

The Thermodynamic Field's Cycles

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The field approach to thermodynamics, proposed by the authors in [1], is used to analyze field cycles similar to the Carnot cycle. The evaluation of energy losses in such cycles turns out to be qualitatively similar to Carnot but there are some essential differences between them. The field estimation includes dependence on a greater number of parameters and contains not only initial and final temperature. This additional dependence let us formulate recommendations to optimize the work of heat engines and the necessary conditions for the efficiency coefficient to exceed 1.

1. Introduction

Deductions following from the Carnot cycle have become an essential obstacle for engineers in their attempts to optimize the work of different heat engines. The field view of thermodynamics proposed in [1] has shown the necessity of re-estimation and other understanding of some thermodynamic problems and quantum mechanics. The idea to revise the analysis of the Carnot cycle naturally appears. What do we see *a priori*?

Although the whole analysis is devoted to heat the main conclusion is the efficiency formula containing only initial and final temperature.

When the problem is analyzed with greater accuracy one sees that the root of the problem lies deeper in the history of the thermodynamics. In the period of the origin of thermodynamics as a science interaction between three concepts was considered: heat which was linked with the concept of the calorie, temperature which was associated with the feeling of "hot-cold" and a coefficient which connects heat and temperature. This coefficient was called entropy. It had become clear, later, that the idea of calorie did not fit some experiments. Instead of reanalyzing the idea and accepting a new concept of calorie, the issue was buried completely, although many experiments were in good accord with it and equations formulated on its basis are widely used today. The well known heat conductivity equation in partial derivatives is an example.

An additional difficulty burdened this problem. Gas was usually used in experiments. And the abstract notion of heat energy was linked with gas characteristics:

$$w = pV, \quad (1.1)$$

Where w is heat energy, p is pressure and V is volume. It seems that it follows just from (1.1) that heat differential must be total

$$dw = pdV + Vdp. \quad (1.2)$$

But only the first item in (1.2) was usually taken into account in experiments. Therefore, and for some other historic reason, heat energy was considered a nonlocal function and they began writing a variational differential δw instead of total dw to take this into account.

Apparently this problem was inherited following an ancient problem which has hindered mechanical investigations up till now. Although work in mechanics is defined as a product of force and path:

$$A = \mathbf{F} \cdot \mathbf{l}, \quad (1.1a)$$

Where A is work, \mathbf{F} is force and \mathbf{l} is path, the work increase is defined as an increase in the product of force and path.

$$\delta A = \mathbf{F} \cdot d\mathbf{l}. \quad (1.2a)$$

But it is clear that a reasonable definition must be

$$dA = \mathbf{F} \cdot d\mathbf{l} + \mathbf{l} \cdot d\mathbf{F}, \quad (1.2b)$$

where dA is a total differential.

The situation with temperature turned out to be somehow better. The third principle of thermodynamics was adopted. It axiomatically declared the existence of temperature. A very accurate procedure for its measurement was determined. The situation was accepted as satisfactory in accordance with the idea: if we are able to measure this means that we understand the essence of the measured object.

Heat is defined as a linear function of temperature in to-day's physics. But how can a nonlocal function, heat energy w , be a linear function of the ordinary function temperature? One can observe that heat conductivity equations are often named temperature conductivity equations in scientific literature. But in accordance with the above adopted definition this is possible only if entropy is constant, i.e. in equilibrium processes. Therefore when entropy is defined as

$$dS = \frac{\delta w}{T}, \quad (1.3)$$

Where δw is a variational differential, T is temperature and dS is the local entropy differential, the situation is completely muddled.

See, we cannot even state a simple thermodynamic problem. We need three independent definitions for it: heat, temperature and entropy. But the first two notions are linked and entropy turns out to be only a linear function of temperature. This means that when any process is in equilibrium, entropy is constant. The second principle of thermodynamics turns out to be unnecessary.

The mechanical dimensions for thermodynamic values were proposed in [1]. This let us divorce the concepts of heat and temperature and produce the analysis which is considered below.

