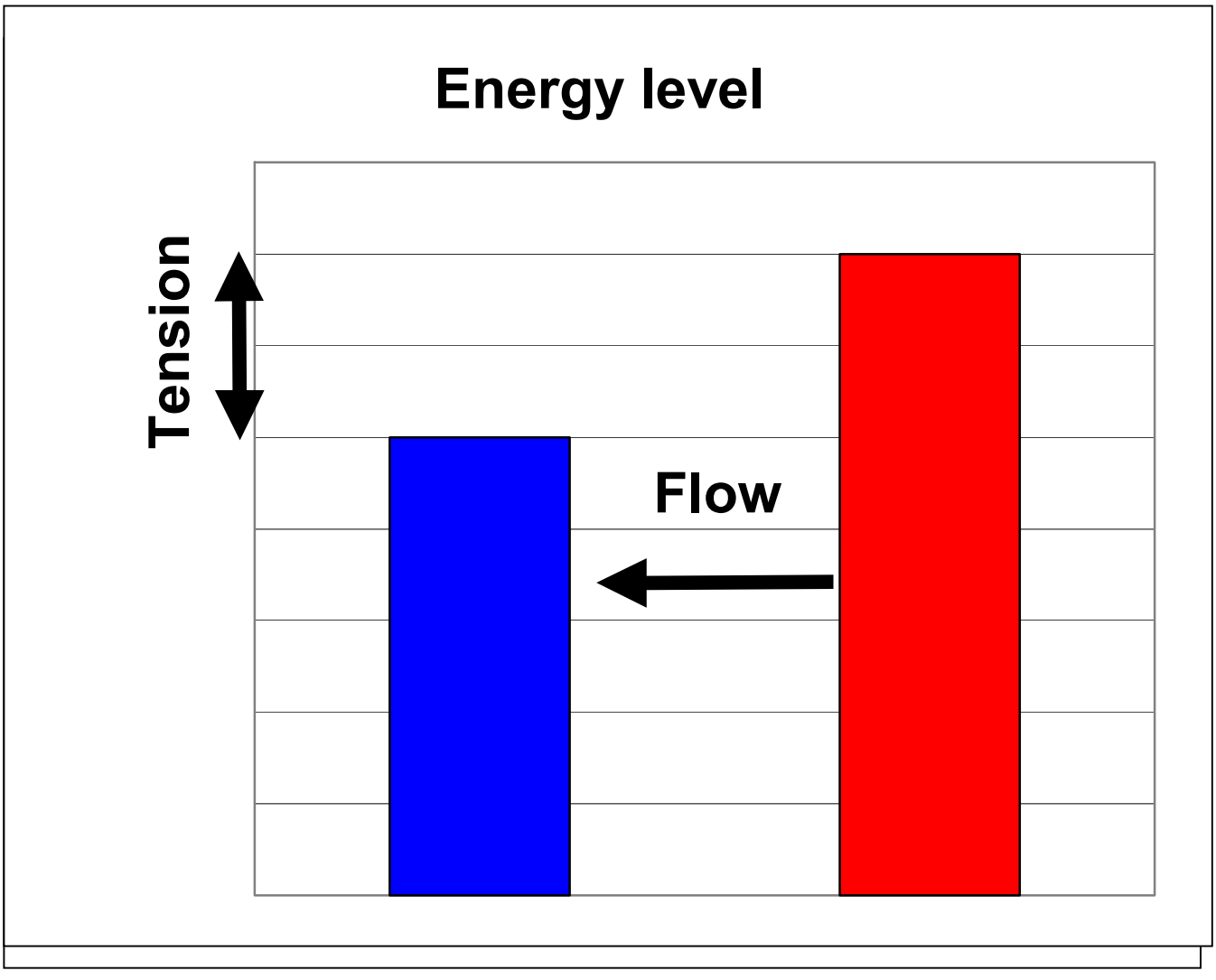
1. Basic Principles

1.1 Thermodynamic base principles – Heat flow

Heat level: Depending upon the level, heat is perceived as cold or warm. A **tension** exists between these energy levels.

