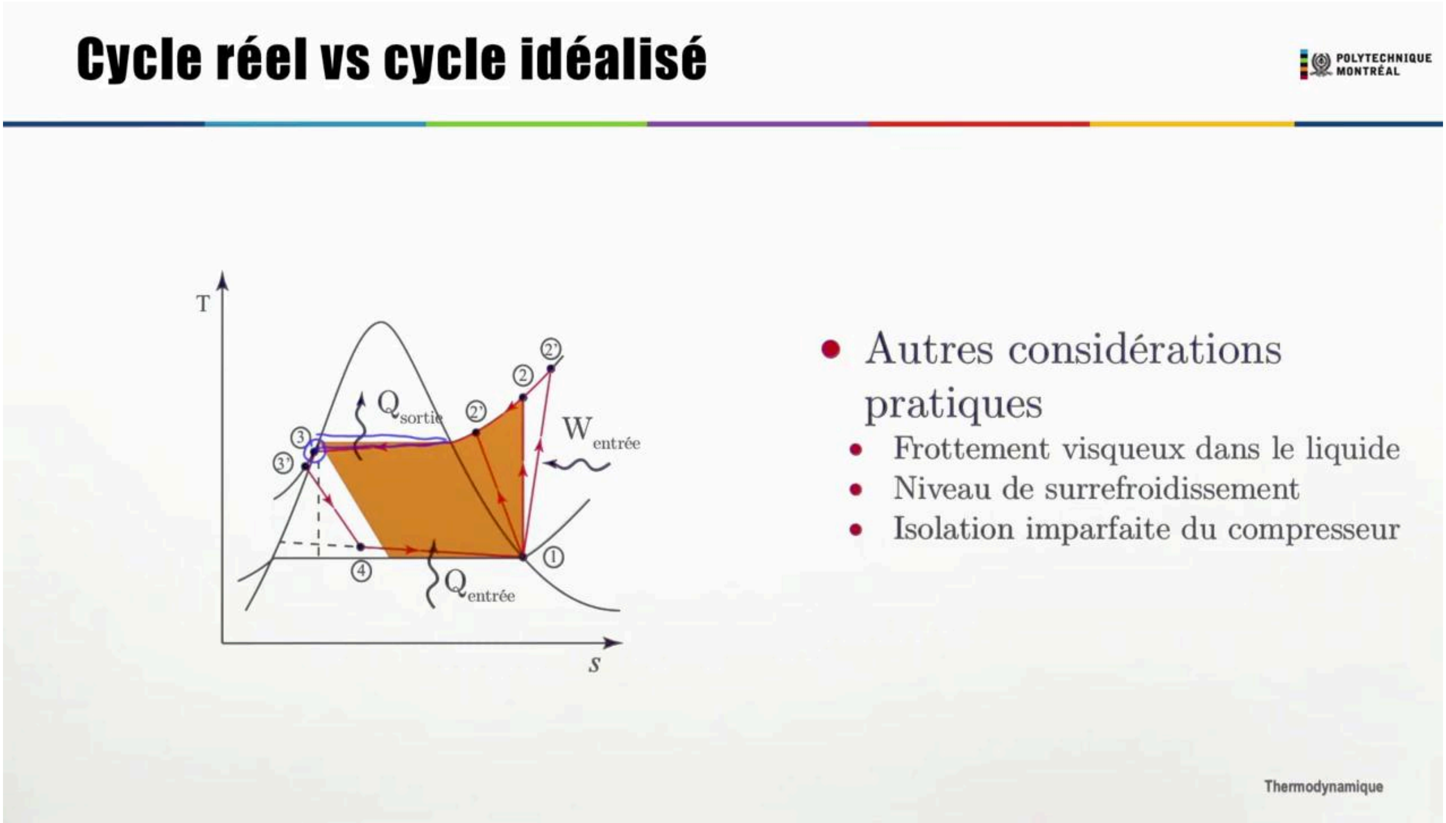
Thermodynamique

Valves and capillary tubes are small devices, therefore the component used here to lower the pressure and usually quite small, it is often only a needle that will restrict the fluid flow area in a pipe. How small the device is. We can often neglect the heat transfer which is carried out at this place. And by doing an open system balance on this system, we realize that as it there is no heat input, there is no work necessarily. The evolution must be isolated. Alpiq. On the other hand, the pressure drop is through the viscous friction of the fluids. These developments are irreversible and not entropic. The fluids used are chosen so that the phase changes are carried out at moderate pressure, producing a useful temperature difference. For example, boiling at -20 degrees Celsius at room pressure is ideal for domestic refrigeration applications. Why ideal? Simply because the temperature is cold enough for a freezer and low pressure in place. Little stress on the mechanical properties of the heat exchangers. We call the fluids that have these properties of the refrigerant or refrigerants. They are often hydrofluorinated carbon to which an air number is applied. For example, Air 134 A is a fluid refrigerant widely used in industry, whose full name is a two tetra fluorine octane with a composition of ch2 f. Cf3. It is -26 degrees Celsius at atmospheric pressure.

Notes

Summary

5m 07s