2. Preliminary Information

The following approach to thermodynamics was proposed in paper [1]

1. New kinematics describing Brownian movement was proposed. It was called surfalinear movement. Such movement velocity has dimension m^2/s .
2. Concept of surfalinear movement was linked with the idea of temperature and thermodynamic wave velocity. Temperature increasing of a particle ensemble means increasing of surfalinear velocities in these group particles'. The very concept of temperature means closeness of surfalinear velocities of the group particles.
3. A concept of the thermodynamic field charge was proposed. It coincides with Plank's constant \hbar . It becomes clear that heat has a frequency dimension and heat energy is just the energy of the thermodynamic charge oscillations $\hbar\omega$.
4. The thermodynamic wave equation is

$$\omega = ST, \quad (2.1)$$

Where ω is heat, S is entropy and T is temperature. One can see that (2.1) is accurate analog of the equation describing light wave:

$$\omega = lc, \quad (2.2)$$

Where ω is frequency of light wave, c is its velocity and l is its wave number which is the inverse of the wave length. Entropy S has dimension rad/m^2 and is an accurate analog of light wave number. It is inverse to the thermodynamic wave square.

5. (2.1) yields that heat energy $\hbar\omega$ has dimension $kg\cdot m^2/s^2$. It can be transmitted into other traditional types of energy with constant coefficient, i.e. it does not differ from them. But thermic or thermodynamic energy is $\hbar T$ peculiar. It means the energy of surfalinear movement of thermodynamic charges \hbar . Its dimension is $kg\cdot m^4/s^2$. It can be transformed into other types of energy with the variable coefficient entropy S . Actually, just its existence, is the cause of the second principle.

It was mentioned above that heat is linearly connected with temperature in today's physics. Thus, when university textbooks talk about the impossibility of completely transforming heat into work, we must understand that they really mean thermic energy. In the framework of field analyses these assertions are essentially different. The aim of this article is to find the conditions for heat transmission into thermodynamic energy and vice-versa in cycles similar to the Carnot one.

It was shown in [2] that the adiabatic process (the process without heat changing) is described with the equation

$$ST = S_0T_0, \quad (2.3)$$

Where S_0 and T_0 are initial entropy and temperature. Adiabatic process definition means that it cannot produce any work because there is no heat increment.

Eq. (2.3) was obtained from field Eq. (2.1) which means that generally heat ω cannot be a linear function of temperature T . This is possible only when entropy is constant, i.e. the process is in equilibrium. But the main problem in thermodynamics is that entropy in (2.1) is variable.

The situation with temperature is partly more understandable. Modern thermodynamics introduces the third principle which axiomatically declares the existence of temperature. But

the third principle does not explain the physical meaning of temperature. Instead, to-day, the temperature concept is substituted by the accurate description of temperature measurement. In the framework of the field approach temperature is the surfalinear velocity of the thermodynamic wave. Therefore we must distinguish the group and phase velocities of the thermodynamic wave just as it is done in electrostatics.

As it is in electrostatics, group velocity transports thermodynamic energy. But today, the accepted methods of measurements determine the average phase velocity of the waves induced by separate particles in a group.

In the middle of the 20th century, specialists in thermodynamics, were shocked by the Purcell and Pound experiment which showed that particle spins in the external magnetic field change to the opposite direction when the temperature becomes sufficiently high [3,4]. This experiment was explained with the supposition that negative temperature begins when infinite positive temperature is attained. It was alleged that just this fact explains the Purcell and Pound effect. Such explanation seems strange because, even if the experiment temperature was very high, it surely did not overcome infinity. In paper [1], the Purcell and Pound experiment temperature was evaluated at about 10^9 degrees and interpreted as light velocity analog. This temperature is a boundary in the following sense: when it is crossed free ether characteristics change. The thermodynamic field stops absorbing energy and begins its returning. Such temperatures are well known in habitual media, e.g. the temperature of boiling water for instance. Today they are called phase transition temperatures. We shall not use this term in order to avoid confusion with thermodynamic wave phase velocity. Boundary velocities (temperature) will be denoted as T_g . They are group surfalinear velocities. Phase velocity (temperature) will be denoted just T .

