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25 April 1979

USSR

TRANSLATIONS ON USSR SCIENCE AND TECHNOLOGY
PHYSICAL SCIENCES AND TECHNOLOGY
(FOUO 24/79)

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CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

UDC 001.812

COMPUTERS IN EXPERIMENTAL PHYSICS

Moscow VESTNIK AKADEMII NAUK SSSR in Russian No 1, 1979 pp 53-61

[Article by A. N. Vystavkin, doctor of technical sciences]

[Text] The growing scale and sophistication of experimental physics and the uninterrupted upward trend in the amount of information gained during experimentation have led to the need of automating experiments with computers and numerical methods.

One of the first automated experiments that were computer-aided in the research centers of the Division of General Physics and Astronomy, USSR Academy of Sciences, were radar studies of the planets. These experiments began in 1961 in the Institute of Radiotechnology and Electronics, supervised by academician V. A. Kotel'nikov. In 1965-1970, the first automated diffractometers for monocrystals were developed in the Institute of Crystallography under the guidance of academician B. K. Vaynshteyn. In 1968-1972 the first automated systems for spectral studies in the submillimeter range were built in the Physics Institute imeni P. N. Lebedeov and the Institute of Radiotechnology and Electronics. Today in the research centers of the Division of General Physics and Stronomy there are upwards of 70 large and small systems for automating experiments. Unquestionably, this is a notable success, all the more so in that numerous systems are original developments. Even so, many more automated systems are needed.

Study of the operating experience with the systems for automating experiments built in our country and elsewhere shows that one of the main effects of their application is shortened times in conducting the cycle of measurements and processing their results. For example, the flow and volume of information in spectral investigations and studies of electrophysical properties of semiconductors are $10\text{-}10^3$ bits/s and $10^4\text{-}10^7$ bits per workday; these times were reduced by a factor of 10 to 30, that is, instead of one to three years in conducting the cycle of studies, only from one to several months is required.

There are times when experimentation is simply not possible without automation. For example, in radar studies of planets digital filtering and signal

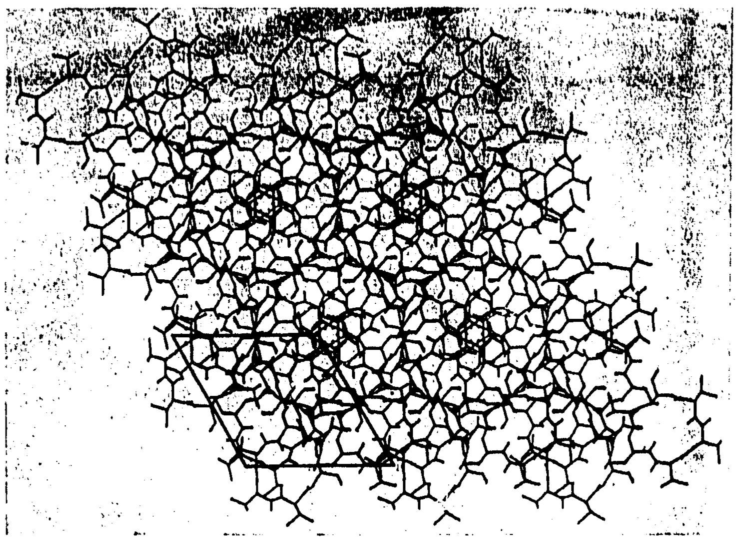

Fig. 1. Structure of peptide structure obtained, interpreted and displayed on a graphics plotter using an automated system

processing on a computer, data can be obtained concerning distances to the planets to a precision of hundreds of meters and concerning planetary velocities to a precision of several centimeters per second immediately after reception of the echo signal, that is, in the real-time mode. This is important in refining the ephemeris times and studying the properties of planetary surface and atmosphere; the data acquired in the real-time mode are necessary to the landing of interplanetary stations.

Another example: investigation--by physical methods--of natural resources on earth from space (these studies are being done by the Institute of Space Studies, the Institute of Radiotechnology and Electronics and other institutes of the USSR Academy of Sciences). The computer processes and displays in conventional colors images of the different parts of the earth's surface[1].

[1] See: R. Z. Sagdeyev, VESTNIK AN SSSR, No 3, 1977.

