

INFORMATION



B.R. Lazarenko among the young scientists V.K. Nevezhin, B.N. Zolotikh, and E.A. Deev in the TsNIL-Elektrom.

Together we are increasing the nationwide business; hence, the attitude towards it should be nationwide, but the things I have described are unsound and uncharacteristic of our style of work. That must not be!

I would like to use these words from the letter of B.R. Lazarenko as an epigraph not only for this particular publication. Such an attitude toward the advanced development engineers and scientists in the Soviet Union was not unique, unfortunately. Today, the situation has only worsened. However, I want to believe that, in our countries, (Russia, Ukraine, and Belarus) people will finally learn to appreciate the most important thing for any political system and any political era, i.e., the intellectual potential of its creative elite.

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Glimpses of the History of Electrosark Machining of Materials (Dedicated to the Centenary of B. R. Lazarenko)

Why the Soviet Union Has Lost the Leadership in Electrosark Technologies

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RETURNING TO THE FIRST DECADE OF THE DEVELOPMENT OF ELECTROSPARK TECHNOLOGIES

Recalling the period preceding the discovery of the electrosark method, we shall note that B.R. Lazarenko worked as a junior researcher in the Lenin All-Union Electrotechnical Institute from 1936, and, in 1938, in the proceedings of this institute, he published his first scientific paper “A Study of the Transfer and Corrosion of Metals under the Action of Electric Discharges in Arcing Tips,” which was the basis for opening the new electrosark method of metal machining.

On June 28, 1943, senior researcher B.R. Lazarenko sensationally defended his candidate of engineering science dissertation “The Inversion of the Electric Erosion of Metals and the Methods of Controlling the Destruction of Electrical Contacts.”

On April 3, 1943, B.R. and N.I. Lazarenko registered the discovery of the electrosark method of metal machining, and, on August 12, 1945, the decision of the USSR Council of the People’s Commissars

on the patenting of this method abroad was published. In the course of 1946, this method was patented in some countries, i.e., Switzerland, France, the United Kingdom, the United States, and Sweden.

In 1944–1946, three monographs of B.R. and N.I. Lazarenko were published *Electric Erosion of Metals* (vols. 1, 2) and *The Physics of the Method of Electrosark Machining of Metals*. Soon, the information on the new methods of electric machining of metals written by Stalin Prize laureate B.R. Lazarenko was published in vol. 7 of the encyclopedia *Mechanical Engineering*.

In 1947, at a meeting of the scientific council of Bauman State Technical University in Moscow, B.R. Lazarenko defended his doctoral dissertation entitled the “Method of Electrosark Machining of Metals.” The degree was awarded to him by the decision of the State Commission for Academic Degrees and Titles dated June 26, 1949.

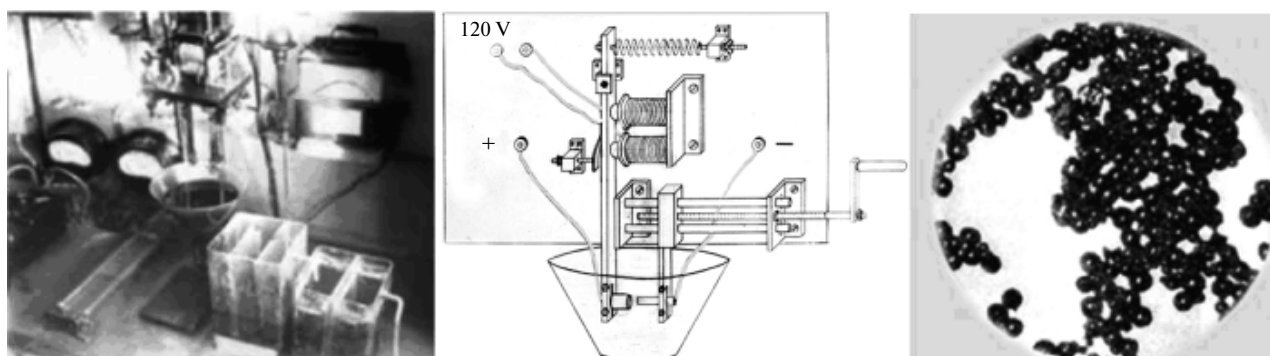


Fig. 1. First electrospark installation for producing powders (“feeder”) that was used to prove the possibility of using the electrospark method for machining of metals for the first time in the world.

Let us refer to the letter “that must not be” written by B.R. Lazarenko on April 27, 1948, i.e., more than 60 years ago:

Everybody knows the role of Russian electrical engineers in the development of both applied and theoretical electrical engineering. However, a special group among them comprises electrical engineers who use electric energy for machining materials, i.e., electric welding, treatment with high-frequency current, and electrospark machining.

The particularly characteristic thing in the development of these methods is that the Russian discoveries initially go abroad, where they explode, and, after that, we—Soviet engineers—have to catch up to the foreign technology that has already advanced beyond us.

To assure ourselves of this, let us consider these three discoveries; as regards the first two, we shall be restricted to reminding the reader of only some factors, and we shall use the example of electrospark machining, since it is the event of today, to observe why and how this takes place.

In 1882, the Russian engineer Benardos discovered the method of electric arc welding. In 1914, the United States began to widely use this method of welding metals together for the restoration of ships. Interest in the “new” process appeared in Soviet industry only in about 1923 due to foreign trips of our engineers. A dramatic change in the development of electric arc welding took place in the Soviet Union only in about 1929–1930, i.e., 50 years after the discovery of the method and 15 years later than in the United States.

In 1924, the Russian engineer Vologdin discovered the method of high-frequency hardening of materials. In 1930, it was widely used in foreign technology. In 1941, the Americans wrote about the Russian scientists who “have hit upon using electricity for maturing wood” and not only widely used this method on an industrial scale but also began the mass production of high-frequency (household) appliances even for drying vegetables, bread, etc. We are now only organizing the production of machines, including valve generators, and up till now our plants have used either artisa-

nal installations with extremely low efficiency or “Ajaxes” and captured equipment.

The question is what are the reasons that allow for such a shameful state of affairs, inhibit the development of Soviet technology, and actually are responsible for the transfer of Soviet technology abroad?

In all the cases, these reasons are common. So, using the example of the method of electrospark machining of metals, we shall trace the history of its development.

The first period of development (1935–1939) is a period of the initial accumulation of experimental data and their generalizations and a period of the construction of working theories and hypotheses (Fig. 1).

The attitude of the authorities to this work is moderate.

The attitude of the scientific world is condescending.

The attitude of industry is indifferent, because the useful effect of these works is zero.

The second period of development (1939–1942) is the appearance of the general contours of the new method of metal machining, when it becomes excessive to use a cutting tool and there is no need to regard the hardness of the material under machining. The large-scale distribution of information on these works began (Figs. 2, 3).

The attitude of the authorities is moderate.

The attitude of the scientific world (particularly, of toolmakers and production engineers) is cautious.

The attitude of industry is the demand for immediate disclosure of the information for its implementation.

The third period of development (1943–1946) (Figs. 4–11). The main technological processes are optimized; the first designs of electrospark devices are constructed. The basic laws governing the process are found. In industries with a high economic effect, home-made electrospark machines are used. Exten-

¹ The figures in the letter were selected by B.I. Stavitskii.

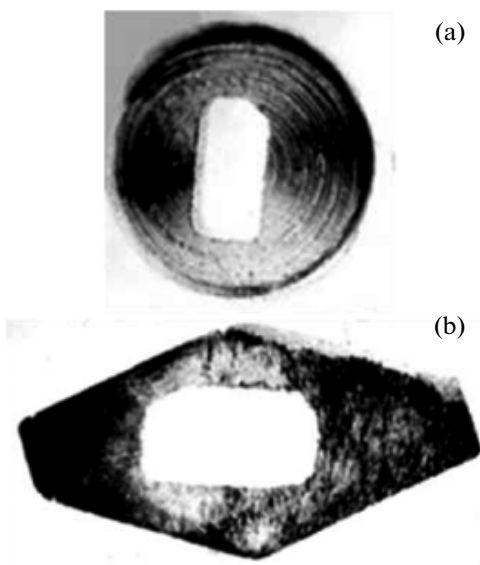


Fig. 2. (a) Steel and (b) hard-alloy workpieces that were used for the first time in the world to prove the possibility of using the electrospark method to produce holes reproducing the profile of copper electrodes.



Fig. 3. Device for removing broken instruments from the shells of Katyusha projectiles (the early 1940s).



Fig. 4. First electrospark installation with a vibrator (1944).



Fig. 5. EIS-KMP electrospark machine (1944).

sive information on the method is distributed through the mediums of the press, cinema, and radio. The inventors of the method are awarded the title of Stalin Prize laureates. The first information appears from the United States and Great Britain (Ilox, Drafto, and Thomas Cos.), which report the new method of metal machining with a recommendation for machines produced by these companies.

The attitude of the authorities is bureaucratic soulless.

The attitude of the scientific world (physicists and power engineers) is absolute support.

The attitude of experts (toolmakers, production engineers, and machine-tool operators) is sharply hostile ("It is impossible to process metals without tools," "All that is nonsense and fraud; this method must be prohibited").

The attitude of the industry is for every possible assistance and support. Insistent demands are expressed for at least basic technical documentation, for assistance in the assimilation, and consultations.

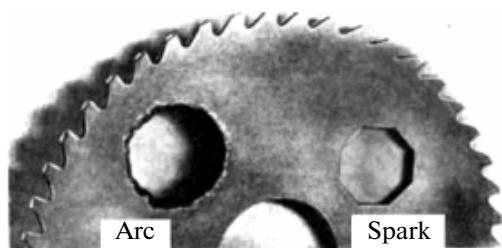


Fig. 6. Holes made in a milling cutter using (left) arc and (right) spark circuit tuning.



Fig. 7. Carving of a saw element by trepanning.



Fig. 8. The inscription "Nauchis' delat' chernuyu rabotu v nauke!" (Learn to do the dirty work in science!) made by the electrosark method on glass.



Fig. 9. Portrait of V.I. Lenin made on a plate of blue steel.