Everything said above complicates the description of isothermal process because we are compelled to refer to all group velocities as phase velocities.

Let us say that a process is naturally isothermal, if the equation

$$\omega = T_g S \quad (2.4)$$

is valid for it. Here ω is field heat, S is field entropy, $T_g = \text{const}$ is the group velocity of a thermodynamic wave (group temperature).

Condition of T_g stability actually means that the whole heat transferred to the field is spent for entropy increase. And symmetrically: the heat taken away from the field decreases only entropy. The characteristic example is water evaporating and vice-versa. This means that T_g actually characterizes the medium in which the process takes place, or to be more accurate, the boundary between different states of this medium. But, before evaporating water is heated for some time, the phase velocity of the thermodynamic waves, induced by water particles, changes.

It was shown in [1] that group and phase velocities are connected by the equality

$$T_g = T + S \frac{dT}{dS}. \quad (2.5)$$

One can see that phase velocity T depends on entropy. Eq. (2.5) solution is

$$T = T_g + \frac{\nu}{S}, \quad (2.6)$$

Where ν is a constant characterizing the process. It has the dimension of heat. Because T depends on entropy it is necessary to use a thermostat in order to keep temperature stable. The thermostat increases ν in (2.6) and compensates entropy increasing keeping T stable. Let us rewrite (2.6) in another form

$$S(T - T_g) = \nu. \quad (2.7)$$

$S > 0$, therefore, when $T < T_g$, ν is negative, and the process needs additional energy. If $T > T_g$, then ν is positive, the field extracts energy until the medium has changed its structure (water has become vapor). If the structure has changed (water has become vapor) T_g increases up to a new value when new restructuration begins. (2.7) means that when $T = T_g$, ν becomes zero: there is neither energy absorption nor extraction.

Thus if entropy is fixed in an isothermal process we always lose energy except for the case, $T = T_g$. But, in reality, entropy changes in the process. Let entropy change from S_2 to S_3 , i.e. the heat has also changed from ν_2 to ν_3 . Thus instead of (2.7) one obtains

$$(S_2 - S_3)(T - T_g) = \nu_2 - \nu_3. \quad (2.8)$$

We assume that

$$T \leq T_g. \quad (2.9)$$

This yields that: if $S_3 > S_2$, then $\nu_2 > \nu_3$, i.e. $\nu_2 - \nu_3 > 0$. When entropy is increased our energy expenditures for the field decrease. In the opposite case $\nu_2 - \nu_3 < 0$, i.e. decreasing entropy we increase our energy expenditures for the field.

3. Field Cycles

The field concept lets us consider thermodynamic cycles in field terms. We shall consider the field analog of the Carnot cycle.

It is known that the Carnot cycle consists of four parts: two adiabatic and two isothermal ones.

Let us consider its field analog in Fig. 1.

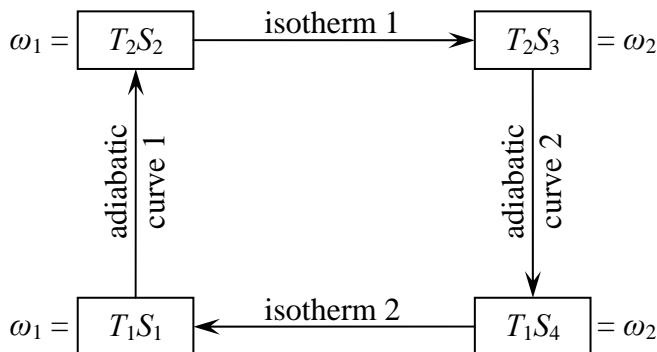


Fig. 1. The field cycle

We start from a state with heat ω_1 , i.e. in accordance with (2.1) from temperature T_1 and entropy S_1 . We transmit this state adiabatically into state T_2S_2 . In accordance with the adiabatic process definition we stay with the same heat ω_1 , but temperature and entropy change. For simplicity we determine that $T_2 > T_1$, i.e. temperature is increased. Of course we could do this only by decreasing entropy, i.e. S_2 must be less S_1 , $S_2 < S_1$.

