Soviet Computer Technology—1959

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"... let us scientists continue to exchange information in friendship and peace."—*From a Russian toast.*

Summary. The paper presents a factual account of the trip of the U. S. technical delegation in computers to the Soviet Union. It includes the itinerary, descriptions of specific Soviet computers, descriptions of certain computing centers, a discussion of Soviet computer-oriented education, and a description of current circuit and component development. In appendices are given the instruction repertoire of the URAL-I and the URAL-II machines, and an analysis of some magnetic cores. The paper is extensively illustrated and contains a bibliography of relevant Soviet documents.

EDITOR'S NOTE: In contemplating the large amount of factual information, impressions and statistics which our delegation obtained in the two weeks we spent in the Soviet Union, it seemed advisable to me to present this material by topic, rather than to recite it in the chronological order of collection. I have, therefore, arranged the information under subject headings which appeared to be fitting. For this reason much of the text which follows represents my own wording, although each delegate may recognize phrases, sentences, or entire sections as being his own.

Because of the difference between the Roman and Cyrillic alphabets, the rendition of Russian names into English is subject to considerable variation. In this report I have attempted to use consistently the system of transliteration adopted by the United States Board on Geographic Names. In many instances the names of the Russians we met were available to us in both the Cyrillic and Roman alphabets; consequently I have been able to verify the English rendition.

From visits of previous groups to the Soviet Union and from open literature sources, a certain amount of information about Russian computer development has gradually been accumulated. In order to maximize the effectiveness of our visit, the delegation made a strong effort not to investigate those areas which previously had been described. However, in order to make this report comprehensive within itself, I have taken the liberty of including a small amount of material from other sources. In particular, I have carried forward some of the information obtained by the Scott, Carr, Perlis, Robertson group who visited the Soviet Union in August 1958.[1]

I have also cross-checked a few other references in an effort to reduce conflicts between our information and that previously reported. It is hoped that this present report represents an essentially correct picture of the Soviet computer field as it is visible to visitors from the western world.

I have elected to report in a positive and definite style, but there is, of course, always a possibility that our factual material may be wrong. Among other things, the difficulty of communicating across a language barrier introduces uncertainties into the information.

Organization of the Report. This report has been divided into the following major sections:

History of the Delegation
Itinerary
Organizations
Specific Machines
Other Machines
General Development of Machines
Applications
Circuits and Components
Major Machine Components
Education
Chinese Developments

Under "Organizations" is also included a certain amount of technical material of a miscellaneous nature which did not conveniently fit into other sections.

History of the Delegation

As a result of negotiations between the National Joint Computer Committee of the United States and the Academy of Sciences of the Soviet Union, an arrangement was concluded whereby a Russian delegation would visit this country in April of 1959 and an exchange American delegation would visit the Soviet Union in May of 1959. From April 19 to May 1 the Russian Delegation of seven visited approximately twleve factories, installations, research establishments and other activities in the United States. The details of this group's itinerary and discussions have been published separately.[2]

Because the exchange had been arranged in the name of the National Joint Computer Committee as a representative of the computer societies of the United States, and because this was an exploratory trip, it was considered desirable that each of the three societies which comprise the National Joint Computer Committee, as well as the

[1] See: (1) *Status of Digital Computer and Data Processing Development in the Soviet Union*, ONR Symposium Report, ACR-37. (2) *Comm. Assoc. Comp. Mach. 2*, No. 6, (June 1959), 8.

[2] See: (1) *Comm. Assoc. Comp. Mach., 2*, No. 11 (Nov. 1959). (2) *Trans. PGEC*, Vol. EC-8, No. 4 (Dec. 1959).

NJCC itself, should be represented on the delegation. Six of the eight members of the delegation were therefore officers of the NJCC or its member societies, or representatives of one of these. The two other positions were a representative of the many governmant departments which participated in the Russian visit to this country, and the interpreter for the group. The delegation was fortunate in having as a member Professor Lipman Bers of New York University; because of his personal stature as a mathematician and his fluent knowledge of Russian, we were able to obtain insight into Russian mathematics and social life.[3]

The members of the American Delegation were as follows:

Name	Affiliation	Representing
Morton M. Astrahan	International Business Machines Corporation	Chairman of the Delegation, Past Chairman of NJCC
Samuel N. Alexander	National Bureau of Standards	United States Government Agencies
Paul Armer	The RAND Corporation	Vice Chairman, NJCC
Lipman Bers	Institute of Mathematics, New York University	Interpreter
Harry H. Goode	University of Michigan, Bendix Systems Division	Chairman, NJCC
Harry D. Huskey	University of California	Vice Chairman, Association for Computing Machinery
Morris Rubinoff	Philco Corporation	Chairman, Computing Devices Committee, American Institute of Electrical Engineers
Willis H. Ware	The RAND Corporation	Chairman, Professional Group on Electronic Computers of the IRE

In addition, Mesdames Astrahan, Alexander, Armer, Huskey, and Ware accompanied the group. Each member of the delegation was financially supported by his own organization, or by a special grant from the government. Each wife paid her own way.

In an international exchange of this kind it must be recognized that the difference in language is a serious barrier to the interchange of information. While the delegation had available the finest of interpreters, and while the translating in general was very good, in all cases the necessity of communicating across a language barrier hindered the free flow of ideas. It was apparent on many occasions that an inadvertent mistranslation of a single word changed the meaning of a key sentence or misdirected the entire conversation. For this reason it was often necessary to rephrase and repeat a question several times in order to convey the proper implication. If information set forth in this report differs seriously from that reported elsewhere, there is, in addition to the difficulties imposed by the language difference, the possibility that some of the work in question is still experimental and may therefore have changed since an earlier report.

[3] Professor Bers used the occasion to establish contact with mathematicians in the Soviet Union. A copy of his report can be obtained by writing to him.

Itinerary

The delegation arrived at Vnukovo Airport, Moscow, at approximately 10:35 p.m. Sunday, May 17, 1959. We were met by our host, Academician Sergei A. Lebedev, and three members of his Institute: Victor K. Zeidenberg and Aleksei S. Fedorov, electrical engineers, and Miss Anna I. Martynova, a linguist. The men were transported to the Hotel Sovetskaya by bus, while the women and Miss Martynova traveled to the hotel by car. It is appropriate at this point to express publicly the gratitude of the delegation to their host and to the technical guides who were to make the stay of the delegation in Russia so pleasant, so cordial, and so memorable.

Monday, May 18

After the necessary but time-consuming exchange of dollars into rubles, the group traveled to Academician Lebedev's Institute of Precise Mechanics and Computing Techniques, which is located at 51 Leninskiy Prospekt in the southwest section of Moscow. In the morning the work of this Institute was generally discussed and a visit was made to the BESM-I installation. Following lunch we visited laboratories working on the following topics:

1. Transistor parameters
2. Transistor circuits
3. Core materials
4. Core switching time
5. Thin magnetic films
6. Magnetic circuits

We met or spoke with the following people:

I. S. MUKHIN, Deputy Director of the Institute
V. A. MELNIKOV, Engineer
V. V. BARDIZH, Engineer
P. P. GOLOVISTIKOV
Yu.I. SHARAPOV
—— VASILEV

[4] It is frequent in Russia for an organization to be named in honor of an important personage. This is done by coupling the name of the institute to the name of the person with the word "imeni" which means "in the name of." The proper name of the Steklov Institute is, therefore, the Institute of Mathematics imeni V. A. Steklov. Frequently such long titles are shortened by using the man's name to describe the institute. Another example is that of Moscow State University imeni M. V. Lomonosov, which is frequently called simply Moscow State University or, sometimes, Lomonosov University. On other occasions an institute is referred to by the title of its director. For example, the Institute of Precise Mechanics and Computing Techniques is sometimes referred to as Lebedev's Institute, although this particular case creates confusion because of the Institute of Physics imeni P. N. Lebedev.

Fig. 1. At the Moscow Computing Center of the Academy of Sciences.

Tuesday, May 19

The group visited the Moscow Computing Center of the Soviet Academy of Sciences. This organization and part of the Steklov Institute for Mathematics[4] share a building at

Akademichesky Proezd
Dom No. 28
Moscow V-134.

We discussed the work of this organization and visited the Ural-I, the Strela-III[5] and the Besm-II installations. We met or spoke with the following people (fig. 1):

A. A. Dorodnitsyn, Director of the Computing center, Aerodynamicist

V. A. Ditkin, Deputy Director of the Computing Center

V. M. Kuzochkin, Head, Programming Laboratory

A. P. Yershov, Head, Theoretical Programming Department

V. P. Smizyagin, Chief Engineer

P. T. Chushkin, Scientific Staff Worker in Aerodynamics and Gas Dynamics

Following lunch the group split into two parts. Bers, Goode, Rubinoff and Ware discussed with G. B. Linkovsky his theory of the memory function in the human brain. The rest of the group visited and heard described the Besm-II.

Wednesday, May 20

In the morning the group visited the Institute for Scientific Information in Moscow, located at Baltiiskaya Ulitsa 14, and discussed its work on information storage, retrieval and dissemination. We discussed at some length plans for automating these functions with Professor L. I. Gutenmakher. We met or talked with the following people:

Professor A. I. Mikhailov, Director, All-Union Institute of Scientific and Technical Information (VINITI)

Professor L. I. Gutenmakher, Head, Laboratory for Electro-Modeling

——Rakov

——Cherny

In the afternoon the group reconvened at the Institute for Precise Mechanics for a discussion of language translation. We met or talked with the following people:

I. S. Mukhin, Deputy Director of the Institute, in charge of language translation research

V. V. Ivanov,[6] Head, Language Translation group

——Korder, Assistant to Mukhin

V. V. Parshum,[7] German-to-Russian translation

G. A. Volchek, Japanese-to-Russian translation

(Mrs.) T. M. Nikolayeva, Russian-to-other-languages translation

V. A. Voronin, Chinese-to-Russian translation

——Bobitsky,[8] Russian-to-other-languages translation

(Miss) A. I. Martynova, English analysis (one of our technical guides and the principal Soviet interpreter)

(Mrs.) G. P. Zelenkevich, Mathematician

N. O. Korolev, Mathematician

M. B. Yefimov, Japanese-to-Russian translation

Thursday, May 21

The group again split. Goode and Rubinoff visited the Institute for Automation and Telemechanics at 15A Kalanchevskaya Ul., Moscow 15. They discussed analog computing devices and developments in switching theory and remote control. They met or spoke with:

Boris S. Sotskov, Deputy Director

A. M. Gavrilov, Senior Professor

B. Y. Kogan, Engineer

——Petrovskiy, Secretary of the Institute

——Parkhomenko

——Gruenberger, Staff Engineer

G. K. Moskatov

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[5] Occasional references in the literature have suggested that different versions of the Strela machine exist. For instance, in *Datamation*, Vol. 5, No. 4, page 14, reference is made to the Strela-III machine installed at the Academy Computing Center. Other references in the literature mention a Strela-I, a Strela-II and a Strela-IV.

[6] Affiliation uncertain. He may be a general consultant to IPMCT and also affiliated with The Institute of Language Studies of the Academy of Sciences, with the Committee for Applied Linguistics of the Academy of Sciences, with Moscow State University, and with the Institute of Pedagogical Sciences.

[7] Spelling uncertain—may be Parshin.

[8] Spelling uncertain—may be Barbitsky.

The rest of the group visited the Lomonosov campus of Moscow State University and its computing center. The work of this computing center was discussed and the STRELA and SETUN installations were visited and described. We met or spoke with the following:

Academician S. L. SOBOLEV, Head, Computing Chair, MSU

I. S. BEREZIN, Director of the Computing Center

M. R. SHURA-BURA, Professor of Numerical Analysis

N. P. ZHIDKOV, Professor and Senior Scientist

N. P. BRUSENZOV, Chief Engineer of the SETUN machine

The Director of Moscow State University was host to the delegation at a formal luncheon in the university. At this time we met or spoke with the following people:

Academician I. G. PETROVSKIY, Rector, Moscow State University

N. P. ZHIDKOV, Professor and Senior Scientist

Academician I. M. GELFAND, Professor of Mathematics, MSU

Academician I. R. SHAFAREVITCH, Professor of Mathematics, MSU

Academician S. L. SOBOLEV, Head, Computing Chair, MSU

Ye. M. LANDIS

I. S. BEREZIN, Director, Computing Center, MSU

——NIKIFOROV, Head, Foreign Dept., MSU

M. R. SHURA-BURA, Professor of Numerical Analysis

The part of the delegation which had visited the Institute for Automation and Telemechanics arrived in time to join the luncheon.

In the evening Academician and Madame Lebedev were host to the delegation at their Moscow apartment. Following an outstanding example of Russian hospitality, the group departed on the overnight Red Arrow Express for Leningrad.

Friday, May 22

The delegation visited the Computing Center of Leningrad University, which is physically located in the building of the Institute of Mathematics and Mechanics. The address is:

Fak. Vychislitel'nyy Tsentr
Matiko-Mekhanicheskiy
10 Pinikh D. 33
Leningrad, B-178 B. O.

We discussed at some length the curriculum for training of computer-oriented mathematicians. We later visited installations of the URAL-I, the EV-80, the MN-M and the MPT-9 analog machines. We met or spoke with the following people:

Professor S. V. VALLANDER, Director, Institute of Mathematics and Mechanics; Hydrodynamicist

M. K. GAVURIN, Deputy Director, Computing Center; Professor in the Theory of Functions

A. N. BALUYEV, Second Deputy Director, Computing Center

—BULOVSKY, Research Assistant, Programmer, Statistician

S. Ya. FITIALOV, Research Associate, Programmer interested in Mathematics and Linguistics

Professor D. K. FADEYEV

Mme. V. H. FADEYEVA

Mme. O. A. LADYZHENSKAYA, Mathematician, interested in partial differential equations

Professor S. G. MIKHLIN, Mathematician, interested in integral equations

Professor M. L. TSETLIN, Logician, interested in the Theory of Automata

Saturday, May 23

The group visited the former summer palace of the Czars at Peterdvorets; in the afternoon we visited other historical sights around Leningrad. Saturday evening we returned by overnight express to Moscow.

Sunday, May 24

In the afternoon the group visited the Kremlin and, in addition to the more usual tourist sights, were privileged to have special permission to see the Great Palace of the Kremlin.

Monday, May 25

The group split into three sections. Armer met privately with Yershov to discuss matters of programming and operation of the Academy Computing Center. Ware met with a group of BESM engineers to discuss general matters related to design philosphy, reliability, components, and so forth. He spoke with:

V. V. KOBELEV
V. S. BURTZEV
V. Ya. ALEKSEYEV
M. V. TYAPKIN
V. N. LAUT

The rest of the group left by plane for Penza to inspect the computing machine factory and to see the URAL-I machine in production. (Address: Vavod Schetno Analicheskikh Mashin, Penza.) They also saw the prototype of the URAL-II and learned its characteristics. They met or spoke with the following:

V. A. MOTKIN, General Manager
V. A. BUANOV, Deputy General Manager
V. M. STEPANOV, Engineer of Soviet Production
A. M. IVANOV, Engineer of Regional Production
A. D. PAVLOV, Engineer
B. I. RAMEYEV, Chief Design Engineer

Tuesday, May 26

The group reconvened at the IPMCT for a roundtable discussion. Such topics were discussed as digital differential analyzers, the relation between digital differential analyzer and general-purpose machines, the inter-connection of computing machines by communication networks, reliability of transistors, machine organization, etc. The people whom we met and spoke with are as follows:

——Bachin
E. F. Berezhnoy
P. P. Golovistikov
N. N. Chentsov[9]
Yu.I. Sharapov
S. G. Kalashnikov[9]
K. S. Neslukhovskiy
M. V. Tyapkin
A. N. Laut
——Kuzmichev
O. K. Shcherbakov
V. Ya.Alekseyev
——Galskiy
P. S. Oraevskiy
——Pitkevich
V. V. Kobelev
V. V. Bardizh

Wednesday, May 27

In the morning and early afternoon, the group visited a facility of the Moscow Computing Machine factory where we saw and heard described a hitherto undisclosed machine, the M-20. We met or spoke with the following people:

I. I. Konyakhin, Director of the facility
M. K. Sulim
——Kondramov
——Solovev

We again were treated to Russian hospitality with a sumptuous luncheon served in the Director's office.

Late in the afternoon the group flew to Kiev where they were met by a party from the Computing Center of the Ukrainian Academy of Sciences and driven to the Hotel Ukraina.

Thursday, May 28

The group visited the Kiev Computing Center of the Ukrainian Academy of Sciences located at:

Bolshaya Kitayezskaya 115
Kiev 28

We discussed the work of the computing center and learned of some of their automatic programming work. We also visited and had described the Kiev computing machine, a special purpose analog computing machine, the Sesm computer, and some experimental work in character recognition.

We saw or spoke with the following people:

V. M. Glushkov, Director, Computing Center, Academy of Science, Ukrainian SSR

B. N. Malinovskiy, Proxy of the Director of Scientific Matters, Candidate of Technical Sciences

A. I. Kondalyev, Scientific Secretary, Candidate of Technical Sciences

G. E. Pukhov, Head of Department, Doctor of Technical Sciences

L. N. Dashevskiy, Head of the Department (in charge of Kiev machine), Candidate of Technical Sciences

Yu. V. Blagoveshchenskiy, Chief Scientific Associate, Candidate of Technical Sciences

V. N. Ostapenko, Chief Scientific Associate, Candidate Physico-Mathematic Sciences

E. L. Yushchenko, Head of Department, Candidate of Physico-Mathematic Sciences

Z. L. Rabinovich, Chief Scientific Associate, Candidate of Technical Sciences

V. E. Shamanskiy, Head of Department, Candidate of Physico-Mathematic Sciences

I. T. Parkhomenko, Chief Engineer (acting)

Yu. T. Mitulinskiy, Chief Engineer

V. A. Kovalevskiy, Chief Scientific Associate, Candidate of Technical Sciences

V. I. Skurikhin, Chief Scientific Associate, Candidate of Technical Sciences

N. N. Pavlov, Junior Scientific Associate, Candidate Technical Sciences

R. Ya. Chernyakh, Candidate of Technical Sciences

V. V. Kraynitskiy, Chief of Department

That evening we were the guests of Dr. Glushkov and other members of his organization at the Dynamo Restaurant in Stadium Park in Kiev.

Friday, May 29

The group returned by air to Moscow and spent the balance of the day preparing for departure.

That evening a farewell dinner was given for the delegates and their wives by Academician and Madame Lebedev at the Hotel Ukraina. In addition to the Lebedevs, the U. S. delegates and their wives, the technical guides and interpreters, also present were Professor Ditkin, Mr. Bardizh, Mr. V. S. Petrov, Director of the Moscow Computing Machine plant, and Mr. P. S. Oraevskiy, Staff of the Presidium Office of the USSR Academy of Sciences.

Saturday, May 30

The delegation departed from Vnukovo Airport, Moscow, via Aeroflot TU-104A Jets, some of the party proceeding to Copenhagen and the remainder to Amsterdam.

It is interesting to note that the only locations where the group was requested not to take photographs were the computing machine factories at Penza and at Moscow, the Institute of Automation and Telemechanics, airports and coastal locations. At no time was there any restriction on making notes. A number of the photographs which were taken by various members of the group have been included with this report, in order to illustrate some of the machines seen and some of the new developments in Soviet computer technology.

In judging the quality of the pictures included in this report, bear in mind that conditions for photography were not always ideal. Some of the illustrations are reproduced

[9] Initials uncertain.

from 35 mm color slides; others are reproduced from black and white negatives taken by subminiature cameras, or from black and white prints. In some cases a picture is an enlargement of a portion of the original.

It is hoped that the illustrations, though not always technically excellent, will contribute to a sense of familiarity with Soviet personnel, places and machines.

Organizations

The Institute of Precise Mechanics and Computing Techniques

This was the host Institute to our delegation (fig. 2). Prior to coming to this Institute as its Director, Academician Lebedev was at the Kiev Academy of Sciences and was responsible there for the construction of the MESM digital computing machine, said by the Kiev workers to be the first electronic computing machine in continental Europe. Subsequent to his coming to Moscow as Director of IPMCT, Academician Lebedev has been responsible for the development of the BESM-I, BESM-II, and other machines.

