PROSPECTS FOR THE PRODUCTION OF ELECTRICITY BASED ON HEAT

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Abstract. *This article investigates the prospects of producing electricity from heat through theoretical and experimental analysis of thermoelectric processes in different media. It examines the relationship between temperature, particle motion, voltage formation, and material properties, using mathematical models for two- and three-medium systems. Special attention is given to the Seebeck effect, capacitor-based structures, heterogeneous conductors, dielectrics, electrolytes, and systems with unequal electrode surfaces. Experimental tests using copper, aluminum, zinc, iron, graphite, activated carbon, PTFE, oil, and salt water demonstrate temperature-dependent voltage generation, often showing nonlinear behavior. The findings indicate that electrical energy can be generated from heat sources without traditional cooling mechanisms. The study concludes that such systems may support environmentally friendly low-power sensors and sustainable energy applications.*

Keywords: *thermoelectric effect, heat, electricity, Seebeck effect, thermodynamics, capacitor systems.*

Introduction

In modern energy, the search for alternative energy sources and their effective use are becoming increasingly relevant. Due to the global energy crisis and environmental problems, the search for new energy sources alternative to traditional fuels has become necessary.

The possibilities of direct conversion of thermal energy into electrical energy are being widely researched. Thermoelectric phenomena are one of the most promising directions in this field. Devices created on the basis of these effects make it possible to obtain electricity from industrial emissions, exhaust heat from car engines, and other heat sources.

Goals and objectives

Objective: Theoretical and experimental study of the processes of generating electrical energy in various environments under the influence of heat, assessment of the possibilities of practical application.

Main tasks:

Analysis of the theoretical foundations of thermoelectric phenomena

Mathematical modeling of various material systems

Conducting experimental experiments and analyzing the results

Evaluating the prospects of practical application and making proposals is effective and promising in practical application.

About heat.

Heat, i.e., the temperature of the medium, has historically undergone many stages, and theories have even been built, assuming that temperature is a separate thermal element. Currently, temperature is an integral concept of physics and is a fundamental concept such as mass, space, energy, and motion. It should be noted that temperature, mass, and energy cannot exist without

each other, and vice versa. We can substantiate this fact as follows. According to kinetic theory, the average kinetic energy of a particle is directly related to temperature:

$$\langle E_k \rangle = \frac{1}{2}mv^2 = kT \quad (1)$$

where m - particle mass, v - velocity, k - Boltzmann constant, T - absolute temperature. On the other hand, Einstein's famous equation expresses the inseparability of energy and mass:

$$E=mc^2$$

where c is the speed of light in a vacuum.

Combining the above two equations, we can find the critical temperature for each particle:

$$T_c=\frac{mc^2}{k}$$

In general, the theoretically highest possible temperature is Planck's temperature:

$$T_P=\sqrt{\frac{\hbar c^5}{Gk^2}}\approx 1.417\times 10^{32}\ K$$

From the above reasoning, we can calculate the critical temperatures for different particles:

Electron:$T \approx 5.9 \times 10^9$K, Proton:$T \approx 1.1 \times 10^{13}$ K, Neutron:$T \approx 1.1 \times 10^{13}$

The lower limit of temperature, unlike classical physics, is that in quantum mechanics, even at absolute zero, particles have energy:

$$E_0=\frac{1}{2}\hbar$$

This is called zero-point energy and is a consequence of Heisenberg's uncertainty principle.

Just as mass and energy, as well as motion, are integral parts of matter, temperature is also a type of quantity. From this, we can draw the following conclusions.

At T > 0: Motion exists → Energy exists → Mass exists → Matter exists.

At T = 0: Theoretical case, practical lack → Matter cannot disappear. Since temperature is the source of energy, we will discuss the prospects for obtaining energy based on temperature, in particular, its conversion into electrical energy.