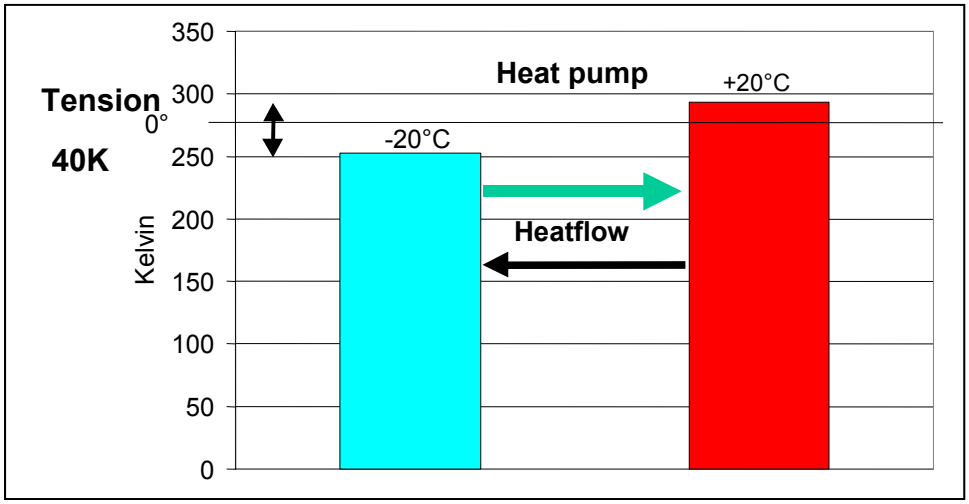
Heat flow: Because of this tension, if two heat levels are connected by means of a conductor, a heat flow exists from the higher to the lower heat level and this continues until the same level is reached for both.



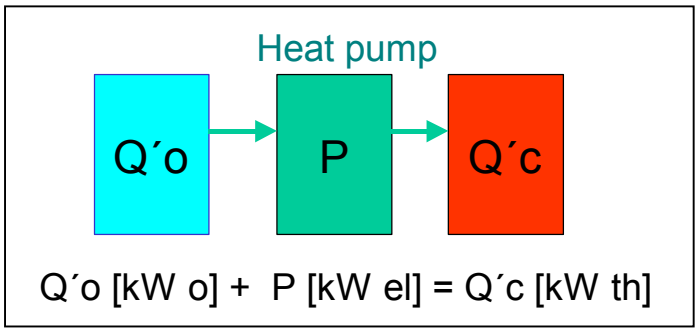
Heat flow = Tension (temperature difference) / Heat conduction - Resistance

1.2 Thermodynamic base principles – The heat pump

If there is a need to reverse the heat flow, heat from the cooler area must be transported (pumped) to the warmer area. The types of units required for doing this are called heat pumps or refrigeration equipment, depending upon their function.



Work must be performed by the unit in order to raise the heat to a higher level.



The diagram shows the heat and energy flow for a heat pump.

Q´o = heat extraction = refrigeration performance
P = power uptake by the unit
Q´c = heat outflow = waste heat