The building itself is reminiscent more of an academic building than an industrial building. It is equipped with the usual offices and laboratory facilities as well as a large lecture hall. Within an office the decor tends to be ornate; the entrance door is frequently padded on both sides with what appeared to be leather, and heavy drapery usually hung across the doorway and at the windows. The ceiling height was somewhat higher than that of contemporary American construction, but we felt in general that working conditions in the offices and in the laboratories were good. There appeared to be an adequate amount of room and the workers were comfortably supplied with material and equipment. The building was constructed in 1951. Many things testified to the steady and heavy usage which it has received. In Russian tradition, the floor is parqueted and of unfinished oak. As in nearly every building, there are two sets of permanent windows for weather protection.

Most of the discussions which took place at IPMCT fit naturally into other parts of this report; however, the discussion of the second Tuesday afternoon was so heterogenous that it is included here. This discussion had been suggested by Lebedev in order to give a large number of his staff an opportunity to exchange information with the delegation. During a discussion of digital differential analyzers it was indicated that the interest at IPMCT in this device was as an adjunct to a general-purpose digital computer. The opinion was expressed that the DDA might be a very useful device to process input information for certain kinds of problems to be handled by a general-purpose machine, e. g., partial differential equations. Such a capability might be added to the BESM-II. They were familiar with the American literature on this subject and asked by name about the TRICE machine. Other unnamed institutes in Russia are actively engaged in designing and constructing digital differential analyzers.

In a discussion about the structure of machine instructions, Lebedev commented that they had in the past preferred three-address instructions; but, since larger stores and longer addresses have appeared, they now tend toward single-address instructions because the word length for a three-address format becomes too long for the precision needed in the arithmetic. They have made an analysis of a number of problems which shows that most machine operations are two-address in nature; the opinion was expressed that a two-address instruction format might be an eventual and reasonable compromise.

The Institute of Automation and Telemechanics is considering combined analog-digital computing systems for some of their problems. It has been their experience that unacceptable errors accumulate when large problems are attempted with an analog computer. Because of higher unit costs for digital equipment, more money is available for it than for analog equipment.

IPMCT hopes to improve the speed and logical design of their machines by using special vacuum tube structures for binary adders and switching. They feel that ferrites are not fast enough for such special structures, nor do semi-conductors appear to have a place for this purpose. Low temperature, thin film magnetic devices are being seriously considered for more sophisticated, multiple-element switching devices.

There seemed to be general agreement between the Russian group and the delegation on the techniques for faster machines. Suggestions included: simultaneous operations such as overlapping the fetch of the next instruction with the execution of the present instruction; making slower units work in parallel to feed faster units; accelerating fast units by improved circuit techniques, or more sophisticated logical devices; inclusion of new multiple operation instructions in the machine repertoire; increasing the size and speed of the working store. In connection with the size of the working store, it was felt by the Russians that so far as scientific calculations are concerned a large store may help programming efficiency more than it contributes to increased machine speed.

We were asked about transistor reliability in our

FIG. 2. The Institute of Precise Mechanics and Computing Techniques.

machines and we in turn inquired about their comparable experience. They referred to a working experimental transistor machine elsewhere in Moscow which contained several thousand transistors. Their life experience indicated that a few tens of transistor failures had occurred in a few months of operation, of perhaps five hours per day. They expect to publish details of this machine soon.

They have experimented somewhat with computing machines connected to communication lines, but this is not a regular technique. They felt that machines coupled by communication networks is not a technique to be studied of itself. The details of each application would depend on the problem to be solved. Lebedev maintained strongly that it does not make sense to share a problem between several machines linked by communication channels, although he did admit that for special purposes it is reasonable to transmit data over lines to the machine.

The Moscow Computing Center of the Academy of Sciences

The Computing Center of the Academy of Sciences was formerly a part of IPMCT. As it expanded it moved to its own building, of which it now occupies the first and third floors. The second floor is occupied by mathematicians of the Steklov Institute.

About 95 per cent of the machine hours at the computing center are devoted to scientific and technical work; in the course of a year about 100 different institutes put problems on the machines. About half of the machine time is used by computing center personnel themselves with outside institutes using the other half. The outside customers all do their own programming, and, for the most part, are physicists and engineers who have received training in programming from the computing center. At the moment there are approximately 300 people in the computing center; but it was estimated that 1,000 people would be required to do all of the programming for the work being done on their machines—the STRELA, the URAL-I, BESM-I and the BESM-II. Apparently the computing center still makes extensive use of the BESM-I, even though it is located in the nearby IPMCT building. It appears that BESM-II, although just finished, provides production time. A typical problem was said to be approximately 500 three-address instructions and would take about ten days to be programmed and coded. In such a problem ten programming errors would be regarded as a poor showing.

The general mode of operation is as follows. Programmers from the outside who come to the computing center with a problem apply to the scientific secretary of the computing center. He assigns someone from the computing center to provide any assistance needed by the outside programmer. In general, an operator is provided for each machine, and only programmers with specific permission can operate the machine personally. Normally a programmer can expect only one code check pass per day at a machine; with a very high priority he might get two or three passes.

A programmer is required to submit his manuscript in ink. Examples of manuscripts which we saw indicate that often a manuscript is written in pencil until it is thought to be correct, and then redone in ink. The manuscript is then keypunched twice, and the two decks compared, before being sent to the machine. The output cards are handled on an off-line printer.

In general, there is a reasonable amount of cooperation between the machine designers and the programmers, with the programmers taking a considerable part in the design of machines. However, their experience has been that in most organizations which received a machine a local group of engineers was willing and eager to change the character of the machine. In this connection it was observed that the interchange of routines for STRELA machines was virtually impossible because no two of the machines were alike. It was also suggested that the same situation prevails for the URAL-I machines. As a result, user organizations do not exist for the URAL-I or STRELA. Dorodnitsyn thought it was too early to standardize on a specific machine language for the whole of the Soviet Union. He suggested that they plan to design a large number of machines and to construct enough of each to provide adequate operating experience. Perhaps in five years a decision would then be made as to which machine and which language should be chosen for standardization.

The computing center's responsibility is largely for scientific and engineering calculations. A government scientific technical committee has recently been formed and will be responsible for commercial applications of computers. Any special machine required for this work will presumably be developed by laboratories or institutes connected with industry, rather than by those connected with the Academy of Sciences.

The Moscow State University imeni V. M. Lomonosov

Department of Mathematics. Mathematics at Moscow State University is taught in the Faculty (i. e., department) of Mathematics and Mechanics. Most other Russian universities have a joint Faculty of Mathematics, Mechanics and Physics. The Dean of the Mathematics and Mechanics Faculty is now the fluid-dynamicist N. A. Slezkin, who succeeded Kolmogorov. A Mathematics section of the Faculty comprises eleven subdepartments or "chairs," each of which was originally occupied by a single professor, but now includes several people. These chairs and people in charge are as follows:

Analysis (This Chair is the service part of the department. It is responsible for the teaching of mathematics to nonmathematicians throughout the university.)	N. V. YEFIMOV[10]
Geometry and Topology	P. S. ALEKSANDROV
Differential Geometry	S. P. FINIKOV
Differential Equations	I. G. PETROVSKIY
Probability and Statistics	A. N. KOLMOGOROV

[10] Initials uncertain.

Number Theory and History of Mathematics	I. M. Gelfand
Function Theory and Functional Analysis	D. Ye. Menshov
Logic	A. A. Markov
Computational Mathematics (This is the Russian equivalent of Numerical Analysis.)	S. L. Sobolev

During the first two years, a student of mathematics is not attached to a given chair but takes a standard set of courses. After two years he must decide on his specialization. In making this decision he is helped by general expository lectures given by a representative of each chair. The above list of chairs indicates only a partial picture of the overwhelming concentration of mathematical talent at Moscow University. For instance, the Chair of Function Theory and Functional Analysis contains, in addition to its leader, such people as I. M. Gelfand, G. Ye. Shilov. P. A. Raykov,[10a] and others. L. S. Pontryagin and M. M. Postnikov[10a] are attached to the Topology Chair.

The mathematics group at Moscow State University is equaled only at one or two other places in the world.

In addition to the strong mathematics department at Moscow State University, there are prominent mathematicians connected with other institutions of higher learning in the Moscow area. There are also people whose primary assignment is elsewhere, but who also teach at MSU; for instance, S. N. Mergelyan, director of a computing center in Yerevan, the capital of Soviet Armenia; and some members of the Novosibirsk branch of the Academy of Sciences.

The mathematicians in Moscow appear to be very well informed on the work in the United States. They publish a separate journal for translations of foreign papers, and large numbers of foreign scientific books are translated into Russian and published.

Computing Center. The Computing Center organizationally is within the Chair of Computing, although it appears to be independent in the sense that it is separately funded and has its own scientific council of representatives from other Chairs in the University. Originally the Computing Center consisted only of the Chair of Computational Mathematics, of which Sobolev is still the head. In December 1956 they received a Strela machine which was characterized as the first computer that had been built by Soviet industry. The Center now includes two laboratories devoted to different aspects of computational mathematics. One of these is a programming laboratory which is concerned with numerical solutions of applied problems and includes several groups:

Electrodynamics: A. N. Tikhonov
Numerical Weather Prediction: I. A. Kobel
Gasdynamics: G. I. Petrov[10a]
Automatic Programming: M. R. Shura-Bura

Shura-Bura's group is also responsible for the Theory of Programming, and for providing computing services to other people with problems. They charge 600 rubles per hour for the Strela,[11] although the group sometimes does work for industry at no charge, provided it is sufficiently interesting.

The second laboratory at the Center has just recently been formed and concerns itself solely with numerical analysis. It is headed by N. P. Zhidkov.

The Computing Center is responsible for training all mathematicians who are specializing in computers. Forty per cent of the mathematics students at Moscow State University are specializing in numerical analysis, but every mathematician must take at least one year of numerical analysis and computing mathematics. The university provides its own maintenance engineers for their machines.

The university expects to obtain a large, new, industrially-produced machine in a year or two. Future users of this new machine have agreed not to modify it in order that an effective interchange of routines might be accomplished. At the moment an informal users' organization of 20 members already exists for it.

The lack of an alpha-numeric printer is something of a nuisance to the Computing Center, and they hoped that such printers will be available for their machines in the reasonable future.

The Institute of Automation and Telemechanics

It appears that most analog computer developments take place at this institute. It does work not only in the development of specific analog computing devices, but also in the field of remote control devices, design of relay networks and the design of specific devices to assist in analyzing and synthesizing relay networks. We were shown the following devices:

1. A chopper-stabilized operational amplifier whose drift was 13 millivolts over 2 hours, or 66 millivolts over 8 hours. It consisted of an AC amplifier with a 100 cycle to 100 Kc pass-band in parallel with a chopper-stabilized DC amplifier having a pass-band from zero to 100 cycles.

2. Function Generators. One type was the conventional diode-function box, sometimes used in the input or in the feedback position of an operational amplifier. A second type was the drum having on its surface a wire shaped to the desired function; this technique is familiar in the United States.

3. Limiters. Two types were shown.

[10a] Initials uncertain.

[11] The ruble/dollar ratio is artificial in the sense that there is no free market exchange of rubles for dollars. For a tourist or visitor within Russia the exchange rate is set by the Government at ten rubles to the dollar; however, the ratio for commercial purposes is approximately four rubles per dollar. This is verified partially by comparing the airline fare from Western Europe to Moscow with the airline fare from Moscow to the same point in Western Europe. We found that the 10:1 rate is more accurate in terms of purchasing power; at this rate hotel rooms and restaurant meals are slightly less expensive by our standards, but most hard goods are somewhat more expensive.

4. A three-dimensional flight table with a 5 cycle/second response, and amplitudes up to 6 degrees on each axis.

5. An Analyzer machine. This was developed by Gavrilov and Parkhomenko. It is intended to examine the performance of a given relay circuit to see whether it agrees with a previous analysis. It consists of two large cabinets; the left one is a series of jacks, plugs and wires for simulating a desired test circuit of up to 20 variables. The right-hand box contains 480 three-way switches arranged in 20 columns of 24 each. The 20 rows represent the 20 variables of the test circuits and the 24 columns represent 24 time steps. These switches are set to represent the condition of each variable at each switching time. A step switch sequentially progresses through the 24 time periods, in each of which the test in the left box is compared to the state set by switches in the right-hand box. The machine stops if these do not compare identically, and the designer can then study the situation to locate the design error. At each such stop the machine also punches out a 45-column card indicating the condition under which it had stopped. The machine could also simulate "race" conditions in relay circuits by inserting time delay devices of fixed values. This device used relays which had three coils and 15 contacts, five of which are transfer contacts. A new version of this machine will permit including time delays which will be variable by six increments. This new design will also permit interconnecting other devices into the test circuits as well as including a printer and other devices to permit analysis of larger sequential circuits.

6. A Synthesis machine. This machine is intended to synthesize a relay circuit which in some sense is a best one for carrying out a particular switching function. Gavrilov felt that the algorithms for synthesis are not as complete nor as well known as he would like. However, he has developed his own theory of synthesis using simple bridge circuits and can achieve minimal forms. A paper on this subject is expected to appear soon.[12]

7. The Error-Correction machine. This development machine is intended to correct errors at the receiving end of a remote control circuit. It is to correct single errors, and detect double errors; it is to be expandable for multiple error correction and detection. The technique is not that of Hamming, but one which they had devised. The message of N bits is considered as a mathematical group and therefore, the check bits are not necessarily distinguished from the data bits. This seems to imply that some form of dictionary look-up or word translation must be accomplished if the original data is to be reconstructed from this message. The information theory measure of the number of bits being transmitted is not being used; two representative bits out of four will occur if single and double error correction is done, but four representative bits out of four will occur if single error correction only is done.[13]

8. Remote Control Device. This is a switching device which has been developed for remote control applications. It utilizes square loop ferrite cores, power transistors and relays to create a 52-bit switch. It can be used to send several signals along a single twisted pair line for approximately 30 to 40 kilometers without amplification. If some degradation is permitted it can be used for about 200 kilometers. The frequency of operation was not specified, but it is inferred to be of the order of a few kilocycles. This device returns an echo signal to the sending station to verify the correct transmission of the switching instruction. It apparently uses time-division coding, with synchronization either by means of special clock pulses or the alternating current power frequency.

The analog computing equipment at this laboratory had been built in 1957 or 1958. This Institute is also doing simulation in which a person is included in the loop. Such simulations are being used for purposes of design, testing of equipment, training, and predicting performance of complicated systems of equipment and people. Since the operational amplifiers available had responses as high as 30 kilocycles, problems were being solved in terms of seconds per run; occasionally problem solutions were as high as 15 runs per second.

The All-Union Institute of Scientific Information[13a] *(VINITI)*

The Director of this Institute is Professor Mikhailov (fig. 3). The Institute is 7 years old and its purpose is to centralize collection and dissemination of scientific information from the USSR and the rest of the world. It is responsible for receiving foreign periodicals and for translating and disseminating these within the Soviet Union. It is also responsible for producing abstracts in many areas of science. Consequently, this Institute is deeply concerned with the field of information retrieval and it feels that its largest problem is the mechanization of its processes. As journals are received at the Institute, editors mark the parts of the article which are to be abstracted. The editorial board then sends this material to an appropriate individual somewhere in the Soviet Union for abstracting. After the material is returned to the Institute, the abstracts are edited and published. The individuals who do the actual abstracting are workers in the particular field and are paid for their contribution. Mikhailov found that it was necessary to have a computing center just to calculate what each abstractor should be paid. In the field of chemistry they have approximately 20,000 abstractors working all over the country, and they publish approximately 500,000 abstracts per year. This

[12] *Automatika Telemechanika.* See also *Proceedings of the Symposium on Switching Theory,* Harvard University, April 1957.

[13] See M. V. Gavrilov, V. M. Ostianu, V. N. Rodin, B. L. Timofeyev, Realization of schemes for discrete correctors, *Electro Technika,* Doklady, Academy of Sciences, USSR, Vol. 123, No. 6, 1958.

[13a] See: *American Documentation,* Vol. X, No. 1, January 1959, page 5 ff.

publication now appears as 24 volumes per year, and the lead time for producing an abstract is from two to four months after the appearance of the journal. Mikhailov estimated that the lag in the publication of a journal is itself from three to six months, and he hoped, by mechanizing his process completely, to reduce the total time from first typing of the original manuscript to the appearance of the abstract, to three and one-half months. One technique suggested by Mikhailov is to have the original typist prepare some sort of tape from which the final typesetting can be done.

On one wall of Mikhailov's office was a map of the world. From each country a string led to Moscow and an attached number indicated the number of journals received from that country. A few such figures are as follows:

United States	1416
England	844
France	491
Italy	368
Japan	304
Australia	143
India	142
Sweden	133
Canada	123
Germany	123
Netherlands	123
China	104
Spain	91
Denmark	71
Portugal	47
Argentina	42
Brazil	38
Chili	8
Iceland	3
Mozambique	3
Hawaii	2

The additional work on information retrieval and mechanization which this Institute is sponsoring in the Laboratory for Electro-Modeling under Professor L. I. Gutenmakher will be discussed later as a separate topic.

Leningrad University imeni A. A. Zhdanov

Department of Mathematics. The building of the Institute of Mathematics and Mechanics of Leningrad University is a very old one, and was at one time a girls' school. The exterior is an off-shade of yellow which is a very common exterior finish in Russia. The interior floors are parquet, but the wood is very rough and surprisingly of random width; it has been stained a dark red. In the Director's office were pictures of Khrushchev, Lenin, and Engel. The appointments in the room reminded us of the early twentieth century in the United States.

At present the enrollment is 9,000 day students and 6,000 evening students. There are approximately 200 students in the Department of Mathematics, of which 25 are at graduate level. The Department of Mathematics includes four sections; Mathematics, Computing Mathematics, the Computing Center, and Astronomy. The department is divided into fourteen Chairs as follows:

- Mathematical Analysis
- Ordinary Differential Equations
- Geometry
- Algebra and the Theory of Numbers
- Theory of Probability including Statistics, Information Theory and Game Theory
- Mathematical Physics
- Computing Mathematics
- Fluid Mechanics
- Hydrodynamics
- Elasticity and Plasticity
- Theoretical Mechanics
- Mechanics of Rigid Bodies
  - Celestial Mechanics
  - Astrophysical Mechanics
  - Stellar Mechanics
- Geodesy and Gravity

FIG. 3. Professor A. I. Mikhailov, Director, All-Union Institute of Scientific and Technical Information (VINITI).

In addition, the Mathematics Department has a general service function to teach mathematical topics to other departments of the University. Except for one or two theses, the Mathematics Department is not yet performing any experimental work in computing machines, but they hope to inaugurate work in this field soon.

The Computing Center. This Computing Center has just recently been founded and regards its first responsibility as training of students. Its second responsibility is service calculating for the university, while last is calculation for outside people. The Center has a URAL-I machine, various punched card calculating machines and several analog devices. One of these is the MPT-9 which contained 50 operational amplifiers; another is MN-M which is a desktop machine capable of integrating a 16th order equation. The amplifiers in these devices had drifts of the order of 10–15 millivolts over 15–20 seconds. The overall accuracy of solution was of the order of 6–8 percent. The Center expects to receive an ARAGATS machine within the coming year, and they plan to begin programing for this machine in the fall of 1959. They intend to install it on a lower floor than the present equipment, which suggests that the URAL-I machine will continue to be operated.

Professor Ladyzhenskaya has developed a scheme of solving a differential equation which utilizes large increments of the variables, but still provides very small errors. The Center has also written a translation routine which will modify the routines written for the Moscow URAL-I machine into routines for the Leningrad URAL-I. They recognize the desirability of having a uniform operating system for any given machine type, but at the moment they expect to develop their own algebraic programming system. A special machine for performing Fourier analysis was mentioned, but not seen. There was also an implication that a special machine was available for analytically manipulating formulas; it was also suggested that formula manipulation had been done on one of the known machines.

There is a branch of the Steklov Institute of Mathematics at the University of Leningrad under Professor G. I. Petrashen, but the delegation did not visit it.

The Computing Center of the Ukrainian Academy of Science, Kiev

This Center grew out of a group headed by Lebedev at Kiev some ten years ago. At that time Lebedev conceived and built the MESM machine, which was said to be the first sequence controlled computer in continental Europe. This machine still exists but is used only for training purposes at another location. Following Lebedev's transfer to Moscow, the Kiev group continued to exist as an arm of the Institute for Precise Mechanics. In 1956 the group became a Computing Center in its own right; it was decided the group should build at least one machine for experience. The Computing Center's new four-story building is slightly over one year old.

The Center, under the direction of Dr. V. M. Glushkov, has designed and built the KIEV and the SESM computers. They have also designed and built specialized analog devices for performing analysis of rigid structures, as well as a 48-integrator electronic analog computer. The Center at Kiev is working on algegraic symbol manipulation and has just begun work on numerical analysis.