3.Theoretical basis

3.1. Main postulate

This research is based on the following theoretical postulate and formula (1). Two homogeneous continuous media are proportional to the difference in the square of the velocities of the particles of the medium due to the stresses arising between them under the action of certain temperature intervals. That is:

$$U=l\left(v_1^2-v_2^2\right)$$

Here, by medium we mean conductors, dielectrics, electrolytes, the coefficient of proportionality, which represents a quantity dependent on the physicochemical properties of the medium. It should be noted that here it is said about certain temperature ranges. The reason for this is, firstly, the limited nature of temperature mentioned above. On the other hand, under the influence of temperature, any medium changes its physical properties. Therefore, the aforementioned postulate holds within certain limits. If the coefficient of proportionality is equal to 0, then it follows that the postulate is incorrect. Below, it will be shown that theoretically this is different from zero, that is, the postulate is valid.

3.2. Case with two continuous media.

Here, the medium refers to conductors, dielectrics, and electrolytes. This theory is based on the aforementioned postulate and formula (1). The first characterizes the stress arising between the media, the second under the influence of temperature. characterizes the random motion of the particles of the medium. Let us assume that two continuous media are given. Let it be given a temperature, and then we will write the energy received by the media (1) as follows.

$$\frac{m_1}{2}v_1^2=kT_1$$

$$\frac{m_1}{2}v_1^2=kT_2$$

If we assume T1 = T2 = T, then from the above expression we obtain the following expression

$$v_2^2=\frac{m_1}{m_2}v_1^2$$

Substituting this expression into equation (2), we obtain the following relation for the voltage:

$$U=hv_1^2(1-\frac{m_1}{m_2})$$

If we consider as $v_1^2=\frac{2kT}{m_1}$

$$U=l\frac{2kT}{m_1}(1-\frac{m_1}{m_2})$$

If we introduce the following markup

$$k_{12}=l\frac{2k}{m_1}(1-\frac{m_1}{m_2})$$

The above expression takes the following simplified form:

$$U=k_{12}\mathrm{T}$$

It's not hard to see

$$k_{21}=-k_{12}$$

This means that if we swap the media, the direction of the voltage will change compared to the previous position.

3.3. State with three continuous media or thermoelectric effect.

Let two media 1,2 be given, and from them, arranged in the sequence 1,2,1, a system with three conditional continuous media is formed, and the connected parts are at different temperatures. Then for medium 1.2 and medium 2.1 we can write the above formula:

$$U_1=k_{12}T_1$$

$$U_2=k_{21}T_2$$

According to the rule of successive addition of voltages, if we add the total voltage, we obtain the following expression.

$$U=U_1+U_2=k_{12}T_1+k_{21}T_2$$

Taking into account equality (4), we arrive at the following simple formula for three media.

$$U=-k_{12}(T_1-T_2)$$

This, in turn, is the Seebeck effect, where the Seebeck coefficient is equal to $k_z=k_{12}$ .That is,

$$U=k_z(T_1-T_2)$$

It should be noted that if the media are homogeneous $m_1=m_2$ The Zebeek coefficient is zero, i.e., the effect does not exist.

As we saw above, based on the postulate, **the Seebeck** effect was obtained. This effect has been proven theoretically and practically. That is,k_z is different from zero. $k_z=l\frac{2k}{m_1}(1-\frac{m_1}{m_2})$ to the expression if we pay attention, m_1 m_2 is different from zero and not equal to each other, and k is also not equal to zero. It follows that for this expression to be zero, it is necessary and sufficient that l is equal to zero. In conclusion, if the Seebeck effect exists, our accepted postulate is valid, and conversely, if our postulate is correct, the Seebeck effect exists. Let's consider the dependence of the above condition on the contact surface of the continuous medium. For this, we will assume the following. Let the media be arranged in the sequence 1, 2, 1 and the temperature be the same, i.e., T. Suppose that points 1,2 and 2,1 are points of contact of heterogeneous elements, and the corresponding voltages are:$U_1=k_{12}T_1$ and $U_2=k_{21}T_2$. According to the law of uniform current in a common circuit, we can write the following expression

$$\frac{U_1}{R_1}=\frac{U_0}{R_1+R_2}$$

Here R_1,R_2 we can write, respectively, in parts 1.2 and 2.1 of the chain.