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A system for automating crystal growth for laser application, in the Physics Institute imeni P. N. Lebedev, maintains the electric power fed into the crystallatization unit in accordance with a given law in time to within a precision of 10^{-4}. The system affords crystal homogeneity that is practically ideal for the given application; this makes it possible to build new high-capacity infrared crystals. The systems for automating crystallographic investigations, developed in the Institute of Crystallography, can form and interpret the diffraction patterns of crystals contained in a cell to a precision of hundreds of atoms in different positions. Fig. 1 shows the structure of the peptide crystal. A X-ray diffraction pattern of this crystal, its interpretation and the image of the structure were obtained with a computer.

Apart from the automation system it is not possible to rapidly control the hundreds of element-panels of the RATAN-600 radiotelescope in the source tracking mode; without automation systems it is also not possible to conceive of the functioning of facilities built in the Physics Institute for studies of laser thermonuclear fusion and so on.

These examples tell us that the computer can rapidly and precisely control a facility for information flows up to 10^7 bits/s, as well as process large data files (10^6-10^8 and larger) in a multiplicity of operations.

Today virtually all research in general physics and astronomy calls for automation. Roughly speaking, these investigations can be divided into the following groups:

space study of the earth, the solar system and deep space

land-based studies of the sun, near-earth and near-solar space and the propagation of radio waves and laser radiation in the atmosphere

astronomy, radio astronomy and radar astronomy

plasma physics

spectroscopy and crystallography

laboratory studies of solid-state physics, low-temperature physics, physical and quantum electronics, hydrodynamics, thermodynamics and so on

Specific requirements on automation develop in each of these groups. An analogous situation exists also in chemistry, in biology, in earth sciences and in other fields of knowledge.

The heavy demand for automating scientific investigations, as well as the need for working out a unified approach led to the automation of scientific studies taking shape as an autonomous scientific discipline. Finding development in it are both methods of investigation and measurement in different fields of science and a number of mathematical subdisciplines; there are also subdivisions in automation dealing with the designing and building of systems for automating scientific experimentation and developing new methods of investigation.

Designing automation systems is preceded by an analysis of the process of scientific investigation. As we know, the following stages can be distinguished in scientific research, in particular, in experimental physics: formulation of the goal of the investigation; literature search and review; choice of the model of the phenomenon or process under study; theoretical analysis and modeling of the phenomenon or process; experimental design; experimental preparations (designing and fabricating the parts and assemblies of the experimental setups and producing materials and structures with new properties); monitoring parameters and states and control of the experimental setup; conducting measurements (acquisition, accumulation and storage of measurement data); data processing, reduction and display; interpretation of measurements and their comparison with the model and formulation of conclusions; and documentation of data and conclusions and placement in archives (reports, publications and data banks).

These stages may overlap, be conducted in parallel and be repeated, but in some volume they are present in any investigation. The computer can be assigned, to a significant extent, the performance of functions that are amenable to formalization and, thus, to programming. This amounts to most of the stages enumerated, save for those stages associated with goal formulation, choice of model and interpretation of results--stages that are heuristic by their very nature, that is, they rely on the investigator's intuition. Still, even at these stages the computer can render much help, by rapidly supplying the necessary information and assisting in displaying the results of the investigation in the desired form.

If one considers that the investigation stages interrelate, one faces the problem of the integrated automation of scientific research, that is, the automation of virtually all research stages.

Besides the stages listed, thought must be given to controlling investigations (monitoring the course of scientific research studies, recording the labor and computing salaries, recording the consumption of material values and so on), which can also be automated.

Domestic and foreign experience shows that it is preferable that the problem of integrated automation of scientific investigations--when there is a large number of tasks diverse in type and size--be solved on an institute-wide scale (or on the scale of a group of allied institutes), with the help of a multilevel, hierarchical, multicomputer measuring and computing complex. A generalized block diagram of this complex, oriented for an institute specializing in general physics or an institute in which physical methods of investigation predominate, is shown in Fig. 2.

The following principles are embodied in the complex:

setting up a fairly high-capacity measuring and computing center (MCC), on a shared-time basis at the highest level, consisting--when there is a large volume of computations--of several large computers equipped with the required set of information display devices, special data input/output units, external memory, devices for effective interaction of investigator with computer and so on

building unified subsystems for automating the lower level, oriented for groups of investigations (for general physics and astronomy these groups were enumerated above) and capable of functioning either autonomously as well as jointly with the MCC, that is, with data transmitted between levels over communication lines or via a magnetic carrier (punched tape, magnetic tape and magnetic disk); and lower level subsystems for automating individual installations or groups of installations in a laboratory (division) are built on the basis of small computers (minicomputers or microcomputers)

optimal distribution of tasks and functions by levels (kinds of investigations or their stages, programming, storage of programs and data and so on)

use of level-homogeneous computers that are also program-compatible between levels, unified modules and blocks and development of homogeneous software on the modular principle

These principles optimally correspond to the organizational structure of an institute that handles a multiplicity of diverse problems and permit the highest operating economy and reliability of the complex to be attained, the use effectiveness of all its components; also, these principles provide for the possibility of the stagewise introduction and development of the complex (expansion, upgrading and modernization).