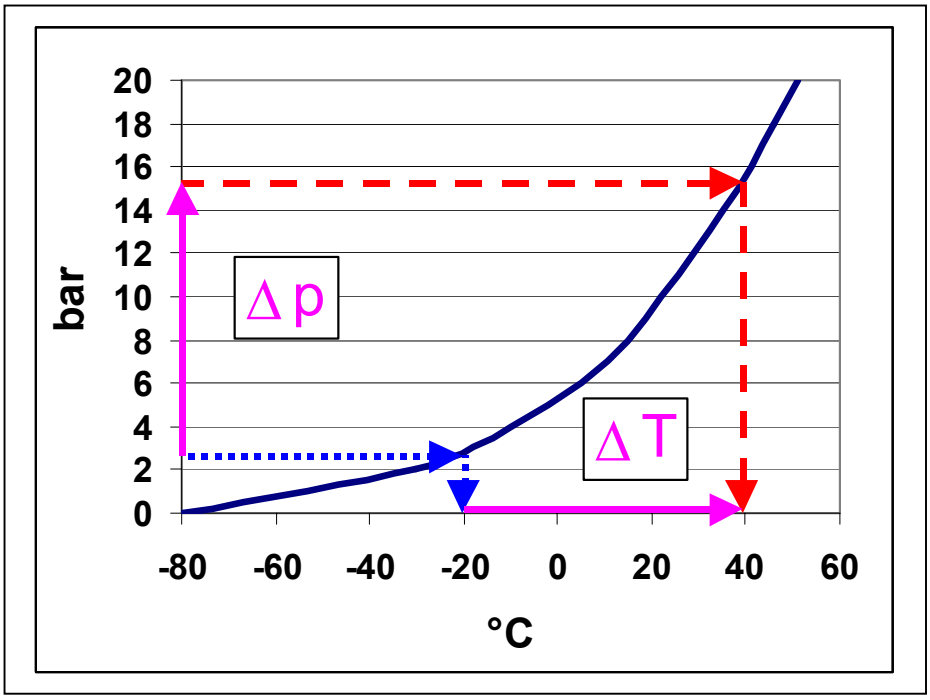
The energy costs that must be paid for a refrigeration unit can be determined from the power uptake P. For the comparison of different types of refrigeration units in this area of technology, the relationship of utilization /expense = Q´o / P = COP is used.

From the technical perspective, refrigeration units can be designed to work in many ways e.g. with semi-conductors (Peletier element), through which electricity flows. However, the most commonly used types of refrigeration units operate using a cooling agent.

2.1 Basic principles for refrigeration agents

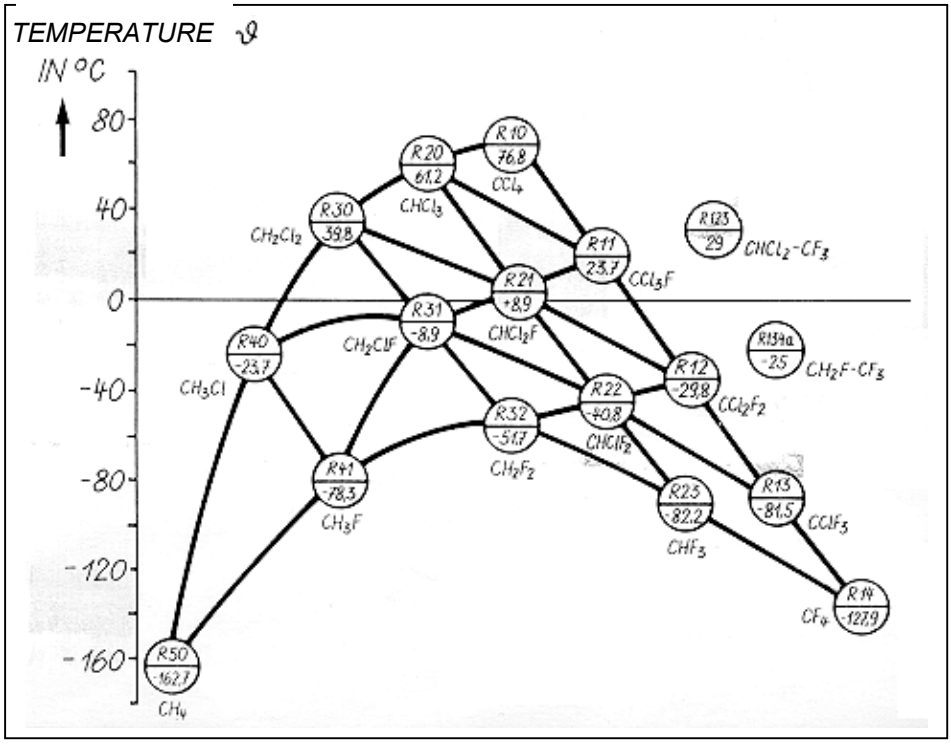
Liquid materials suitable for use as cooling agents are all those which can be heated and condensed as often as desired without any associated chemical decomposition. In this regard, the dependence of the boiling temperature T [°C] on the surrounding pressure p [bar or Mpa] is used. If the surrounding pressure is raised, the boiling point temperature is raised and vice versa!

