

Study of processes using a pulsed plasma electrolysis unit

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A description of a system where plasma electrolysis was studied under different modes of reactor operation (immersion in the electrolyte, light touch, small gap, different polarity of the central electrode, different capacitance of the capacitor, single discharge or continuous operation) is given. The method of determining the ratio of heat released to the electricity absorbed by the reactor is described. A value *greater than* 100% is found only when the anode does not touch the electrolyte but is located at a small distance from it. In other cases, the heat is about the same as or slightly less than the electricity consumed. The results of the analysis of the elemental composition of the electrolyte before and after plasma electrolysis are presented.

Introduction

Starting with Fleischmann and Pons [1], electrolysis has been widely studied as a possible process for the implementation of cold nuclear transmutation (CNT). Especially attractive is the so-called "plasma electrolysis", where the current density is so high that plasma formation occurs near the electrode. A theoretical study of processes occurring in the plasma electrolysis process is contained in articles [2,3]. Especially strong effects occur in the process of *pulsed* electric discharge, when the pressure can increase to hundreds of atmospheres, and the temperature to tens of thousands of degrees, shock waves and cavitation occur [4]. It is clear that such extreme conditions attract CNT researchers. Indeed, during plasma electrolysis process excessive heat was registered [6,7,11,12,15], appearance of tritium [6,8,9], other initially absent nuclides [10,12] as well as effects on devices registering nuclear radiation [6,7,10].

In order to better understand what is happening in devices of this kind, a unit was created that allows researchers to investigate various modes of plasma electrolysis. Particular attention is paid to determining the ratio of heat generated and energy absorbed.

Experimental setup

A 60 W step-up transformer with a diode rectifier was used as a power source. This source provides voltages up to 1300V. The installation diagram is shown in Fig. 1. The capacitor used to store electricity typically had a capacitance of 50 μF , but in a number of experiments, capacitors from 0.2 to 160 μF were used. The current in the capacitor-reactor circuit is determined by the voltage drop across the resistance of 0.01 Ohms. The charging capacitor current is monitored by a voltage drop across a resistance of 1 ohm. To measure the voltage across the capacitor, a 1M / 1k divider is used.

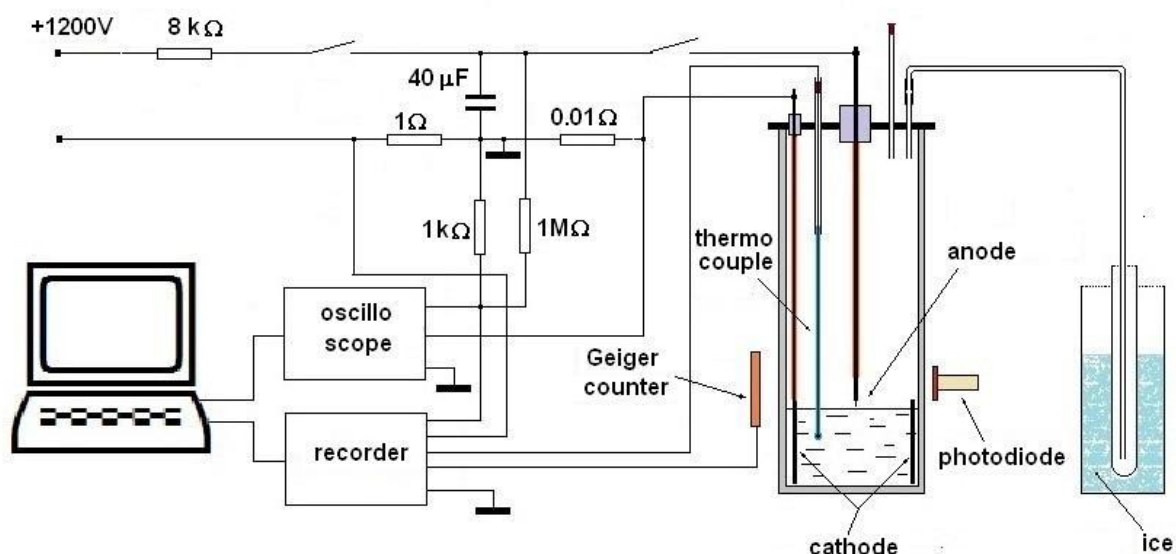


Fig. 1. Experimental setup

The reactor consists of a glass vessel into which an electrolyte is poured. 50 ml of a 10% solution of sodium carbonate (soda) was usually used as the electrolyte. But a number of experiments were also carried out with a solution of sodium hydroxide, potassium carbonate and with pure water. The central electrode - anode is a pointed molybdenum wire with a diameter of 1 mm. The cylindrical cathode is made of nickel foil. Three tubes are inserted into the lid. One of these can be used to refill the electrolyte, another can be used to insert a thermocouple, and the third can be used to remove steam and gases generated during the operation of the apparatus.

