L.I. Anatychuk

L.I. Anatychuk

Institute of Thermoelectricity NAS and MES of Ukraine
1, Nauky Str., Chernivtsi, 58029, Ukraine

ON THE LIFE AND SCIENTIFIC ACTIVITY OF JEAN-CHARLES ATHANASE PELTIER. (BASED ON THE MATERIALS OF THE FILM SHOWN AT THE XVI INTERNATIONAL FORUM ON THERMOELECTRICITY)

The most complete description of Charles Peltier's life one can learn from Frederic Peltier's, his son, book. He writes in the preface to his book "Soon after my father's death I worked out a draft of his life story. It was only my poor health that was able to interfere with fulfillment of this work".

Despite his illness, he did manage to finish his book about Peltier and have it published in 1847 in Paris.

Apart from the book mentioned, 63 scientific publications by Peltier [1-63] and 32 articles and books where the details on Peltier are given [64-95] were used during preparation of this work.

Fig. 1. Jean-Charles Athanase Peltier.

Jean Charles Peltier was born in the north of France in the small town of Ham, 130 km away from Paris. Peltier was born on February 22, 1785. Peltier's father was a shoemaker and his mother was a housewife. They sent young Peltier to school where the teacher could teach him only reading and writing.

Thus, Peltier did not receive any classical education. He was but a self-educated person.

But Peltier was a gifted child. When he was only 10 he disassembled, cleaned and repaired a watch. His father, impressed by the action, decided to help his son become a watchmaker. The father hired his son as an apprentice to a watchmaker, Brown by name, in the town of Saint-Quentin. That man did not possess better human qualities.

Peltier was an inquisitive youth. He was eager to read books by candlelight in the evenings. But Brown forbade him to do so. Peltier then got into the way of reading by moonlight thus driving Brown crazy. Peltier's father, on learning about the situation, took his son back home.

In 1802 at the age of 17 Peltier became a watchmaker apprentice in the famous Breguet Company. Marie-Antoinette, Queen of France, Napoleon Bonaparte, French Emperor and other celebrities wore the watches of this Company.

Peltier worked with great zeal. His endeavours were taken notice of: he was entrusted with making of chronometers, the major watchmaker's achievement.

But Peltier still longed for sciences. In 1815 he received a modest legacy that allowed him to leave work and dedicate his life to science.

In doing so, he practically followed Seebeck who left work after having received a small legacy to devote him to scientific experiments.

The fundamentals of thermoelectricity were laid, therefore, by great enthusiasts, and it was an unmistakable sign of their future success.

At first Peltier was tempted by literature and even wrote some poetry.

Then he turned to studying grammar rules which led him to the enigma of brain potential and the effect of electricity on its work.

Such was a miraculous way that led Peltier to electricity.

In 1827 he purchased an electrophorus machine. In the process of working with it he realized that it was necessary to have a more reliable source of electricity.

At that time it was voltaic pile (Fig.2).

The efforts to improve its operation were directed towards increasing the number of pile elements. M.Donn, for example, had increased the number of elements N from 30 to 3000.

In practice, though, it was somewhat different. The current I in the external circuit was saturated rapidly. At the same time, a great number of elements caused the decrease in stability of the source operation.