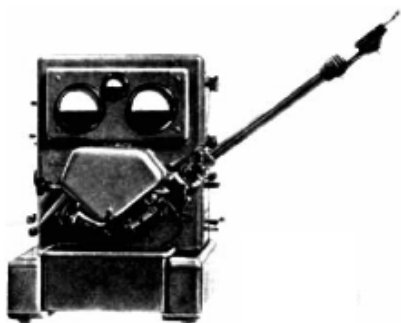


Fig. 10. LKZ-20 electrosark installation for making holes of $0.15^{+0.01}$ mm in sprayers of diesel pump injector units (1957).

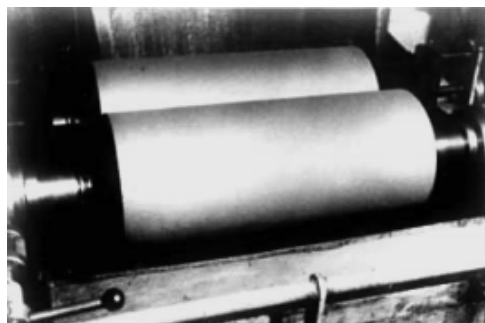


Fig. 11. Electrospark grinding and breaking in of milling rolls (1960).

All these requirements were met to a moderate extent due to the lack of personnel, facilities, and resources.

The fourth period of development (1946–November 11, 1947) In the conditions of the complete absence of orders from the ministries, a mass movement in industry for the assimilation of this method takes place. Our organizational helplessness in providing absolutely indispensable broad assistance to industry is particularly painful. We even do not have the possibility to answer letters. All attempts to somehow increase the capacity of the laboratory, even though the engagement of new employees, fail.

The industry uses do-it-yourself developments and performs processes of electrosark machining of metals at an unacceptably low technical level. The state spends many millions of rubles for the buildup of parallel operations of electrosark machining in various ministries. Absolute organizational chaos takes place in this domain.

The United States display an exceptionally keen interest in this method. The Americans began to exhibit intense activity concerning the use of "Russian erosion machines" and surely develop this line of work.



Fig. 12. In the MMATI laboratory for electrospark machining of materials. Left to right: T.I. Makeeva, D.Z. Mityashkin, B.R. Lazarenko, A.M. Belov, and B.N. Lyamin (1948).

Contesting the Soviet lead, they nonetheless widely inform about this method through careful rewriting of articles from Russian journals, sometimes even without specifying where they borrowed the data. There is the same absence of any support from the authorities, ranging from the director of the Institute and to officials of the Ministry inclusive. **A new major threat appeared: a group of businessmen, ... who, guided only by selfish purposes and having absolutely no interest in the development of the method and the state of affairs, began to clutter up the industry with poor designs.** Having no idea about this method, they began to widely inform industry, giving misrepresentations about the modes of machining, thereby brining the method into discredit. They do not cast in their lot with the method and do not think about the future; the main thing for them is a source of profit today and a source of easy existence. Despite our shortage of personnel, we had to draw a part of our forces from the research work and throw them into the fight against this sloppy work.

The number of technological processes carried out using the electrospark method increases dramatically. The first cohort of electrospark engineers graduates from the Moscow Institute of Aviation Technology (Fig. 12).

The Central Committee of the Communist Party became interested in this direction and, after an appropriate inspection, sent a letter to the Bureau of Mechanical Engineering of the Council of Ministers of the Soviet Union with the recommendation to consider this issue with respect to the further development and introduction of the electrospark method.

On November 11, 1947, a meeting of the Bureau of Mechanical Engineering was held, where seven ministers reported on the effect in industry concerning the use of the method of electrospark machining of metals and pointed out the unacceptable gap between the demands of industry and the information obtained in this direction. The following was decided:

(1) To establish a competent research organization for the further development of works related to the electrospark machining of materials.

(2) To summon an All-Union Conference on Electrospark Machining of Metals in March 1948 for informing on the latest achievements in this domain and for sharing experiences.

(3) To introduce special courses of electrospark machining of metals into the curricula of higher technical institutions in order to ensure the preparation of the necessary personnel.

(4) To constitute a commission of ten people (headed by Saburov) and to charge it, in a month (i.e., by December 11, 1947), to report to the Government a draft decision on the necessary arrangements for the development and implementation of electrospark machining of metals.

I believed that this preliminary decision already predetermined the further course of development of this method and that very soon, owing to the use of this method, thousands of workers would be free for other works and that the public treasury would receive billions of rubles of savings.

In fact, it turned out otherwise.

November 11, 1947, is the beginning of the fifth and perhaps the most significant stage of the development. Elementary logic suggests that it was necessary to create an organization capable of solving any scientific and technical problems independently, an organization with broad production capacities that would produce not only prototypes of electrospark machines but also a small series of machine tools and an organization that would not only coordinate the actions of industry in this direction but also render extensive technical assistance in both the assimilation of the method and the rapid solving of separate problems. At present, our country has all that is required for this method of solving problems.

However, I made sure that this method of solving problems, which is the only right way, did not get full support.

First of all, the project of such an organization proposed by me, which was very modest with respect to its demands and rigorous with respect to a useful effect in the industry, caused perplexity in the Ministry of Electrotechnical Industry. Probably due to this, the project was

initially reduced by about tenfold, then twofold, and finally it was forwarded to the archives of the Ministry.

Second, I was asked to find a room for this newly created organization. Despite the ambiguity of such a course of action, I had to stop part of the work and send engineers to find suitable empty boxes.

With much difficulty, we found the rooms needed and proved that it was possible to occupy them; nevertheless, soon, I was told that they were unsuitable because "sometime the organizations on the territory of which they are located will work there."

Only a month and a half later, the first (and the last) meeting of the working subcommittee was held, where we spoke about the need for further development of the electrospark method. It is characteristic that, two days after this meeting, in Moscow, people who had not been present at the meeting discussed (including by telephone) my report, which included a secret method of remote processing metals (obviously, a new armament in the near future).

The subsequent events appeared to be even more extraordinary; they were directly aimed at preventing the establishment of such an organization. Member of the State Planning Commission Nikitin, in his letter dated February 17, 1948, approved by Saburov, instructed the Ministry of Electrotechnical Industry to be concerned with the study of the physics of the electrospark process and the development of electrical schematics, and the Ministry of Machine Tool Building (which never built electrical installations) was instructed to optimize the designs of electrospark installations and to develop the new technology of electrospark machining (!?).

Soon, the reasons for the appearance of this anomalous phenomenon (the separation of the theoretical base from designers and production engineers) became apparent. It turned out to be the result of the actions of the same group of businessmen who misinformed the authorities.

Having heard of the establishment of an organization that would coordinate the activities of industry and having realized that its appearance would eliminate, once and for all, any sloppy work, along with rich pickings, they developed incredibly intense activities towards preventing the establishment of such an organization.

The first objective for them was to somehow preserve the possibility of contrivance. It was obvious that, if the method of electrospark machining of metals were the only one, where everything was abundantly clear, then every possible artifice would be excluded. Therefore, it was necessary to insist that the decision of the government on the electrospark machining of materials contained one more method of electrical processing of materials differing from the electrospark method at least in name, e.g., an anode-mechanical method. However, this method did not exist juristically. This raised the second problem, i.e.,

to legalize this method; in addition, it must discredit the electrospark method. To accomplish this task, an application unapproved 20 years ago (the authors were Gusev and Ryzhkov) was retrieved from the archives, and the Patent Office of the State Committee of the Council of Ministers of the Soviet Union on science and engineering (Gostehnika) was engaged. *The application was designated as the anode-mechanical method of processing, and, in violation of the legislation in force, they began to look for ways of backdating (1928) the approval of the mythic anode-mechanical method of metal processing.*

Next, the third task appeared, i.e., to prove that the method of electrospark machining of metals was unprofitable and that the anode-mechanical method should be applied instead. For this purpose, the absolute unsuitability of the electrospark method for machining hard alloys was hastily "proved" in the All-Union Research Institute for Instrumentation (director Nadeinskaya), which had no electrospark machines, e.g., for tool sharpening. Every possible noise took place...

Six months passed since the meeting of the Bureau of Mechanical Engineering, yet the level of the organizational forms now became even lower. The above shows that we need some other, unknown to me, procedures and measures to solve organizational problems. Now I ask you like my older friend: what are these procedures? Would you teach me to use them?

For 11 years, I have been working with no vacation and no rest days. My life is my work, and at least this simple argument gives me the right to ask you why are we kept from our work? Why day by day are we more and more distracted from our work? Therefore, we are forced to deal with all sorts of other things, such as, e.g., writing letters like this. Is it ultimately the method that impedes the development of the most important domain of our national economy? Together we are increasing the nationwide business and, hence, the attitude towards it should be nationwide, but the things I have described are unsound and uncharacteristic of our style of work. That must not be!

*Stalin Prize laureate, Candidate of Engineering,
B. Lazarenko
April 27, 1948*

After the events described in the above letter of B.R. Lazarenko, the following events took place. In June 1948, according to a government decree, the Central Research Laboratory for electrical machining of materials (TsNIL-Elektrom) was established as a part of Research Institute-627 (NII-627) of the Ministry of Electrotechnical Industry of the Soviet Union headed by B.R. Lazarenko; in 1953, it was separated into an independent organization and was situated on the territory of the Nikolo-Perevinsky monastery in Lublin.

In the middle of 1950, Gosenergoizdat published the book of Candidate of Engineering B.R. Lazarenko



Fig. 13. Seminar in the Dzerzhinsky House of scientific and technical information: (a) B.N. Zolotykh is delivering a speech; (b) A.L. Livshits, A.T. Kravets, E.V. Kholodnov, A.I. Kruglov, and others in the auditorium; and (c) V.L. Kravchenko, M.N. Ulitin, and others (1957).

and engineer N.I. Lazarenko *Electrospark Machining of Metals*. It was a synoptic representation of the problems associated with the use of electrospark machining of metals, i.e., the method that was widely used in industry at that time. The book focuses on the review of designs of electrospark installations, technological capabilities, and the description of separate processes and operations performed using electrospark machining. In conclusion, the authors estimate the scientific and technological level of development of electrospark machining of metals, which gives the possibility to carry out all the processes and operations that are performed using mechanical methods.

It seemed that everything was fairly well; the popularity of the electrospark method was increasing, but...

In 1955, the TsNIL-Elektrom was transferred to the system of the USSR Academy of Sciences, but what was the price!