If you close switch K1, you charge the capacitor, open this switch and then close switch K2, a single discharge will occur. If both the switches are closed, the unit can operate in continuous operation mode. A mercury switch is used for K2, allowing high currents to be switched. To register current and voltage we used a two-channel computer oscilloscope PCSU200, which allows us to obtain not only the waveforms, but also record data in digital form in the memory of the computer. A four-channel computer recorder PCS10 is used for long recording of signals.

In addition to current and voltage at the anode, the unit allows you to monitor alpha, beta, gamma and X-ray radiation using the Si-8B Geiger counter with a thin mica window. A photodiode was used to register light phenomena.

Effects observed during operation of the apparatus in different modes.

When the anode is lowered into the electrolyte to a depth of approx. 5 mm, a surge occurs at the moment the voltage is applied, after which bubbles are released at the anode and especially strongly at the cathode.

Fig. 2 shows what happens with voltage and current at the anode. After applying the voltage, a pulse is observed with a maximum current value of up to 70A and several pulses of damped amplitude and a decreasing period. After a series of pulses is completed, low-voltage electrolysis occurs at a current of about 150 mA. This nature of the process can be explained by the fact that a sufficiently strong heat release causes the appearance of an electrically insulating vapor-gas shell near the anode, breaking the circuit. The interruption of the energy

supply leads to the destruction of this shell after about 15 ms. Since the capacitor has not completely discharged, the electrical discharge is repeated and the steam and gas shell is formed again. This is repeated until the energy remaining on the condenser is insufficient to form the steam and gas shell. This is followed by conventional low-voltage electrolysis. Due to the low resistance of the anode cathode, almost all the voltage drops at the internal resistance of the power supply (7.3 kOhm) and the power generated near the anode is low (about 1 W).

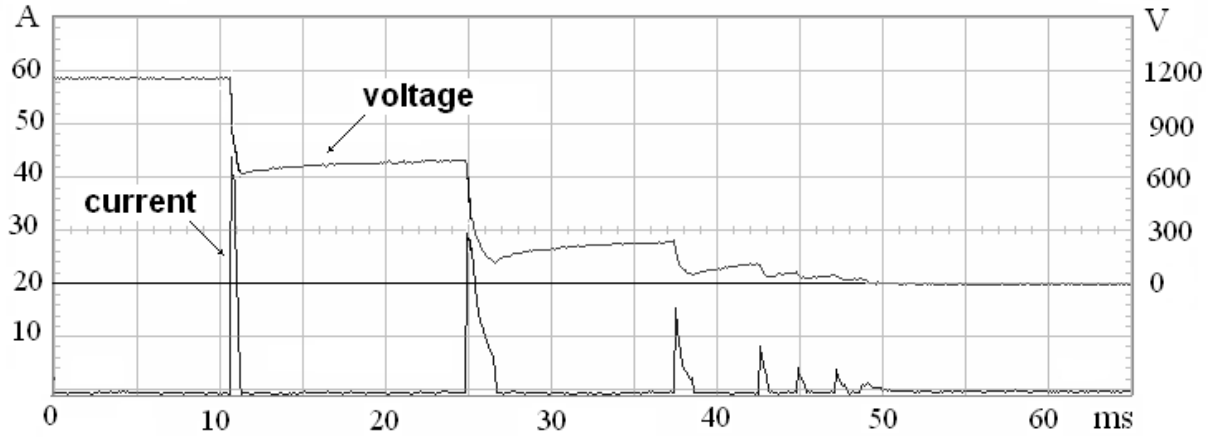


Fig. 2. Oscillograms of current and voltage at the anode at the initial stage of the discharge, when the anode is immersed in a 10% solution of Na_2CO_3 to a depth of 5 mm.

There are two ways to increase the power released near the anode. The first way is to isolate most of the anode from the electrolyte, leaving only a small tip. To do that, you have to put an insulating tube on the anode. When the reactor is operated with such an electrode, a luminous region of about 1 cm in size appears in the water column, the water becomes turbid, filling up with small bubbles, and splashes fly out of the electrolyte.