In addition to the previously mentioned machines, they also have a URAL-I. There is an active group planning the modernization and improvement of the KIEV. They are also actively working on the problem of character and pattern recognition.

The Penza Computing Machine Factory

Penza is a town of approximately 250,000, located 350 miles east and slightly south of Moscow. It is in an agricultural region and is surrounded by many smaller satellite towns. The region produces onions as a major agricultural product, and such manufactured items as textiles, compressors, bicycles, watches and computers. The industrial capacity of this town has developed since the revolution. Schools in the region include a polytechnic institute, a pedagogical institute, a civil engineering institute, and an agricultural institute. For university training, students must go to Kazan, Gorki, Moscow, Seratov, or Voronezh. The factory visited by the delegation also produces, in addition to digital computers, electronic test equipment, card punches and card reading devices, and some analog computers. It is part of a larger complex which produces watches and heavy equipment. Engineering personnel for the factory is obtained by sending manpower requirements to the Central Council on Production. A representative of the factory then participates in the selection of new employees through student interviews. This plant representative also obtains additional information on the student from the graduating commission at his school. When the engineer arrives at the plant he may, if he wishes, take evening courses in the polytechnic institute at Penza.

Plant managers come from technical backgrounds and do not receive specific administrative training; a plant manager, however, may correspond more nearly to a "director of engineering" than to a chief administrative officer.

The factory is in the process of planning a new plant which is to be constructed on the same 180-acre site during the next seven-year plan (1959–1965). At present the factory has about 4,000 workers and has approximately 2 million rubles per year to provide "rest homes"[14] for about 800 people. Last year 6,500 square meters of housing was added which provided 1-, 2- and 3-room apartments for approximately 200 families.

At this factory we saw production of the URAL-I, and also the prototype model of the URAL-II. The characteristics and details of these two machines are included in another section of this report; only information about production techniques will be included here.

The assembly area looked quite modern and had fluorescent lights. The windows were curtained and the walls were painted a restful light blue color. Workers on the pluggable unit assembly line are paid on a piece-work basis and a punched card computing installation is used to calculate the payroll. Separate forms are used to record information about each worker's daily production.

The URAL-I is manufactured in modular fashion. Five basic modules approximately 8 ft. x 3 ft. x 14 in. are needed for the complete computer. Above the level of the console there are glass windows, and below it, metal doors. Cabling is done on layout boards as in this country. Capacitors, resistors, and some of the plastic parts of the machine are not produced at this plant, but most other parts are, such as ferrite cores and magnetic drums. Yield on core production is currently 50 percent. There were 24 machines on the floor at the time. With a produc-

[14] This term does not have our usual meaning. It means "vacation homes" or, more generally, "vacation opportunities."

tion rate of one every four days, more than 120 have been produced at this plant. There were no serial numbers on the machines which we saw.

Marginal checking equipment is brought to the machine while it is still on the production line, and the machine is checked out. A machine is transported as modules to the customer, who is responsible for connecting them together himself. Inter-module power connections are plugged, but signal connections must be resoldered. It takes approximately from two to three weeks after delivery for the URAL-I to be set in operation at the customer's site.

The machine is built of ten types of pluggable packages. Test equipment capable of checking all types was available and provided both maximum and minimum marginal voltages for the package. The debugging crews had available a certain amount of special test equipment, such as a punched paper tape reader which could be used to read a test program into an almost operative URAL-I for its final checkout. Other devices included a paper tape verifier and a keyboard device similar to a desk calculator. The latter had 100 keys arranged in a 10 x 10 array and a plus and minus key. Apparently it permitted establishing a number of ten decimal digits for some particular test purpose. Special test equipment is also available for cycling the ferrite store through special test patterns and displaying the response as a geometric image on an oscilloscope. The usual complement of oscilloscopes and volt-ohm-milliameters was also available.

The back panel wiring of the URAL-I was done on a systematic basis. There is a network of horizontal and vertical interconnections and power distribution wires which form a checkerboard pattern, each square of which is approximately three inches on the side. Within each square are three different connectors associated with that square. Signal and power connections are then made between the connectors and the checkerboard wire. In order to reduce the number of different types of packages in the machine, components are occasionally mounted on the base of the plugs. We were told that these plugs, which use phosphor bronze springs, had proved to be completely adequate. This checkerboard wiring occupies the top half of each cabinet module; the bottom is reserved for power supplies, which use selenium rectifiers. Signals between cabinets are brought out to lugs on the side faces of the cabinet which mate with similar lugs in the adjoining modules. Clocking pulses are distributed across each cabinet by heavy buses. Both wiring tables and scale drawings are used to indicate where back panel connections are to be made and components located. Plugs of solder are used because either resin core solder is not available, or it is thought to be inadequate. No composition carbon resistors were seen, either at Penza or elsewhere in Russia. Low wattage resistors are deposited carbon, whereas higher power resistors are wire-wound units encased in ceramic. The capacitors physically resemble resistors. Curiously, copper oxide rectifiers were observed in the back panel wiring. It was explained that these were needed in some cases to yield a sufficiently low forward resistance combined with a reasonably high back resistance.

In manufacturing magnetic drums the drum itself is first machined to close tolerance and is then sprayed with the brown magnetic dispersion. Following this a lacquer coating is sprayed on the surface for protection. Three clock tracks are physically engraved on one end of the drum. One of these establishes the origin reference of the drum, a second marks the beginning of each word, and the third marks the position of each bit within a word. Recording density is 100 pulses per inch and 4 positions are allowed between words to accommodate timing inaccuracies in the machine.

Three sets of heads are mounted on a drum. One set reads all the even tracks, while the second set reads the odd tracks. The third set is an erase stack for all tracks. Before permitting the drum to rotate, the structure which holds the head is heated for several minutes as a precaution against head scraping.

The price of the URAL-I was quoted at 1.1 million rubles, but as soon as the URAL-II is in production this price will be halved.

Using the same basic components as the URAL-I, the product engineering group at Penza has designed the URAL-II; a different internal organization is used to achieve a much higher speed. The URAL-II was said to be 50 times as fast as URAL-I, but 100 times more effective because of improved organization. It will sell for 1½ million rubles, and its details are given elsewhere in the report. We saw what appeared to be a prototype model. It was being debugged prior to production, and apparently routines were being prepared for it. At the present there are more customers than machines, and the factory does not have to maintain a sales force. They do, however, have people who write equipment descriptions and send them to potential users. Occasionally, factory representatives even visit these potential users to explain the usefulness and desirability of the digital computers.

In another building we were shown about 40 card punches. About half of these were 90-column machines and the other half, 80-column machines; all were generally similar to United States designs. These units appeared to represent the most recent design in Soviet punched card equipment. We saw also a 500-card-per-minute sorter which closely resembled a corresponding American product. It had electro-mechanical sensing of the holes and a set of switches for suppressing specific row selections as in American sorters. It also had a special attachment which permitted collating on 12 columns by means of a plugboard and 12 auxiliary brushes.

Specific Machines

The Soviet development of internally sequenced computers began with the MESM machine, conceived and constructed by Lebedev at Kiev. The development of the field, so far as the Academy of Sciences is concerned, has

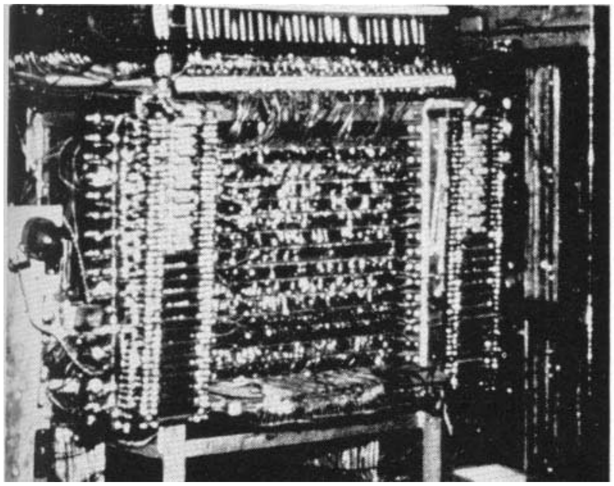

FIG. 4. Magnetic Core Store, BESM-I

centered around Academician Lebedev and his Institute for Precise Mechanics and Computing Techniques. There also has been some parallel development by other laboratories or institutes which are connected with other ministries of the Soviet government or industrial organizations. At the present time cooperation between the Academy's Institute and industrial plants is beginning, and future machine development in Russia may well turn out to be a cooperative venture.

In comparing Russian machines with United States machines, it must be noted that Soviet designers place considerable emphasis on analyzing the set of problems to be encountered by a given machine. A fairly detailed study is made of the number of each kind of instruction which occurs in some class of problems, and on the basis of this statistical distribution the speed of the machine is quoted as so many operations per second. Unfortunately there are several sets of statistics in use; and from our information, it is not always clear as to which set applies to a particular machine. Further, there is also some disparity between the statistics reported at various locations. In the following discussion and in table I, the statistical weighting has been used which is believed to be correct for each machine.

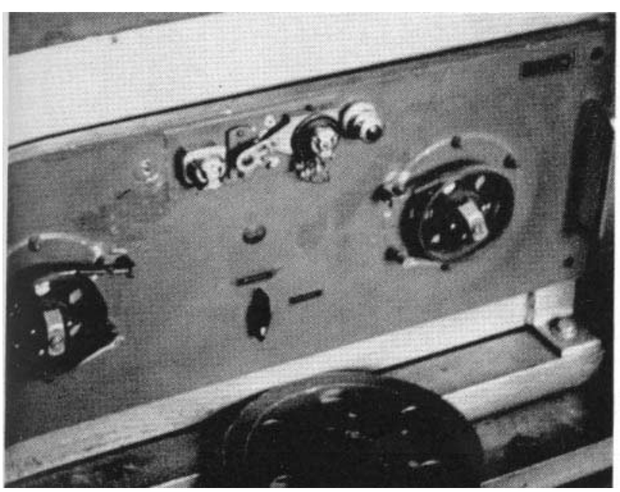

FIG. 5. Magnetic Tape Unit, BESM-I

For some machines it is uncertain as to which might be the correct basis; the speed of the machine in operations per second is not likely to change radically from one statistical basis to another.

The so-called BESM-II statistics as reported at Moscow are:

30 % add-subtract
30 % multiply
3 % divide
37 % all other operations

The so-called STRELA statistics as reported at Moscow are:

25 % add-subtract
30 % multiply
2 % divide
10 % address modification
33 % all other operations

The URAL-I statistics as quoted at the Penza factory are:

17 % add-subtract
17 % multiply
3 % divide
33 % transfer
30 % all other operations

The figures quoted to us by the Leningrad group differed rather significantly. According to them the BESM-II statistics are 68 % add-subtract and 32 % multiply, while the STRELA statistics are 75 % add-subtract and 25 % multiply. It is believed that the statistics quoted to us in Moscow are more likely to be correct.

Table I summarizes the information received on all digital computing machines which were seen. In order to make this table complete a small amount of information has been carried forward from the Scott-Carr-Perlis-Robertson report. Where there is considerable uncertainty as to the accuracy of a figure, it is followed by a question mark.

BESM-I

The BESM-I[15] was originally constructed in the early 1950's with an acoustic delay line store. This store was later changed to a Williams type electrostatic store and recently was again changed to a magnetic core store of 1,023 words of 40 bits.[16]

The core storage element of BESM-I was designed approximately four years ago, and it is clearly an early model of such a store (fig. 4). The store is expandable to 2,047 words, although there was no indication that this expansion would be done. It was indicated that only one BESM-I machine has ever been built in the Soviet Union. The machine requires seven DC voltages between +400 and −400, and is physically constructed of fairly large plug-

[15] See: *J. Assoc. Comp. Mach. 3* (1956), 129.

[16] It will be noticed that the size of many stores in Russian machines is $(2^n - 1)$ words in size. This is because storage location zero is permanently reserved as the location for the numeric constant zero.

TABLE I—Characteristics of Soviet Scientific Computers

Machine	Operational Date	Arithmetic Characteristics: Addition[2] time	Mult[2] time	Div[2] time	Average[1] speed (opns/sec)	Word length	Number representation	Number range	Serial/parallel	Fixed/floating point
STRELA	1953	—	500 (?) μs	—	2000	43	Binary	—	Parallel (?)	Floating
BESM-I	1953	—	270 μs	—	7000–8000	39; mantissa: 32 + sign; exponent: 5 + sign	Binary	—	Parallel	Floating
URAL-I	Approx. 1953 (design) 1955 (production)	10 ms	10 ms	20 ms	100	36	Binary	±1	Serial	Fixed
BESM-II	1959 (prototype)	70 μs	230 μs	230 μs	8000–10,000	39; mantissa: 32 + sign; exponent: 5 + sign	Binary	—	Parallel	Floating
URAL-II	1959 (prototype)	—	—	—	5000	40; mantissa: 32 + sign; exponent: 6 + sign	Binary	$\pm 1 \times 10^{\pm 19}$	Parallel	Both
SETUN	1959	180 μs	360 μs	(none)	4000	18	Ternary	±9	Serial	Fixed
KIEV	Probably 1960	—	200 μs	—	5000–6000	41(?)	Binary	±1(?)	Parallel	Fixed
M-20	1959	—	—	—	20,000	—	—	—	—	—
ARAGATS	Probably 1960	—	—	—	15,000	—	—	—	—	—
Typical large[4] U.S. scientific machines	Early 1959	—	—		[3]5–7000 for production machines; up to 15,000 for one-of-a-kind	36–40	Binary, binary-coded decimal	Fractional or integer	Parallel or mixed	Both
Typical large[4] U.S. scientific machines	Early 1960	—	—		[3]20–25,000 for production machines	36–48	Binary, binary-coded decimal	Fractional or integer	Parallel or mixed	Both

Machine	Control Characteristics: Instr'n format	Number inst'ns	Clock rate (KCS)	Storage: Core storage: Size (words)	Core storage: Cycle-time (microseconds)	Magnetic drum: No. units	Magnetic drum: Words/unit	Magnetic drum: Transfer rate (words/sec)	Magnetic tape: No. units	Magnetic tape: Words/unit	Magnetic tape: Transfer rate (words/sec)	Read only: Size (words)	Read only: Cycletime (microsecs)
STRELA	3 address 1/word	—	—	None. Barrier grid electrostatic store 1023 words		—	—	—	4	200,000	1000	Yes	
BESM-I	3 address 1/word	31	—	1023	10	1	5120	—	4	30,000	—	400	—
URAL-I	Single address 2/word	29	7	None		1	1024	100	1	40,000	75	None	
BESM-II	3 address 1/word	31(?)	—	2047	6	Up to 3 (2 installed now)	6000	12,000	4	30,000	400	None	
URAL-II	Single address 2/word	40	200	2048	12	Up to 8	8192	5000	Up to 10	700,000	1000	None	
SETUN	Single address 2/word	27	200	81	—	1	2268	2000		To be added		—	—
KIEV	3 address 1/word	—	Asynchronous	1024	10	Up to 3 (1 installed now)	8192	5000	—	None	—	512	3
M-20	—	—	—	—	—	—	—	—	—	—	—	—	—
ARAGATS	—	—	—	—	—	—	—	—	—	—	—	—	—
Typical large[4] U.S. scientific machines (Early 1959)	1, 2, or 3 address 1 or 2/word	Up to 200	500–2000	4096–32,768	6–12	2–4	4096–50,000	10,000–50,000	[5]Up to 20	Up to 1,000,000	2500–10,000	None	
Typical large[4] U.S. scientific machines (Early 1960)	1, 2, or 3 address 1 or 2/word	Up to 200	500–2000	4096–32,768	2–12	2–4	4096–50,000	10,000–50,000	[5]Up to 20	Up to 1,000,000	2500–10,000	None	

Machine	Input-Output: Number form	Number input devices	Number output devices	Perforated tape: Width and kind	Perforated tape: Size (words)	Perforated tape: Transfer rate (words/sec)	Card reader rate (cards/min)	Card punch rate (cards/min)	Printer: Colums	Printer: Number characters	Printer: Speed (lines/min)	Power (KVA)	Number components	Price (Rubles)	Quantity produced	Designer/principal personnel
STRELA	—	1-5 card readers	1–2 card punches	—	—	—	60	60	10	Numeric	900–3000	147	7000 tubes, 50,000–60,000 diodes	—	Estimated 10–15	Brusenzov Basilevskiy
BESM-I	Binary(?)	1—paper tape reader	1—paper tape punch	Paper	—	20	None		14	Numeric	900	75	4000 tubes	—	1(?)	Lebedev
URAL-I	9 decimals and sign	1—Perf film	1—Mag tape 1—Printer	Film, 35 mm	10,000	75	None		19	Numeric	100	8	800 tubes, 3000 diodes	1 million	>120	Basilevskiy Rameneyev
BESM-II	—	Probably paper tape reader	Probably paper tape punch, 1—printer	—	—	—	Probably none		14	Numeric	900	—	—	—	To be produced	Lebedev
URAL-II	8—decimal mantissa + sign and 1½—decimal exponent + sign	1–12; with special decoder: up to 100	1—card punch and 1—printer minimum; with special decoder: up to 100	Film, 35 mm	10,000	150	300	100	16 or 96	Numeric	1200	25	—	1.5 million	To be produced	Ramenyev
SETUN	—	Photo-cell paper tape reader	1—paper tape punch 1—printer	German teletype equipment	—	400 chars/sec	None		German RFT Teleprinter			—	4000 cores, 40 tubes, 4000 diodes, 100 transistors 2000 tubes	—	1	N. P. Brusenzov
KIEV	—	1—Perf film now	1—printer now	Film, 35 mm	10,000	75	—	—	19	Numeric	100	—		—	1	Glushkov Dashevskiy
M-20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ARAGATS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Typical large[4] U.S. scientific machines (1959)	—	Usually card reader, magnetic tape, or paper tape	Usually card punch, printer, magnetic tape	Paper, teletype	—	1000 chars/sec	250	120	120	Alpha-numeric (Numeric only	Up to 1200 (Up to 1800)	Up to 100	3000–5000 tubes, 15,000–20,000 diodes	>$1 million	Hundred's	Various
Typical large[4] U.S. scientific machines (1960)	—	Usually card reader, magnetic tape, or [illegible]	Usually card punch, printer, magnetic [illegible]	Paper, teletype	—	1000 chars/[illegible]	Up to 2000	Up to 250	120	Alpha-numeric (Numeric only	Up to 1200 (Up to 1800)	Up to 100	All transistor and diode	>$1 million	—	Various

able units, using vacuum tubes of the general dimensions of the 6SN7. The tape transports connected to this machine are modified audio transports; there are only two tracks — one for information and one for timing signals (fig. 5). The machine was reported to be asynchronous; however, after detailed inquiry it developed that it had an internal clock. Its operations could be variable in time of execution, but only by increments of the clock interval.

The input device to the BESM-I is a photocell paper tape reader (fig. 6). The output includes a high-speed, 14-column, 15-lines-per-second numeric printer, producing only one copy (fig. 7).

The BESM-I has a supplementary 400-word, changeable, read-only store of the diode function table type. There are several locations at which pluggable panels can be manually changed in order to provide certain standard subroutines to the machine without repeated reference to the main core store.

The mean free time between failures on the BESM-I was reported to be approximately 6–8 hours; about 70 percent of the breakdown is in the input-output devices and other electro-mechanical equipment. The BESM-I is operated by the programmers who use it, and therefore in the machine records no accounting is made for restarts or reruns which are due to machine failures. Good performance statistics were not available, but the maintenance engineers (one man per shift) thought there was about 8 percent lost time. Associated with the BESM-I is an off-line printer which is connected by teletype with the Academy Computing Center. This is probably a convenient method for transmitting problems to BESM-I from the Computing Center, which still regards BESM-I as one of its operating machines.

The general appearance and marginal workmanship visible on BESM-I certainly marks it as an older, often-changed machine.