On November 16, 1955, Doctor of Engineering, Prof. B.R. Lazarenko, who was the Deputy Academician Secretary of the Division of engineering sciences of the USSR Academy of Sciences and the director of the TsNIL-Elektrom, was detached for service to the People's Republic of China as a Scientific Adviser of the President of the Academy of Sciences of China. Upon the recommendation of B.R. Lazarenko, the responsibilities of the director of the TsNIL-Elektrom were devolved on the head of the department of physics B.N. Zolotykh.

The detachment of B.R. Lazarenko to China was a gift for the Academy of Sciences of China and a big minus for the development of the electrospark method in the Soviet Union. In the People's Republic of China, he had to participate in the working out of a comprehensive plan for the development of science, to acquaint the engineering community with the capabilities of the electrospark technology, to assist in its implementation in production, to stimulate the foundation of the Beijing Institute of electrospark machining, and to provide communication with the USSR Academy of Sciences....

Despite this trip to China, in late 1957, the Publishing House of the USSR Academy of Sciences published the first issue of the proceedings of the TsNIL-

Elektrom *Electrospark Machining of Metals* edited by B.R. Lazarenko. In February 1958, Boris Romanovich was, after all, recalled to Moscow, and he returned to his duties as director of the TsNIL-Elektrom of the USSR Academy of Sciences.

By this time, the Publishing House of the USSR Academy of Sciences published the monograph of B.R. and N.I. Lazarenko *Electrospark Machining of Conductive Materials* about the method of electrospark machining of materials, which was discovered in the Soviet Union and widely used both in our country and abroad. The physical bases, the energy characteristics, and the advantages of this method were described. The basic schemes, the technological capabilities of the machining, the principles of designing electrospark installations, and various operations performed using this method were presented.

In 1960, under the editorship of B.R. Lazarenko, the Publishing House of the USSR Academy of Sciences published the *Problems of Electrical Machining of Materials* and then the second issue of the proceedings of the TsNIL-Elektrom *Electrospark Machining of Metals*; in 1962, *Problems of Electrical Machining of Materials* was published.

In the late 1950s and in the 1960s, many seminars and meetings on electrical methods of machining materials were held in the country (Figs. 13–18).

After a visiting session of the Division of engineering sciences of the USSR Academy of Sciences in the TsNIL-Elektrom, Academician A.A. Blagonravov, who summarized the session, expressed the desire to exhibit the achievements of electrospark machining of materials at the Exhibition of Economic Achievements with the participation of the TsNIL-Elektrom and other organizations of various branches of industry.

In 1960, this issue-related exhibition was organized in the "Cosmos" pavilion and was a great success. Perhaps, the triumphant progress of electrospark machining of materials began from that event. It occurred because many important problems were solved with the participation of enterprises of the defense industry, and the Experimental Research Institute for Metal-Cutting Equipment (ENIMS) of the Ministry of Machine-Building and Toolmaking Industry (Min-



Fig. 14. Meeting on electrospark machining of metals in the House of defense engineering. B.R. Lazarenko is presiding at the meeting; B.I. Stavitskii is delivering a speech (1958).

stankoprom) found it difficult to counteract them. However, the opposition to the development of electrospark machining of materials on the part of the “fifth column” continued. The more so as the work of the staff of ENIMS and Co. on the so-called electropulse method was nominated for the Lenin Prize (which was never awarded)....

As recently as three years after the return of B.R. Lazarenko from China, a campaign for the transfer of the research institutes and laboratories of engineering from the system of the Academy of Sciences under the jurisdiction of the respective ministries was launched. The TsNIL-Elektrom was transferred to the ENIMS of the State Committee of the Council of Ministers of the Soviet Union on Automation and Mechanical Engineering (later, Minstankoprom), which was the main organizer of the long-term campaign against the electrospark method. Thus, the fate of the TsNIL-Elektrom was decided not in favor of the development of electrospark technologies....

Shortly before this event, i.e., in the beginning of 1961, B.R. Lazarenko had a conversation with the

chairman of the Presidium of the Moldavian branch of the USSR Academy of Sciences Ya.S. Grosul and the Vice-President of the USSR Academy of Sciences A.V. Topchiev. He was proposed to head the Institute for Power Engineering and Automation of the Moldavian Academy of Sciences being created.

In August 1961, B.R. Lazarenko was elected an academician of the Moldavian Academy of Sciences; in December 1961, he was appointed as director of the Institute for Power Engineering and Automation of the Moldavian Academy of Sciences, which was transformed into the Institute of Applied Physics in 1965.

The protestation of leading experts, the chairman of the Scientific Council of the USSR Academy of Sciences on the problem “New Processes of Production and Processing of Metal Materials,” the president of the Academy of Sciences of the Ukrainian Soviet Socialist Republic Academician B.E. Paton, the Coordination Council on New Methods of Processing Materials in the Defense Industries, and others against the transfer of the TsNIL-Elektrom to the Minstankoprom was ignored.

The opposition to the development of the electrospark method and its authors on the part of a group of leading experts in machine-tool building headed by the ENIMS was continuously increasing since the time of registration of the method and especially after awarding the Stalin Prize to the authors of the method. As a consequence, the decision of the Bureau of Mechanical Engineering of the Council of Ministers of the Soviet Union dated November 11, 1947, on the establishment of a competent research organization for the further development of works related to the electrospark machining of materials was never implemented for the reasons stated in the above letter of B.R. Lazarenko.

Meanwhile, in the early 1950s, i.e., seven or ten years after the official registration of the method of electrospark machining of metals in the Soviet Union and its patenting abroad in 1946, the first foreign companies appeared that began to design and produce electrospark equipment.



Fig. 15. B.R. Lazarenko is receiving a delegation from the People's Republic of China in the TsNIL-Elektrom (1958).



Fig. 16. Exposing the electrospark technology in the TsNIL-Elektrom to participants of the meeting (1958).

In 1953, K. Inoue registered the Jàðàð Laboratory for electrospark machining of metals, i.e., a company for the production of electrospark machines, which was the first such company in Japan and one of the first in the world. Some time later, the Swiss companies AGIE (AG fur industrielle Elektronik) and Charmilles began the development and production of electrospark equipment. In 1976, leading experts of Japax established the FINE Sodick Co., which at present is a worldwide leader in the domain of electrospark machining of materials.

Unfortunately, for tens of years, the engineering policy of the machine-building industry of the Soviet Union was greatly affected by the ENIMS, which was the leading institute of Minstankoprom. Machine-tool building is the core of mechanical engineering: the technological advance of many industries depended on the proper policy of this ministry.

In its time, the prestige of the ENIMS was high, the studies of its scientists were appreciated in our country and abroad; however, the known plants, i.e., ZIL, MZMA, VAZ, KamAZ, etc., were equipped with imported spark erosion (electrospark) machines and equipment. This took place owing to the lobbying of foreign spark erosion equipment by the All-Union

Association Stankoimport. It happened because the policy of the Department of Electrophysical and Electrochemical Methods of Processing of the ENIMS, which was headed by Doctor in Engineering A.L. Livshits, had led to the situation that the Soviet Union, which had the lead in this domain for a long time, was losing its winning position year after year.

Using the authority of the reputable leading institute of machine-tool building of the country, the activities of the mentioned department were based on the thesis, "the things made by others are bad." So, the green light was given to in-house developments regardless of the quality and novelty of the designs. This may be confirmed by the fact that, for tens of years, many industry-significant developments were rejected for one reason or another, to put it mildly, without good reason. Thus, e.g., none of the models of precision machine tools developed in the system of the Ministry of the Electronic Industry (a great many of them had been designed by the mid-1970s) was put into production in the system of the Minstankoprom.

The quality of these machines can be judged at least from the fact that they were repeatedly awarded gold medals at many international exhibitions and fairs as early as the 1960s (Figs. 19, 20). Moreover, in 1963,



Fig. 17. Electrospark coordinate installation based on A207.23 with a thyatron pulse generator and an NC system at the exhibition of electronic engineering in Moscow.



Fig.18. Cosmonaut A.G. Nikolaev is acquainting himself with electrospark technologies in the NII-160.



Fig. 19. Specialized exhibition of electronic engineering in Budapest (1964).



Fig. 20. A207.23 electrosark coordinate installation at the Leipzig Jubilee Fair (1965).



Fig. 21. Electrosark coordinate installations: (at the right) A207.23 and (at the left) A207.27 with an embedded thyatron pulse generator with an Olivetti NC system at the company.

these works were awarded the Lenin Prize. And, as we know, the Lenin Prize in Science and Engineering, as well as the Stalin Prize in its time, was awarded for works having worldwide priority.

Electrosark equipment produced by the Ministry of the Electronic Industry of the Soviet Union was supplied to industrially advanced countries (Fig. 21). It was in great demand in our country as well; however, its production was evidently insufficient. Our industry could have possessed a sufficient number of these machines if the department of the ENIMS had not insulated itself from "alien" developments.

At many all-union conferences, scientists spoke in favor of the reactivation of such a center as the TsNIL-Elektrom of the USSR Academy of Sciences. But, alas, the decision of the interindustrial problem depended on the employees of the ENIMS, who did not support this idea. Regardless, the organization people addressed with this proposal was, e.g., the State Committee on Science and Engineering, and it necessarily arrived for approval to A.L. Livshits as the sole representative of the only "specialized" organization. He was a chairman of the section of electrophysical and electrochemical methods of processing of the Council on Mechanical Engineering of the State

Committee on Science and Engineering of the Soviet Union, and the members of the council ensured a majority to him. *As a result, the Soviet Union paid dearly for this "monopoly," because, being a pioneer in the domain of electrosark technology, it found itself among the laggards.*

In November 1977, the newspaper of the Central Committee of the CPSU *Sotsialisticheskaya industriya* (Socialist Industry) (founded in 1969) under the heading "How to Accelerate the Implementation" in the article "Ours and Aliens" raised the problem of the negative attitude of the Department of Electrophysical and electrochemical Methods of Processing of the ENIMS, as the leading organization of machine-tool building, to the works performed by "alien" organizations.