Fig. 3 shows the oscilloscope waveforms obtained in this process. The current has the character of pulses lasting 200-300 μs with a time interval of about 1 ms. The current in the pulse is up to 10 A. The pulse amplitude increases many times as the voltage increases from 500 to 550 V.

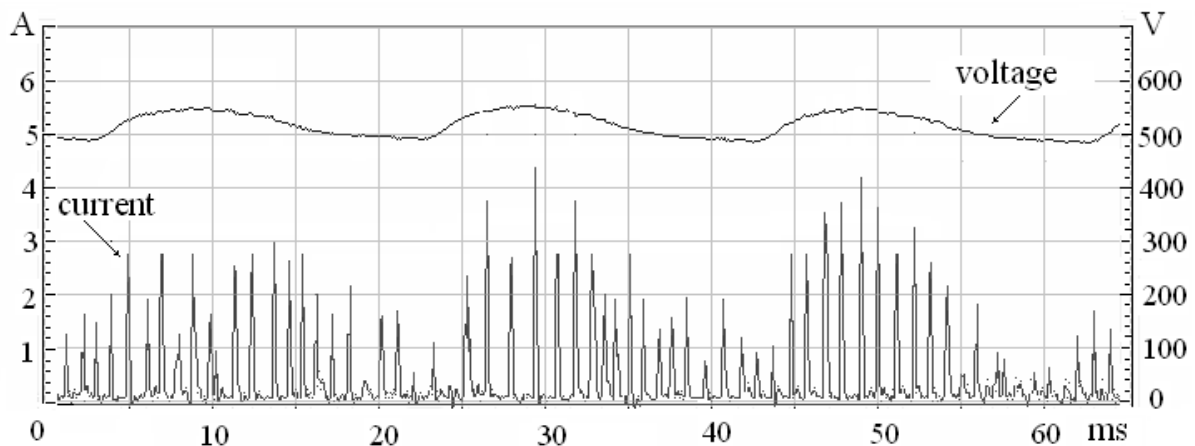


Fig. 3. Current and voltage oscilloscope waveforms at the anode when the anode is isolated from the electrolyte except for the tip

Another way to increase the power near the anode is not to lower the anode deeply, but only to touch the surface of the electrolyte slightly with the pointed tip. When the apparatus is

operating in this mode, the electrolyte splashes strongly. The entire volume of the electrolyte is filled with many small bubbles. In the contact area you can see an area glowing yellow, and a "snake" of blue runs along the anode. Gradually the above-electrolyte space is filled with a mist. In addition, flashes occur over a period of 2-3 minutes, covering the entire above-electrolyte space. Most likely, this is due to the ignition of hydrogen formed at the cathode. After several hours of operation, a black precipitate can be seen.

The oscilloscope shows (Fig. 4) that in this mode, there is a sequence of discharges of about 1 ms, with a current of up to several tens of amperes. The energy release in each discharge is 2-3 J. These discharges occur at a rate of 20-30 times a second.

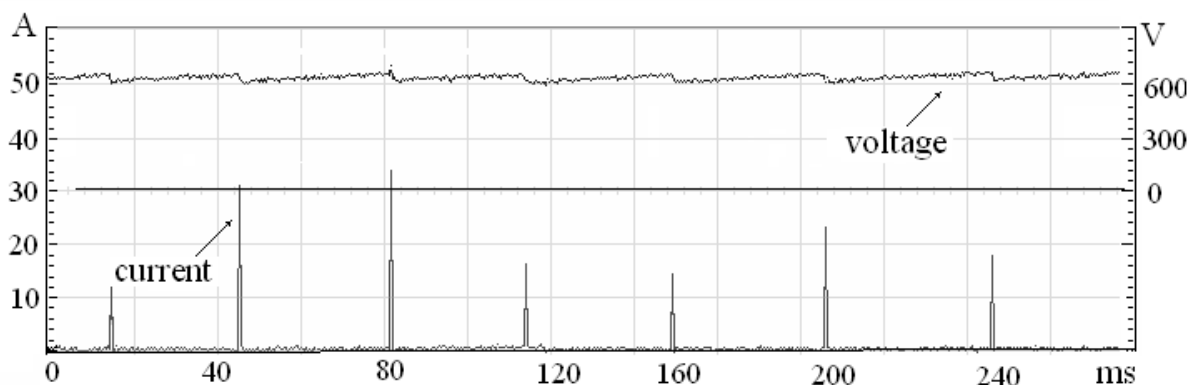


Fig. 4. Current pulses in continuous operation with the anode slightly touching the electrolyte