In the majority of cycles thermodynamics seen so far, it was generally justified to neglect pressure losses due to viscous friction in pipes and heat exchangers in refrigerators. On the other hand, the pipes are generally small and the fluids used are very viscous. So it frequently happens that the temperature or the state at the output of a component is slightly different from the state at the entry of the next component. This can be seen for example in the diagram CS illustrated here, or, contrary to the idealized body in which it is assumed that the temperature is constant during the phase change. In the evaporator or in the condenser instead. In the real case, the temperature drops gradually as the pressure in the condenser gradually decreases. Also to ensure that the expansion valve which is located at point three, receives only a saturated liquid and not a dysphasic mixture, it is necessary to slightly oversize the condenser so that they can be produce a compressed liquid and not just a saturated one. It prevents that following a slight drop performance of the condenser, we end up with a mixture out of phase at point three, which would cause a noisy trigger.

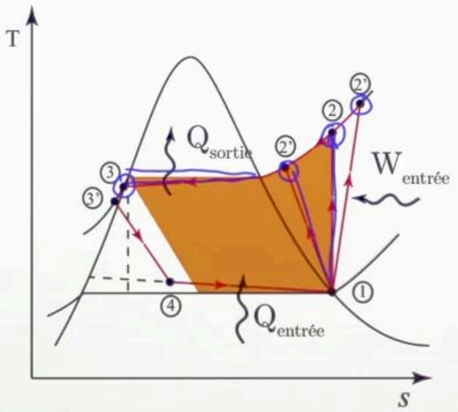
Notes

Summary

6m 34s

Cycle réel vs cycle idéalisé

POLYTECHNIQUE MONTRÉAL



- Autres considérations pratiques
  - Frottement visqueux dans le liquide
  - Niveau de surrefroidissement
  - Isolation imparfaite du compresseur