Here is the opinion of E.M. Levinson, a well-known scientist and expert and one of the pioneers of electrosark machining, which was published in the newspaper *Sotsialisticheskaya industriya* no. 25 (2627) dated February 10, 1978, in the article of the newspaper correspondent V. Andryushuk "It Is Not Difficult to Praise Oneself," *For thirty years of work, I repeatedly had to face the opposition on the part of the ENIMS's department headed by Aleksandr Livshits to everything that did not originate from him and his associates. The*

personal and departmental interests have been retarding the progress in this domain for many years. It is these interests that are responsible for the situation that the national economy-significant developments of scientists are not implemented.

The idea of the loss of opportunities, the local application of scientific achievements, the departmental narrowness, and the associated technology gap was expressed in the newspaper by Doctors of Engineering D. Vasiliev, G. Meshcheryakov, and others. The alarming situation with the coordination of works in this domain was discussed at an extended meeting of the section of electrical methods of processing of the Scientific Council of the State Committee on Science and Engineering.

It was written in the official reply of the Deputy Minister of the Machine-Building and Toolmaking Industry of the Soviet Union A. Prokopovich to the editorial board that the Minstankoprom considered the fundamental issues described in the article with the participation of heads of the engineering office and the ENIMS and gave relevant instructions to subordinate research institutes on the strengthening of control over the objectivity of their decisions. The “conclusion of the Council for Science and Engineering,” which was attached to the letter, denied the criticism outright by arguing that the equipment for electrophysical and chemical processing designed in the system of the Minstankoprom meets the top level of quality and that the coordination of works in this domain is adequate.

However, this was contrary to the opinion from the plants. It was written in a letter from the Moscow Plant of Hard Alloys, “We use a 4D721 machine, which is precision according to the specifications, only for roughing-out. We tried to solve the problem of the production of press molds using the 4D721 and 4D722 Minstankoprom machines. However, we failed, because these machines did not provide the declared performance.”

Comment is superfluous.

FEATURES OF THE ELECTROSPARK GENERATION OF GEOMETRY IN WATER

One of the major problems of improving the quality of electrospark machining using an electrode wire is the optimum choice of the material of the wire and its manufacturing quality. In addition, studies and the experience of production show that the accuracy and the quality of the generation of the geometry of the pieces (the roughness of the machined surface, its physicomechanical properties, and the size of the resultant nicks-and-burrs) are affected by the duration and intensity of the spark discharges generated by the pulse generators. It is found that the efficiency of the spark discharges increases with the decreasing time of the lag from the instant of the voltage pulse generation. In turn, this is provided by the stability of the optimum value of the interelectrode gap. In

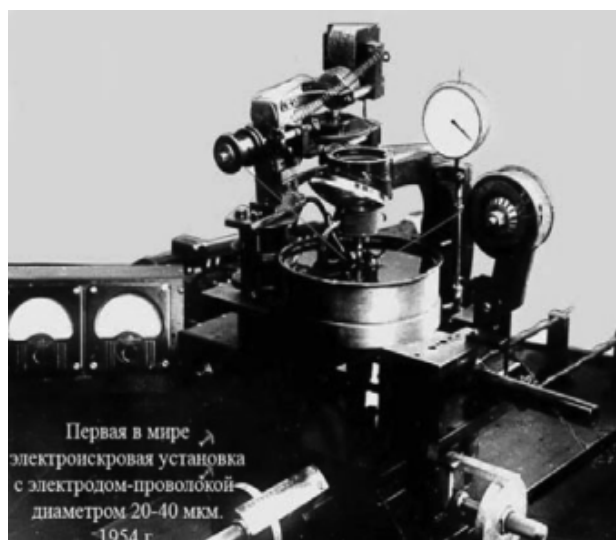


Fig. 22. First in the world electrospark installation with an electrode wire with a diameter of 20–40 μm . NII-160, Fryazino, Moscow oblast (1954).

addition, the electrospark machining is most efficient in water, which became possible due to using new generators of bipolar voltage pulses of microsecond duration, which exclude the occurrence of electrochemical processes and made it possible not only to significantly improve the quality of the machined surface but also to increase the rate of the generation of the geometry.

For the first time, the electrospark machining using an electrode wire with a diameter $<40 \mu\text{m}$ was used at the end of 1953 for cutting narrow grooves in the face planes of tool electrodes for preparing grids in klystron diaphragms.

Figure 22 depicts the photograph of the first in the world electrospark installation for preparing tool electrodes for the electrospark production of square-mesh grids. The winding of a wire from a coil with an allowance of the wire of 1500 to 4500 m to a receiving coil with a diameter of 25 mm is performed using an SD-2 electric motor at a rate of 100–150 mm/min. The wire is uniformly wound on the receiving coil by means of an appropriate cam gear. The wire is directed by two U-shaped polished rollers situated at the bottom of a bath with kerosene and pulled by the braking of the coil with the wire by a flat spring. The distance between the rollers is selected to be minimal to reduce the effect of the ohmic resistance of the wire on the discharge circuit. The vertical motion of the workpiece to be machined (a tool electrode for preparing grids) occurs via the micrometer displacement of a MBM-1 microscope with a vernier reading accuracy of 0.002 mm or a dial reading accuracy of 0.01 mm.

Figure 23a shows the photograph of a 7-mm copper electrode for making grids in klystron diaphragms. Using a VA-3 electrode wire with a diameter of 30 μm ,

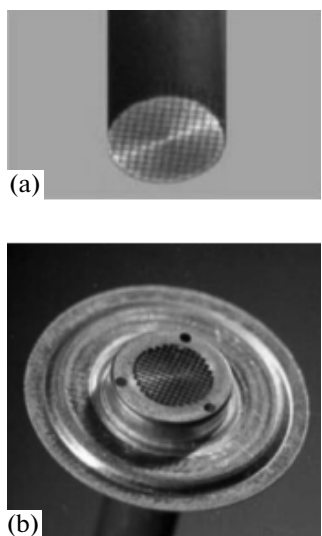


Fig. 23. (a) Seven-millimeter electrode with 26 grooves with a width of 50 μm cut on its end surface to a depth of 2 mm and (b) a copper grid with 152 meshes (0.45×0.45 mm) and connecting strips between them of ≤ 30 μm .

26 grooves with a width of 50 μm are cut on the end surface of the electrode to a depth of 2 mm in two orthogonally related directions. This electrode was used to “broach” grids with 152 square meshes (with a size of 0.45×0.45 mm) and the connecting strips between them < 30 μm in klystron diaphragms using the electrospark method (Fig. 23b).

The dependence of the gap width a on the electrode voltage (U_0) is linear and, for the case of cutting grooves in kerosene, can be represented by the formula

$$a = 0.125 U_0.$$

Thus, using a VA-3 tungsten wire with a diameter of 30 μm , it is possible to cut grooves with a width of 45–60 μm in one pass and, using a 40- μm wire, grooves with a width of 55–70 μm can be cut (for $U_0 = 60$ –120 V). Wider grooves are cut in two passes.

In early 1955, two more problems appeared in the production of components of microwave vacuum-tube devices of millimeter-wave magnetron anode blocks and slow-wave structures of backward-wave tubes (SWS BWTs), which were solved involving the electrospark method of generating geometry using a thin wire (VA-3 or MCh).

The first 20-resonator magnetron anode blocks made of oxygen-free MB copper with a thickness of 3.6 mm of two standard sizes ((1) $d = 6$ mm, $D = 7.58^{+0.02}$ mm with 0.4- to 0.02-mm-wide lamellae inclined at an angle of $18^\circ \pm 6'$ and (2) $d = 3.6$ mm, $D = 5.02^{+0.02}$ mm with 0.24 $^{-0.02}$ to 0.02-mm-wide lamellae) were prepared in January 1956 using an EKU-1 experimental setup based on a BMI-1 large measuring microscope. The time of production of one block (without any process automation) is 1.5 h for the

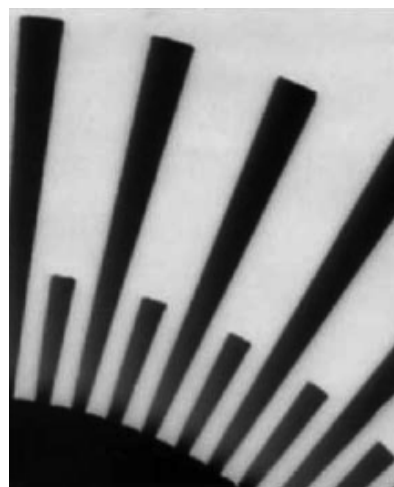


Fig. 24. Silhouette of a portion of the 80-resonator magnetron anode block.

first type and 40 min for the second. The average rate of the geometry generation is 3.6 mm^2/min at $W_0 = 200$ μJ .

The time of the electrospark production of the second-type anode blocks via “broaching” was about 50 min. In addition, it requires the preliminary fabrication of a 5-mm electrode by electrospark contouring the block profile cut by a wire.

Figure 24 depicts the silhouette of a portion of one of the magnetron anode blocks prepared in March 1956. The number of resonators is 80. They are inclined uniformly at an angle of $4^\circ 30' \pm 2'$. The lamella width is $0.165^{-0.02}$ mm, the inner diameter $d = 8.4^{+0.01}$ mm, $D_1 = 10.7^{+0.01}$ mm, $D_2 = 15.2^{+0.01}$ mm, and $h = 2.3^{-0.03}$ mm. The contour perimeter is more than 400 mm. The machine time of cutting the perimeter of the block resonator is 4 h.

In the late 1950s, in Research Institute-160 (NII-160; later, the State Research and Development Enterprise Istok), it got about that the electrospark method was used in Japan for preparing 3-mm-wave magnetron anode blocks. This event made it possible to publish our works (they were started in the early 1950s) on studying the possibility of the electrospark production of components of vacuum-tube devices (e.g., the production of millimeter-wave magnetron anode blocks using a thin tungsten wire), which had been off-the-record.

For comparison, Fig. 25 shows the Japanese copper anode block of a 3-mm-wave magnetron.

It has 62 lamellae with a width of 0.1 mm inclined at an angle of $5^\circ 48'$. The figure in the immediate vicinity depicts an enlarged silhouette of its portion (a). The block was prepared in 1957 by Japax by broaching the profile using a special tool electrode of silver-impregnated pressed tungsten. The time of the production of one block was 20 min.

