C2.2 Cooling without electricity – Tracking down technology

1 Refrigerator

Many foods such as cheese or meat spoil rather quickly at room temperature. However, at a constant low temperature between +4 and +8 degrees Celsius, they remain fresh and can be stored longer. That's because bacteria that spoil foods cannot multiply as quickly at these low temperatures.

Figure 1: The inside of a refrigerator.

Figure 2: The back of a refrigerator. One can see the pipes for the coolant and the "cooling fins" as well as the compressor (at the bottom).

How a refrigerator works

A refrigerator generates cold air by drawing heat out of the air in the refrigerator. The **evaporator** is located inside the refrigerator in the back wall. It consists of pipes in which a coolant flows. Coolant is a liquid that evaporates at very low temperatures (4 degrees Celsius or lower). The coolant needs energy to evaporate. It obtains the energy from the heat in the air inside the refrigerator. When the coolant evaporates, the temperature becomes cooler in the refrigerator. (It's kind of like water or rubbing alcohol on the skin).

A **compressor** pumps the evaporated coolant from the pipes inside the refrigerator to the **condenser**, which is attached to the outside of the refrigerator on the back wall. In the process, the vapor is compressed and the coolant becomes liquid again. In order for the coolant to release the heat that it previously absorbed during evaporation, a large surface area is required during subsequent compression. Therefore, the compressor pipes have a winding path and cooling fins. The coolant has cooled off when it reaches the end of the condenser and is

pumped back into the pipes inside the refrigerator by the compressor. There it evaporates again, and the cooling cycle starts over.

The compressor is operated with electric current, which provides the energy for compressing the coolant. To conserve energy, the refrigerator is automatically turned on by a temperature regulator (thermostat) when the temperature gets too high. This happens, for example, when the door is opened, when new warm foods are placed inside, and when the ambient air is warm. Despite the best insulation, heat can still get inside the refrigerator. As soon as the desired lower temperature is reached inside the refrigerator, the thermostat turns the refrigerator off again.

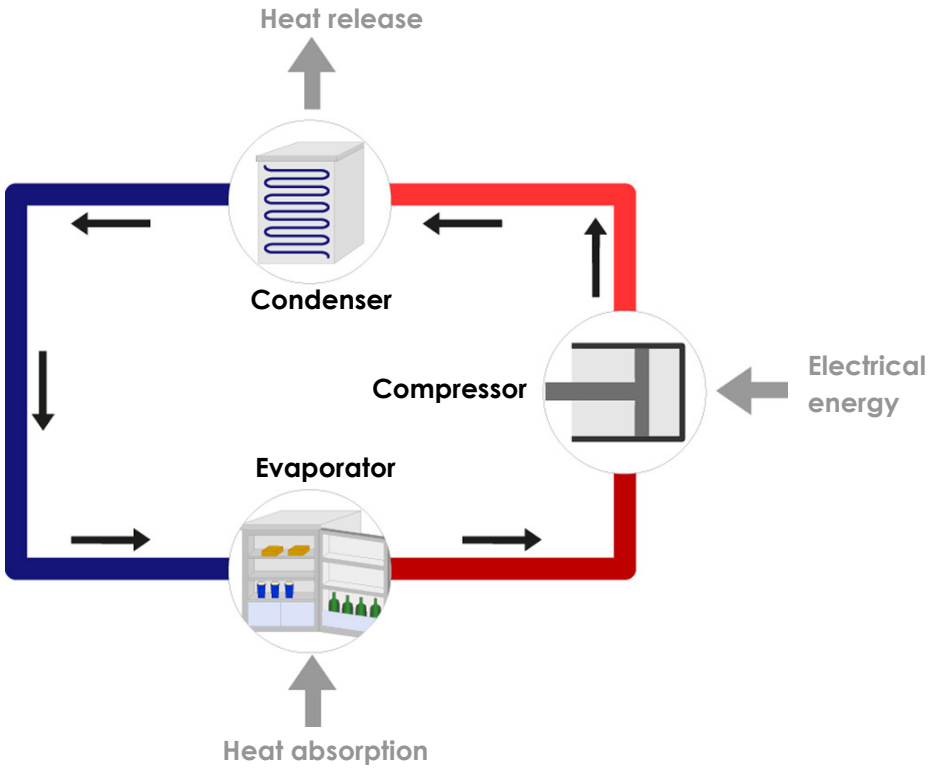

Figure 3: Functional diagram of a refrigerator.

2 Air conditioning in a commuter train

In the summer, air conditioning helps make temperatures inside of a train comfortable.
Train cars are not very well insulated, so the air inside would get quite hot in the summer without air conditioning. Each time the doors open, the hot outside air enters the cars. The air conditioning can keep the temperature in the train at a constant temperature that's pleasant for the passengers.

Figure 4: Air-conditioning system on a train roof.

How an air-conditioning system works:

An air-conditioning system also has a cooling circuit with a coolant that boils and evaporates at low temperatures. The air conditioner of a commuter train usually consists of a device inside the passenger compartment and another device on the train roof. The coolant evaporates in the interior device. The energy needed for the evaporation is drawn out of the warm air inside the train, and the passenger compartment cools down. Then the gaseous coolant is suctioned into the exterior device and compressed by a compressor. The air that flows through the device on the roof of the train cools down the coolant. The air surrounding the train becomes warmer. Now the coolant is liquefied in the condenser and can be pumped into the interior again. The cycle starts over.
Air conditioners are also installed in cars and buildings. And devices known as "split air conditioners" can also work as heaters in buildings. The heat is drawn out of the outside air and is released in the interior so that the temperature inside rises.
Trains have an extra heating system for winter, though, to keep passengers nice and warm.