Especially strong effects are observed when there is a gap of a few tenths of a millimeter between the anode and the surface of the liquid before applying voltage : there is a dazzling flash of white light, accompanied by a strong sound and a surge of electric current. The discharge does not develop immediately, but a few milliseconds after applying a high voltage to the anode. The current in the pulse is much larger than in previous cases (up to 1000 A) with a duration of about 50 μ s (Fig. 5). Here, in addition to the oscilloscope waveform obtained by using soda solution as an electrolyte, the waveform obtained by using sodium hydroxide is shown. It can be seen that in both cases the course of the process is the same.

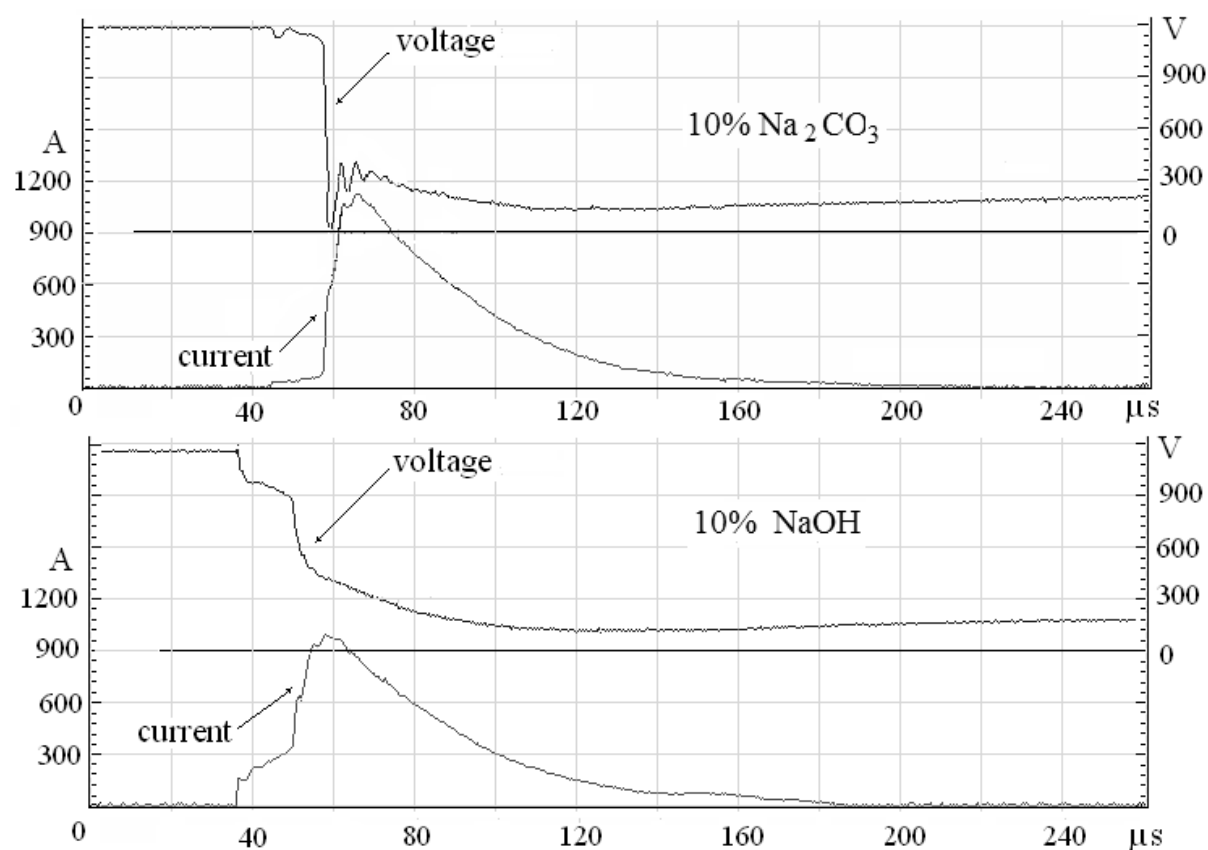


Fig. 5 . Oscilloscope waveforms of signals when the tip of the anode was at a distance of about 0.5 mm from the solution.