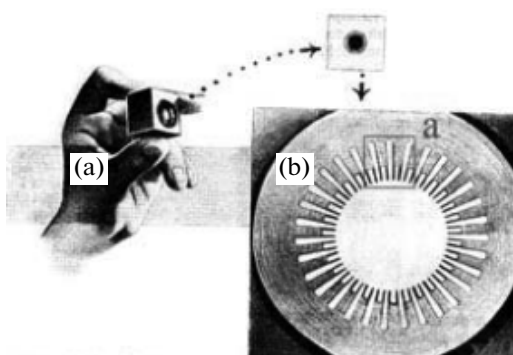


Fig. 25. Japanese 62-resonator anode block, which was “broached” by the electrospark method using an electrode of silver-impregnated pressed tungsten, and a silhouette of its portion (at the bottom) (1957).

The advantages of the electrospark generation of the geometry of these components using an electrode wire with a diameter $<40\text{ }\mu\text{m}$ in comparison with the electrospark broaching using a tool electrode were obvious, the more so in the early 1960s, due to the resulting possibility of using bipolar voltage pulse generators, which provided the use of ordinary water in the capacity of an interelectrode medium. The presence of pulse transformers excluded the shock hazard for the operators. Computer-driven control systems, which appeared somewhat later, made it possible to automate the process of the electrospark generation of the geometry of pieces at the almost complete absence of “cuttings.”

Simultaneously with the assimilation of the technology of electrospark production of magnetron anode blocks, the technology of the production of SWS BWTs operating in centimeter, millimeter, and submillimeter wavelength ranges was optimized. Initially, an electrode wire with a diameter of $30\text{--}60\text{ }\mu\text{m}$ was used; then, with smaller diameters ($15\text{ to }6\text{ }\mu\text{m}$).

Figure 26 shows samples of SWS BWTs: Fig. 26a depicts the silhouette of a portion of the SWS of a 1-mm-thick chromium copper, which was cut with a VA-3 tungsten wire with a diameter of $40\text{ }\mu\text{m}$. It has 153 pins with a width of 0.4 mm and a height of 5 mm in increments of 0.8 mm . The SWS's width is 6 mm , and the length is 123 mm . The average rate of the generation of the geometry is $6\text{ mm}^2/\text{min}$ at $W_0 = 500\text{ }\mu\text{J}$. Figure 26b depicts a part of the waste remaining after cutting the system in two passes.

The production of pierced components of SWS BWTs required the removal of internal stresses that appear in workpieces in their preparation using conventional methods, i.e., annealing at a given temperature. This need arose from the fact that, in the course of the generation of the geometry of the SWS pins, they deviated on one or the other side due to the stresses present in the metal, which appeared either in

its rolling or after the mechanical treatment of a work-piece.

Figure 27 shows a ring-type copper SWS with a thickness of 2.5 mm and its portion. The pin width is 0.1 mm , the height is 0.9 mm , and the spacing apart is 0.15 mm .

At the same time, the electrospark machining in kerosene is accompanied not only by the intense contamination of the working zone with products of its decomposition but also by the pollution of the resulting surfaces. However, the chemical purification of the surfaces of the produced components (grids and SWSs), which were contaminated with kerosene decomposition products, faced significant difficulties related to shape defects. The average rate of the machining in kerosene using a VA-3 wire with a diameter of $30\text{--}40\text{ }\mu\text{m}$ was $4\text{--}6\text{ mm}^2/\text{min}$ for copper, $2.2\text{ mm}^2/\text{min}$ for a VK-11 hard alloy, and $1.6\text{ mm}^2/\text{min}$ for tungsten.

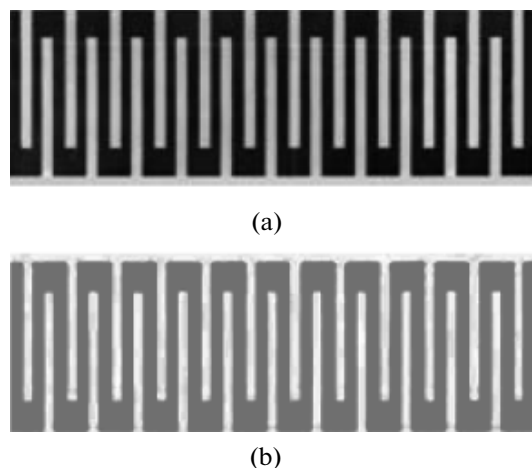


Fig. 26. (a) Silhouette of a portion of the SWS of chromium copper and (b) the waste remaining after cutting the system.



Fig. 27. Ring-type copper SWS and its portion.

As it turned out, the use of electrospark machining in such fluids as ethyl alcohol, distilled or industrial water, and their mixture with ethyl alcohol makes it possible not only to reduce the contaminations but also to increase the rate of the machining of copper and its alloys as well as refractory metals and alloys.

Figure 28 shows the dependence of the rate of the machining S (mm^2/min) of VT-15 tungsten on the percentage of ethyl alcohol in the water. The maximum rate of machining with a VA-3 electrode wire with a diameter of $30\ \mu\text{m}$ $S \approx 8\ \text{mm}^2/\text{min}$ corresponds to the content of alcohol in the water within 30–40%. This is almost fivefold as compared to the machining in kerosene and three times as much as in water and ethyl alcohol.

In their early works, the authors of the electrospark method formulated the requirements concerning the interelectrode medium as follows.

The choice of the composition of the liquid medium used for dimensional electrospark machining of metals is far from insignificant. The fluid to be used as an interelectrode medium must meet the following basic requirements: it must exhibit a low viscosity; it must not give off noxious vapors and gases; it must be nonflammable, inexpensive, and chemically neutral to the electrode material; and finally it must not lose its basic properties while in service.

It is obvious that, except for particular cases, all these properties are found to the maximum extent in ordinary industrial water. It would be the best interelectrode medium if electric pulse generators were designed to intermittently feed a strictly dosed portion of energy to the electrodes at appropriate intervals with the electrodes remaining free of voltage at all the other times. However, since electric pulse generators of this kind were not used yet and, therefore, the electrodes are permanently alive during their operation, the conductivity of water has an adverse effect on the process...

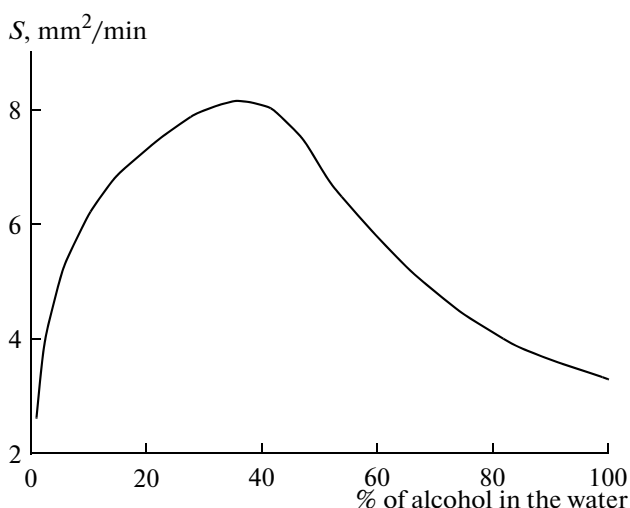


Fig. 28. Dependence of the rate of machining of VT-15 tungsten (S , mm^2/min) on the percentage of ethyl alcohol in the water. A VA-3 electrode wire with a diameter of $30\ \mu\text{m}$.

The electric pulse generators of this kind were new transistor and thyatron generators of bipolar voltage pulses, which were designed in the early 1960s in the electronic industry of the Soviet Union. This event rendered the possibility of precision electrospark machining of pieces in ordinary water and contributed to a significant increase in the efficiency and accuracy of the process and to an improvement of the quality of the machined surface and the working conditions.

The ratio of the amplitudes and durations of the pulses of direct and inversed polarity governs the process's efficiency and the quality of the machined pieces.

The electrospark production of high-precision pieces in water using generators that form unipolar voltage pulses even of microsecond duration is impossible without the occurrence of electrochemical processes and a significant reduction in the accuracy and quality of the machining.

The design of generators of microsecond bipolar voltage pulses with a strictly defined form made it possible to almost exclude the undesirable electrochemical processes.

This yields an important feature of the precision electrospark machining of materials, i.e., the use of microsecond bipolar voltage pulses with strictly defined ratios of the amplitudes and durations of the pulses of forward and backward half-waves, which renders the possibility to perform the machining in ordinary industrial water.

The use of new electrospark equipment with microsecond bipolar voltage pulse generators for producing SWS BWTs with millimeter and submillimeter wavelengths made it possible to

—increase the yield of SWSs twofold;

- decrease high-frequency losses in the systems;
- design new low-voltage wide-band BWTs in the middle and shortwave ranges of submillimeter wavelengths with characteristics that exceed the parameters of the best samples of the C8P Co. (France);
- design high-quality, more reliable, and durable microwave devices with smaller dimensions and weight and BWTs operating at shorter waves; and
- simplify the production technology for low-resistance semiconductor materials through reducing their waste; ensuring a good surface quality; eliminating scratch marks, chips, score marks, and mechanical inclusions of foreign materials; and making it unnecessary to apply the deep etching of crystals and to use an abrasive slurry and soap solutions.

The Conditions for Electrosark Production of Pieces in Ordinary Water

Due to the extensive use of precision electrosark machinery equipped with programmed numerical control (NC) generators, the information on the possibility of electrosark producing of high-precision pieces in ordinary tap water without additional purification and deionization is of particular interest for designers and consumers of this technology.

The more so, as some publications of foreign companies in the late 1990s contained the statement that precision machining must be carried out in a hydrocarbon liquid (oil or kerosene) and that water can be used only for less accurate work. Moreover, in the opinion of some experts, “the cutting of contours with small geometric elements using a wire with a diameter <0.1 mm in water is a technological profanation.” This assertion was substantiated by the fact that the side clearance is much greater upon cutting in water than in a hydrocarbon liquid and that the machining in water is accompanied by electrochemical processes that lead to the etching of machined surfaces and to the deterioration of the machining accuracy. The last statement is valid for using RC generators and generators that form pulses with a constant component of voltage across the electrodes. The opinion about the impossibility of performing precision works in water is surprising, because new methods for producing high-precision pieces using the electrosark method, including in water, were developed in the electronic industry of the Soviet Union as early as 45 years ago. Among them, we can mention the method for producing pieces with an electrode wire with a diameter <0.05 mm and the method of successive contouring of the profile of a tool electrode. In 1963, the Lenin Prize was awarded for the development of these methods, which consolidated the global priority of the Soviet Union in the formulation of highly precise methods of electrosark machining of materials.