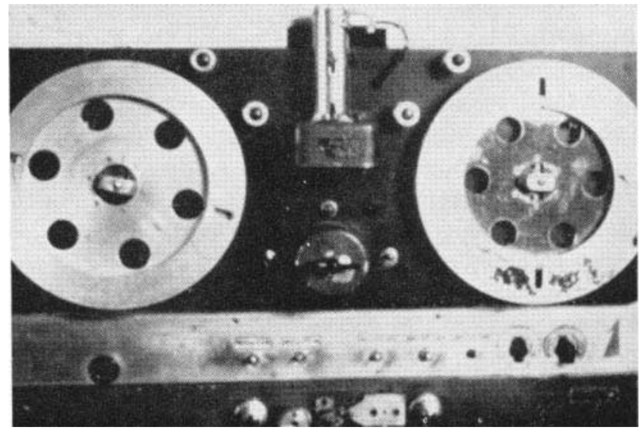

FIG. 6. Paper Tape Reader, BESM-I

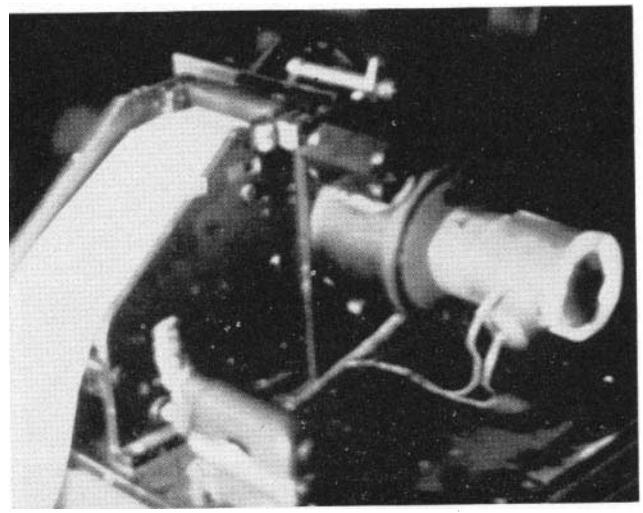

FIG. 7. Output Printer, BESM-I

BESM-II

This machine is organizationally like the BESM-I and presumably will accept routines which were written for BESM-I (fig. 8). Its construction and circuit technology are different, however. Physically it consists of 24 cabinets each about 3 ft. wide, and about 7 ft. high; this includes the cabinets for the four tape units. Its internal store is initially 2,047 words but will be expanded at a later date to 4,095; it is a word-organized end-fire design (fig. 9). The cores themselves are 1.4 millimeters outside diameter, and each plane is 128 × 48. There are 16 such planes in the store. The store is designed with 48 bits per word, although only 40 of these are required by the machine. The cycle time of the store is 6 microseconds, although the basic cycle time of the machine is 10 microseconds; this is a carry-over from the design of BESM-I where 10 microseconds were required for a cycle of the electrostatic store. Of the 6 microsecond store cycle, 1.5 microseconds are required for address decoding, then 0.6 microseconds for reading.

Two cores are used for each bit. There were three arguments advanced to us for this choice. One was that uniformity of cores was sufficiently bad that only by using two cores per bit could a yield as high as 80 percent be achieved from the core production. The second pos-

FOOTNOTES TO TABLE I

[1] These speeds are quoted with respect to some statistical distribution of instruction types. The particular distribution which is appropriate is not always known. These rates are, as appropriate, three address/single address, fixed point/floating point operations per second.

[2] These speeds usually include necessary accesses to the store, including that for the instruction fetch.

[3] In arriving at these figures, the BESM statistics were used and a factor of 2.5 was used to adjust the single address machines to a three-address basis; floating point execution times were used. These rates are therefore 3-address floating point operations per second. Admittedly, this measure does not allow for sophisticated instruction types (e.g., indexing, buffered input-output), but it does measure the ability of a technology to produce switching circuits in a given speed range.

[4] Does not include LARC, STRETCH, nor machines which are intended primarily for data processing; e.g., 501, 7070.

[5] May be much larger in special cases, as in some data processing applications.

[6] Only one tape unit was seen on the STRELA at the Academy of Sciences Computing Center; four tape units have been reported on other STRELA's.

sibility is that by using two cores per bit the load which the switch core in the end-fire switch must drive is constant; and the third possibility suggested to us was that the second core on each bit provided redundancy in case the first one fractured or failed. The current to drive the switch cores is obtained from large vacuum tubes and, as in the United States design, the core stack is force air-cooled. In order to avoid extraneous ground noises, twisted pair buses have been used.

Between stages of the shift register is a 0.3 microsecond delay line; even so, to shift any number of places less than 16 will require 65 microseconds because of some peculiarity

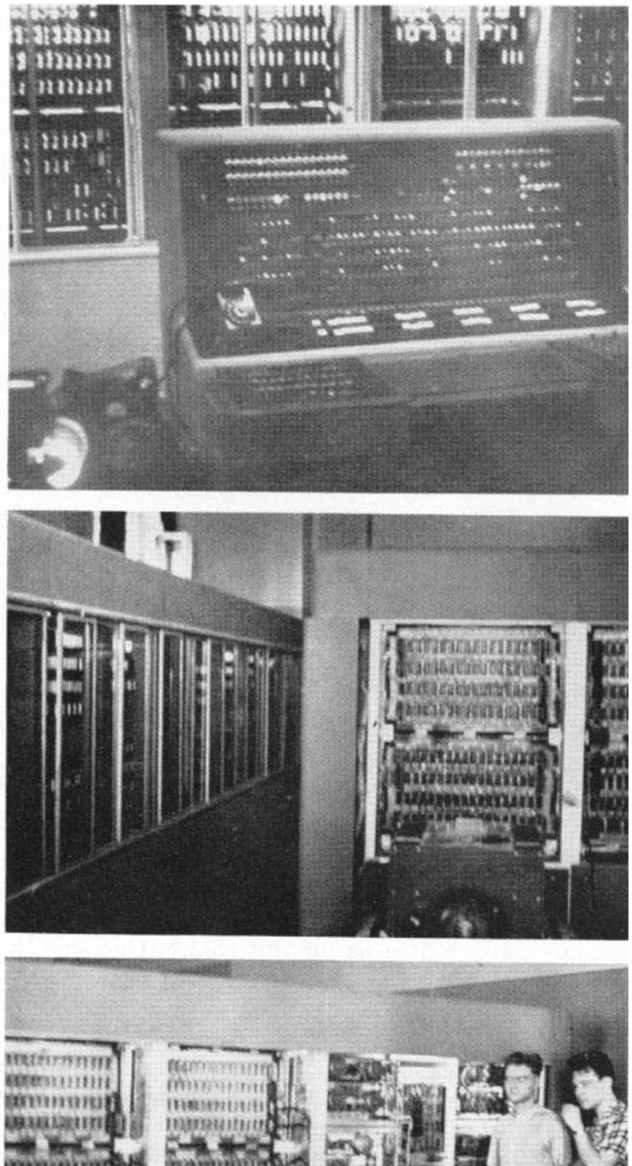

Fig. 8. BESM-II

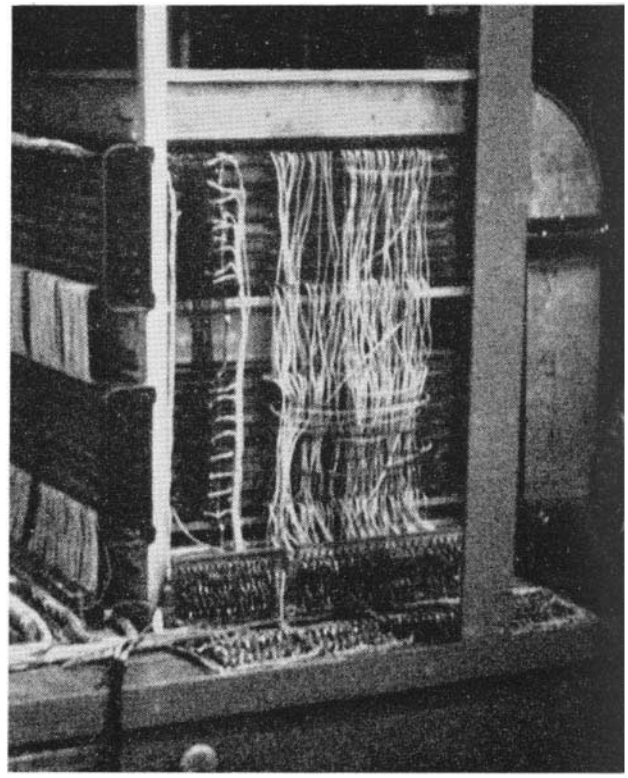

Fig. 9. BESM-II Core Store

of the internal structure. Addition time is 70 microseconds, including 4 accesses to the store; multiplication and division are each 230 microseconds, including accesses to the store. The word format is 32 bits plus sign for the mantissa, and 5 bits plus sign for the characteristic.[17]

There are two magnetic drums of 6,000 words each and four magnetic tapes of 30,000 words per tape. As in Besm-I, the magnetic tapes have two tracks and move at 2 meters per second. One track is for information and the other for timing signals. Starting and stopping is done at the reel, which implies that these units are efficient only for transferring large blocks of information; 1.5 meters of tape is allowed between blocks of information and the designers felt that they could guarantee interchangeability of tape between transports. Tape density is 7 to 8 bits per millimeter, and the method of recording is discrete pulses on a saturation bias background. A modulo 32 count of the number of words transferred is automatically made for tape records and blocks of drum information. This count is stored in a special 5-bit counter which can be addressed by the routine and therefore used to verify that the correct number of words has been transferred.

Germanium diodes have replaced the vacuum tube diodes of Besm-I. The new style of pluggable unit construction does not use printed circuits in the model which we saw, but it is expected that printed boards will be used in the production model of this machine (fig. 10).

[17] While this accounts for only 39 bits, the store was definitely reported as having a 40-bit length. There may be a parity check.

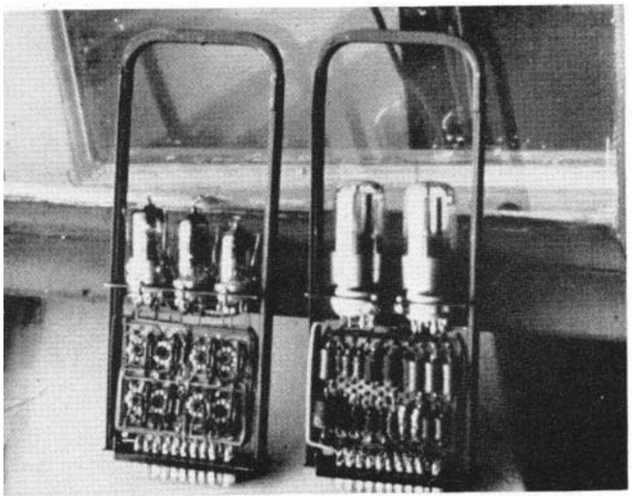

FIG. 10. Pluggable Packages, BESM-II

At the time we saw the machine it was in the final stages of debugging. We were told by Dorodnitsyn that it would be fully operational in June 1959. Miscellaneous remarks led us to believe that some amount of production time has already been realized from this model, and that routines for it have probably already been checked out. The decision has been made to place this machine in serial production.[18] The location of production was unspecified, although it was thought that it would probably not be in Moscow or Penza, but might be in Siberia. The size of the BESM-II production was suggested to be a few tens of units.

There were three independent groups of engineers working on the BESM-II. One of these was from Lebedev's Institute, which is responsible for completing and debugging the machine. A second group was from the Computing Center which will have to maintain it; and the third group was from the Georgian Academy of Sciences at Tbilisi, which apparently is scheduled to either get or to build a BESM-II.

In debugging this machine, test routines and marginal checking are being used. There is manual control permitting ±10% variation in all voltages. Design tolerances are ±10% on the 6 volt heaters, ±4% on the negative bias voltages, and ±2% on the positive supply voltages.

We were told that the design of the BESM-II had been completed in a few months and that the biggest job which faced the Institute was not that of completing the machine, nor of designing it, but rather the time of preparing production drawings for the factory.

The BESM-II is designed for a different final checkout procedure than is common in the United States. One complete machine is assembled at the factory and thoroughly checked out. Since each cabinet of the machine consists of several removable panels (fig. 11), this completed and tested machine is then used as a test device in which production panels are tested in the environment of a completely checked out system. Such a removable panel for BESM-II contains approximately 50 plug-in packages, and is removable as a unit by means of screws. Most of the connections to such a panel are made by plugs, although some signal leads are soldered connections and sometimes also coaxial cable. The intent is to produce the structural frames of each machine, and to hand-inspect them. Panels will be individually tested at the factory in the environment of the previously checked-out and completed machine. A new machine will be assembled for the first time on the customer's premises, and any remaining troubles will have to be dealt with at that time.

[18] The Russians use the phrase "serial production" to indicate that an item is to be made in succession in a production facility. Our term of "mass production" is used to describe the scale of activity concerned, rather than the number of items produced; e.g., production of one battleship would be regarded by them as mass production but not serial production.

BESM-II has punched paper tape input and output. With respect to the statistical weighting of 68% add-subtract, and 32% multiply, the BESM-II operates at 10,000 floating-point 3-address operations per second.

URAL-I (Figs. 12, 13)

A 19-column rotating wheel printer is in production for URAL-I. Its speed is 100 lines per minute, and the printing mechanism includes a facility for suppressing printing in any desired column. The URAL-I magnetic tape contains six channels, three of which are used at a time to read the 12 lines of information required for the 36-bit word. There are 104 words per meter, which implies that the recording density is 1,248 bits per meter. The linear tape

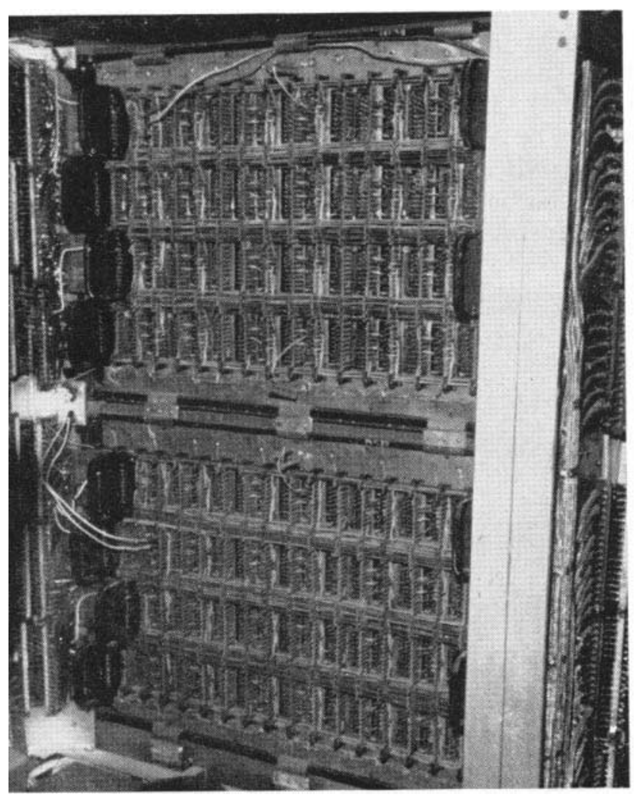

FIG. 11. Rear Panel Wiring, BESM-II

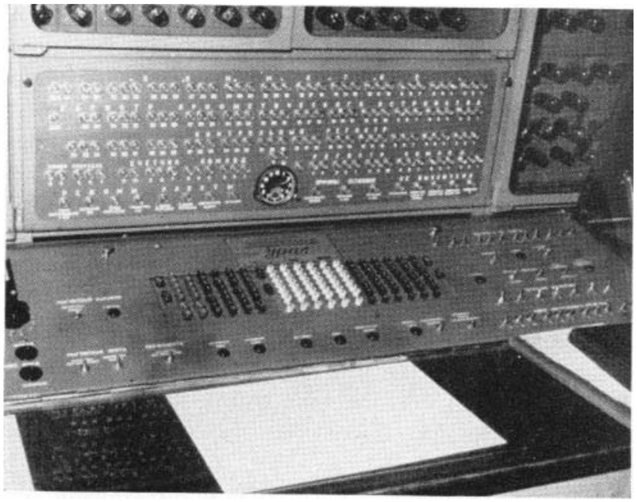

FIG. 12. Console, Ural I

speed is 0.75 meters per second resulting in a transfer rate of 75 words per second.

Characteristics of the URAL-I are summarized in table I. Appendix I gives the instruction repertoire of this machine.

URAL-II

This machine has a 200-kilocycle clock rate, compared with the 7-kilocycle rate for URAL-I. In addition, it is a floating-point, parallel machine, constructed of germanium diodes and vacuum tubes. It contains several new instructions, including those for floating-point. It contains error-checking, including automatic computation of check sums for input-output devices. Other possible input devices mentioned were punched cards (300/min), communication lines, and random number generators. The usual output devices will be a printer and card punch (100/min). The printer is numeric only, 20 lines/sec, and can be either 16 or 96 columns. Connection between the URAL-II and its input-output devices is through the arithmetic unit, where a check sum is formed on every 100 words. A special selection word using a separate bit per input or output device allows up to 12 input devices and 12 output devices without the need for a decoder. Information can be transferred to several output devices simultaneously.

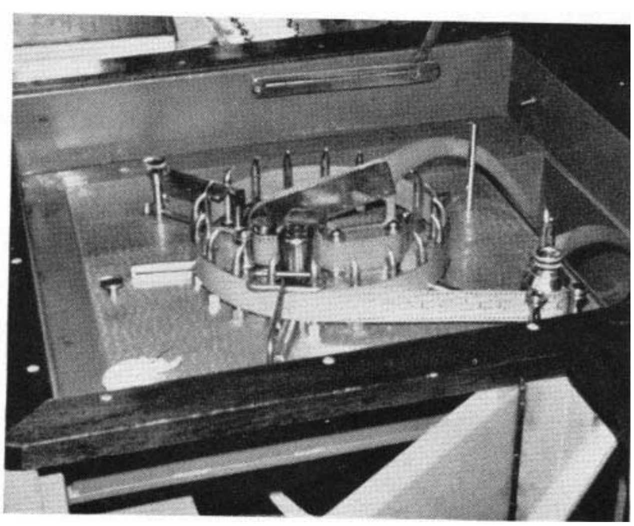

FIG. 13. Perforated Film Unit, URAL I

The storage hierarchy in URAL-II is a 2,048-word core store (12 μs cycle), an 8,192-word drum (maximum of 8 drums), and magnetic tapes of 700,000 words each up to a total of 5 million words. Each of the 20 planes in the core store consists of four 16 x 16 arrays assembled on thin plastic frames ($\frac{1}{32}$ in. × 4 in. × 4 in.). The store operates in a coincident current mode, has only one core per bit, and has four sense windings. By selecting two Y wires and one X wire, two bits are read out from the 64 x 64 plane at a time. It therefore can be thought of as 4,096 20-bit words, or 2,048 40-bit words. They achieve a 50% yield on cores made at the factory. Core windings are soldered to a mounting wire which is held to the frame by being threaded through a pair of holes. Special test equipment is available for cycling the store through special patterns. Drive current tolerance is ±30%.

The punched tape input and output is similar to that of URAL-I. Continuous loops of perforated 35mm movie film are read at the rate of 150 numbers/second (1.5 meters/second linear motion). The reading device uses photo diodes. The tape has eleven channels, and one word is written across it in parallel; decimal digits are written along the tape in 8–4–2–1 code. A special nine-column decimal keyboard is used for tape preparation. Normally a URAL-II has one punch station but two readers which operate in parallel to compare 200 numbers per minute.

The URAL-II magnetic tape is also similar to that of URAL-I. 35mm film is used as a base for the magnetic medium, and punched holes mark the records. The tape reads 1,000 words/second at a linear tape speed of 1.5 meters/second.

The word format is: 8 decimal digits plus sign for the mantissa (33 bits), and 6 bits plus sign for the exponent. The range is therefore $\pm 1 \times 10^{\pm 19}$, and the word length is 40 bits. Based on the statistical distribution of 17% add-subtract, 3% divide, 17% multiply, 33% transfer, and 30% other operations, the speed of the URAL-II is 5,000 operations/second.

The URAL-II instruction repertoire is given in Appendix II.

STRELA

This machine (fig. 14) was designed by an industrial construction bureau and serially built at the Moscow Computing Machine plant; it is now referred to, because of its age, as the "Old Woman." It is a big machine and uses specially designed electrostatic tubes in the store. The cycle time of the barrier grid store is 500 microseconds, and 27 points are regenerated between consultations. One STRELA had five card readers and two card punches,

[19] See: *High-Speed Computing Devices*, ERA STAFF, McGraw-Hill, p. 84. Also: *Annals of the Harvard Computation Laboratory*, Vol. 27, p. 145.