The graph shows the relationship curve for the boiling point temperature of a cooling agent. At a pressure of ca. 2.5 bar, it has a boiling point temperature of –20°C. If the pressure is raised to ca.15 bar, the boiling point temperature rises to 40°C



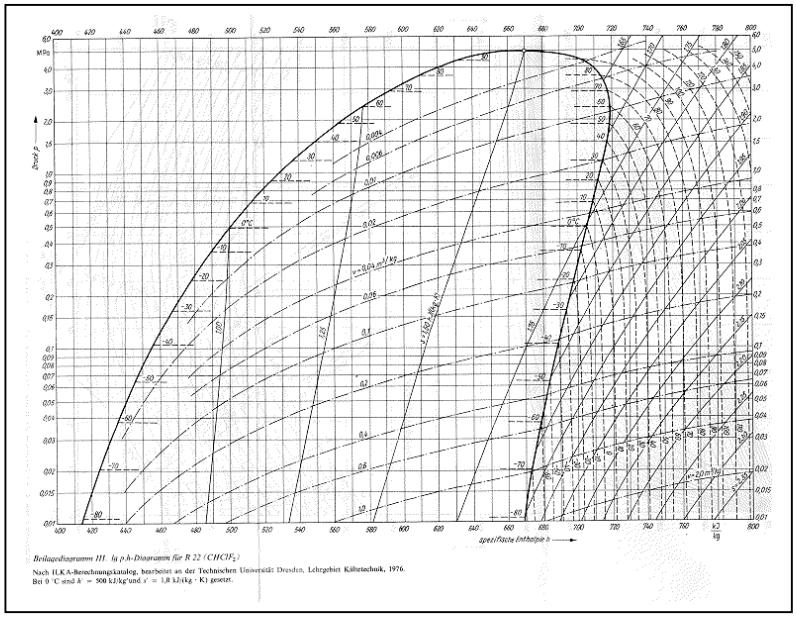
Cooling agents are chosen for their ability to boil (vaporise) at low pressure at the desired temperature for the cool room. Subsequently, the pressure is raised by the refrigeration equipment to the point required to effect the heat removal necessary.

Some organic cooling agents can be mixed (without them separating again once in operational use) and so the desired characteristics can be adjusted.
The diagram shows mixtures that enable the desired boiling point to be adjusted.