As early as the late 1950s, electrosark machining was performed in distilled water to produce submilli-



Fig. 29. Portion of an SWS BWT produced using a 15- μm electrode wire. A groove of 18^{+2}_{-2} μm ; the pins have a width of 36^{-2} μm and a height of 0.16 mm.

meter SWS BWTs (Fig. 29). In addition, it was a full-scale production rather than an exotic preparation. The number of components produced annually in 1961–1962 by one operator was more than 1000. More than 25% of them were produced using a 15- μm electrode wire; 40%, using a wire with a diameter of 30–40 μm . Depending on the mode of machining (voltage across electrodes U_0), the interelectrode gap was 1–5 μm . To produce extremely small SWSs of electronic devices, a VA-3 tungsten wire even with a diameter of 6–10 μm was used since 1960. Depending on the mode of machining (voltage across electrodes U_0), the interelectrode gap was 1–2 μm , and the width of the grooves cut by this wire in thin wafer packs ranged from 8 to 12 μm .

Note that the minimum diameter of the wires used in foreign electrosark equipment was 0.030 mm. Herein, the groove width was ≥ 38 μm ; in four passes, 48 μm . Thus, the minimum clearance was ≥ 4 –9 μm .

In the electronic industry, in the electrosark production of various components of electric devices, pure water (distilled or potable) is mainly used as an interelectrode medium. It has advantages over other fluids, not only owing to its lower cost and noninflammability but also because the electrosark machining in water is not accompanied by the contamination of the working zone with the products of the medium's decomposition in the discharge channel. In addition, the process's efficiency is enhanced, and the quality of the machined surface is improved.

However, in the case of generators that form single voltage pulses with a constant component, i.e., unipolar pulses, water electrolysis is observed. Undesirable electrochemical phenomena take place on the electrodes.

An uncontrolled electrochemical process of etching of the machined surface leads to a loss of accuracy, an increase in the corrosion, and the oxidation of

pieces. The machining of molybdenum and its alloys becomes impossible due to the appearance of a dielectric oxide film on their surfaces.

To remove these disadvantages, on the basis of the general considerations known in electrochemistry, the method of electrospark machining was proposed in the Soviet Union, which implied the avoidance of undesirable electrochemical processes owing to the use of bipolar voltage pulses, for which the average voltage of the positive pulse sequence is equal to the average voltage of the negative pulse sequence.

Later, it was found that the fact that the sequence of single voltage pulses does not contain a constant component is sufficient to eliminate the undesirable electrochemical phenomena during electrospark machining in water. In the event of a spark discharge between the electrodes, the voltage across the electrode gap decreases sharply, the total current passes through the breakdown channel and is concentrated in the working zone; therefore, the electrochemical processes in the ambient environment almost disappear. To ensure the targeting of the electrospark process, the amplitude of a positive pulse in the sequence of bipolar voltage pulses must be significantly higher than the amplitude of a negative pulse. In this case, the probability of a breakdown of the gap due to the impact of a positive voltage pulse applied to the piece is much greater than that of negative pulses. Therefore, the repetition rate of the “direct” machining pulses of current, which serve to remove the material from dimples, is also higher. The impact of negative voltage pulses can lead to a “breakback” of the medium and the formation of “inverse” machining pulses of current, which cause an additional consumption of the tool electrode.

The optimum current pulses for obtaining the machined surface with the roughness $R_a < 1 \mu\text{m}$ are the pulses that not only remove a maximum amount of the material per pulse but also ensure its removal in the fine phase, and the surface under formation is covered with dimples of a spherical shape without solidified splashes of molten metal. This is possible when the

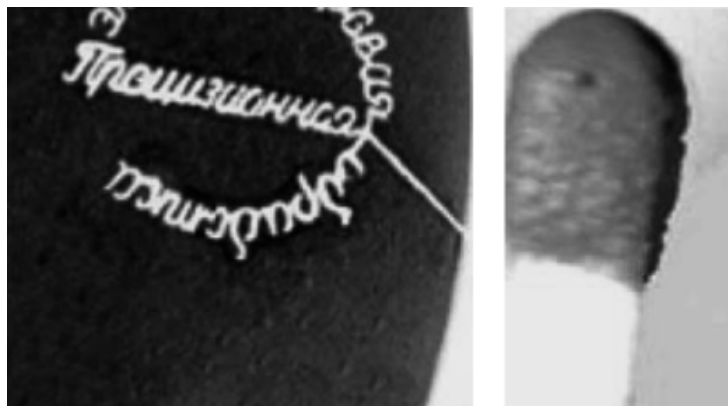
material is removed in the vapor state. A decrease in the duration of the current pulses leads to an increase in the quantity of the pulse energy consumed for overheating and evaporation of the substance. It follows from the measurements of the current pulse durations in precision machining modes using an RC circuit with a current pulse amplitude up to 100–200 A, a thyatron generator with a current amplitude up to 600–700 A, and a transistor shaper with a amplitude up to 100 A, that the pulse duration in precision machining modes does not exceed 3–4 μs .

When analyzing the features of the machining in water, we should mention one more important circumstance. Although the resistance of water is much less than the resistance of such fluids as oil or kerosene, still it is $\sim 10^4\text{--}10^6 \Omega \text{ cm}$, which is many times higher than the internal resistance of a working pulse source. Hence, the value of the current flowing through the interelectrode gap in the no-load operation is determined by the significant resistance of the medium rather than by the internal resistance of the source of the working current pulses as in the event of the breakdown of the gap.

Single voltage pulses that are most appropriate in form for precision electrospark machining in water are rectangular bipolar pulses with no constant component for which the positive pulse amplitude is at least two times as much as the amplitude of the negative voltage pulse and the duration ranges within 3 and 4 μs .

THE ROLE OF THE ELECTRONIC INDUSTRY IN THE DEVELOPMENT OF THE PRECISION ELECTROSPARK MACHINING OF MATERIALS

The years of the Great Patriotic War are the period of the formation of the domestic microwave electronic industry as a part of the People's Commissariat of the Electrotechnical Industry of the Soviet Union. Its development began in 1943 owing to the NII-160



The inscription “Pretsizionnaya elektroiskrovaya obrabotka” (Precision Electrospark Machining) is cut in a 6-mm-thick VK-6 plate using a VA-3 wire with a diameter of 0.04 mm. An image from the motion-picture of 1961.

and the pilot plant (instituted under the auspices of the Fryazino factory Radiolampa), which was oriented mainly at the development and production of electronic devices for radar engineering,

This event coincided with the official registration of an outstanding discovery of the twentieth century, i.e., electrospark machining of materials. It is symbolic that it was the Fryazino NII-160 that was destined to become a leading organization in the country for the further improvement of the method of electrospark machining of materials and to open new horizons for its use.

The studies that were carried out during 1954–1958 in the State Allied Research Institute of the State Committee of the Council of Ministers of the Soviet Union on Radioelectronics (NII-160) proved not only the possibility but also the feasibility of using the electrospark method for producing high-precision components of microwave vacuum-tube devices and ingenious instruments. It was shown that ***it is impossible to prepare some microwave electronic devices not involving the new methods of electrospark producing of high-precision components.***

The Laboratory of electrospark machining of materials, which was organized on March 12, 1957, as a part of the Experimental Design Bureau of Machine Building of the NII-160, was reorganized in the department of electrical methods in 1960. As a result of their work, the following appeared within the first five years:

- new methods of producing high-precision pieces;
- the first in the world electrospark installations for producing pieces using a wire (diameter 30–40 μm);
- electromechanical systems of digital program controlling for producing centimeter, millimeter, and submillimeter SWS BWTs;
- bipolar pulse generators that made it possible to produce pieces in ordinary tap water, instead of kerosene, without its purification and deionization;
- electro- and photocopying systems of producing pieces with intricate shapes by copying a templet and an enlarged drawing.

The method came into wide use for producing high-precision pieces in radioelectronics and other defense industries. By the early 1960s, the electronic industry had become not only the most active user of the new method of material machining but it also had to initiate its own research and design-engineering works on the invention of ingenious methods of electrospark generation of geometry and crucially new electrospark equipment and to produce it in quantities required for the industry, effectively counteracting the negative attitude towards the electrospark method on the part of the ENIMS, which was a leading organization of the Minstankoprom.

The achievements of electrospark technologies in the production of high-precision pieces and the development of appropriate equipment for the radioelectronic industry, as well as the effect of foreign analogs on their development and the achievements of electrospark technologies in the Soviet Union in the 1960s, were described in detail in 2006 in the international information-technical journal *Oborudovanie i Instrument* for professionals (ser. Metalloobrabotka) in nos. 2–6/2006.²

It was written in the annotation to the article “From the History of Electrospark Machining” (2007, no. 1 (85)), *For the first decades of the development of electrospark technologies, almost all the current worldwide leaders concerned themselves with studying the Soviet achievements and tried to copy them in their installations. There were two main causes of the leading position of the Soviet Union: the technology originated in this country and was used for the production of advanced weapon systems.*

It is pertinent to analyze the causes of the inhibition of the development of the electrospark method in the Soviet Union, particularly in the new Russia, and to answer the question why did the idea of electrospark machining prove to be actually “owned” abroad (first of all, in Japan) and why has the Soviet Union and its legal successor, i.e., the Russian Federation, lost the leadership in electrospark technologies?

By the late 1970s and the early 1980s, this question had not arisen.

For the first time, electrospark installations for the production of pieces using a VA-3 electrode wire with a diameter of 0.03–0.04 mm were shown in 1960 abroad (in the Czechoslovak Socialist Republic and the United States) at the exposition stands of the TsNIL-Elektrom of the USSR Academy of Sciences. Along with the installations, samples of components of devices and instruments were exhibited as well as products of arts and crafts that demonstrated the possibilities of the new electrospark technologies developed in the NII-160, which was headed from 1953 to 1961 by M.M. Fedorov (Fig. 30). He gave the green light to the development of the precision electrospark machining of materials not only in his institute but also in the radioelectronic industry and contributed to its expansion in the related branches. He was deservedly awarded the title of a Lenin Prize laureate in 1963 for the development of new methods of producing high-precision pieces. It was a “golden” time for the development of electrospark technologies.