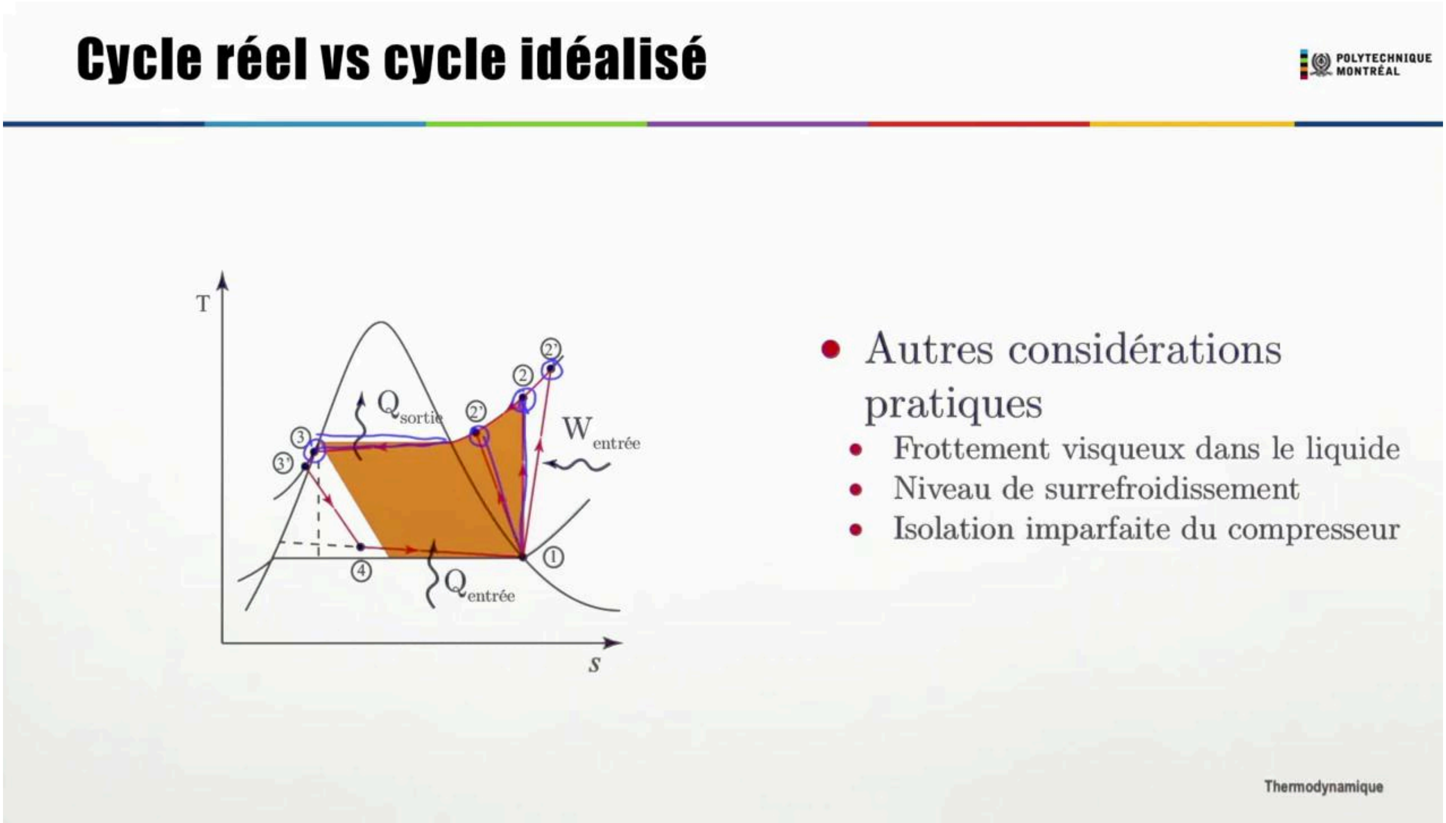
Thermodynamique

Finally, for the employees that we have seen so far, we were always looking for a good Insulate the compressor to prevent energy from leaving the system. Here, it is the opposite. All losses resulting from insulation of the compressor represent a reduced load for the condenser and furthermore minimize the compression work. As can be seen here in the diagram TS, if the compression was entropic, thus perfect and reversible, we would end up at point two here if it is in the places. So we create entropy, we have friction and therefore we have a compression which is imperfect. But we have a compressor that is perfectly insulated. We're going to be at point two and we've done more work and more heat must be removed from the condenser. On the other hand, if our compressor is badly isolated, we find ourselves at the point of premium that killed here. And the results are that we have done less work to compress and in addition that we has less energy to extract from the system in the condenser. This concludes a module on analysis thermodynamics of refrigeration and thermal pumping cycles. Both types of circles use external work to transfer of heat against a large temperature time and therefore, we have seen that it is necessary to know which application is targeted.

Notes

Summary

7m 41s



To be able to calculate a performance coefficient. We have also seen an idealized cycle that allows an analysis thermodynamics and consider the properties main refrigerants used in the cycles.

Notes

Summary

8m 50s