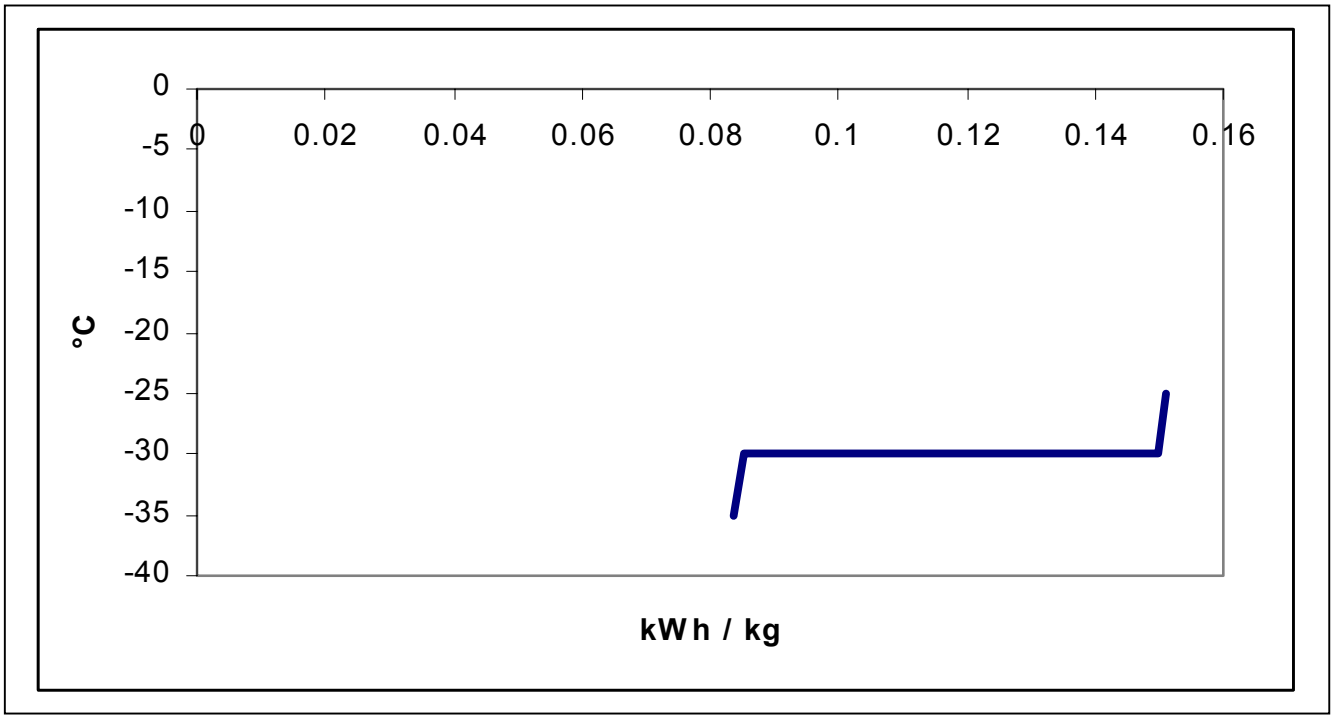
2.2 Refrigeration agent limits

The use of a refrigeration agent is limited by its chemical characteristics. Fundamentally, these are their stability with regard to pressure and temperature. These are shown in so-called p/h diagrams for individual refrigeration agents (in this case R22). From such diagrams the maximum pressures and temperatures that refrigeration agents can withstand can be ascertained.
A further important factor is their compatibility with the lubricant used in the refrigeration unit.



2.3 Energy removal

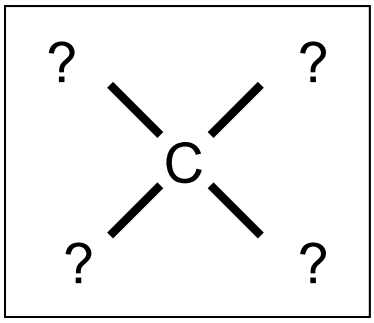
The refrigeration agent vapourises (boils) and, because of this, extracts heat from the freezer room.



During the transitional phase from a liquid to a gas, the temperature of the refrigeration agent does not change. The boiling point temperature is set by the pressure in the evaporator. **More than 90% of the energy transfer occurs as a result of this transitional phase.**

2.4 Refrigeration agent nomenclature

The abbreviation used for cooling agents is the letter R followed by a three-digit number. Cooling agents are differentiated into organic (R10...600, where 400..500 are used for blends) and inorganic (m R700).



Organic refrigeration agents consist of short chain hydrocarbons (HC) and are volatile (low boiling point). Organo-halogen refrigeration agents (with chlorine, Cl., and fluorine, F) were introduced as safe refrigeration agents because they were neither combustible (and thus explosive) nor toxic.

Refrigerant R xyz (R0yz....6yz)