Our second step is to isothermally go to another heat state

$$\omega_2 = T_2S_3. \quad (3.1)$$

The temperature is stable in the process but entropy has changed (has become S_3). Correspondingly the heat has become

$$\omega_2 \neq \omega_1. \quad (3.2)$$

At the third step we adiabatically return to temperature T_1 . Entropy also changes and becomes equal to S_4 . But the heat remains stable and equal to ω_2 . In order to conclude the process we must isothermally change S_4 for S_1 keeping temperature equal to T_1 . Let us try to understand what we have obtained and what we have lost in the cycle.

Let us return to the isothermal process 1.

Heat change is described by Eq. (2.8) in order that the heat increment be positive, ($\nu_2 - \nu_3 > 0$), entropy increment must be negative: $S_2 - S_3 < 0$, i.e. $S_3 > S_2$. Experimental observation yielded the conclusion: entropy always increases.

Let us return to the second isothermal process.

$$(S_4 - S_1)(T_1 - T_g) = \nu_4 - \nu_1, \quad T_1 < T_g. \quad (3.3)$$

If $S_4 - S_1 < 0$ (entropy in the process increases), then $\nu_4 - \nu_1 > 0$ (heat decreases), and vice versa.

There are connections between entropies in the two isothermal processes:

$$S_1 = \frac{T_2S_2}{T_1}, \quad S_4 = \frac{T_2S_3}{T_1}. \quad (3.4)$$

Thus Eq. (3.3) can be rewritten

$$(S_4 - S_1)(T_1 - T_g) = -\frac{T_2}{T_1}(S_2 - S_3)(T_1 - T_g) < 0, \text{ i.e. } S_4 > S_1. \quad (3.5)$$

Thus our energy losses for the field in the second isothermal process are bigger than in the first one because entropy decreases in the second process. Let us say this another way. We lose less energy in the first process because the heat loss velocity decreases with the entropy increase. The picture is symmetric in the second isothermal process. Let us compare the loss velocity (3.5) with the loss velocity in the first process:

$$(S_2 - S_3)(T_2 - T_g) > 0. \quad (3.6)$$

One obtains the total loss change in the two processes summing (3.5) and (3.6):

$$\begin{aligned} \alpha &= (S_2 - S_3)(T_2 - T_g) - \frac{T_2}{T_1}(S_2 - S_3)(T_1 - T_g) \\ &= (S_2 - S_3)T_g \left[\frac{T_2 - T_1}{T_1} \right] < 0. \end{aligned} \quad (3.7)$$

Certainly instead of (3.4) we could write

$$S_2 = \frac{S_1 T_1}{T_2}, \quad S_3 = \frac{S_4 T_1}{T_2} \quad (3.4a)$$

And obtain instead of (3.5)

$$(S_2 - S_3)(T_2 - T_g) = -\frac{T_1}{T_2}(S_4 - S_1)(T_2 - T_g) \quad (3.5a)$$

And instead of (3.7) another expression for

$$\begin{aligned} \mathfrak{x} &= (S_4 - S_1)(T_1 - T_g) - \frac{T_1}{T_2}(S_4 - S_1)(T_2 - T_g) \\ &= (S_4 - S_1)T_g \left[\frac{T_1 - T_2}{T_2} \right] < 0. \end{aligned} \quad (3.7a)$$

In (3.7) \mathfrak{x} is expressed in terms of the first isothermal process and in (3.7a) it is expressed in terms of the second isothermal process. \mathfrak{x} has a heat dimension and is always negative. This index characterizes inevitable energy losses in the cycle.

Let us consider the reverse cycle

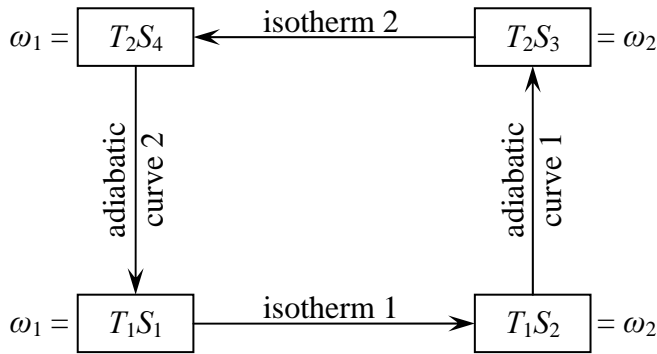


Fig. 2. The reverse cycle

One obtains just as in the direct cycle

$$\mathfrak{x} = (S_1 - S_4)T_g \left[\frac{T_2 - T_1}{T_1} \right] > 0. \quad (3.7b)$$

Thus the considered cycle is reversible; \mathfrak{x} has become positive.