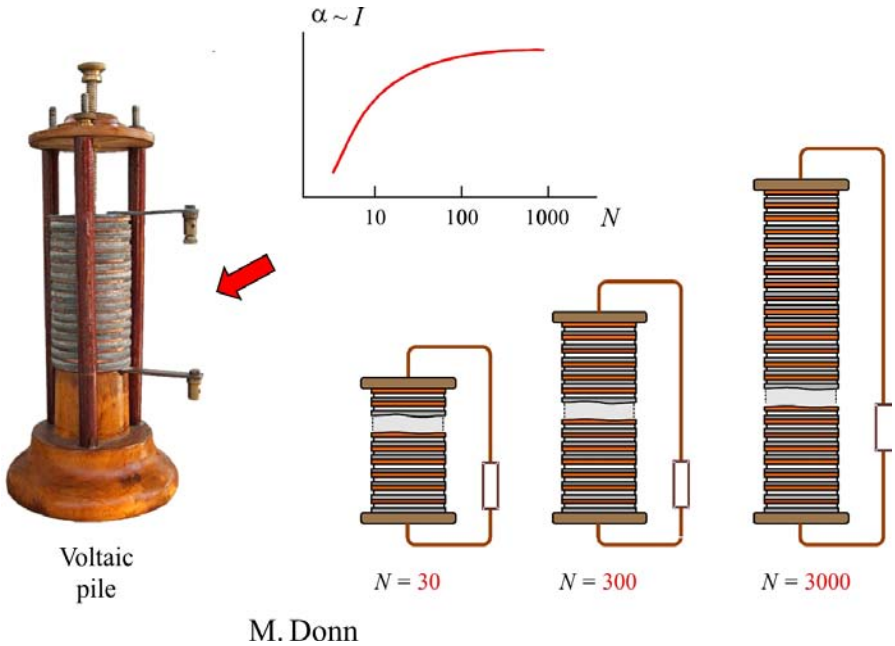

Fig. 2. Effect of voltaic cells number on the amount of current in the external circuit.

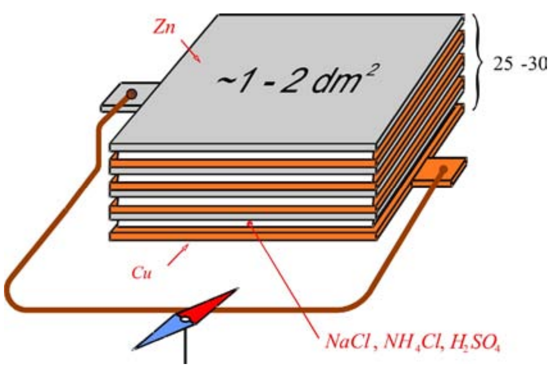

Рис. 3. Galvanic element that Peltier used.

Peltier chose a different way (Fig.3). Instead of increasing the number of elements, he increased their area to 1-2 dm^2. He used only about 25 to 30 elements and obtained some good results.

On July 19, 1830 Peltier pronounced those results for the first time during his speech held in the French Academy of Sciences.

Peltier made good use of thermoelectric sources. The first source of this kind was created by Oersted and Fourier in 1824. Peltier studied its properties thoroughly. He established the dependence of the generated current on:

– the length of legs of thermocouples,

Fig.4. French Academy of Sciences where Peltier reported on the results obtained.

– the cross-section of legs of thermocouples,

– the number of in-series connected thermocouples,

– the level of heating of junctions of thermocouples.

Relying upon these data, Peltier created thermoelectric current sources for his experiments.

It is universally recognized that Ohm was the first to use a thermogenerator for experimental verification of his law in 1826. But it was Peltier who used a thermoelectric source earlier, in 1824, when he discovered his famous effect.

Peltier realized quite well that his experiments required highly sensitive and handy electric current measuring instruments.

Fig. 5. Schweigger's galvanometer.

A magnetized needle reacting to magnetic field excited by electric current served as such instrument at that period. This idea was brilliantly implemented by Schweigger, a German physicist, in 1820.

The device consisted of two pancake coils with a magnetic needle between them.

Peltier admired this device but realized that it was not suitable enough for carrying out experiments. That is why Peltier developed his very handy high-sensitivity galvanometers. The principal part of the said galvanometer was a magnetic needle haft on the spine. Friction between the spine and the depression in the magnetic needle was the main reason for the galvanometer low sensitivity. The similar requirement for minimal friction between axes and their latches in watches was crucial for their proper work.

Therefore, Peltier surely used his high-class watchmaker's experience to minimize friction.

The excitation of magnetic field in galvanometers was generated from a single loop ribbon conductor in the circuits with low resistance. For the circuits with increased resistance magnetic field was produced by a multiloop coil.

Peltier widely used thermocouples for temperature measurements in his experiments. Antoine César Becquerel, a French physicist, fabricated a thermocouple of copper and iron in 1823 and connected it to Schweigger's galvanometer thus being able to measure temperature in the range from 0 to 300 ^{O}C.

With all his accuracy, Peltier set to studies on the properties of thermocouples as temperature measurers.

Firstly, he established that temperature readings depend strongly on the length 1 of the contact area of conductors. Short junctions should have been used.

Secondly, short junctions should have sizes very close to the diameters of the conductors.