Complexes of this kind are being constructed at present (not considering institutes with a nuclear physics specialization) in the Institute of Radiotechnology and Electronics, the Physics Institute imeni P. N. Lebedev and the Engineering Physics Institute imeni A. F. Ioffe, USSR Academy of Sciences; they are projected, further, in several dozens of academy centers.

Choice of the type and makeup of interfacing equipment between experimental setups and laboratories devices with the computer is one of the primary tasks in building multicomputer and single-computer systems for automating scientific investigations. Of all the existing systems for interfacing a process with a computer, the CAMAC system (CAMAC: Computer-Aided Measurement, Automation and Control) is the most popular international standard; it has the highest operating speed and universality. This then served as the basis for its selection as the primary standard in building interfacing equipment in the centers of the USSR Academy of Sciences.

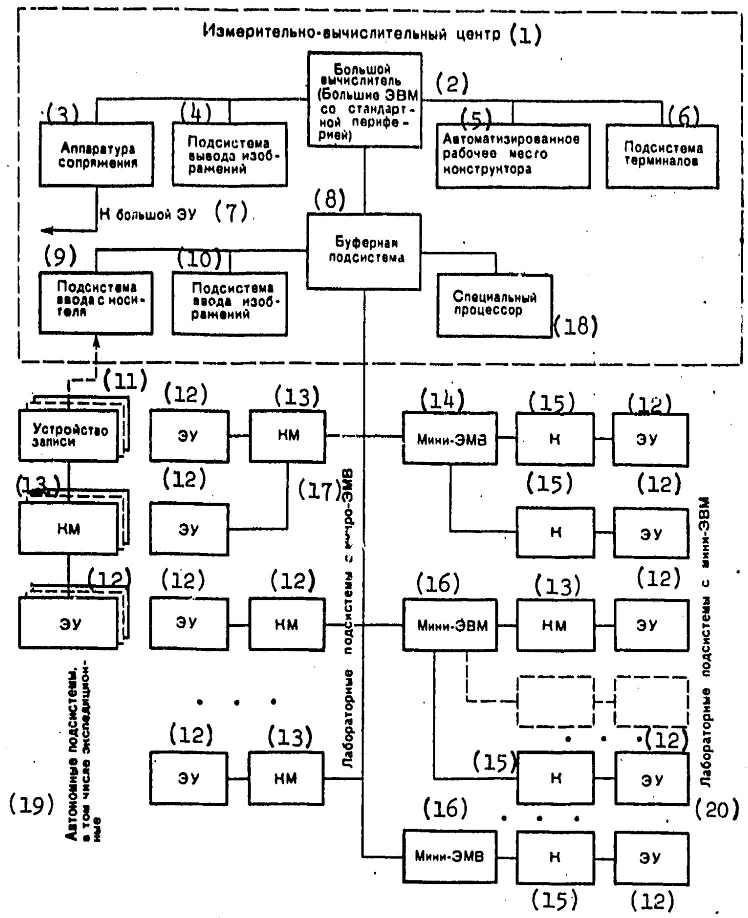

Fig. 2. Generalized block diagram of multicomputer, hierarchical measuring and computing complex for automating scientific investigations in an institute specialing in general physics

Key: 1. Measuring and computing complex
2. Large computing unit (large computers with standard peripherals)
3. Interace
4. Image output subsystem
5. Automated designer's work station
6. Subsystem for terminals
7. To large experimental setup
8. Buffer subsystem

[Key concluded on next page]

[Key to Fig. 2, on preceding page, concluded]

9. Subsystem of input with carrier
10. Image input subsystem
11. Write unit
12. Experimental setup
13. CAMAC crate with microcomputer
14. Minicomputer
15. CAMAC crate
16. Minicomputer
17. Laboratory subsystems with microcomputer
18. Special processor
19. Autonomous subsystems, including dispatch subsystems
20. Laboratory subsystems with minicomputer

Conceptually, the CAMAC system consists of the following. Specialized functional modules are built to control individual parts of a facility acquire information from measuring instruments and sensors and output information to facilities not incorporated in the computer (oscillograph, graphics plotter and so on). The modules are built up in relation to the task and are inserted into a sectionalized frame (crate) interfaced with a computer. Up to 25 regular or the corresponding number of double, triple and other sizes of modules can be inserted into a CAMAC crate. All the modules are connected into a unified data highway. The dimensions of the modules, the number and order of the connections, the power supply and strength of the electrical signals and the commands are standardized; this permits the modules of different manufacturers and unified programs to be employed.