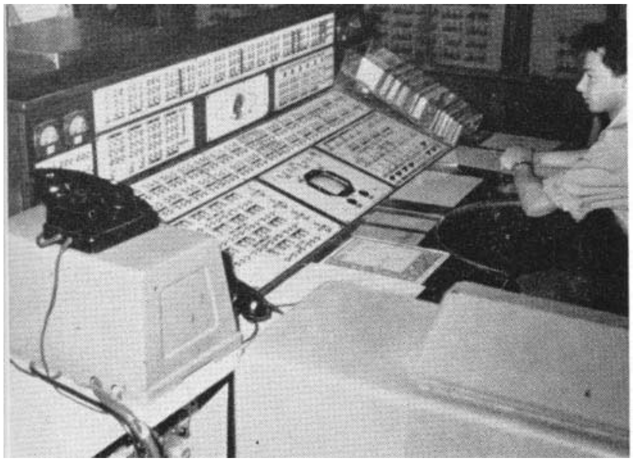

FIG. 14. Console, STRELA

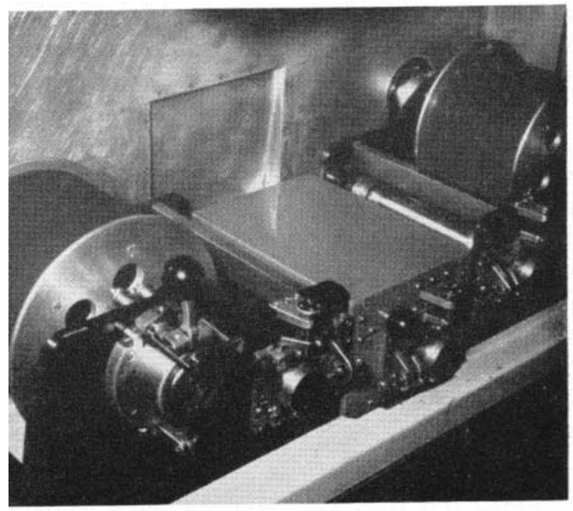

FIG. 15. Magnetic Tape Unit, STRELA

while a second STRELA had only one of each. The machine at the Computing Center operates seven days a week and requires a maintenance staff of three engineers per shift. About 18 hours per day of useful running time can be achieved; 3 to 4 hours per day is devoted to preventive maintenance, and the balance of the day is unscheduled maintenance. This machine was designed in 1948, although the installation at the Academy Computing Center was not made until 1957. The precise number of machines manufactured is uncertain but it was suggested that at most a few tens had been constructed.

The STRELA tape unit is approximately 4 inches wide (fig. 15). A word is written in parallel across the tape which is recorded at a linear density of 2.5 bits per millimeter. The reading rate is 1,000 numbers per second, and reading is in terms of a block. For reliability great emphasis is placed on programmed check sums.

The STRELA, like the BESM-I, also has some interchangeable wired subroutines which can be used for such things as sine, logarithm, etc. It also has about 10 groups of stored constants of 16 bits each. The card readers and card punches were quoted at about 60 cards per minute.

The inadequate reliability of the STRELA store leads users to program check sums into their problems. There is some possibility that a core store may be retrofitted to this machine.

SETUN

This base-3 machine being constructed at Moscow State University appeared to be in operation when we saw it (fig. 16). It was explained that the choice of base-3 was made because it can be shown that in some sense a base of 3 provides the most efficient utilization of equipment.[19] Since a base-3 electronic technique is not available, they decided to construct a base-4 machine and to utilize only 3 of the 4 possible states. The unused 4th state in each case is available for some form of checking. This machine is regarded as experimental, and as an educational training program for engineers. In part they felt that SETUN was a protest against the huge, complicated machines being built elsewhere. It was thought easier to operate a simple machine at their center. The machine contains 4,000 magnetic cores, 4,000 germanium diodes, approximately 100 transistors, and 40 vacuum tubes. It operates at a 200-kilocycle clock rate. It uses 1 MC transistors which are rated at 150 milliwatts dissipation at 25 degrees centigrade, but can tolerate a maximum of 100 degrees centigrade.

SETUN has only 81 words of storage and 27 different instructions. It is a single-address, fixed-point machine, with 18 ternary digits per word. The point is fixed between the second and third digits from the left. It is serial and contains two instructions per word. There is no divide instruction.

The ferrite core store can be regarded as having 162 9-digit words because the half-words can be addressed. The drum store contains 2,268 half words. Number representation of SETUN requires 2 binary digits per base-3 digit; therefore, a 9-digit, base-3 word, will require 18 tracks on the drum. There are three such groups of 18 tracks on the drum, or a total of 54 heads. In each band of 18 tracks there are 756 words recorded in parallel;

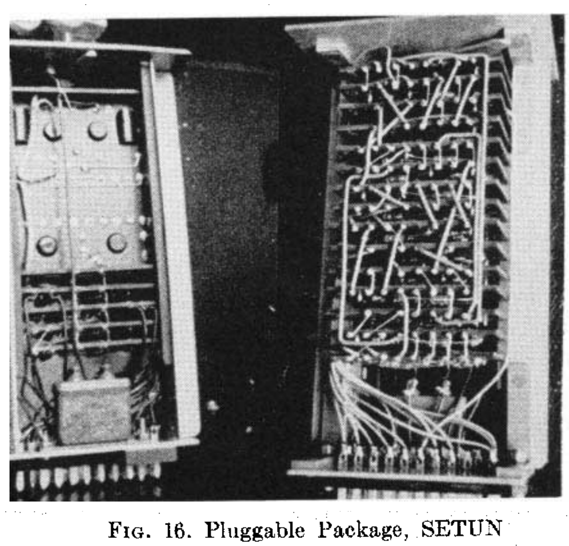

FIG. 16. Pluggable Package, SETUN

there are thus 756 bits around the 13-inch circumference. It is planned to add magnetic tapes to this machine at some later date.

Addition time is 180 microseconds, including all accesses. Fetching of the next instruction is overlapped with execution of the previous one. Multiplication time is 335 microseconds, and transfer of control is 100 microseconds. Setun includes a normalizing instruction (shifting operations to facilitate programming of floating-point), one index register, and teletype input and output. The German type RFT teleprinter is partially base-9 and partially base-3. A 9-digit word is printed as two base-9 digits, then one base-3 digit, then two more base-9 digits. The characters used are:

Base-9	ᔭ,Ɛ,Ƨ,I,0,1,2,3,4
Base-3	i,0,1

Five-level punched paper tape is used for the input and output.

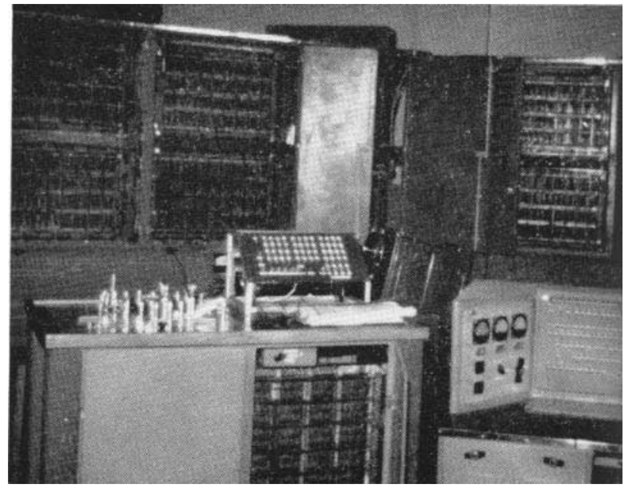

Fig. 17. General View, KIEV

KIEV

This machine is expected to be completed by December 1959; a substantial part is already operational (fig. 17). It is in five cabinets in a semi-circular arrangement and requires a floor area of approximately 20 × 35ft. It is truly asynchronous and operates at a speed of 5,000 to 6,000 operations per second. It uses static flip-flops, but diode-transformer gates. Pulse sources are blocking oscillators having two independent transformers in the plate circuit. One is for the regeneration required by the blocking oscillator itself; the other, for driving the output. The machine has arithmetic, logical and block-transfer instructions, is binary and has a word length of 40 bits. The arithmetic unit is capable of adding, shifting, multiplying and dividing.

The principal store is a 1,024 word ferrite store of the end-fire Besm-II type.[20]

The store is autonomous, and has separate checking, which suggests that there may be a wired-in independent test routine. There is also a 512-word read-only store which is based on a transformer technique; its read time is approximately 3 microseconds. This passive store, when expanded to larger size, will contain the automatic program and the binary-to-decimal and decimal-to-binary conversion routines. There are also 8 words of storage which can be set from switches. There will be 3 drums of the same type as the Besm-II; only one is presently installed. At the moment the input and output is paper tape.

There are seven types of standard circuits in this machine. Each cabinet of the machine contains its own power supply. Because of this modular construction and the truly asynchronous organization, it was observed that expansion and modernization is very simple. It was also stated that convenient marginal "conditions for prophylaxis" exist. An improved version of the Kiev machine is under way, and we noticed a substantial amount of Besm-II type equipment on hand for this purpose. In the modernized version, arithmetic operations might be automatically repeated under marginal conditions and the result compared; this is a type of checking being considered.

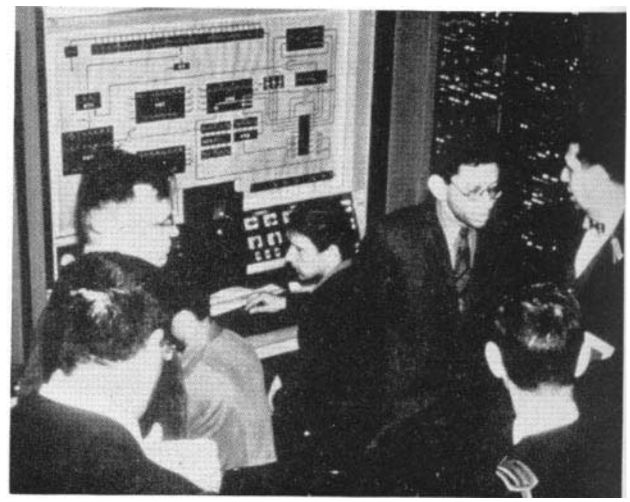

Fig. 18. General View, SESM

SESM

This machine (fig. 18) is a special-purpose digital computer which is intended to solve sets of linear equations of orders up to 120. The design is expandable to orders of 480 and is based on the Gauss-Seidel iteration technique. The solution time depends on the number of zero elements in the matrix and on the distribution of these elements. For an 18 × 18 matrix which was rather ill-conditioned, a solution had been achieved in 148 iterations and about 2 hours. A rough rule of thumb[21] for the time in seconds required for one iteration is: the number of non-zero elements divided by 20.

[20] This particular type of store is frequently referred to in Russia as the "Z" system.

[21] This rule-of-thumb does not agree with the previous example, but these were the data that were collected.

The input is presently punched paper tape at a rate of 27 decimal digits per second; the speed at which the machine can achieve a solution is limited by this device. The output is on an adding machine-type printer. The SESM was conceived by Lebedev, but designed and constructed by Rabinovich. A magnetic drum contains 34-bit recirculating registers for arithmetic purposes. The recording density is 3 bits per millimeter. The internal clock rate is 50 kilocycles.

Special-Purpose Analog Computer at Kiev

This machine was designed to analyze the stresses in three-dimensional rigid structures. It was conceived and constructed by Professor Pukhov. It consists of three panels, each of which has 48 potentiometers arranged in six rows and eight columns. These are used to represent the elastic constants of the bars. Up to 18 flexible rods and 9 rods in torsion can be accommodated in the model. This machine uses all passive elements, operates on D.C. and achieves approximately 5 per cent accuracy. It can also be used to give dynamic solutions, although normally it is used for static solutions. It provides three-dimensional solutions, rather than the two-dimensional ones obtained by other workers. They are planning a new desk-size machine of similar kind, capable of accommodating 70 rods.

MN-M *and* MPT-9 *Analog Computers*

These two machines (figs. 19, 20) are well-known and have been exhibited at various trade fairs and exhibitions. No new information about their capabilities was obtained.

M-20

In deference to Academician Lebedev's desire to have the first publication of M-20 details appear in the Soviet literature, the delegation has agreed to withhold publication of information about this machine until the Russian paper appears. Data on this machine will be published later as a supplement to this report.

ARAGATS, RAZDAN, YEREVAN

These three machines are under development at the Institute of Mathematical Machines in Yerevan, Armenia.

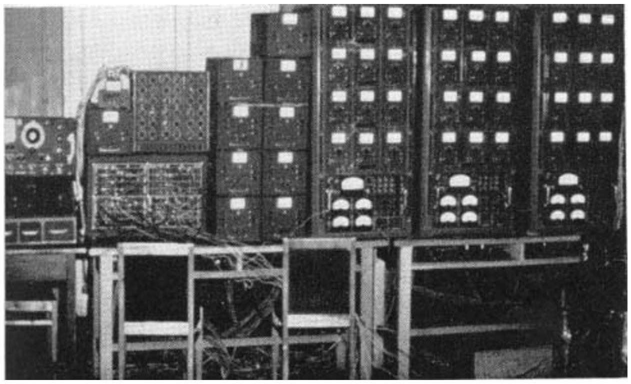

FIG. 19. MPT-9 Analog Computer

The delegation was unable to arrange a visit to this facility although S. N. Mergelyan, when visiting the United States, gave some details of these machines. The ARAGATS, based on a statistical distribution of 25% multiply and 75% add, is reported to be a 15,000 operations-per-second vacuum tube machine. One is to be delivered to the Computing Center at the University of Leningrad in approximately one year.

The RAZDAN is to be the first all-transistor machine in the Soviet Union and is to have a speed of from 4,000 to 6,000 operations per second. It was thought by IPMCT workers that all of the circuit development work necessary for this machine would be done at Yerevan and would not draw on the work at Moscow.

The YEREVAN is said to have a highly developed logic and instruction repertoire, although it is the slowest of these machines—2,000 operations per second. It is to be a vacuum tube machine.

These three names are respectively a mountain, a river, and a city in Armenia. According to an article in an American Russian-language newspaper, these three ma-

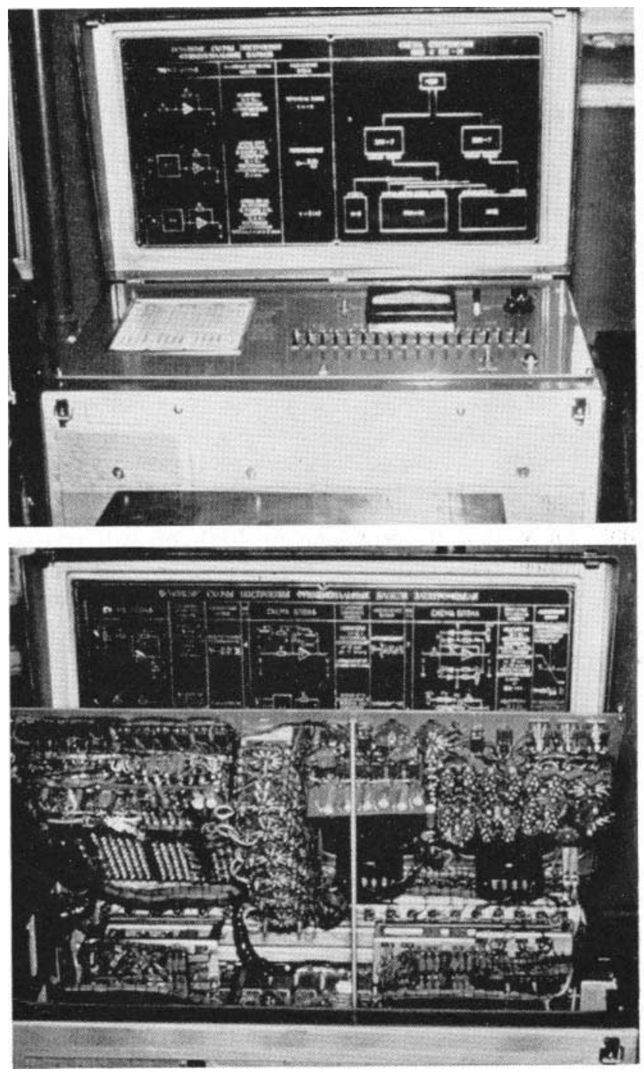

FIG. 20. MN-M Analog Computer

chines are all to be completed in 1959. This same article quoted the addition time of the ARAGATS as 5 microseconds.[22]

LEM-I

This machine was not seen by the delegation, although the Director of the laboratory in which it was built, Professor L. I. Gutenmakher, did meet the delegation and discuss his work at some length. A reference to the machine is included here in order to call attention to the availability of an English translation of an article partially describing the machine.[23]

EV-80

This machine (fig. 21), built in 1950, physically resembles the 604 punched-card calculator produced in the United States. The electronic component is very similar in design, but the card device contains three card feeds, rather than the one of the U. S. machine.

Punched-Card Equipment

Some of the older models of Russian punched card equipment were seen at the Academy of Sciences, Moscow Computing Center. We saw a key punch and a verifier, each of which looked very much like earlier model United States counterparts. We also saw a machine for comparing cards. It operates at 40 cards per minute and at the Computing Center was usually used to compare the outputs of two STRELA runs of the same problem. The tabulator (fig. 22) operates at approximately 100 cards per minute, and has 70 numeric positions for printing. It also has an 8-position multiplier and 80 counter positions. The tabulator uses a key punch as its summary punch. We also saw a card sorter which resembles its United States counterpart and operates at approximately 300 cards per minute.

Test Equipment

In most of the laboratories and computing centers which we visited we saw one or both of two common oscilloscopes. The model IO-4 has a pass-band from 20 cycles to approximately 6 megacycles. It consists of two boxes and usually is mounted on a dolly. The model DESO-1 oscilloscope is a twin-beam unit; one of its amplifiers has a response from approximately 200 cycles to 80 megacycles, and a guaranteed rise time of 15 millimicroseconds, but a gain of only 100. Its fastest sweep is 0.3 microseconds across the face of its 5-inch tube, so that this equipment is capable of resolving approximately 5 millimicroseconds. Curiously, a small voltmeter is included on the front panel to monitor the AC line voltage. We were also told that oscilloscopes with pass-bands of 200 megacycles and a rise time of 5 millimicroseconds were production items. It appeared that their oscilloscopes generally did not have a pass-band down to zero cycles.

Other Machines

A number of other machines, some of them special purpose, have been referred to in Soviet literature and by members of their delegation. Mention of them is made here simply to indicate their existence and the scope of the Soviet computer activity. None of these machines was seen by the American delegation, nor is much information available.

VOLGA	General purpose, not yet completed.
POGODA	Special purpose, weather prediction.
KRYSTAL	Special purpose, crystallography problems.
GRANIT	Special purpose, statistical problems.
M-2, M-3	These two machines are general purpose, and are associated with I. S. Bruk; he is associated with either a different laboratory of the Academy of Sciences or an industrial design bureau.
LUCH	Thought to be general purpose.
M-50	Thought to be in the final stages of design and construction; likely to be a follow-on to the M-20.

General Development of Machines

We accumulated fragmentary information which indicates in part how the Soviet Union controls research. Subordinate to the Council of Ministers is, among other organizations, the Academy of Sciences, GOSPLAN (State planning committees), and the Ministry of Higher Education. Each of these can conduct research either on its own initiative or on request. The work at Moscow State University, for instance, is within the Ministry of Higher Education, while the work at IPMCT is within the Academy of Sciences. The Institutes of the Academy are sometimes specialty-oriented (IPMCT—computers) and sometimes task-oriented (VINITI—information dissemination). In the event that (say) a laboratory of a university and a laboratory of an Academy institute happened to fall into competition in some area, the decision to resolve, to fund, or to control this parallel effort would need to be made in the Council of Ministers.

Decisions related to the production of computers and perhaps to designated research toward new ones are evidently made in the planning committees of GOSPLAN and perhaps in the State Scientific-Technical Committee attached to the Council of Ministers. The personnel of an Institute may participate in the activity of these bodies although the Institute itself does not cast such decisions.