In the mid-1960s, the order of the Minister of the Electronic Industry of the Soviet Union A.I. Shokin initiated the showdown of achievements of enterprises

² The international information-technical journal *Oborudovanie i Instrument* for professionals (Ser. Metalloobrabotka), 2006, no. 2 (75), pp. 34–42; no. 3 (77), pp. 44–47; no. 4 (79), pp. 6–10; no. 5 (79), pp. 26–33; no. 6, pp. 28–36.



Fig. 30. M.M. Fedorov, Lenin Prize laureate, director of the NII-160 in 1953–1961. The portrait is cut in a millimeter plate using an electrode wire (1978).

of the electronic industry abroad (including the precision electrospark equipment designed in the Research Institute of Electronic Engineering (NIIET)):

—In November 1964, A207.23 and A207.13/20 in the People's Republic of Hungary (at the specialized exhibition of electronic engineering).

—In March 1965, A207.23 and A207.13/20 at the Leipzig Jubilee Fair.

—In 1966, A207.23 and A207.13 in Italy and Japan; A207.23 in Zagreb (The Socialist Federal Republic of Yugoslavia); A207.23 and A207.30 in the Czechoslovak Socialist Republic at the International Fair in Brno.

—In 1967, A207.23 at the “EXPO-67” in Canada (for six months).

—In 1970, A207.23 with a NC-board at the “EXPO-70” in Japan.

The electrospark installations designed in the NII-160 in the 1960s were superior to the world level; they were awarded gold medals at the fairs in Leipzig and Zagreb and repeatedly in the Exhibition of Economic

Achievements of the Soviet Union. The successful demonstration of the precision electrospark equipment abroad triggered the appearance of the order of the Minister of the Electronic Industry of the Soviet Union A.I. Shokin in April 1970 concerning the establishment of the Special Design-Engineering Department (SKTO) as a part of the NIIET. To create conditions for the intensive development of electrospark technologies, the order stipulated the assignment of the construction being built next to the NII-160 for the SKTO with the respective laboratories, design offices, the electrospark pilot-production division, and the mechanical-engineering workshop.

However, in common with the decision of the Bureau of Mechanical Engineering of the Council of Ministers of the Soviet Union on the establishment of a competent research organization for the further development of works related to electrospark machining of materials dated November 11, 1947, which was never implemented, history repeated itself. New powerful forces counteracting this process, as in the case with the TsNIL-Elektrom more than 20 years ago, made every endeavor to “procrastinate” this order and for it to be not executed in practice.

After the completion of building of block no. 16 for the SKTO, the following divisions were disposed in it: the mechanical-engineering workshop, the design office for electrovacuum equipment, the Technical Inventory Bureau, the planning and economic department, and other services of NPK STM-6 (which bore no direct relation to the electrospark machining of materials); department 62 for the electric methods of material machining was disposed there partially (the design office and laboratories). The electrospark pilot-production division (Fig. 31), which was a testing ground of the department for optimizing electrospark technologies and a link with design engineers of electronic devices, was almost completely transferred to



Fig. 31. Electrospark pilot-production division of department 62: (a) in 1961 and (b) in 1962.

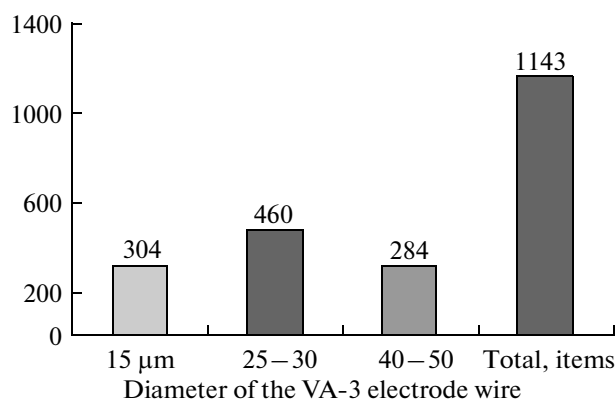


Fig. 32. Number of SWS BWTs produced using a VA-3 electrode wire with a diameter of 15–50 μm in 1962. Total: 1143 items.

one of the shops of the Renii plant of the Research Institute Istok.

The pilot-production division of the department was used not only for optimizing the technological processes of producing components of electronic devices but also for producing batches of pieces, figurine-shaped instruments, and a variety of souvenirs for advertising new methods of electrospark generation of geometry (Figs. 32, 33).

There was left no stone unturned to procrastinate the collaboration with the Italian company Olivetti, which was started through Tekhmasheksport and Elektronzagrannostavka, and the Italian company STANITALIANA concerning designing electrospark aggregates with Olivetti NC systems (for extensive use); it was reduced to nothing due to the superfluity of the intermediaries. In addition, the production of installations for export was hindered in every possible way. The proposal of STANITALIANA to form permanent groups of experts for the promotion of the Soviet precision electrospark equipment designed in the electronic industry for export to the western market did not meet with support.

In addition, the efforts of domestic experts concerning designing fitting program control systems for electrospark equipment failed, and the proposal of the RATCHIS Co., which it made in the end of 1980, to equip our installations with NC systems produced by the company was unfortunately ignored, notwithstanding that the company did not protest against the delivery of our aggregates with its NC systems for export and guaranteed, if necessary, their service maintenance. Probably, a certain role here was played by the sense of esprit de corps of officers of the Ministry of the Electrotechnical Industry of the Soviet Union as affected by the opinion of experts who developed domestic control systems. As is known, by that time, the FANUC Co. produced at least 100 electrospark wire-cutting machines equipped with modern

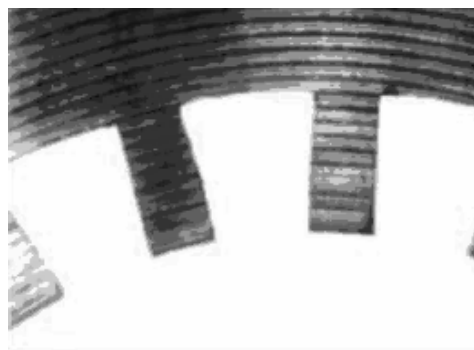


Fig. 33. Fragment of a 10-resonator block: $D = 6.7$ mm, $d = 5.4$ mm. Lamellae of 0.4 mm; the length is 0.82 mm.

4-coordinate NC systems per month. Unfortunately, similar systems were absent in the electronic industry, and Olivetti, in spite of all its exertions, had not yet designed similar systems for our electrospark equipment.

INHIBITION OF THE DEVELOPMENT OF ELECTROSPARK TECHNOLOGIES IN THE 1990s

Until the late 1980s, the annual output of electrospark equipment of the mechanical-engineering workshop of Istok had been increasing and reached 185 items (Fig. 34).

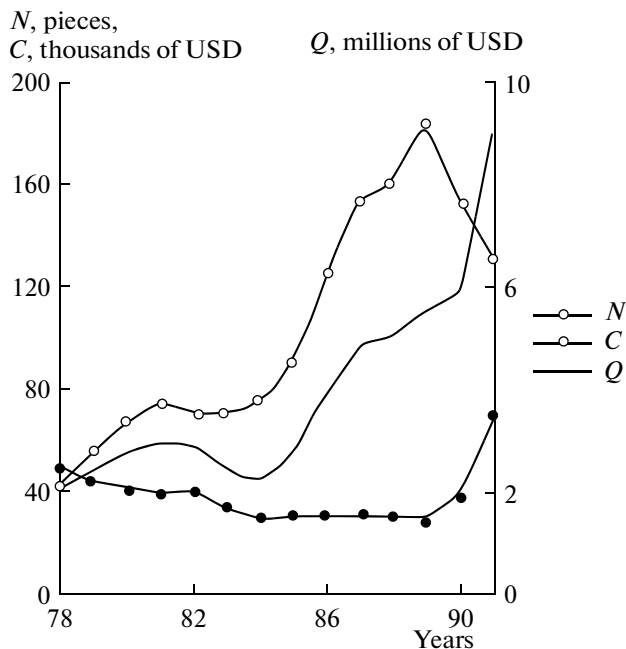


Fig. 34. Output of electrospark machines (N , items); their average cost (C , \$ thousands) and overall production (Q , \$ millions).

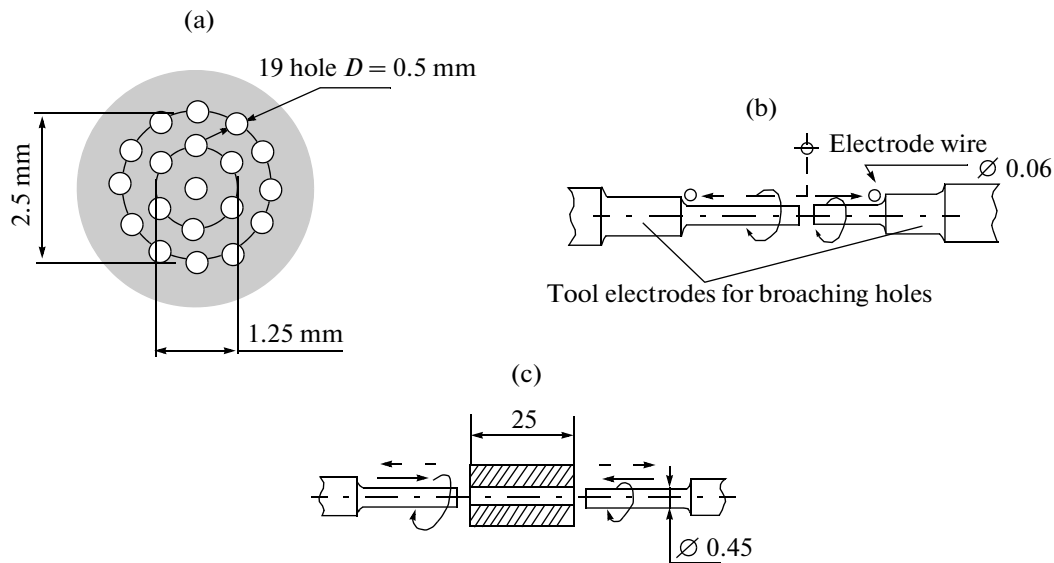


Fig. 35. (a) Cross section of 19 transit channels of MBTs of microwave devices: $L = 25$ mm, a diameter of 0.5 mm; diagrams of (b) the turning electrodes and (c) broaching the channels using them from two sides.