Experience in developing the CAMAC equipment and the automation systems based on the CAMAC in the Institute of Radiotechnology and Electronics, USSR Academy of Sciences, in the Institute of Automation and Electrometry, Siberian Division, USSR Academy of Sciences, and in other institutes showed that the base set of modules ensuring a wide range of experiments in general physics is not too large--40-50 types. Incidentally, it differs appreciably from the set of modules for investigations in nuclear physics.

Multicomputer complexes that have the CAMAC equipment as the lower-level subsystems lend themselves naturally to organizing the interfacing of these subsystems with the MCC under the CAMAC standard, for which only the interfacing module is added to the crate. The CAMAC equipment optimally should be used also for unifying into the multicomputer complex computers of different types in cases when for some reason computers differing in standards are used in the institute[2].

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[2] See: Yu. Ye. Nesterikhin et al, AVTOMETRIYA, No 4, 1974.

A large volume of work is required in developing and putting together the complex software support. Software is constructed just like the complex--by the hierarchical modular principle. The standard software that is part of the computers is used to the fullest; it is supplemented by system software for intercomputer interfacing and for working with the CAMAC equipment, software of the shared-time system, the information retrieval system, the design planning system, as well as the extensive applied software for solving specific theoretical and experimental problems and operations research tasks.

Advances in systems for automating scientific research is bringing on the scene new research methods. In particular, a transition is projected from the simple breakdown of routine and creative functions (stages) between computers and the investigator to the fruitful interaction of investigator and the automated system (interactive mode) as the research proceeds.

The first steps in this direction have already been outlined. By way of example, we can mention the dialog system of spectral studies in the submillimeter range, based on a fourier spectrometer[3]. We know that in spectral measurements in the submillimeter range using thermal sources, the investigator deals with low radiation energy; this requires a long signal buildup time. Extending the range of test frequencies and increasing resolution and the signal-to-noise ratio in this situation involves a large increase in the measurement time--up to dozens and hundreds of minutes.

Envisioned in the system is the selection of the appropriate ratio of frequency interval, resolution and signal-to-noise ratio based on preliminary measurement of the signal-to-noise ratio when there is a zero interferometer path difference and based on measurement of a scanning interferogram, with the recording of the appropriate scanning spectrum. These two stages and the selection of the above-mentioned parameters are executed in the interactive mode. After these procedures are carried out, the working interferogram is recorded; it is then transformed into the spectrum in the automatic mode. As a result, the experimental time is shortened by 10-15 times.

We presented an example of the interactive mode in selecting the appropriate levels at which the experiment was conducted (planned). The interactive mode can be altered also when the experimental findings are being processed. Exemplifying this is the processing of spectra recorded with a submillimeter diffraction spectrometer (Fig. 3). After the computer executes the fourier-transformation of the spectrum and displays its plot, from the fourier components the experimenter identifies and sends to the computer a command to isolate the interference component caused by the interference of the radiation between the sample faces, and transmission averaged over the interference

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[3] See: A. N. Vystavkin et al, AVTOMETRIYA, No 2, 1978

period, by discriminating the white noise of the receiver (more exactly, its high-frequency components)[4].

Application of the described method of processing measurement data and the data of the interactive mode of its realization significantly extends the potentialities of diffraction spectroscopy and speeds, by a factor of ten, the processing of the spectra measured.

The interactive mode is suitable also at other investigatory stages; it optimally measures up to the process of scientific investigation.

The dialog of investigator and automated system is a method of organizing the interactive mode. The appropriate software and hardware are necessary for an effective dialog in the system: convenient keyboard, graphic and other information display devices, accessories for entering marks on the alphanumeric files, graphic and video images and so on. Year by year, these devices are developing and improving.