The Institute of Automation and Telemechanics is organizationally in the Department of Technical Sciences of

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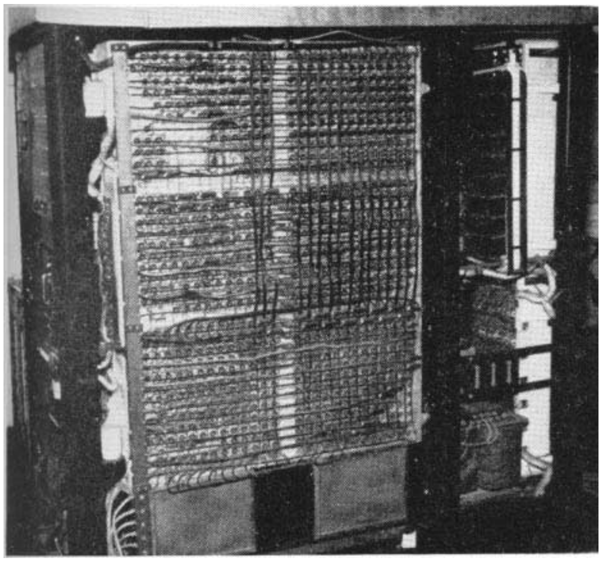
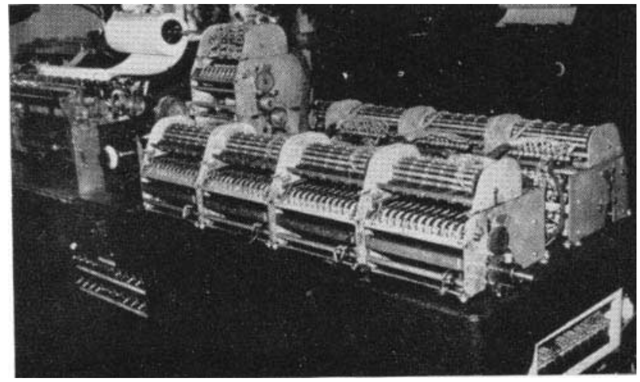
[22] See: *Novoye Russkoye Slovo* for Wednesday, May 20, 1959. The article is a partial reprint of an original article appearing in a Soviet teen-age magazine, *Ogonek*. The information from this source was made available by Mr. Eugene Zaitzeff of the Bendix Systems Division, Ann Arbor, Michigan.

[23] See: *Radio Technika*, No. 3, March 1959, Moscow, pp. 47–57. *Comm. Assoc. Comp. Mach. 2*, No. 10, October 1959. A translation of this article is also available from the United States Joint Publications Research Service, Suite 300, 205 East 42nd Street, New York 17, N. Y. Document No. 705-D.





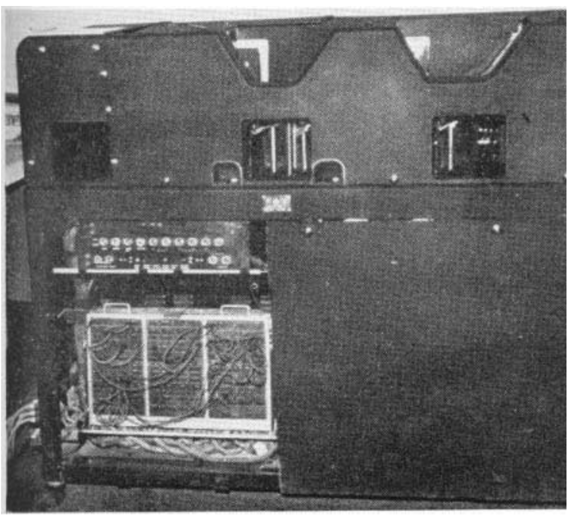


Fig. 21. EV-80

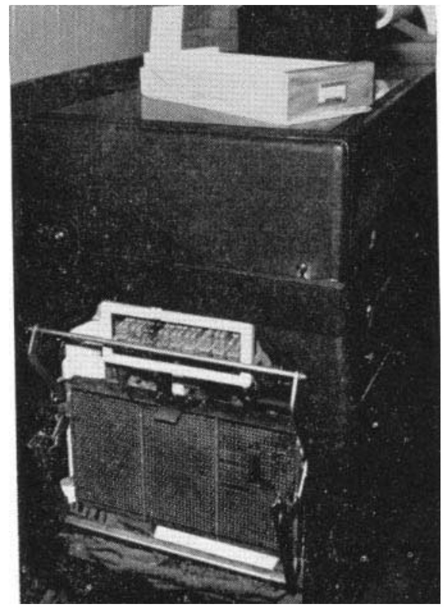


Fig. 22. Tabulator

the Academy; the Steklov Institute and the Moscow Computing Center are in the Department of Physico-Mathematical Sciences. The two universities are organizationally in the Ministry of Higher Education. There are numerous other institutes of these two departments of the Academy, and there are several other departments. In addition, there are research institutes attached to GOSPLAN, to other All-Union Ministries, and to various state committees. It is quite possible that computer developments are in progress in some of these areas; the contacts with the western world in computing matters have been almost exclusively through Lebedev and his Institute.

Applications

Machine Translation of Languages at Leningrad

At Leningrad University a group of 80 people is working on machine translation. This Experimental Laboratory of Machine Translation is headed by Dr. Nicoli D. Andreyev and includes S. Ya. Fitialov of the Leningrad University Computing Center and G. C. Tseiten,[24] a logician. Research on translation by automatic means is also done at three places in Moscow, at Kiev, at Yerevan and at Gorki.

They have separated the problem into analysis and synthesis. Under analysis is included several steps of which only morphology and syntactical analysis have yielded to their studies. Morphology is the identification of a word in a dictionary plus its declension or conjugation; they feel that they have a solution to this. Syntactical analysis is difficult in Russian because the word order is freer than in English.[25] Fortunately, they have found that scientific Russian is not so varied in its syntactical structure, and consequently they feel that they can handle its analysis. Since the other problems of analysis have not been solved, nothing has yet been done on the problem of synthesis.

[24] Name uncertain. This may be M. L. Tsetlin, referred to previously, or it may be G. S. Tseytin.

[25] In addition to translating other languages to Russian, the Soviet research effort also includes the translation of Russian to other languages; hence the great interest in Russian syntax. There is no known research in this country interested in translating English to any other language.

FIG. 23. Professor L. I. Gutenmakher

A conference on mathematical linguistics has been recently held at the University of Leningrad and a Proceedings is expected to be published. The Leningrad group has already published one book on the subject of machine translation and hopes to publish two more in 1959. They also told us of a very complete three-volume Russian grammar which has been published by the Soviet Academy of Sciences.

Machine Translation of Languages at the Institute of Precise Mechanics and Computing Techniques

The language translation work at this Institute began in 1954 and an algorithm adequate for initial experiments was completed by May 1955. For the first experiment on BESM-I, three English books of 400 pages each were analyzed and a dictionary of approximately 2000 entries was hand compiled. The algorithm for this experiment contained approximately 12,000 3-address instructions. In this first experiment the machine routine and the vocabulary were contained in the magnetic drum and tape stores.

Their English dictionary has grown to approximately 2500 entries and each experiment processes approximately 2000 sentences. An algorithm exists for analysis of English grammar and they have developed a dictionary for the Chinese-Russian work. The Japanese-Russian work is just starting, but a dictionary for words having a single meaning and the analysis algorithm already exist. The groups working on the various languages work separately but exchange their ideas and techniques freely.

The IPMCT group presently feels that a dictionary of approximately five to six thousand entries of technical terms is sufficient for one complete area such as mathematics. They also feel that approximately 45 percent of the content of a technical article will be words not peculiar to the technical area. Therefore, a total dictionary of approximately 10,000 entries is felt to be sufficient for most work. They anticipate that for some time as much as five to ten percent of the words in a new article will not be found in a dictionary of this size.

Although their initial work used "binary" algorithms which proceed directly from the source language to the target language, they now feel that it is desirable to translate the source language into an intermediate language from which an exit to any desired target language can be made. In this connection Mrs. Nikolayeva and Bobitskiy[26] are attempting to construct algorithms for translating Russian into an intermediate descriptor language. Such an intermediate language would establish for each word in the source material a set of descriptive characteristics which define the use of the word and its context. In this connection their sentence structure analysis algorithm first identifies the stem of each word and then identifies any endings, prefixes, etc., which may be present. The next step of the algorithm identifies clauses, phrases, and word groups and also tries to resolve these structures. By consulting the dictionary at each step they also establish grammatic features for each word. So far, very little progress has been made in constructing the synthesis algorithms which reconstruct the material in any desired target language.

Present experiments still use the BESM-I, which is a limiting factor. The lack of alphabetic input-output facilities on this as well as on other machines is a serious limitation to actual machine verification of the algorithms. N. L. Korolev, who took part in the early experiments, indicated that he felt a special machine for language translations might be about as follows:[27]

(1) An input character reading device based on some simple logic.

(2) A large read-only store of perhaps 100,000 words for the dictionary and a large part of the routine.

(3) A small internal operating store of perhaps one or two thousand words.

(4) Simple logical instructions not necessarily including alpha-numeric capability. The logic would probably use a Boolean algebra of two arguments.

Some of the algorithms which have been written utilize tables. In particular, the IPMCT group uses an idiom table and marks any word which might be part of an idiom. Preposition tables which relate classes of words to meanings of prepositions are also used.

Information Retrieval

The Laboratory for Electro-Modeling, directed by Professor L. I. Gutenmakher (fig. 23), is approximately 21 years old, having first been organized in 1939. At that time the function of the laboratory was the analog modeling of physical phenomena. In 1945 the goals of the laboratory were redirected, and in 1953 the most recent objectives

[26] This may be Barbitskiy.

[27] The LEM-I at Gutenmakher's Electro-Modeling Laboratory has many of these features. It may be an experimental special machine to test language translation concepts.

FIG. 24. Kovalevskiy and the Experimental Character Reading Device

were stated to be the modeling of mental processes and of the brain. The first efforts will be directed to mechanizing such logical mental processes as reading and abstracting. At present, this Laboratory includes the following groups:

1. A logical-mathematico department.
2. A mathematical linguistics department.
3. A department of mechanical methods in chemistry.
4. A department of storage devices.
5. A department of permanent and erasable stores.
6. A department of machine elements.
7. A department of machine exploitation.
8. A department of analog electrical modeling.

Professor Gutenmakher felt that the problem of mechanizing automatic abstracting consisted of three parts: first, obtaining visual characters in some coded form; two, storing this information in some efficient form; and three, forming the abstract, which is thought to be the most difficult part. He felt that special purpose, rather than general purpose, machines are desirable. For this reason the LEM-I machine was constructed to test components developed in this laboratory and to investigate some techniques for information retrieval, and perhaps machine translation.

This Laboratory has developed a form of read-only store which utilizes sheets of paper on which have been printed small capacitors.[28] It was stated that 100,000 bits of this capacitor storage is now operating in the laboratory and that the store is now ready for production by industry. In this store, data is retrieved on the basis of a descriptor, rather than on the basis of a direct address. Thus simulation of the characteristics of such a store on a conventional general-purpose machine is difficult and ineffective for their experiments. Although the store responds to a descriptor rather than an address, it still contains a fixed word length for each descriptor. Professor Gutenmakher indicated that his laboratory is working on algorithms and equipment for information retrieval and that it has already developed an algorithm for describing an associative store; this algorithm resembles those which are being developed for machine translation. This Laboratory is also independently developing magnetic elements for their special machines. Magnetic elements will be used because of the requirement for reliability.

The work of the Laboratory for Electro-Modeling appears to parallel the work in the United States on the use of heuristic techniques in information processing. Professor Gutenmakher felt that what he called the associative technique was another way of describing the heuristic approach. He also indicated that they have now given up trying to describe the activity of mental processes by partial differential equations.

Rakov, a colleague of Gutenmacher's, has constructed a punched card information retrieval system which can scan 400 abstracts per minute. Each card in the file has from one to 24 descriptors associated with it.

Apparently the Laboratory for Electro-Modeling at one time was organizationally part of the Institute for Precise Mechanics and Computing Techniques, but was transferred to the Institute for Scientific Information. It is uncertain whether the laboratory still has this status or exists as an independent organizational entity in the Academy of Sciences.

Character Recognition

Work on character recognition is being done at the Institute for Precise Mechanics and Computing Techniques, but there was no discussion of this subject. At the Steklov Institute, Dubinsky is working on the idea of drawing a series of parallel lines through a line of print and then attempting to identify the characters by examining the intersections of the series of parallel lines with the letters. We did have an extensive discussion about the character recognition research at the Computing Center at Kiev.

One technique was demonstrated and discussed by Kovalevskiy (fig. 24) and Pukhov. The technique is an edge-tracing scheme in which the beam of a cathode ray tube scanner moves either clockwise or counter-clockwise depending on the output of a photo cell which views the reflection from the 1-inch-high character under test. The scan is arranged so that after it has moved 0.1 inches in a straight line, it seeks to determine whether it is in a black or white area. If black, the beam turns perpendicularly in a counterclockwise sense and continues to scan for another 0.1 inches. If white, the beam turns perpendicularly in a clockwise sense and scans for the next 0.1 inch. Therefore, the beam tends to follow the outline of the character. In order to assure stability of the edge-following, the scan is arranged so that if a transition from black to white occurs in the first half of a 0.1-inch increment, the length of the

[28] See: (1) *Comm. Assoc. Comp. Mach. 2*, No. 6, June 1959, p. 11. (2) *Avtomaticheskoye Upravleniye i Vychislitenaya Tekhnika*, Moscow, 1958, p. 136. Available, translated, from U. S. Joint Publications Research Service, 205 East 42 Street, Suite 300, New York 17. JPRS: L-871-N, 50 cents. (3) *American Documentation*, Vol. 10, No. 1, January 1959, p. 13ff. Contains pictures of the storage device.

next increment is made shorter. On the other hand, if the transition from black to white is found in the second half of the step, the following increment is made slightly longer. It is intended that the pattern information generated by this scan will be stored in a computer and from it will be computed the average direction of the line, quantized to the nearest 45 degrees. It is believed that a sequence of such quantized line directions will then characterize each character. When the scanning reader is actually connected to a computer, it may be necessary for the computer to control the motion of the scanning beam on the basis of previous history.

A more elaborate concept suggested by Glushkov involves the scanning of a square in order to determine its average darkness. The beam would be programmed to scan adjacent squares in order to determine the direction of maximum darkness and to move in that direction. The associated logical equipment would store this direction and control the motion of the beam accordingly. The direction and curvature of motion would then be computed using first and second differences. A large change of direction would indicate that such an inflection point should be recorded. If necessary, a coarse measure of length, such as short, average or long, will also be computed for each line segment. It is hoped that from such a scanning scheme, a set of invariant characteristics can be determined for each character. Initially they intend to utilize approximately 50 words of storage and it was thought that the associated logic would be constructed in terms of inexpensive magnetic core components.

Theory of Human Memory

Linkovsky (fig. 25), an engineer who has worked in both applied and pure mathematics, formulated a theory of the memory function in the human brain several years ago.[29] He conjectures that the memory function of the brain is supplied by a collection of nonlinear oscillators. Experiments have shown that there are two autonomous memory systems possible, one of which preserves the pulse amplitude as it is (relative memory), and the second of which quantizes the height (absolute memory). He believes that the memory function in the brain is of the absolute kind. He argues that a nonlinear oscillator can operate in two fashions: relatively by integrating sets of pulses or, absolutely, by merely repeating any pulse form which comes to it. Such an oscillator will oscillate if the duration of the excitation pulse τ' is less than the lag time of the circuit τ in the following equation:

$$x(t) = A[x(t)]\, x(t - \tau),$$

and if A is of the proper form. For A of the form

$$A(x) = \sum_i a_i x^i(t),$$

FIG. 25. G. B. Linkovsky

the system will oscillate if the initial value is a solution of the equation

$$A(x) = 0.$$

Initial values which are step functions of a size equal to the real roots of the polynomial equation

$$A(x) = 0$$

are solutions. Further, combinations of such pulses of height equal to the real roots will also be solutions.

A pulse consisting of the sum of three pulses of durations τ_1, τ_2 and τ_3, and each of whose amplitudes is a solution of $A(x) = 0$, will be remembered so long as

$$\tau_1 + \tau_2 + \tau_3 < \tau.$$

In this context, the roots of A(x) are essentially eigenvalues. For a discrete delay line of the type which this theory postulates, only signals of eigenvalue amplitude can be accommodated. Therefore, the quantized and stored wave shape cannot degrade with time except through accidental discrete jumps, which means that the memory function is very reliable. As the polynomial A(x) degenerates to a constant, the system becomes the conventional delay line capable of storing a signal of any amplitude, and therefore representing absolute memory.

Linkovsky estimates that the nervous system has 14×10^9 such nonlinear oscillators. Each sense organ quantizes the information which it receives into pieces that can be remembered. A signal whose duration is greater than the maximum permitted by the eigenvalues of the polynomial A(x) is automatically distributed over several such memory oscillators. He believes that a repeated stimulus can cause static changes to take place in nerve cells and therefore some parts of the brain may have static memory; the brain as a whole, however, exhibits both static and dynamic memory. He concludes that since natural systems tend to be discrete and that since his theory can explain a discrete memory, the natural system may be a complete system of memory. His belief is that the nerve fibers form feedback loops and with the synapses permit the nonlinear oscillations.

[29] The journal containing this work is uncertain. It may be the *Memoirs of the Popov Society* or the *Journal of the Institute of Biophysics*; publication may have been in 1955, or may not yet have occurred.

Weather Forecasting

At the time of our first visit to BESM-I, a weather problem was on the machine. The particular model in use had been developed by Dr. Bugaev, the Director of the Weather Forecasting Institute in Moscow. The model uses 500 lattice points and is for the northern hemisphere. It predicts the pressure and vorticity pattern of the 500-millibar level. Twenty minutes of machine time is required for a 24-hour forecast.

Digitally Controlled Machine Tools

In the STRELA location at the Computing Center of the Academy of Sciences in Moscow, there was a unit capable of providing X, Y, and Z coordinates for positioning of a machine tool. Simple parabolic interpolation is used but the overall accuracy of control is limited by the machine rather than by the computation. It has not yet been decided whether all of the tapes necessary for industrial use will be computed at a central location, or whether each plant will contain its own computation facility.

Automatic Programming[30]

The first automatic programming system for the STRELA was completed in 1955. In 1956 one was completed for the BESM-I, and in 1957 one was completed for the STRELA-III at the Academy of Sciences Computing Center. Finally, in 1958 an automatic programming system for the STRELA-IV at Moscow University was completed. Each system required approximately nine man-years of effort. The lack of alpha-numeric input-output devices has handicapped Soviet progress in this field.

Interchange of routines for the STRELA machines has been difficult or even impossible because each installation has changed the machine to suit itself. The same situation also prevails for a number of URAL-I machines. Therefore each center has had to construct its own automatic programming system. Some people in the Soviet Union feel that it is not yet time for them to standardize on a machine language. Their intent is to design many computers and to produce enough of each one to accumulate a substantial body of experience. In perhaps five years, they believe it will be possible to select the best one for large-scale serial production. Meanwhile, translations of United States papers dealing with FORTRAN, FORTRANSIT, UNICODE, IT, and ALGOL are being prepared and disseminated to interested users.

Orbit Calculations

Preliminary orbit computations have been done at the Computing Center of the Academy of Sciences in Moscow, although final calculations are done elsewhere. These calculations were done on existing serially produced machines rather than on machines constructed especially for the purpose; however, the machines are specially organized.[31] There are special organizations which perform the orbit calculations, although the Steklov Institute is sometimes involved in the preliminary design of the computing routines.

Some orbit calculations apparently have also been performed by Shura-Bura at Moscow University Computing Center, although they are concerned about the accuracy of the calculations and insist that only radar data is available as input. There was considerable interest in the question of the transmission of data over long distances.

Linear Programming

A particular transportation problem was described to us. It involved the distribution of building sand by a fleet of trucks operating from eight sources and delivering to 100 sites in the Moscow area. The problem was first solved by the Simplex Linear Programming method and required approximately three hours on STRELA. A new method was evolved which produced a solution in approximately 30 minutes. This work was done jointly by the Computing Center and the Institute of Complex Transport Problems; the actual work on the 8×200 matrix was done by Yu. A. Oleinik. A paper on this new technique is in process. Some linear programming work is also being done for the Institute of Railway Transportation Problems.

Numerical Analysis

Although work on electronic computers started in the Soviet Union a few years later than in the United States, the Russians have a long established tradition of outstanding work in numerical analysis. This is due partly to the strong development of applied mathematics. The Soviet Union is currently making a strong effort to foster numerical analysis as a part of the intensive development of computing. Approximately 40 percent of the mathematical students at Moscow University specialize in numerical analysis, although the Chair of numerical analysis is only four years old. This was achieved in part by raising the stipend for students in numerical analysis and by lowering the academic requirements for maintaining this fellowship.[32] All mathematics students, regardless of their specialization, are required to take courses in numerical analysis and programming and to have some practical experience with computing machines.