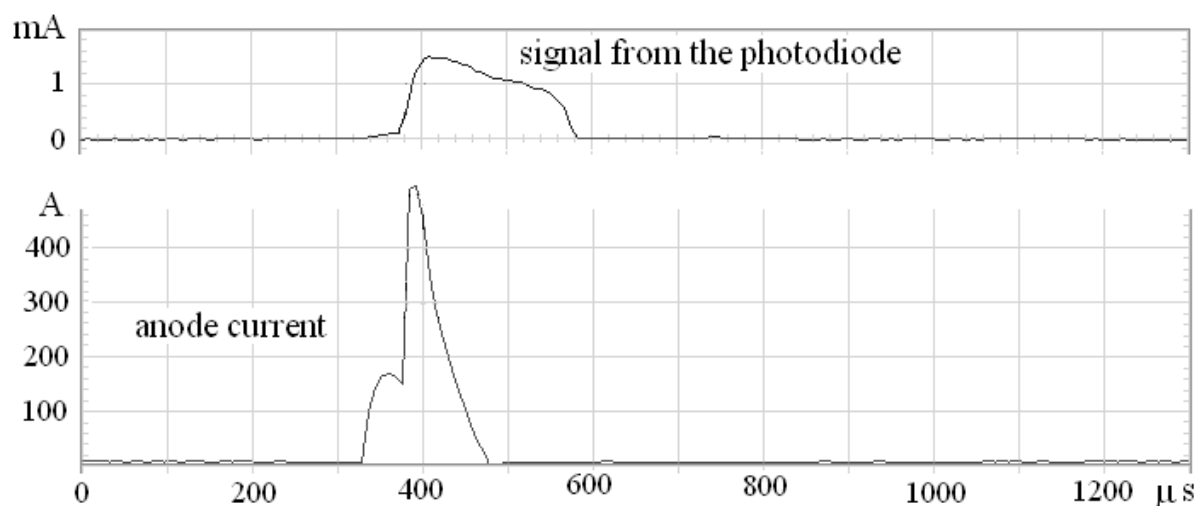


Fig. 6. Oscilloscope waveforms of the current of the anode and the accompanying electric discharge flash of light. The anode is separated from the electrolyte surface by a gap of about 0.5 mm.

Fig. 6 shows the change of light intensity accompanying the electric discharge, when the anode is separated from the electrolyte surface by a small gap. The flash intensity is so great that in order to avoid overload, the photodiode had to be protected with black paper with a hole

with a diameter of 0.1 mm. The light flash continues for approximately 100 μs after the current pulse is over.

It should be noted that light flashes “in touch mode”, in contrast to flash with a gap, are much weaker, have a yellow colour and are similar in shape to a current pulse.

If a minus rather than plus is applied to the central electrode when lightly touching the electrolyte surface, after one or more flashes the discharge starts to resemble a burning flame. The central electrode is red-hot. Apparently, this kind of activity is due to the fact that since the central electrode has become a cathode, it emits hydrogen, which burns immediately. The oscilloscope shows that the initial flashes are associated with current pulses up to 100A lasting about a millisecond. Later on, the current spike mode becomes chaotic.

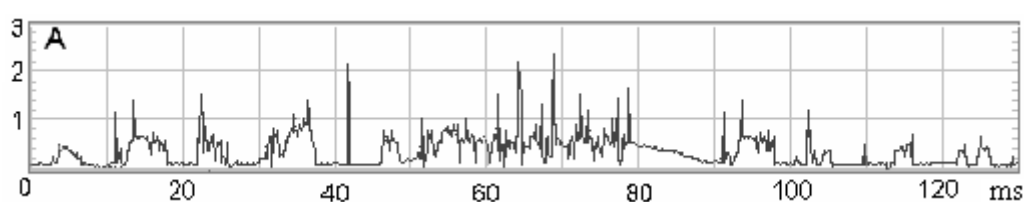


Fig. 7 . Oscilloscope waveform of current when there is a negative voltage on the reactor's central electrode.

If pure water (bidistillate) is used as an electrolyte, with positive polarity on the central electrode when the surface of the electrolyte is lightly touched there is a compact bright luminous area of blue colour with a size of about 1 mm, and the electrode gradually becomes incandescent. A soft hiss is heard.