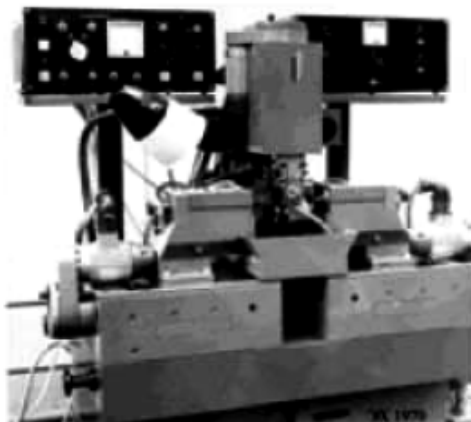


Fig. 36. EKh 1970 combined electrospark aggregate with a 15IPCh-3-001 NC system for producing small-diameter transit channels of multibeam microwave devices.

However, after 1989, the output began to decrease by 20% annually on the average: a sharp inhibition of the development of enterprises of the military-industrial complex took place in the country; in this connection, the financing of works in the domain of electrospark technologies was reduced. This led to the almost complete cessation of research activity on improving these technologies, particularly, due to the liquidation of defense ministries, including the Ministry of the Electronic Industry and, as a consequence, due to the termination of funding of the complex targeted program Elektronika-Iskra (Electronics-Spark).

Along with this, unfortunately, the research on the development of electrospark technologies for making

a large number (tens to hundreds) of small holes (with a diameter of 0.4 to 0.2–0.1 mm) in transit channels of multibeam tubes (MBTs) was never brought to termination (Figs. 35, 36).³

Due to the cessation of these works, the designers of promising MBTs with the number of transit channels above 50–100 had to abandon the advanced technology and to accept the necessity of using prefabricated brazed constructions of MBT units and the technology of their production dated back to the middle of the last century.

In late 1992, the works on improving electrospark technologies in the NPO Istok were almost ceased, and, in the early 2000s, the department of electrospark machining of materials in the Federal State Unitary Enterprise NPP Istok (now the Russian Agency for Control Systems in the Science Town of Fryazino) went into liquidation.

At the same time, the OOO NPK Del'ta Test was organized in Fryazino by "new Russian businessmen," which, as judged by the advertising, is concerned with the production of electroerosion equipment.

However, the fact that this production is based on the developments of electrospark equipment of Istok is concealed. The editorial board of the journal, unfortunately, made haste to publish the anonymous article "New Electroerosion Machines ARTA: Made in Russia," having split the continuation of the article "From the History of Electrospark Machining" into two parts

³ One of the versions of these technologies is described in the International information-technical journal *Oborudovanie i Instrument* for professionals (Ser. Metalloobrabotka), 2006, no. 6



Fig. 37. (a) A207.79 electrospark aggregate of the NPO Istok and (b) ARTA 320 machine of the OOO Del'ta-Test.

and postponed its continuation to the next issue of the journal, which broke the integrity and the value of this publication.⁴ The publication that advertised the ARTA machines did not contain the key point, i.e., a reference to the fact that the basic machine modules were developed in the early 1970s in the NIIET—The Research Institute Istok of the Ministry of the Electronic Industry of the Soviet Union (now the Federal State Unitary Enterprise NPP Istok).

Figures 37 and 38 depict the photographs of the A207.79 and A207.93M electrospark aggregates produced by the NPO Istok and the ARTA machines for comparison. These photographs show an obvious borrowing of the style of the precision electrospark equipment designed in the NPO Istok. This style was registered as early as in the 1970s in industrial design certificates and described in the dissertation of Candidate of Art Criticism N.M. Denisov.

Unfortunately, the publication (in the journal) contained only minor references, such as as follows:

—the ARTA-Kh.7 NC system was designed on the basis of Advantech industrial computers;

⁴ The international information-technical journal *Oborudovanie i Instrument* for professionals (Ser. Metalloobrabotka), 2006, no. 6 (see 2006, no. 3 (77), pp. 48–49).

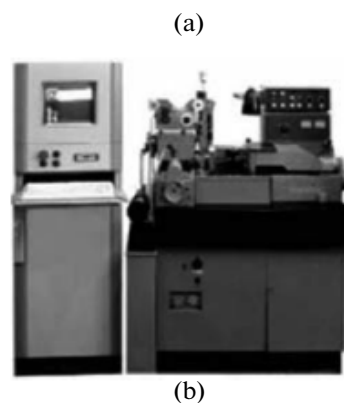


Fig. 38. (a) Eliur 5-200 electrospark aggregate of the A207.93M model with an embedded pulse generator and computer-aided control by five axes by an NC system and (b) an A207.86 machine of the NPO Istok with an Arta-2.7 NC system and an Arta-3M generator.

—the new rewind/pull-up unit was based on a DC motor (Taiwan) and a powder brake clutch (United States);

—the water treatment plant was based on Grundfos pumps.

As regards the possibility of using ordinary water without deionization, it is well known and it was first implemented as early as 1960; it is employed for electrospark equipment of the Research Institute Istok, in which the machining is performed without etching the edges and the equipment does not require the protection of operators against electric-shock hazard and is environmentally safe.

Original designs of the actuating units that are mentioned in this publication, i.e., slackless “male/female” screw pairs, V-guides with a cross arrangement of rollers, and all that sort of “innovations,” have been used in Istok machine modules for decades; for them, it was stipulated to install, if necessary, optical rules and diamond guides instead of ceramic ones. The increase in the machine axis motion never presented difficulties, yet, for incompe-

tent leaders, it was always a way to divert the engineering forces from actually important developments.

The advantage of the ARTA-3M-5 generator based on MOS transistors, i.e., high performance “*amounting up to 80–90 mm²/min for steel even for operations in ordinary tap water*”, does not impress one without specifying the roughness of the machined surface, the diameter of the electrode wire, and the thickness of the piece to be machined. The significant surface roughness (approximately 17 to 4% of the groove width) in the case of using thin wires (with a diameter of 12–50 μm) also sets a gaze.

It would be more appropriate to put this publication about the “new” ARTA machines later, e.g., into no. 6 (83) 2006; in that case, readers of the journal could have compared it with the publication about the new-generation electrospark aggregates of the Research Institute Istok (published in 2006, no. 6 (83), pp. 28–36) in order to make sure that the above is true.

Unfortunately, the editorial board accompanied the publication about the “successes” of the OOO Del’ta-Test with a foreword, which is surprising because the assertion that “*the electroerosion equipment of the ARTA series produced by the Russian enterprise Del’ta-Test is fully capable of competing with foreign analogs*” is in contrary to the facts, because the newly designed ARTA machines involve ball screw assemblies that are employed in similar equipment by most producers of spark erosion machines, which are significantly behind the Sodick Co., which is the worldwide leader in the domain of electrospark equipment. Here the OOO Del’ta-Test stepped back in the “improvement” of the electrospark equipment of the Research Institute Istok, which used original slackless screw pairs that provided an adequate positioning accuracy in the production of high-precision components of electronic devices and never used ball screw assemblies!

In addition, as we know, the OOO Del’ta-Test does not have relevant experts to carry out research on improving electrospark technologies. This yields the use of the term “electroerosion” instead of “electrospark,” which represents the occurring processes most exactly.

WHEN AND HOW THE JAPANESE AND THE SWISS BEGAN TO LEAVE THE SOVIET UNION BEHIND IN ELECTROSPARK TECHNOLOGIES

It is impossible to provide an unambiguous answer to the question when and how did the Japanese and Swiss companies begin to leave the Soviet Union behind (and managed to drop it behind?) in electrospark technologies. This question is many-sided, because it involves the scientific bases of the method, various techniques of studying this extremely complex process, methods of forming surfaces, various designs of electrospark equipment, its components, numerous

devices, gears, fields of application of this process, and many other things. This is a task of a separate study.

There is no cause to categorically insist that the Soviet Union was left behind in electrospark technologies, because many of the ideas that appeared in the Soviet Union in this domain have not been fully implemented and are frozen at present.

Up till now, the possibilities of the electrospark machining of materials using ordinary water (including tap water) as an interelectrode medium have not been completely implemented abroad not only in the case of producing pieces using an electrode wire but also in the case of methods of copying the profile of the tool electrode. Foreign companies also underestimate the efficiency of using thin wires for the electrospark generation of geometry.

The gap of the Soviet Union in the electrospark generation of geometry of figurine-shaped pieces became apparent by the mid-1970s in the global gap of the country in the processes of computerization of production rather than in the field of electrospark technologies. Subsequently, this gap was not completely bridged due to the outbreak of the restructuring of the national economy and, above all, due to the absence of a relevant competent scientific and production organization in the country, which was not established because the authors of the method had no time and their associates were shy of perseverance, energy, and financial capacities.

The problems of financing research and development works played an important role in the resulting gap of the Soviet Union in the development of electrospark technologies.

Thus, for example, one of the leading Japanese companies spends more than 3.5 million dollars only for research (developments are a separate item). Five plants in Japan, the maintenance center, and the management of the company employ almost 900 people. For comparison, the Department of Electrospark Machining of Materials of the NPO Istok, the number of employees of which, together with the pilot-production division, did not exceed 100 people in its best days, was allocated at least next lower order sums for research and development works. Unfortunately, there was no modern plant to produce precision electrospark equipment.

The actual level of spark erosion equipment produced by the plants of the Minstankoprom, according to the documentation of the ENIMS and the special design bureau, was never above the level of equipment produced by other ministries.

Thus, the main cause of the lag of the Soviet Union in electrospark technologies compared to foreign companies is negative and due the contemptuous attitude of the powerful kindred of hereditary officials of all ranks to the formation of a domestic branch of the promising trend of electrospark machining of materials, which opened infinite possibilities of its effective use in any branch of production...