The quality of the work in numerical analysis in the Soviet Union is impressive. The group at the Academy Computing Center has been applying a method originated by Dorodnitsyn for solving boundary value problems in difficult configurations. The method consists of replacing the partial differential equation by a system of ordinary differential equations. While restricted to two-dimensional problems it is applicable to a wide class of linear and non-

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[30] See: (1) *Comm. Assoc. Comp. Mach. 2*, No. 6, June 1959, p. 11 ff. (2) Status of Digital Computer and Data Processing Development in the Soviet Union, *ONR Symposium Report*, ACR-37. (3) *Datamation 5*, No. 4, p. 14.

[31] This may imply special input-output devices, or it may imply a group of machines netted by communication links.

[32] These special inducements for students in numerical analysis have recently been abolished.

linear situations. In the detached shock wave problem, Dorodnitsyn's method appears to be the only approach in which the solution starts from the geometrical outline of the given body rather than from an assumed shock wave front. The method is semi-empirical, and complete theoretical justification of the method has been sidestepped in favor of the achievement of practical results.

At Moscow University the research in numerical analysis centers in Lusternik, Berezin, Zhidkov and Sobolev. In Leningrad, Ladyzhenska has developed a method for solving differential equations using large steps while simultaneously achieving small errors. Kantorovich, who is one of the discoverers of the linear programming technique, is going to the Novosibirsk Scientific Complex, where a strong development in computational mathematics is expected. Russian work in numerical analysis is published in a special journal.

The Russians seem to have succeeded in attracting more of the powerful theoretical mathematicians into numerical analysis and computational mathematics than has the United States. The intellectual climate in Russian mathematics makes it easier for an abstract mathematician to make valuable contributions to applied problems. Related fields in mathematics, such as game theory and cybernetics, were at one time under a cloud of ideological suspicion, but this has now been removed and many prominent Russian scientists are entering these fields.

Circuits and Components

Thin Films

The development of thin film magnetic devices appears to be in its early stages. We were shown experimental vacuum evaporated deposited film samples on glass plates. These films were circular in shape, had been deposited at a pressure of 10^{-4} to 10^{-5} millimeters of mercury at a temperature of 200° to 500° centigrade and were permalloy (80% nickel and 20% iron). The films were from 500 to 2000 Å thick and exhibited an exceptionally square hysteresis loop. They ultimately hope to achieve a switching time in the order of 20 to 50 millimicroseconds.

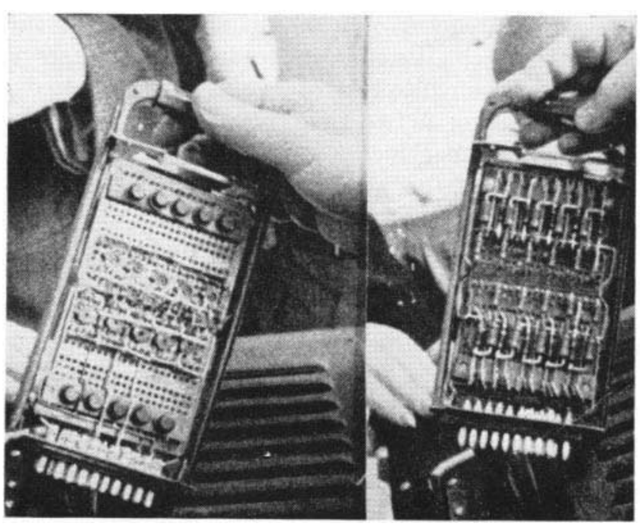

FIG. 26. Pulggable Transistor Package

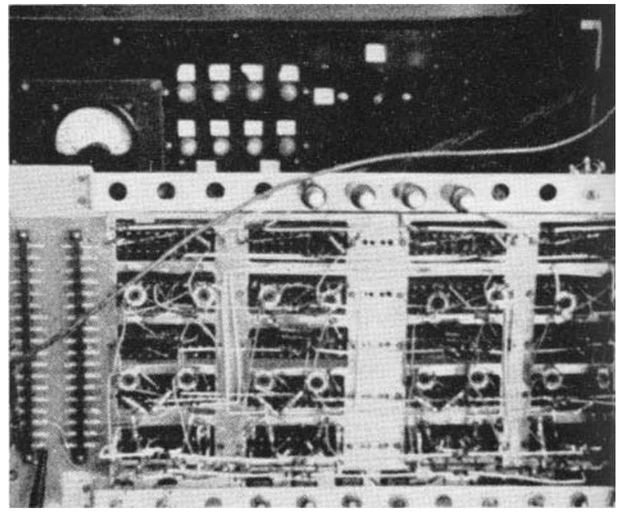

FIG. 27. Mounting Frame for Transistor Packages

The experimental setup for determining the hysteresis loop at 50 cycles per second permits placing the sample film in a uniform magnetic field on a table which can be rotated to orient the sample with respect to the field. Compensating coils were provided to adjust for field nonlinearity. Surrounding the solenoid which generated the uniform AC field was a rectangular wire frame through which direct current could be passed to rotate the direction of the uniform field.

Kobelev indicated that they were not presently doing any low temperature thin film experiments at IPMCT, but that such work was being done elsewhere.

Ferrite Cores

An experiment was demonstrated for investigating the switching time of magnetic core materials. The particular sample shown was being switched at a 100-cycle-per-second rate, in a coincident current mode at 0.5 microseconds. The rise time of the current pulses was approximately 10 millimicroseconds; with increased drive the same cores could be switched at 80 millimicroseconds. Under these conditions the switching field was the order of 5 to 6 oersteds. The cores were approximately 3 millimeters in outside diameter, and the H_c was approximately 1 to 2 oersteds.

We also saw in operation equipment for automatic testing of cores. It is similar to that which is used in this country for the same purpose.

Transistor Circuits

Transistor circuits were demonstrated using industrially produced PNP alloy diffusion transistors with a 120-megacycle alpha cutoff. Four hundred megacycle transistors are available but are in use only in communication circuits. In one laboratory we observed an experiment for determining optimum characteristics of transistor triodes by the systematic determination of the small current breakdown voltage. For the 120-megacycle transistor typical reverse current is five microamperes at a reverse base-emitter voltage of 2 volts.

A flip-flop was demonstrated which exhibited a 20-millimicrosecond rise time and was changing every 200 millimicroseconds. The transistor logic circuits which we saw utilized the current switching *OR* and *AND* configurations; an exclusive *OR* version also exists.

We also observed a ten-stage transistor-core shift register packaged in a plug-in unit. They have experienced no particular difficulties with the contacts of a Jones-like plug. The frame into which these particular packages were inserted was also shown (figs. 26, 27). Figure 28 shows the schematic of the SETUN ternary shift register.

Miscellaneous

The engineers in charge of machine development at the Institute of Precise Mechanics and Computer Techniques indicated that the recombination time of the best Russian diodes is 0.1 microseconds. With the uncertainty in the definition of the term itself, it is not clear whether this compares favorably or not with the best presently available diodes in the United States. There seems to be some interest in the Soviet Union in developing specialized beam switching tubes for purposes of logical operation rather than storage. Soviet standard radio or television tubes exhibit an average life of 5 to 10 thousand hours and therefore it has not been necessary to develop special long life types for computer usage.

Soviet design philosophy appears to parallel that in this country. They derate the current capability of tubes by 50 percent. They also derate the power rating of resistors by 50 percent, but, in general, they operate

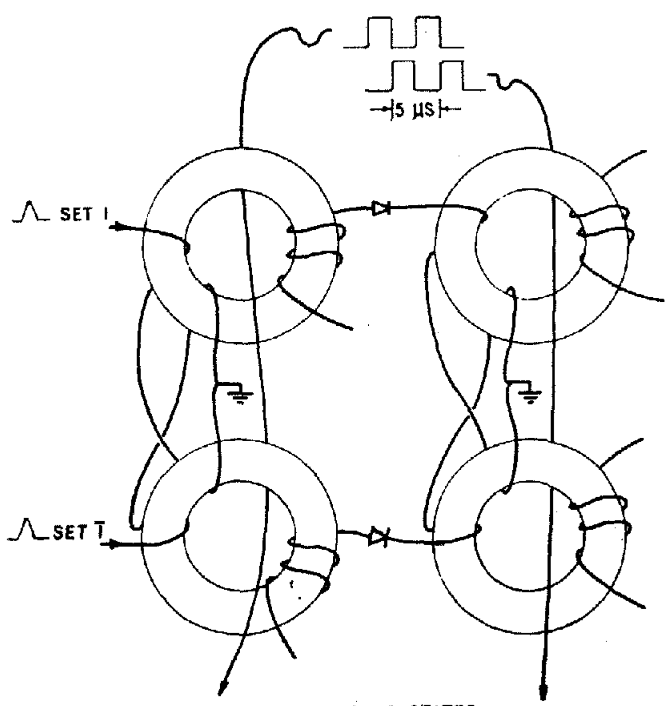

FIG. 28. Schematic of SETUN Ternary Shift Register

capacitors at 100 percent of rating because their production test procedure tests the capacitor to double its working voltage during manufacture. Common resistors have a 5 percent tolerance, but occasionally they match pairs for particular applications such as a voltage divider.

Major Machine Components

Magnetic Drums

Some magnetic drums appear to be in serial production by industry. The unit used on the BESM-II machine was also used on the KIEV machine and was seen in other places. A summary of magnetic drum characteristics is shown in table II. In this table the unit listed under BESM-II is the one which appears to be an off-the-shelf item of commerce.

Magnetic, Paper and Film Tapes

Early machines utilized punched 35-millimeter cinema film. The punched film handler of the URAL-I is shown in figure 13. A similar transport is also used on URAL-I to handle 35-millimeter magnetic film. Both tapes of URAL-I are closed loops, implying that a reverse mechanism does not exist. The perforated tape operates at $1\frac{1}{2}$ meters per second with a data rate of 75 numbers per second, and at a packing density of 50 numbers per meter. The data transfer rate on the magnetic tape is also 75 numbers per second.

The STRELA is equipped with a magnetic tape unit whose tape is approximately four inches wide. A word is written on this tape completely in parallel. Figure 15 shows this unit.

The magnetic tape units of the BESM-I are modified audio tape transports and are shown in figure 5. The perforated tape reader also uses a similar transport.

Table III summarizes the characteristics of the magnetic tape transports of the various machines.

Input/Output Equipment

The BESM-I uses punched paper tape input and output. The BESM-II will also use punched paper tape input and output. Both machines also have a 15-line-per-second, 14-column numeric-only printer (fig. 7). The STRELA uses punched card input and output. The card equipment appeared generally similar to that in use in this country for the same purpose although the operating rates are somewhat slower. A full line of numeric 80-column and 90-column punched card equipment is presently manufactured in the Soviet Union, and such equipment will probably be coming into increasing use for input/output facilities of computers.

Two new printers were demonstrated. At Penza the rotating drum printer intended for the URAL-II was seen. Timing signals are provided by illuminating a sequence of slots cut into the circumference of a hollow cylinder at the end of the drum. The passage of the slots is read by a set of germanium photo diodes; the data to be printed is stored in a magnetic core matrix on a character-by-column basis. At the STRELA location of the Computing Center of

TABLE II

Characteristics of Soviet Magnetic Drums

Drum	Speed (RPM)	Diameter (inches)	Length (inches)	Circumferential Packing (pulse/inch)	Axial Packing (tracks/inch)	Number of Tracks and Heads	Capacity (words/drum)	Head Spacing (mils)	Head Gap (mils)	Transfer Rate (words/sec)	Remarks
Laboratory (Penza)	1500	15–18	—	—	—	44 tracks 88 heads 2 stations	4000 bits/track	—	—	—	—
URAL-I	6000	—	—	—	—	—	2048 half words	—	—	100	—
URAL-II	6000	—	—	100 (4 pulses/mm)	4 (6 mm between tracks)	—	8192	0.8–1 (20–25 microns)	40(?) (1 mm)	5000	Expect 6 months with no inspection of drum; spare drum to be supplied with each machine; customers will report troubles.
BESM-I	—	—	—	75 (3 pulses/mm)	—	100	6000 40 bit	1.2 (30 microns)	—	—	
BESM-II	1500	12 (30 cm)	16 (40 cm)	75 (3 pulses/mm)	10 (2½ mm between tracks)	44 tracks 88 heads	6000	0.24(?) (6 microns)	—	12,000	Similar drum ran 3 years on BESM-I without trouble.
Typical U. S. early 1959	1800	8–12	12–36	100–400	10–20	—	8000–50,000	0.25–1	0.25	10–50,000	Special drums are as large as 400,000 words with a recording density of 1000 pulses/inch.

TABLE III

Characteristics of Soviet Magnetic Tapes

Machine	Width	Linear Speed (inches/sec)	Start/Stop	Density (bits/in)	Words/tape	Transfer Rate (words/sec)	Tracks
BESM-I	¼″	—	4 secs (?)	—	30,000 (?)		2
BESM-II	¼″	80 (2 meters/sec)	seconds	200 (8 bits/mm)	30,000	400	2
URAL-I	35 mm	30 (0.75 meters/sec)	ms	32 (1248 bits/meter)	40,000	75	11
URAL-II	35 mm	60 (1.5 meters/sec)	ms	210 (8300 bits/meter)	700,000	1000	11
STRELA	4″	16	seconds	62 (2½ bits/mm)	200,000	1000	43
M-20	—	—	—	—	—	—	—
Typical U. S. early 1959	½″–3″	75	5–10 ms	200	1,000,000	2500–10,000	7 to 36

the Academy of Sciences an experimental numeric-only printer was demonstrated. This device is not yet fully operational, and it is hoped that it will ultimately achieve a rate of 50 lines per second, 10 characters per line. The principle of operation of this printer is shown in figure 29. As is seen from this figure, the zeros in any line are inserted at one position of the paper, the ones of the same line are inserted in the following position, and so forth. Therefore to completely print only one number requires 10 advances of the paper. However, in printing a long sequence of numbers, 10 lines at a time are being completed. Such a printer requires that 10 complete lines of information have to be prepared and stored within the computer. There is also a rather complicated refill and release cycle necessary to couple the printer and the machine proper.

Table IV summarizes the characteristics of the known printers.

Magnetic Stores[33]

The 1024-word store designed at the Institute for Precise Mechanics and Computing Techniques has served as the model for the stores of subsequent large Soviet machines. The same storage device is being used in BESM-II[34] and also in the KIEV machine. Contrary to the usual store organization in this country, the Soviet so-called type-Z

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[33] See V. V. Bardizh, "Magnetic Internal Memory with Direct Selection," Moscow, 1958. This paper was presented at the 1958 University of Michigan Summer Conference. See S. A. Lebedev, "Certain Works in the Sphere of Computing Techniques," Moscow, 1956. This paper was presented at a 1956 conference in Stockholm.

[34] Aleksei Fedorov, one of our technical guides, was largely responsible for the design of the 2048-word version used in BESM-II and other machines.

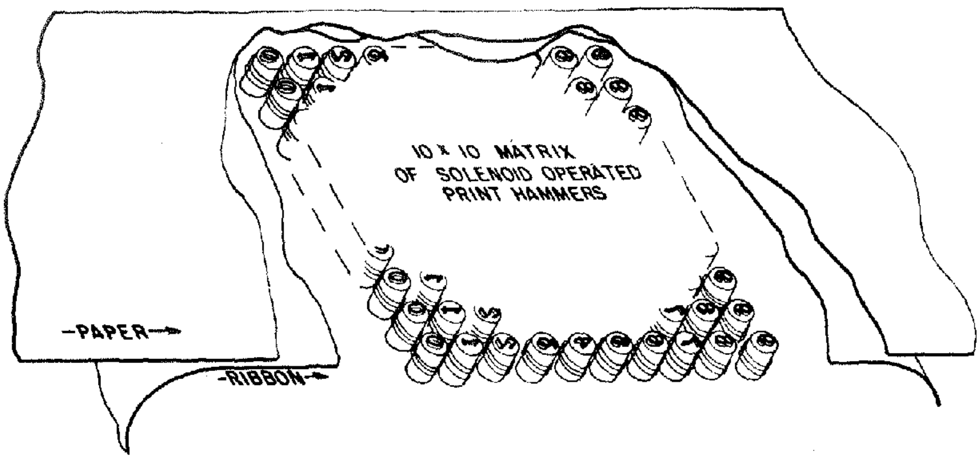

FIG. 29. Schematic of 50 lines/sec Printer

system is not a coincident current read; an N-way decoder switch is used to end-drive all columns of the desired word (fig. 30). Approximately one and one-half times switching current is applied to the core for reading. Writing into the store is, however, coincident current.

In order to minimize the change in load presented to the end-drive switch, two cores are used for each bit. In this way the same number of cores changes state at each cycle regardless of the digit content of the word. The cycle time of the standard type Z store is 6 microseconds, although in the BESM-I and BESM-II machines it is used at a 10-microsecond cycle. The basic unit of construction is a rectangular frame which contains both storage and switch cores. Each frame contains 128 48-bit words or a total of 12,288 storage cores (128 x 48 x 2) and also contains the 128 switch cores. These frames are then stacked to provide over-all stores of 1024, 2048 or 4096 words. So far, no machine has utilized all of the 48 bits provided. The extras are regarded as spares in case of fabrication difficulties.

An experimental store has also been built using two cores per bit and operating with a total cycle time of 0.2 microseconds. The cores in this experimental unit have an inside diameter of 1 millimeter and the current drives have a rise time of approximately 30 millimicroseconds. There is also in serial production by industry a 64-word by 50-bit store with a one microsecond cycle time. It is possible that this unit is not a coincident current type but rather a magnetic shift register type.[35]

Experimental transistor stores have been constructed, but adequately fast high current transistors are not presently available. It was estimated on the basis of their experience that the inductive voltage for 40 cores is of the order of ½ volt.

The magnetic core store for URAL-II is a one-core-per-bit coincident current type.

TABLE IV
Characteristics of Soviet Line Printers

Machine	Columns	Characters	Printing Rate (lines/sec)	Remarks
BESM-I	14	Numeric	15	Roll paper; no carbon copies; no format carriage control
BESM-II	14	Numeric	15	
STRELA	10	Numeric	50	Experimental, not yet completed; roll paper
URAL-I	19	Numeric	1.6	
URAL-II	16 to 96	Numeric	20	
KIEV	19	Numeric	1.6	
Typical U.S. early 1959	Up to 120	Alpha—numeric—up to 56 characters	Up to 15	Fanfold paper, multiple copy, format carriage control

Other Components

Typical other types of components are shown in figure 31.

Education[36]

The career of a student begins with ten years in elementary and high school. All students not in the upper five percent of the graduating class are required to have two years of working experience before applying to an institution of higher learning. A high school graduate is permitted to apply to one university only, and if rejected he cannot hope to gain admission at that time to another school. Admission to a university used to be based primarily on the result of competitive examinations. For mathematics, such an examination might cover mathematics, physics, a foreign language, Russian language and Russian history. The average entering age of university students is 17 and approximately 90 percent of them have government living expense fellowships.

After admission a student devotes five full years to study. During the first two years all students in a field

[35] There is some uncertainty whether the cycle time is 0.3 μs or 1 μs. The best guess is a 1-μs cycle time but a 0.3-μs access time.

[36] See: Soviet Commitment to Education, U. S. Department of Health, Education and Welfare. The report of the first official U. S. education mission to the U.S.S.R.; available from U. S. Government Printing Office for 70 cents.