$$R_1=\frac{U_1}{J_1}$$
$$R_2=\frac{U_2}{J_2}$$

In this case, the current strength J_1,J_2 at points 1, 2 , and 2,, respectively. If we denote the current flowing per unit area as μ and the cross-sectional area in sections 1.2 and 2.1 as S_1,S_2 , the above expression takes the following form

$$R_1=\frac{U_1}{\mu S_1}$$

$R_2=\frac{U_2}{\mu S_2}$

Our above assumption, namely, due to the temperature uniformity at points 1,2 and 2,1, the absolute values of the voltage are equal and opposite $U_1=-U_2$. We will denote this value in the future by U. Summarizing these results, we obtain the following formula for the total voltage through the areas

$$U_0=U(1-\frac{S_1}{S_2})$$

If we take into account the voltage formula between two media $U=k_{12}T$ if we take into account the value, the above formula takes the following form

$$U_0=(1-\frac{S_1}{S_2})k_{12}T$$

From this formula, it follows that in a thermodynamic system, when the temperatures of two adjacent parts are the same and the cross-sections of the adjacent parts are different, the voltage is different from zero. From the formula, it is clear that the effect does not occur if the areas of the adjacent parts are equal.

3.4. Case of three heterogeneous continuous media.

Let them be arranged in the sequence 1,2,3, respectively. If we assume that the temperatures at junctions 1,2 and 2, 3 are the same: T , then, respectively, if we denote the voltage between them as $U_1.U_2$, the above formula will be as follows:

$U_1=k_{12}T$
$U_2=k_{23}T$

In this case, k_{12}, k_{23}- corresponding proportionality coefficients. The voltage between the common media 1 and 3 will be

$$U=(k_{12}+k_{23})T$$

It should be noted that from the formula it is clear that if medium 3 and medium 1 are the same, then the voltage is equal to zero. That is, for this effect to occur, it is necessary that all three media have different physical properties.

4.Analysis of results

4.1. Theoretical conclusions:

It can be concluded that theoretically, electrical energy can only be obtained from heat. In particular, the above-mentioned:

$$U=(1-\frac{S_1}{S_2})k_{12}T \quad (6)$$

$$U=(k_{12}+k_{23})T \quad (7)$$

$$U=(k_{12}+k_{23})T$$

serve as the basis for this. It should be noted that in the classical thermoelectric phenomenon, electrical energy can be obtained only if there is a temperature difference between the correspondingly connected parts, i.e., $U=k_{12}(T_1-T_2)$. This method of cooling is the most inconvenient. In the next section, we will demonstrate experimentally that electricity can only be obtained in heat.

It should be noted that this theory is based on the fundamental formula (1). It is known that this formula historically expresses the relationship between the average kinetic energy of gas particles and temperature. Above, this idea was hypothesized for any medium in general. In this case, for any medium, this relationship may not be linear. If this formula is considered as an indefinite function, the theory becomes even more generalized. That is:

$$\langle E_k \rangle = \frac{1}{2}mv^2 = kf(T)$$

In this case, it's not difficult to continue the above logical thoughts

$$U=(k_{12}+k_{23})f(T)$$

The exact form of the function f can be obtained experimentally, arising from certain ranges of media and temperatures. Indeed, the study[1] states that this relationship is nonlinear for some media.

4.2. Practical experience analysis:

4.2.1. Let us consider the case when the medium 1 is a conductor, the medium 2 is a dielectric, and the medium 3 is a heterogeneous conductor from the medium 1. In general, such a device is an electric capacitor, i.e., two conductors and a dielectric between them. It should be noted that, besides temperature, there are other factors influencing the self-charging of capacitors (without an external power source), but the most important is temperature. 40x2 cm copper and aluminum foils are wrapped using thin paper separator, placed in a glass container filled with oil, and are hermetically sealed.

