

3 Carnot efficiency

Subject:

The relatively low efficiency of thermal engines is caused by the fact that heat can only partially be transformed into work. The fraction of the total amount of heat which can be transformed into work under ideal conditions is called the *Carnot efficiency*. If T_2 and T_1 are the temperatures of the reservoirs of the incoming and of the outgoing heat, respectively, the Carnot efficiency is $\eta = (T_2 - T_1) / T_2$.

Deficiencies:

What appears as a peculiarity of thermal engines is nothing more than the expression of a strange inconsistency. For comparison, let us consider a mechanical example, which had already been used by *Carnot*: A mill, perhaps in the Black Forest, with a water wheel of a height $h_2 - h_1 = 5$ m and situated at $h_2 = 1000$ m above sea level, gets with every kg of water a potential energy $m \cdot g \cdot h = 10$ kJ. From this amount it can use, in ideal conditions, only $m \cdot g \cdot (h_2 - h_1) = 50$ J. Thus, the “*Carnot*” efficiency is

$$\eta = (h_2 - h_1) / h_2 = 0,005.$$

An identical mill on the lower Rhine, say at $h = 20$ m above sea level, would have an efficiency of 0,25. Here, we have generously calculated the potential energy against sea level. Compared to the approximately 20 MJ of potential energy when calculated with respect to the center of the earth, the resulting efficiency for both mills gets really depressing: $\eta = 2,5 \cdot 10^{-6}$.

One feels immediately that something is wrong here. Apparently, the Carnot efficiency has nothing to do with either the mill, or with the steam engine, but only with the position of the effective levels h_2 and h_1 or T_1 and T_2 , with respect to the fictitious reference level.

Origin:

S. Carnot, who wrote down his ideas before the energy principle was formulated, did not know the quantity η . He compared the steam engine with a water mill. For him the work originated, just as in the case of the water mill, from the difference of the “potential energy” of the heat in the reservoir of the incoming and the outgoing heat.

Disposal:

In thermodynamics, the concept is as superfluous as in mechanics. Described as an “entropy mill”, the heat engine is just as trivial as a watermill.

Georg Job, University of Hamburg