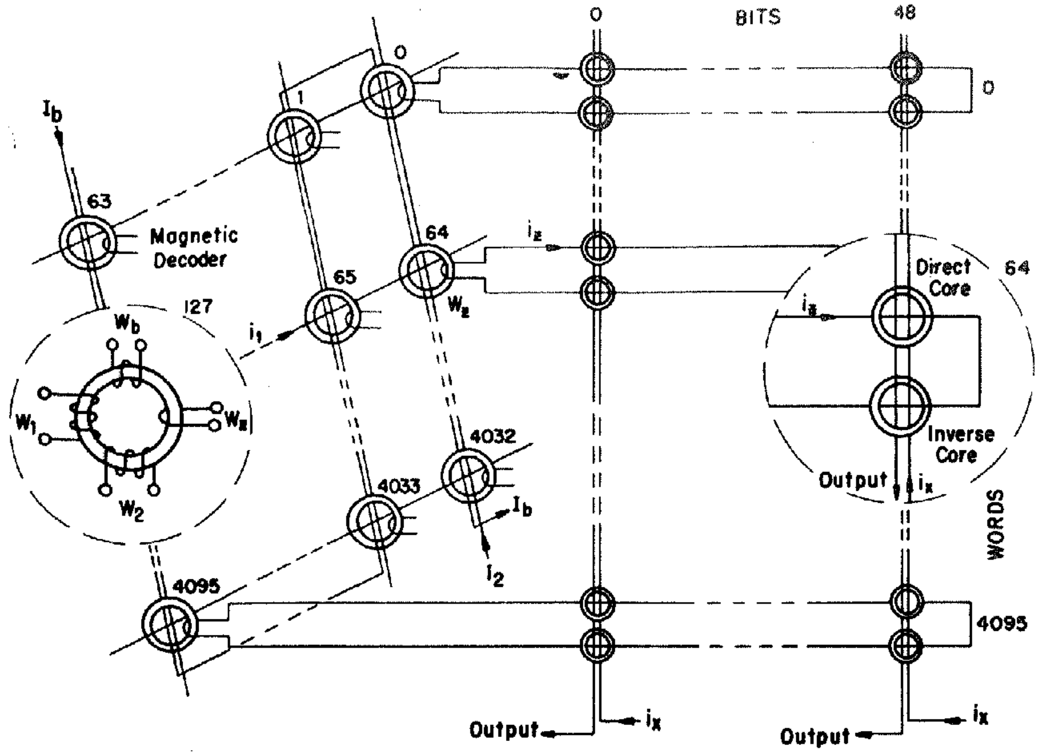

FIG. 30. Essential Features of the Type Z Store (This drawing is patterned after one in a paper by V. V. Bardizh.)

take the same courses, but during the final three years, specialize to a certain extent within the field. The program of study for each specialty is rigidly prescribed. By looking up his plan of study, a student will know in advance which courses he must take during each year, which term papers and examinations he will have in each course, and in which weeks these examinations will take place.

Every student is required to take 11 terms of ideological subjects, such as Marxism-Leninism, dialectical materialism, history of the Communist party, political economy, and economics. He is also required to take four terms of a foreign language and four terms of physical education. In his five years, a student will have to pass 32 oral examinations, will have to submit 36 reports, and write 8 term papers. During his final term a student is required to write a diploma dissertation and to acquire some practical experience. Prior to graduation he is expected to take two state examinations: one in Marxism-Leninism, and one in his speciality.

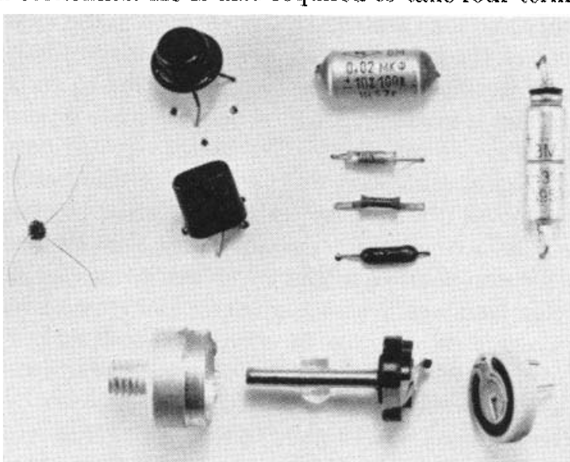

FIG. 31. Various electronic components:
P-403A Transistor Capacitor
Capacitor Capacitor
Wound Core P-406 Transistor Resistor
Diode
Potentiometer

Each undergraduate student is assigned an advisor (teacher), although his final grade is granted by the Scientific Council of the university. The Scientific Council is also responsible for recommending a student to graduate study. During each semester docents (associate professors) and the full professors lecture and hold recitations for the classes. The examinations are given by the assistants although a student's final examination is required to be given by his assigned teacher. During the five years of study there are examinations on four subjects each half year. Two or three months before graduation, each student is appointed to a job according to his specialty; he cannot leave or be dismissed from this job for three years. If there is no opening in his field, the university is obliged to find him a position in a related field. The appointments of students to jobs are apparently controlled by a Central Council for Production.

A research worker may lecture or may supervise a thesis, but he is not permitted to teach until he has succeeded in a competition and shown competence in his field by means of publications or accomplished work. On the other hand, any teacher is permitted to do research work.[37]

[37] Notice the very particular sense in which the word "teacher" is used in the Russian connotation.

The content of each course is determined by the Ministry of Higher Education, though the preparation of the detailed program is done by the professors. The lectures are supposed to adhere to the prescribed content rather rigidly since the students are to be examined on everything stated in the program and on nothing else. A Russian mathematical graduate will have a shallower knowledge in each field than his American counterpart, but he will be familiar with a larger number of fields. The Russian student will also be unacquainted with modern terminology and modern methods but, unlike the American student, every Russian mathematician has a three year foundation in physics and has been required to take a minimum number of courses in computer mathematics.

The diploma paper which a student writes under the direction of his advisor in his tenth term is approximately at the level of the bachelor's thesis in American universities. It must be publicly defended before an audience which includes the professors belonging to the relevant chair, the advisors, the referees and any students who may wish to attend. After successfully passing his final thesis defense, a student graduates either simply or "with distinction." Then he either becomes an "aspirant" or must take a job. If he is required to take a job because of poor grades, he has little chance subsequently to attain a higher degree.

Future scientific workers are recruited from the ranks of the aspirants. An aspirant "aspires" to the first advanced degree, that of "candidate." He takes no formal courses in his three years of graduate work but must write a candidate's thesis and defend it at a stiff public examination. This candidate's thesis is written under the direction of an advisor and appears to be at a level slightly below that of a Ph.D. thesis in leading American universities. A candidate is entitled to teach at an institution of higher learning, but to achieve the rank of professor he must generally earn the highest learned degree, that of "doctor."

The doctor's degree is also acquired by publicly defending a thesis. This thesis is written completely independently and must constitute a significant contribution to knowledge. Only a few doctor's degrees are awarded each year in the field of mathematics. Thus, while a Russian candidate is approximately between the American M.S. and Ph.D., a Russian doctorate degree is somewhat beyond that of the American doctorate.

The Role of the Soviet Academy of Sciences in the Scientific Life

The All Union Academy of Sciences of the USSR and the 15 Republican Academies of Sciences play a dominant role in the scientific life of the Soviet Union. The bulk of the scientific research work in Russia seems to be carried out by the various Institutes of the Academy. Each Institute seems to be a largely independent unit organizationally, is often housed in a single building, and is strongly influenced by the personality of the director, who has two deputies, one for scientific matters and one for business matters. He is assisted by a Scientific Council consisting of the senior members of his Institute.

The scientific employees of an Institute are both professors of institutions of higher learning and graduates of universities, with or without advanced degrees. The support staff consists of technicians, clerical workers, etc. A professor working at an Institute may devote any percentage of his time to his work. For some, the Institute seems to be a secondary affair, a role corresponding to consulting in the United States. For others, the Institute is the principle job even though an institute employee may also give a course at a university.

An Academy Institute performs no direct teaching functions even though some of the employees may be aspirants who work on a candidate dissertation under the direction of a senior member of the Institute. Students required to gain practical experience may acquire it by working at an Institute. For instance, students come to the Institute of Precise Mechanics and Computing Techniques for practical experience in both the design of computers and the programming of computers. Such students not only come from all over Moscow, but from all over the Soviet Union and China, and spend three months there. An Institute may also give evening courses of a nature similar to the extension courses of American universities.

The highest class of membership in the Soviet Academy is that of Academician. The number of Academicians in a given field is relatively small and fixed by law, and election to the Academy is considered the greatest honor which a Russian scientist may achieve. A member of the All Union Academy receives a salary of 5000 rubles per month in addition to any salary he may receive from his job. He is also entitled to an official car and to preferred housing. A member of a Republican Academy receives a salary of 3500 rubles per month. A second class of membership is that of Corresponding Member, who receives a salary half that of an Academician. In 1946 each Academician of the All Union Academy received a "Dacha," or summer home, near Moscow.

The Economic Status of Scientists

In evaluating typical Russian salaries it must be remembered that the highest income tax in the Soviet Union is 13 percent and that all other taxes are indirect. Further, medical care and certain other services are provided cost free by the government. Living conditions are below American standards, and in all cases the percentage of income devoted to rent is much lower than that in the United States. Remember also that while the tourist exchange rate is 10 rubles per dollar, the "commercial" exchange rate is approximately 4 rubles per dollar.

For mathematicians in a research institute, university graduates start at 1050 to 1350 rubles per month, candidates at 1850 to 3000, and doctors at 3500 to 6000 rubles per month. The scale for engineers at similar Institutes is slightly higher. For comparison, a charwoman receives 420 rubles per month, a chauffeur 500 rubles, an average skilled worker 800, a taxi driver 1200 rubles, a high school teacher from 600 to 1500, while old age pensions range from 400 to 1250 rubles per month.

Professorial salaries are fixed all over the Soviet Union. A professor receives 4500 rubles per month plus an additional 500 if he is in charge of a Chair. If an Academician, he also receives the additional stipends previously noted. Professors often supplement their income by consulting or part-time teaching at other universities. If well-known, a man may obtain such additional work easily and may devote as much as one and one-half days her week to this second job, for which he is paid at half rate. A particular individual may have a full-time appointment at one institute, may be working at a second job at another, and perhaps consulting for a third and a fourth. To some extent the salary structure of scientific workers depends on the importance of the Institute. Mathematicians and physicists are among the top cevals.

It is also possible to earn additional income by authoring scientific books. The rate per page seems to depend upon the status of the author and upon the subject of the book; for a man just below the status of full Academician, a typical figure is 2000 rubles per 16 printed pages.

The salary structure for programmers is shown in table V.

The Novosibirsk Development

It is a general belief in Russia that the future of the Soviet Union is closely allied with the development of the immense and largely unexplored natural resources of Siberia. M. A. Lavrentyev is credited with persuading the Soviet Government to establish a powerful scientific center in Novosibirsk. Academicians Khristianovitch and Sobolev are the other two leaders of the Novosibirsk project.

This new scientific establishment is intended to be a nerve center for the development of Siberia. Novosibirsk itself is already a large industrial city, and it is now to become the site of a large complex of scientific institutes and training centers for scientists. A new Siberian division section of the All Union Academy has been created with Lavrentyev in charge. The government has also created ten new positions for Academicians; among the new appointees are mathematicians I. N. Vekua and A. I. Maltsev, and the hydrodynamicist P. Y. Polubarinova-Kochina. Several other outstanding scientists have been invited to join the Novosibirsk Center; among them are L. V. Kantorovich of linear programming fame, and A. P. Yershov of automatic programming. It is intended to create a new university there whose rector will be I. N. Vekua. There is also planned a Siberian Mathematical Journal and a Siberian edition of the Doklady.

TABLE V
Typical Salaries for Programmers

Status in Research Institute	Salary (Rubles/month)
Junior Scientific Worker	
non-Candidate	1050–1350[1]
Candidate of Sciences	1850–2000
Senior Scientific Worker	
Candidate	2500–3000
Doctorate	3500–4000[2]
Head of Laboratory	
Doctorate	3500–6000
New Graduate—starting	1050
non-Degree—1 year experience	1200[3]
Degree—1 year experience	1350

[1] An engineer's in this category is from 1200–1800.
[2] In exceptional cases this may have an upper limit of 6000.
[3] This will be 1300 for industry.

Chinese Developments

A number of Chinese engineers and programmers were observed in various laboratories during our visit. Apparently they have come to Moscow for training. It was indicated that the Chinese have developed a machine for themselves which is partly ferrite logic and partly vacuum tube logic and which has a capability between that of the BESM-I and the BESM-II. The Chinese are also supposed to have developed a machine which is completely their own design. It operates at approximately 5000 operations per second and is presently being readied for serial industrial production.

Acknowledgments

Many people have contributed to this report. Each member of the delegation contributed his transcribed notes or a complete manuscript; each member also assisted me in reading rough drafts of the complete report and in resolving conflicts and ambiguities in our information. At RAND, many people have assisted me. Professor K. E. Harper, Dr. D. G. Hays, Barbara Scott, Andrew Kozak, and Dolores Mohr, all of the staff of the Machine Translation Group, and Margaret Penington of the library staff contributed their linguistic skills to the translation of various items, the transliteration of names, and the tedious task of determining initials. The photographs were prepared by L. R. Mockbee; and the line drawings by G. N. Lucas. T. W. Zeihe and I. D. Greenwald helped resolve uncertainties in the meaning of certain instructions of the two URAL machines. F. J. Gruenberger read the manuscript editorially. Lastly and importantly, my secretary, Mrs. Dorothy Crabb, and Miss Jessie Gutteridge typed the many drafts of this lengthy document with its unfamiliar names and places. Each of us now feels somewhat more familiar with Russian computing technology, their research institutes, and their scientists.

Appendix I

Instruction Repertoire of URAL-I

Appendix II

Instruction Repertoire of URAL-II

[Appendices I and II will appear in a future issue.]

Bibliography

Composite List of Publications Received as a Result of the USA-USSR Cultural Exchange, April–May 1959
(Most publications are in Russian; a few, in English or French)

I. BOOKS

Title	*Author*	*Source*
* Session of the USSR Academy of Sciences on Scientific Problems of Production Automation: complex automation of production processes, scientific problems of telemechanized production, basic problems of automatic control; 15–20 October, 1956, 215 pp.	A. V. Topchiev, Ed. (Academecian)	USSR Academy of Sciences, Moscow 1957
* System of Standard Sub-Programs—Moscow 1958, 229 pp.	E. A. Szogolav, G. S. Rosliakov, et. al. Edited by Prof. M. P. Shura-Bura	Physico-Mathematical Literature Publications
* Program of Automatic Programming for High Speed Electronic Computers—Moscow 1958, 116 pp.	A. P. Yershov	USSR Academy of Sciences Computing Center
*° Problems in Cybernetics, Vol. 1—Moscow 1958, 268 pp.	A. A. Liapunov, editor	Physico-Mathematical Literature Publications
* Theoretical Questions of Mathematical Machines, 1st Collection—Moscow 1958, 230 pp.	Yu. I. Bazilevsky, editor	Physico-Mathematical Literature Publications
* Collection of articles on mathematical logic and its applications to some problems of cybernetics		USSR Academy of Sciences, Steklov Institute of Mathematics
* Vychislitel'naia tekhnika. 1958. Computing Engineering, 1958.		USSR Academy of Sciences, Institute of Precise Mechanics and Computing Techniques
* Computing Mathematics, 1957–58, 3 Vols.		USSR Academy of Sciences, Computing Center
* Conference on the Development of Soviet Calculating-Machine and Instrumentation Engineering. Moscow 1956. Plenary Meetings.		Unknown
° Programming for Digital Computing Machine—URAL I, Moscow, 1957, 415 pp.	V. N. Bondarenko, I. T. Plotnikov, P. P. Polozov	Artillery Engineering Institute imeni F. Z. Dzerzhinskiy
° Materials on Machine Translation Vol. I, Leningrad, May 1958, 228 pp.	N. D. Andreyev, editor	Leningrad University Publishing House

II. TABLES

The Institute of Precise Mechanics and Computing Technique, USSR Academy of Sciences, is the source of all the following tables.

Title	*Author*
* Tables of Integral Sin and Cos.—Moscow, 1954, 471 pp.	Prof. V. A. Ditkin, Editor-in-Chief
* Mathematical Tables of Integral Exponential Functions—Moscow 1954, 300 pp.	Prof. V. A. Ditkin, Editor-in-Chief
* Tables, e^x and e^{-x}, Moscow 1955, 144 pp.	Prof. V. A. Ditkin, Editor-in-Chief
* Jacobi Polynomial Tables, Moscow 1954, 249 pp.	L. N. Karmazina

III. DICTIONARIES

° Anglo-Russian Dictionary of Computer Technology, Vol. 1, Moscow 1958, 93 pp.	V. K. Zeidenberg and T. S. Loseva	Institute of Precision Mechanics, USSR Academy of Sciences
° Anglo-Russian Dictionary of Automatic and Controlled Measured Instruments	L. K. Ptashni	

IV. CATALOGS

Title	*Source*
° Catalog of Published and To-be Published Books, Second Quarter, 1958	Physico-Mathematical Publications
° Catalog of Computing Machines, 51 pp., 1956(?)	Central Bureau of Technical Information, Instrumentation and Sources of Automation
° Catalog of Electronic Mathematical Machines—Apparatus Infrashort Range Frequency, 1957	Central Bureau of Technical Information, Instrumentation and Sources of Automation

° In possession of one or more members of the delegation.
* In possession of the library of the Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, Pennsylvania.

V. REPORTS

The Institute of Precise Mechanics and Computing Techniques, USSR Academy of Sciences, is the source of all the following reports except the last four.

Title	*Author*
*⁰ Application of BT-1 and K-28 Type Ferrites in Operating Magnetic Storage Units, Moscow, 1958, 33 pp.	M. P. Sycheva, A. I. Fedorov, et. al.
* Japanese Language Analysis in MT, Moscow 1958, 25 pp.	M. B. Yefimov
*⁰ On Machine Translation from Chinese into Russian—Moscow 1958, 34 pp.	V. A. Voronin
* Basic Elements and Some Circuits of Computer Units—Moscow 1958, 24 pp.	N. M. Sotina, Yu. A. Khetaurov
* Measurement Methods of Ferroelectrics with Rectangular Hysteresis Loop—Moscow 1958, 19 pp.	L. V. Kutukov
*⁰ A Steady State Calculation for a Transistorized Digital Computer Unit—Moscow 1958, 40 pp.	Yu. I. Sharapov
* Some Problems of Small Thin Tape-Wound Magnetic Core Production—Moscow 1957, 15 pp.	V. V. Bardizh, Yu. I. Vizun
*⁰ Some Problems of Ferrite Core Switching—Moscow 1958, 19 pp.	V. V. Bardizh
* Reading Transformer Circuits for Storage Units Using Barrier-Grid Memory Tubes—Moscow 1958, 15 pp.	V. N. Laut
* A Point-Contact Transistor Pulse Shaper—Moscow 1958, 22 pp.	Yu. I. Senatorov(?)
*⁰ Programmed Access Magnetic Memory—Moscow 1958, 17 pp.	V. V. Kobelev, Yu. I. Vizun
* A Dynamic Flip-Flop with Negative Pulse Condenser—Charging—Moscow 1958, 12 pp.	A. N. Zimarev
* An Operational Register with a Magnetostrictive Delay Line—Moscow 1958, 38 pp.	E. F. Berezhnoy
⁰ On Magnetic Polarity Reversal of Mn-Mg and Ni-Zn Ferrites—Moscow 1958, 13 pp.	V. V. Kobelev, I. I. Nadashkevich
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⁰ Magnetic Internal Memory with Direct Selection—Moscow 1958, 16 pp. (English Translation)	V. V. Bardizh
⁰ Test Equipment for Determination of the Basic Characteristics of Magnetic Cores—Moscow 1957, 20 pp.	Yu. I. Vizun
⁰ Characteristics of Ferrite Cores with Rectangular Hysteresis Loop, First Edition—Moscow 1957, 20 pp.	V. V. Bardizh
⁰ Digital Computer Basic Units Using Junction Transistor Elements of Pulse-Potential Type—Moscow 1958, 35 pp.	Yu. I. Sharapov
⁰ Some Principles of Designing Magnetic Permanent Storage Devices—Moscow 1957, 37 pp.	Yu. I. Vizun
⁰ Experiments with Automatic Translation on the Electronic Calculating-Machine BESM—Moscow 1956, 28 pp.	I. S. Mukhin
⁰ Experiments with Automatic Translation on the Electronic Calculating-Machine BESM—Priroda, August 1956	G. P. Zelenkevich, N. L. Korolev, S. N. Razoumovskiy
⁰ Accelerating Multiplication and Division in High Speed Digital Computers—Moscow, 1958, 25 pp.	V. S. Burtzev

Title	*Author*	*Source*
⁰ Concerning the Problem of Machine Translation of Languages—Moscow 1956, 35 pp.	D. Panov	USSR Academy of Sciences
⁰ Questions of Computer Mathematics and Techniques (Articles) Third Edition—Kiev 1958, 98 pp.		Academy of Sciences
⁰ Les Experiences de Traduction Automatique de l'Anglais en Russe a l'Aide de la Calculatrice BESM	N. L. Korolev, S. N. Razoumovskiy, G. P. Zelenkevitch	International Congress on Cybernetique Namur 1956
* Les Chiffres de Base du Developpement de l'Economie Nationals de l'U.R.S.S. pour 1959–1965. Theses du rapport du camarade N. Khrouchtchev au XXI[e] Congres du P.C.U.S. Moscow, 1958.	N. S. Khrushchev	Unknown