It's a very different picture with clean water and *minus* on the central electrode. The process starts with a single flash, then the luminous area gradually expands to a diameter of 2-3 cm. The electrode is red-hot. It can be assumed that this is due not only to electrodes but also to the combustion of hydrogen released on the cathode by electrolysis of hydrogen.

In both cases, when using pure water, the discharge occurs at a voltage of 600-700V. Unlike electrolytes with solutions of hydroxide and sodium carbonate, there are no strong current pulses. The current fluctuates randomly with an average value of about 100 mA.

The ratio of heat in plasma electrolysis and energy consumed

By knowing the temperature response of the unit to calibrated joule heating, which is determined by passing current through a resistor, the measurement of the heat generated during plasma electrolysis with an error of only a few percent is not a big problem. It is more difficult to determine how much electricity is absorbed *precisely by the reactor*, and not lost in wires, transformers, or in other ways. In a number of experiments [7, 9, 15], an electric meter connected to the transformer was used to estimate the consumed electricity. But this raises questions about the reliability of the results obtained. In experiments with plasma electrolysis, reliable measurement of the *energy spent by the reactor* is not easy to carry out, since it is consumed by *pulses of an* unstable shape and amplitude, and the electric meter gives accurate results only for a sinusoidal current with a frequency of 50 Hz. The problem is complicated by

the energy loss in the capacitor, which depends not only on the discharge current, but also on the shape and duration of the pulses.

In *this* study, the determination of the electrical power consumed by the reactor was made by multiplying the instantaneous values of current and voltage, simultaneously measured *directly on the electrodes of the reactor*. This is made possible by the fact that the used data logger allows not only to display the signal progress on the computer screen, but also to store instantaneous measured value values with a preset periodicity of up to one tenth of a microsecond. The electricity consumed is determined by numerical integration.

Table 1, as an example there is shown a fragment of the table with measurement results near the moment of discharge switching on in the mode of light touch of electrolyte surface by anode. The first three columns of time, current and voltage are oscilloscope data. The fourth is the result of multiplying the current by voltage, i.e. power. The fifth is the result of multiplying the power by the time interval between measurements, plus the value in this column by one row above. This is the energy consumed by the reactor.

μs	V	A	W	J
159,04	1163	0,0	0	0
159,20	1163	0,0	0	0
159,36	656	0,0	0	0
159,52	1022	206,3	210762	0,034
159,68	1041	178,1	185361	0,063
159,84	1041	168,8	175605	0,091
160,00	1050	168,8	177188	0,120
160,16	1041	159,4	165850	0,146

Table 1. Fragment of the record of the results of measurements of voltage and current on the reactor anode made with the PCSU200 computer oscilloscope (first three columns) and calculation of instantaneous power and electricity consumption (last two columns)

Experiments to determine the heat and energy consumed were carried out for different reactor operation modes. Fig. 8 shows, as an example, records of the recorder, obtained during thermal measurements of reactor operation in the mode of light touching of electrolyte surface by anode. The reactor was surrounded by synthetic wool insulation. First of all, calibration heating was made with a resistor immersed in the electrolyte, which allows to determine the sensitivity of the system to heat emission. Then, similar measurements were made with the discharge turned on. The power and electricity consumption were determined by the computer oscilloscope data. The heat release was determined by the magnitude of the change in the signal taken from the thermocouple, using the sensitivity of the system already measured in the calibration measurement.