We started from ω_1 heat and came to ω_2 . $(\omega_2 - \omega_1)$ is the heat participating in the cycle. It was obtained by the working body from the external medium. The heat \mathfrak{x} is the inevitable energy loss absorbed by the field. The energy loss coefficient is

$$\theta = \frac{|\mathfrak{x}|}{\omega_2 - \omega_1}. \quad (3.8)$$

One obtains from the first isothermal process

$$\theta = \frac{(S_2 - S_3)T_g(T_2 - T_1)}{T_1 T_2 (S_2 - S_3)} = \frac{T_g(T_2 - T_1)}{T_1 T_2} = \frac{T_g}{T_1} \left[\frac{T_2 - T_1}{T_2} \right], \quad (3.9)$$

Where θ characterizes the ratio of the heat transmitted to the field to the total energy. We isolated the expression characterizing the Carnot cycle in square brackets in order to distinguish our formula from the traditional one. The coefficient before the square bracket exceeds 1, i.e. the whole expression can be greater by 1 as well. If so, the following inequality holds

$$T_g \geq \frac{T_1 T_2}{T_2 - T_1}. \quad (3.10)$$

The analyses of the partial derivatives show that the right hand expression in (3.10) is the increasing function of T_1 and the decreasing function of T_2 . This means that we must find the medium with the minimal boundary temperature for which the inequality (3.10) holds. Thus we must take $T_2 = T_g$ and T_1 which is minimal for this medium. For instance for water $T_2 = T_g = 373^\circ$, $T_1 = 273^\circ$. One obtains

$$\frac{T_1 T_2}{T_2 - T_1} = \frac{373 \cdot 273}{100} > 373. \quad (3.11)$$

Thus it is impossible for the processes with water to exceed 1. But do such media exist at all?

Let us simplify condition (3.10), i.e. let $T_2 = T_g^{\max}$, $T_1 = T_g^{\min}$, where T_g^{\max} is the upper and T_g^{\min} is the lower boundary temperatures. Thus (3.10) becomes

$$\frac{T_g^{\min}}{T_g^{\max} - T_g^{\min}} \leq 1. \quad (3.12)$$

From here

$$T_g^{\max} \geq 2T_g^{\min}. \quad (3.13)$$

4. Comparison with Carnot Cycle

The Carnot cycle consists of 2 adiabatic and 2 isothermal processes. In T, S coordinates it is usually described as

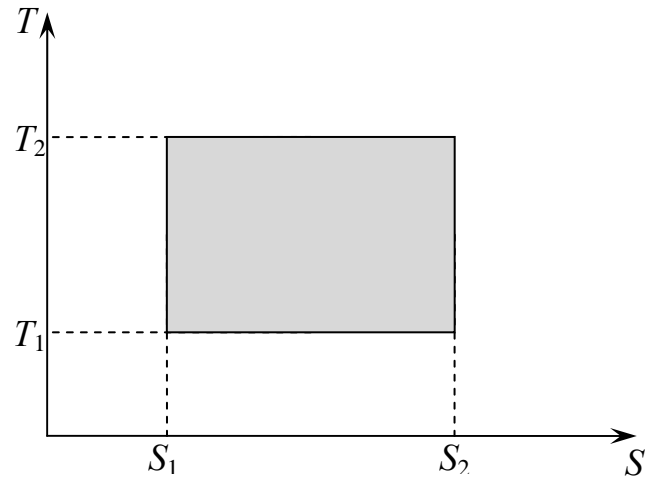


Fig. 3. The Carnot cycle

It is believed that the drawn rectangle square represents efficient work in the cycle and $T_2(S_2 - S_1)$ rectangle square is the heat transmitted to the machine.