Thirdly, poor contacts cause increase in the electric resistance of the junctions leading to distortions of temperature measurements.

Fourthly, Peltier established that when the temperature of liquids was measured with thermocouples, readings strongly depended on the depth of their immersion.

Fifthly, Peltier also established that thermocouples temperature readings depend upon the lengths of conductors connecting them to the galvanometer.

The performed researches encouraged Peltier to develop a witty device with amazing sensitivity, which played a decisive role in discovery of his famous effect. It is so called Peltier's thermoscopic clip (Fig.6).

In the figure you can see a variant of this device. It contains "jaws" 1 of two thermocouples that elastically grip the object of temperature measurements 2 with a steel plate 3.

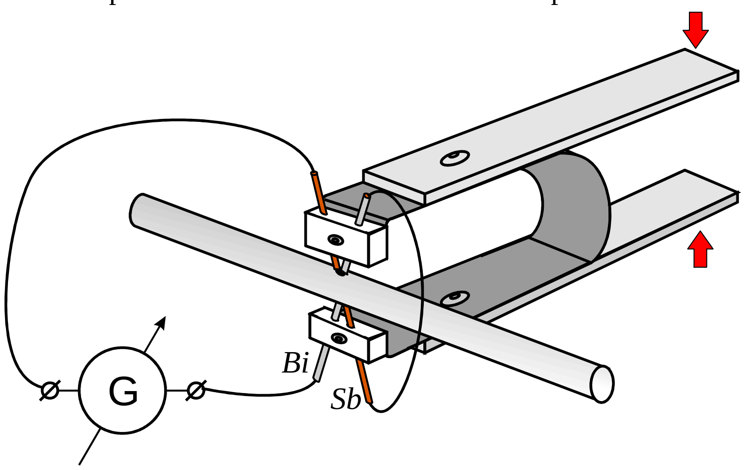

Fig.6. Peltier's thermoscopic clip.

The legs of thermocouples were fabricated of bismuth and antimony. Large values of thermoEMF coefficients of these materials and application of two in-series thermocouples made the said device especially sensitive.

To harmonize electric resistances of thermocouples and a galvanometer, a special coil with 80 loops of copper wire for magnetic field induction was used.

The device created by Peltier was, actually, a multiplier that consisted of two thermocouples.

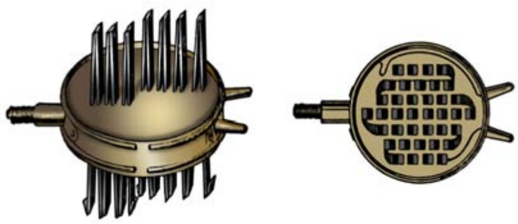

Fig.7. Nobile's multiplier.

As early as 1830, an Italian physicist Nobeli developed a multiplier consisting of 38 *Bi-Sb* components (Fig.7).

The device was so sensitive it was able to register the heat of human body in a dark room from the distance of 9 to 10 m. In fact, it was a prototype of a heat direction finder.

Therefore Peltier took special measures of precaution to eliminate negative influence of various external heat sources on measurements with his device.

The variety of means of experiment enabled Peltier to set a series of experiments that resulted in discovery of his famous effect.

It was very popular at that time to measure electric resistivity of metals. Peltier was also tempted to do this. He started measuring bismuth and antimony resistances because others failed to do it.

Peltier succeeded in casting of rods of bismuth and antimony with the diameter of 0.5 mm and length of 45 mm.

A thermocouple was used by Peltier as a current source. The galvanometer was a low-resistance one and consisted of a thick copper wire loop and, surely, a magnetic needle. Deflection of the magnetic needle when a rod with unknown resistance was used was compared to the rod with certain resistance.

This was how Peltier managed to do what no one else was able to. He was a venturesome researcher longing to do something what all the rest failed to do.

There was nothing special about this experiment, except bismuth and antimony rods. It was them that played a critical role in the Peltier effect discovery.

Peltier was led to experiments that resulted in discovery of his effect by the idea that at small currents new thermal effects should occur.

In Peltier words: "Till now thermal effects caused by electric current have not been measured with the help of sensitive devices so that we could enjoy the variety of phenomena occurring when the intensity of current is low".