z = F

y - 1 = H

x + 1 = C

rest = Cl oder C

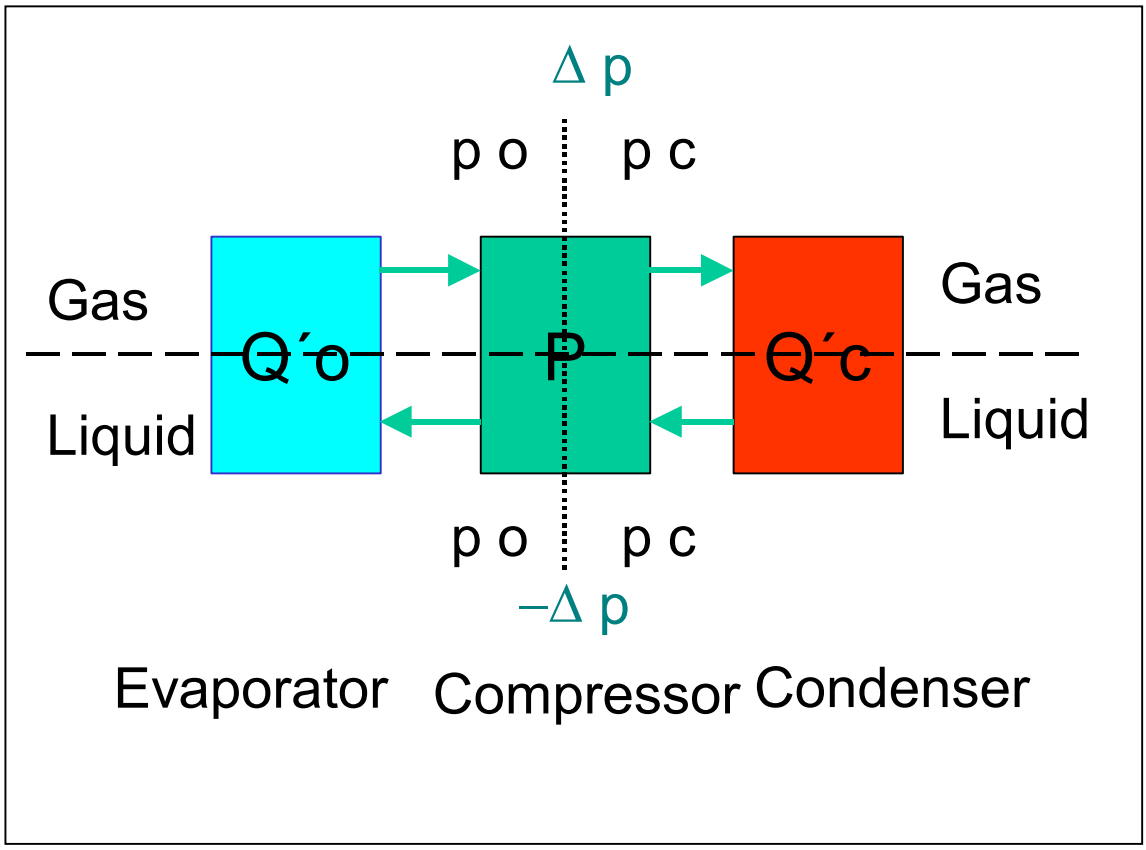
Unfortunately, these chlorofluorocarbon agents have been proven to be damaging to the world's ozone layer. Their destructive potential is measured as ODP (ozone destruction potential). For this reason they are now being substituted BY hydrofluorocarbon agents which are not supposed to be so damaging. All organo-halogen refrigeration agents also contribute strongly to increases in the greenhouse effect. This is shown by the GWP value (Greenhouse Warming Potential = 10,000). This value compares the influence of one molecule of the refrigeration agent with one molecule of CO2.

Inorganic refrigerant R7yz, yz = molmass

In the case of inorganic refrigeration agents, ammonia dominates (NH3, R717). Unfortunately this agent is poisonous and inflammable (explosive). However, because of its outstanding characteristics it is used in conjunction with high safety standards. Other cooling agents are water (H2O, R718), which is used in the low-pressure area (<1 bar), and carbon dioxide (CO2, R744).

3 Refrigeration units

Refrigeration units that use refrigeration agents normally work using closed circuits. An example of an exception is the chemical industry where the refrigeration agent can be an intermediary product that can be re-processed after condensation.



A refrigeration unit consists of an evaporator, a working unit (compressor), and a liquefaction unit (condenser). In the evaporator, heat is taken up because the refrigeration agent vaporises. The working unit compresses the refrigeration agent. A pressure increase occurs. In the condenser, the refrigeration agent is cooled down and thus condensed in the presence of a medium that removes heat e.g. external air. In a closed refrigeration agent circuit, a pressure reduction results and the refrigeration agent is returned to the evaporator.