If we assume that the relationship is linear

$$V=14.10\cdot T-259.90$$

where the degree of correspondence R2=0.972

If approximated through quadratic regression, the degree of correspondence, i.e., accuracy, increases, including R2=0.987, and the relationship formula

$$V=0.335T^2-7.27T+67.42$$

4.2.2.

In this case, we make a capacitor using copper and aluminum foil PTFE $(C_2F_4)_n$ tape as a dielectric. The dimensions are 40x1 cm, and we place this roll in a metal container and seal it hermetically (for example, with epoxy glue). The experiment gives this result.

$$V = 3.33T - 110.1.$$

4.2.3.

Having repeatedly considered the experiment in section 4.2.1 for the copper-zinc pair, we see the temperature dependence according to the regressions.

$$V= 5.246T - 161.58$$

where the error is 0.92, if we study the experimental data using quadratic regression.

$$V=0.1193T^2-5.965T+79.93$$

In this case, we obtain an error of 0.99. It should be noted that in the above two experiments, no electrochemical reactions occur between the electrodes, because the dielectric is located between the electrodes, and ion exchange is not allowed.

4.2.4. This experiment is based on formula (6), i.e., cases involving homogeneous electrodes with different surfaces. Electrode 1 is made of iron in the shape of a cylinder and aluminum foil is attached to it in a ratio of 1.3. When heating this device several times to 306 C, we came to the following conclusion. Linear regression of experimental data

$$V=0.0242T-6.1269$$

where the error is R=95, if we look through quadratic regression, we can observe a decrease in error R=98, i.e.

$$V=0.0002866T^2-0.1381T+16.7382$$

4.2.5. This experiment also involves electrodes of the same chemical composition, but with different surfaces. 1 electrode is graphite, 2 electrodes are activated carbon. In this case, the experiment has prospects, since in previous cases the current in the element was very small, since the medium between the electrodes was a dielectric, and the internal resistance is undoubtedly very high. However, in this case, conductor 3, i.e., salt water. To monitor the current strength, a resistance of 10 kΩ was connected. If we find the experimental data in linear regression, the error is high, i.e., R=88.

$$V=0.262T+11.82$$

Low error through quadratic regression R=98

$$V=0.00792T^2-0.387T+24.10$$

4.2.6. In this experiment, we will see identical electrodes with different surfaces. Electrode 1 is activated carbon, electrode 2 is activated carbon, the surface area of which is less than electrode 1 in the ratio 10:1. 3. salt water as a medium. It should be noted that this device is an asymmetric supercapacitor. In this case, the elements are charged at a level of 1 V, and the charge in this case is electrostatic. On the other hand, such an element also has the property of accumulating energy with increasing temperature. This element is sealed with 6 cm² of heat-resistant dielectric plastic with an activated charcoal fabric, and a synthetic fabric soaked in salt water is placed between them as a separator and hermetically sealed. Experimental tests of this element without resistance are as follows.

$$V=0.27T+7.33$$

If the resistance is 10com

$$V=0.25T+2.33$$

It should be noted that such an element is stable, there is no chemical reaction, and during 1 year of experimental tests, the voltage-current characteristics do not change under a load of 10 kΩ resistance.

Prospects for practical application

The research results can be applied to low-power sensors. Most importantly, it can be an environmentally friendly and sustainable energy source.

Conclusion

As a result of the conducted theoretical and experimental studies, we came to the following main conclusions:

1. It has been proven that it is theoretically possible to generate electricity using only a heat source. Cooling mechanisms are not required for this.

2 Mathematical models for systems of three media have been developed, and their good agreement with experimental results has been shown.

3. It was confirmed that the properties of the material are the main factor determining the thermoelectric efficiency.

4. Experiments show that the voltage-binding function is not always linear. In the constructed theory, instead of (1) in general

$$\langle E_k \rangle = \frac{1}{2}mv^2 = kf(T) \quad)$$

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