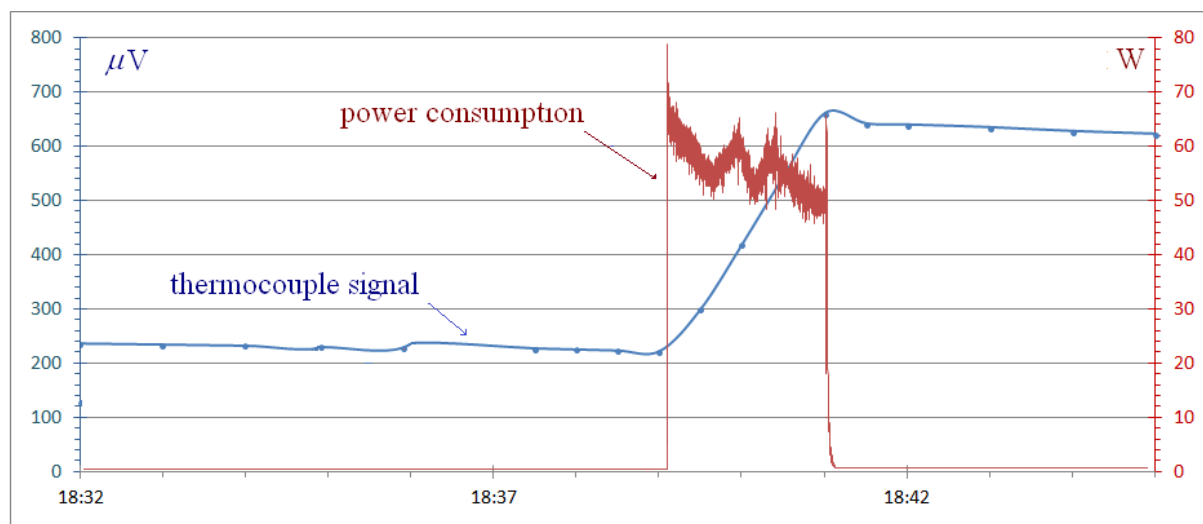


Fig. 8. An example of recording a signal from a thermocouple when the discharge is turned on and the power consumed by the reactor.

A comparison of the generated heat and the consumed electricity was made, in addition, by a method similar to the method used in the experiments of Yu. N. Bazhutov - by measuring the amount of evaporated water during the boiling of the electrolyte [6,7]. To reduce heat loss, the reactor was surrounded by synthetic wool insulation. Steam was vented through a plastic tube and condensed in a test tube cooled by melting ice. In addition to heating by discharge in the mode of lightly touching the surface of the electrolyte with the anode, a similar experiment was performed, but with heating by Joule heat using a resistor immersed in the electrolyte.

Of particular interest is the measurement of heat released in a *single* discharge. However, the above-described reactor gives too little temperature response to a single discharge. Therefore, for such studies, a special small-mass reactor was made containing only 10 ml of electrolyte. It also has a pointed molybdenum wire anode and a nickel cathode. The reactor is equipped with a thermopile of four copper-constantan thermocouples and is surrounded by a layer of synthetic wool. The same electrolytes were used as in the large reactor. The similarity of the oscilloscope waveforms indicates that the processes in both reactors proceed similarly. Fig. 9 shows examples of recordings of the recorder obtained from measurements with single discharges.

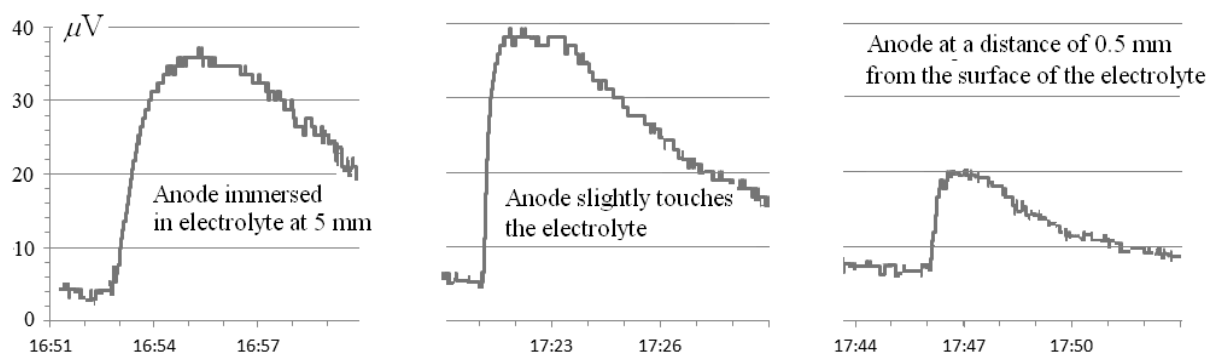


Fig. 9. Signals from thermocouples from single discharges during different reactor modes. Electrolyte - 10% NaOH solution

Table 2 shows the results of determining the thermal coefficient (the ratio of the heat generated to the energy absorbed by the reactor) for various reactor operating modes (immersion in the electrolyte, light touch, small gap, different polarity of the central electrode, different capacitor capacitance, single discharge or continuous operation). It can be seen that the number *exceeds unity*, i.e. there is an excess of heat only when the anode does not touch the electrolyte but is at a small distance from it. In other cases, the heat is about the same as or slightly less than the electricity consumed. We can assume that this is due to the fact that part of the energy is spent on decomposition of water into hydrogen and oxygen due to electrolysis or pyrolysis. The appearance of hydrogen is confirmed by periodic flashes in the above-electrolyte space during a sufficiently long period of reactor operation.