The Carnot thermic coefficient is usually defined as

$$\eta = \frac{(T_2 - T_1)(S_2 - S_1)}{T_2(S_2 - S_1)} = \frac{T_2 - T_1}{T_2} = 1 - \frac{T_1}{T_2}. \quad (4.1)$$

Let us consider it in greater detail.

The rectangle in Fig. 3 appears because the adiabatic process is considered isentropic and temperature in an isothermal process is believed to be constant today. The field analysis shows that these suppositions are wrong.

1. The thermodynamic wave Eq. (2.1) yields the result that when we fix certain heat ω_0 in adiabatic process (adiabatic condition) we cannot fix entropy S_0 : in that case immediately temperature T_0 must be fixed in accordance with Eq. (2.1) and the process stops. Therefore when we increase T_1 up to temperature T_2 along the adiabatic curve 1 we must inevitably decrease entropy S_1 up to S_2 . Symmetrically when the adiabatic process 2 takes place: when temperature T_2 is decreased to T_1 we inevitably must increase entropy S_3 up to S_4 .
2. The picture in the isothermal process is similar. Only the boundary temperature T_g stays stable in them. The phase temperature inversely depends on entropy (Eq. (2.6)). In order to keep the temperature stable we need additional heat to compensate for the entropy increase. But in this case a third coordinate should appear in Fig. 3 to show this additional heat. One finally obtains: field cycle in T, S coordinates appears as in Fig. 4.

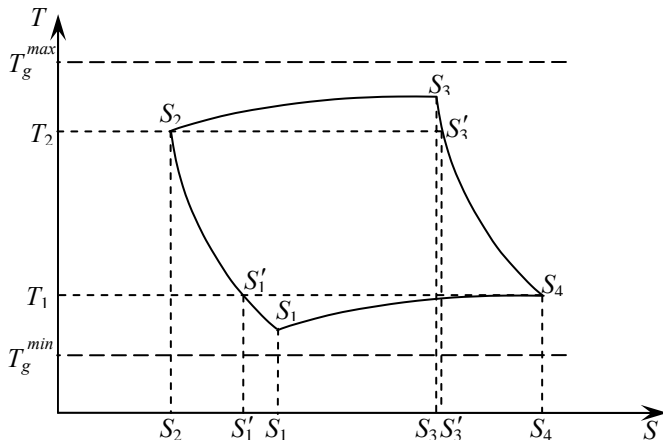


Fig. 4. The field cycle

Hyperbolic parts link S_1 and S_2 , S_3 and S_4 , instead of straight lines in Fig. 3. If the thermostat is not used the phase temperature will not be stable and the real process will go from S_2 not to S_3' (dashed line) but to S_3 closer to T_g . Symmetrically

the second isothermal process will go to S_1 and not to S_1' (farther from T_g). Just these differences between Fig. 3 and Fig. 4 are determined by (3.7) and (3.9).

5. Conclusion

We have shown above that the second isothermal process in the direct cycle induces the greater energy losses for us.

1. Perhaps we could use a nonclosed/open cycle? In Carnot's terms perhaps we could work without a cooler? In field terms the problem would be to extract energy just from the field for instance from ocean. Nowadays when we understand the accurate physical sense of heat and entropy such a problem does not seem fantastic. But the previous serious experimental program should be completed.
2. It was recommended above to work at the boundary temperature T_g . In this case the whole supplied energy transmits into entropy and vice-versa. The problem is that the very medium changes under such temperature. Therefore media in which heat completely transforms into temperature with fixed entropy seem very interesting for investigation. Such a medium is theoretically well known: it is ideal gas. It was shown in [1] that ether possesses this quality. We mentioned in section 2 that having overcome the ether boundary temperature T_0 we could extract energy just from ether. But the scalar theory of the thermodynamic field proposed in [1] is not enough for this. The Tensor field theory is necessary for this. These authors hope that such a theory will appear in due course. Certainly a big experimental program is necessary on this topic.

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