It is well-known now that Joule-Lenz heat is proportional to the square of current, whereas the Peltier effect – to the first degree only. Therefore, with the decrease of the amount of current the Joule-Lenz heat will decrease rapidly thus giving chance for the Peltier effect to reveal itself. It is what exactly happened during Peltier experiments.

But Peltier knew nothing about that. One can but admire Peltier's keen insight in his expectations of new effects at small currents.

The layout of the experiment that led to the Peltier effect discovery consisted of a thermogenerator, low-resistance galvanometer and bismuth and antimony rods, fabricated before (Fig. 8).

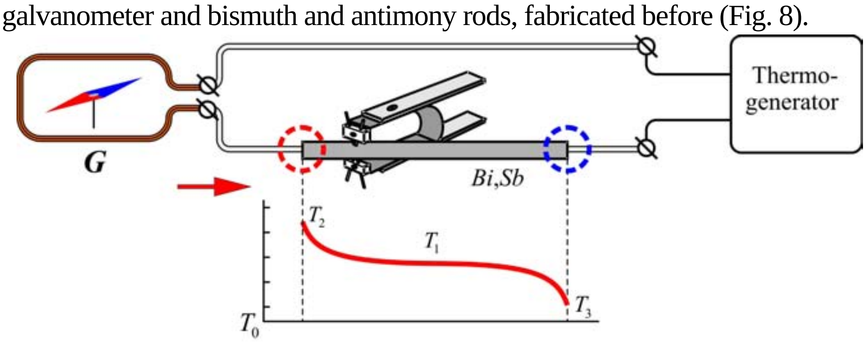

Fig.8. Layout of the experiment that led to the Peltier effect discovery
1 - temperature distribution along the rod, T_2, T_3 - temperature anomalies.

A thermoscope for measuring temperatures along the wires was employed.

Peltier sent the electric current through the rod and measured its heating with the thermoscope. In full agreement with Peltier's suggestions, a uniform heating by the current was observed in central parts of the samples. In the contact areas of samples with conductors, though, obvious temperature anomalies were observed, such as additional heating to temperature T_2 at one side and cooling to T_3 at the other. When the direction of current was changed, the temperature distribution became reversed.

Therefore, the Peltier effect consisted in anomalous heat release and absorbing at the areas of two different conductors connection if electric current was sent through them.

The discovery of his effect was promulgated by Peltier in 1824.

Peltier, certainly, expected some response to his discovery in contemporary scientific circles. Unfortunately, it did not happen. The Peltier's discovery attracted very little attention of the scientific community. There existed several explanations for this fact.

First, nobody saw any real use of this effect. Second, the discovery was made by a poorly educated man who might have simply been mistaken. And third, the effect was impossible to repeat in other laboratories.

The latter is easy to explain by absence of devices as sensitive as those developed by Peltier in other researchers' laboratories.

To convince the others in the presence of his effect, Peltier invents an extraordinary simple, elegant and, in his own opinion, persuasive experiment that was called a "thermal cross".

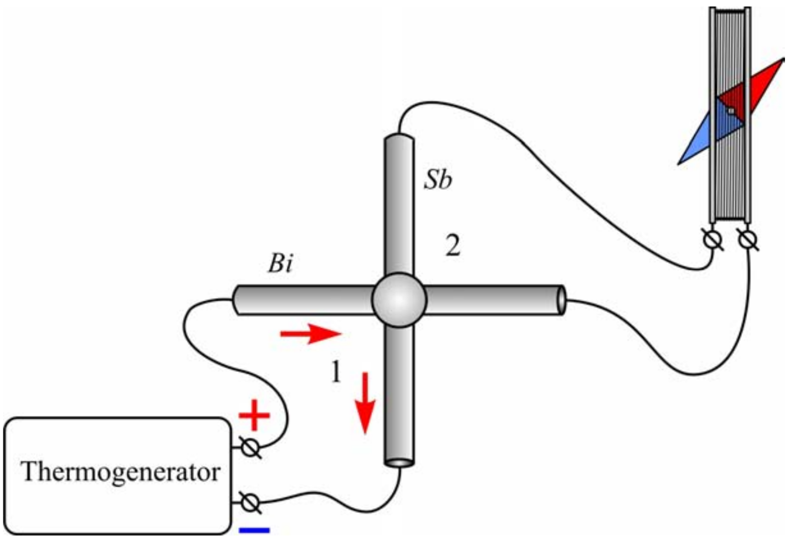

Fig.9. Peltier's thermal cross.
1, 2 – thermocouples of Bi and Sb, 3 – galvanometer.