Table 2. The ratio of heat and energy consumed at different reactor operating modes

Video	electrolyte	electrode position	mode	+ or -	max current, A	capacity, μF	thermal coefficient
1	Na_2CO_3	immersed	long	+	0,18	50	0.84-0.88
	Na_2CO_3	immersed	onedischarge	+	35	50	1.02-1.05
	NaOH	immersed	onedischarge	+	300	50	0.86-0.97
2,3	Na_2CO_3	touched	long	+	20	50	0.85-0.99
4	Na_2CO_3	touched	long	+	70	0,2	0.67-0.71
6	Na_2CO_3	touched	long	-	250	50	0.89-0.98
5	Na_2CO_3	touched	onedischarge	+	20	50	0.83-0.95
	NaOH	touched	onedischarge	+	120	50	0.82-0.92
8	H_2O	touched	long	+	0,17	50	0.61-0.66
7	H_2O	touched	long	-	1,2	50	0.87-0.99
	Na_2CO_3	clearance	onedischarge	+	1100	50	1.44 - 3.9
	NaOH	clearance	onedischarge	+	1030	50	1.33-1.43

A feature of the mode in which an excess of the released heat over the consumed electricity is detected is that in this case the maximum current density is reached - of the order of 100,000 A / cm^2 . All other modes provide a significantly lower current density. I note that it is precisely the high current density that distinguishes the experiments of Bazhutov [6,7], Velikodny [15], Urutskoev [13], Adamenko [14], Vachaev [12], who observed anomalously large heat releases and other phenomena characteristic of CNT.

Table 3 shows the results of elemental analysis in the electrolyte before the experiments, as well as in the electrolyte and sludge, after 8 hours of operation of the reactor in "light touch" mode. The analysis was done by atomic emission spectrometry with inductively coupled plasma. The appearance of molybdenum and nickel in solution and sludge is explained by the transition of these elements from electrodes. It can be assumed that small amounts of iron and copper also appeared from electrodes as impurities to basic metals. Although it is not clear why in this case cobalt, which is the main impurity in nickel, did not appear. Multiple increases in calcium and especially silicon content attract attention.

	solution		sediment
	before electrolysis mg / liter	after electrolysis mg / liter	after electrolysis %
Na	32000	32000	21
Ni	< 0.5	6.8	3.1
W	< 20	< 36	< 2
Mo	< 5	3700	2
Fe	< 1.4	< 3	0.16
Pb	< 2	< 3	< 0.07
Ti	< 1	< 2	< 0.02
Cr	< 2	< 9	< 0.04
Cu	0.5	2.1	0.05
Zr	< 1	< 2	< 0.02
Si	13	160	2.3
Ca	7.5	25	4

Table 3. The content of elements in the electrolyte before and after plasma electrolysis.

Radiation measurement

A SI-8B counter with a thin mica window was used, which makes it possible to register alpha, beta, gamma, and x-ray radiation. It should be noted that Geiger counters are the most noise-resistant detectors of ionizing radiation, because they have very high internal amplification and give out pulses that do not require highly sensitive amplifiers. Low

sensitivity to interference in experiments with plasma electrolysis is very important, since, obviously, kiloampere and kilovolt pulses inevitably give the strongest interference.

In the described experiments, *usually* the count rate did not noticeably differ from the background. Current pulses and pulses from the counter appeared independently. But sometimes an increase in the pulse count rate was observed by approximately an order of magnitude. The reactor operating mode did not have obvious features. Before and after these rare anomalies, all the equipment worked fine.

Conclusions

In experiments on a setup with a capacitor charged to a voltage of about 1200 V, connected to a pointed electrode located in or near the surface of the electrolyte, the following was observed.

To operate the reactor with solutions of sodium carbonate and hydroxide as an electrolyte at a positive voltage on a pointed electrode, a pulsed mode of operation is typical. At negative voltage, the current fluctuates randomly.

When distilled water is used as an electrolyte, chaotic current fluctuations occur both at positive and negative voltages.

A significant excess of heat over the consumed electric energy was observed only in the regime when the pointed anode was separated from the electrolyte surface by a small gap. This mode is characterized by the highest current - more than 1000 A at maximum. This achieves a current density of the order of 10^5 A/cm².

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