The device really had the shape of a cross of two bars connected in the middle. One bar was made of bismuth, the other – of antimony. Such thermal cross formed two thermocouples, 1 and 2, connected at their junctions.

The experiment was as follows: electric current was sent through one of the thermocouples which, due to the Peltier effect, caused the junction cooling. The presence of such cooling was registered by the second thermocouple.

But even such experiment failed to convince sceptics.

The end to any doubts as for the Peltier effect was put by Lenz, a scientist from St. Petersburg, in 1838.

For this purpose he developed an experimental setup (Fig.10), the main parts of which were two rectangular bars of bismuth and antimony soldered in a butt joint. There was a hole where a drop of water was placed at the junction.

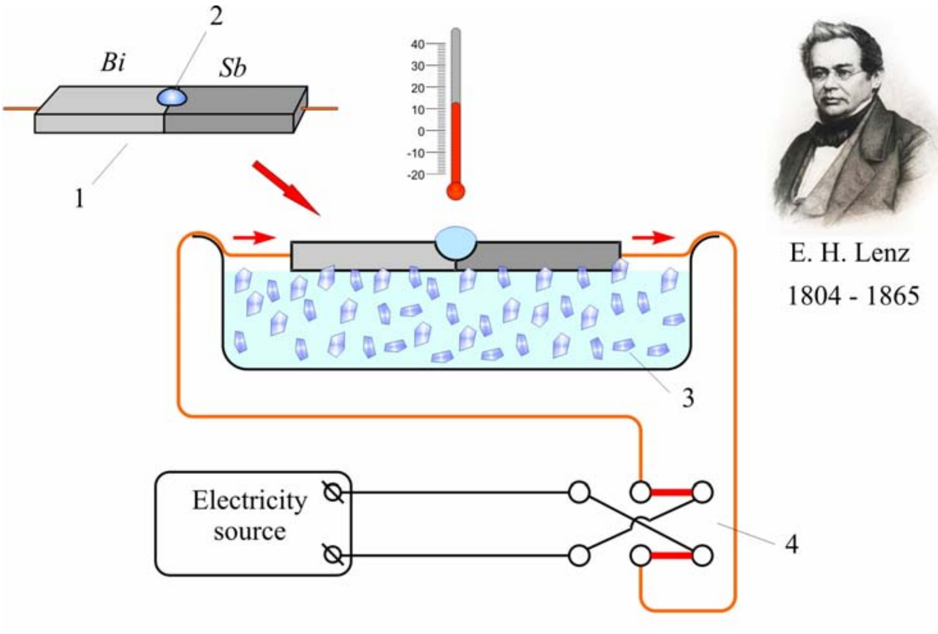

Fig.10. Lenz experiment layout
1 – rod of Bi and Sb, 2 – hole with a drop of water,
3 – melting ice, 4 – current switch

The rod was driven into contact with the surface of water with pieces of melting ice floating on it. The ends of the rod were connected to the source of electricity with the current switch. The switch served for changing the direction of the current.

When the current passed from bismuth to antimony, a drop of water froze and the temperature of -4.5^{O}C was registered by the thermometer. When the current direction was reversed, the drop of water melted.

This is the way the Peltier effect was rehabilitated and Lenz became famous as the first one who got ice from thermoelectricity.

After acknowledgement of his effect, Peltier became captivated by other researches. He studied the effect of electricity upon plants.

He developed a highly sensitive humidity meter where he employed a thermopile.

He studied electric potentials occurring between the Earth and air. For these purposes he used a wire one end of which was placed at the height of 25 metres, whereas the other one was put into a well 12 metres deep. An ultrasensitive galvanometer was embedded into the breakage of the wire. He established the connection between the readings of the device and weather conditions.

In general, he made a great contribution into development of the metrology scientific base.

Peltier lived at a very high speed. He worked to the point of exhaustion. He wrote: “I would rather die 10 years earlier and leave behind discoveries that will remind people of me”.

Peltier did implement his life plan. He died on October 27, 1845 at the age of 60 and a half. His name is familiar to the entire educated world.

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