Besides the above-listed stages of scientific investigations in introducing automation, there is one more: program preparation and debugging. When organizing the interactive mode, it is very important that the investigator master programming and dialog techniques (without programmer participation), since it lets the investigator modify the experimental conditions directly during the investigation; when specific tasks are programmed, the investigator can apply procedures based on physical features and so on. That is why it is necessary to shorten and simplify the stage associated with programming. For example, this task was successfully solved in the series 2200 Wang minicomputer. The computer uses a quite powerful language, WANG-BASIC and simple program debugging means in the dialog mode, with an indication of the location and kind of errors. The dialog is much simplified in that the 44 main instructions in the programming language and the 20 arithmetic operations and the built-in functions are actuated by pressing the right key, just as in a pocket or desktop calculator. The other instructions, as usual, are formed letter by letter. Learning the minimum set of instructions does not take much time. Also, it does not need to be memorized, since it is entered on the keyboard. Obviously, this experience must be taken into account in the future when developing new minicomputers.

Interest lies in systems that will provide for the possibility of monitoring the process of investigation and remembering by the investigator of departures from the adopted program or some general rules, accumulation of research experience and its presentation in convenient form in later studies, analysis of the effectiveness of the interactive mode and the possibilities of its improvement and so on. Research in building these systems has only just begun.

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[4] See: T. M. Lifshits et al, ZHETF, Vol 72, No 3, 1977.

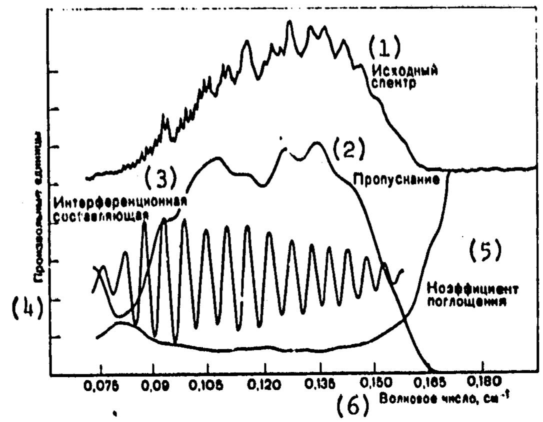

Fig. 3. Transmission spectrum, computed spectral components and transmission coefficient of $Bi_{1-x}Sb_x$ specimen

Key: 1. Initial spectrum
2. Transmission
3. Interference component
4. Relative units
5. Absorption coefficient
6. Wave number, cm^{-1}

Another source of new research methods that are computer-aided is computational physics--a new division of mathematical physics, concerned with developing numerical methods as applied to theoretical physics and the processing of the results of physical experiments. One primary direction in the advances in computational physics is the computer experiment (or numerical modeling)[5], which is an investigation--using a computer--of a mathematical model of a phenomenon, process or device. It significantly replaces a real physical experiment in those instances when the experiment is costly, protracted or relatively inaccessible. The computer experiment, moreover, is easily controlled and affords broad variation of conditions and the safe realization of critical regimes.

Finally, the validity of a model unquestionably is verified in real conditions, but this verification after detailed investigation of the model by

[5] See: A. A. Samarskiy and Yu. P. Popov, PRIRODA, No 4, 1975.

computational methods becomes much less laborious and requires much less time than the full investigation of the phenomenon or process with a real object.

It appears natural to merge computer and real automated experimental setups into a unified complex, by providing for recourse to the real object for comparing the consequences from the model studied with numerical methods, and also to secure additional information with the goal of correcting or modifying the model. This approach is already in use in investigations of processes in plasma, ion scattering in crystals and so on.

New approaches and concepts relying on numerical methods and applied to the description of physical phenomena are to be anticipated. Just as fourier analysis, Green functions, Feynman diagrams and other mathematical methods led, each in its time, to new physical concepts and made possible a fuller understanding of the fundamentals of given physical phenomena, the new methods of computational physics will promote an even profounder penetration into the principles of nature. As applied to physical experiments, the new concepts must permit constructing a model of a physical phenomenon expressed in terms of computational physics and represented by the appropriate algorithm, naturally, with the optimal division of functions between the real and the computer experiment.

Prior to automating scientific investigations, just as prior to an autonomous discipline, there are technical and organizational problems, in addition to purely scientific problems. Constructing automated systems--and they are now needed by the dozens and hundreds--calls for a unified, scientifically substantiated approach. At work developing this approach is the Council on Automating Scientific Research, along with the complex of scientific-organizational measures in this field in the USSR Academy of Sciences. As noted above, CAMAC was adopted as the standard in the academy. A program for designing and building systems for automating scientific investigations was developed by the USSR Academy of Sciences in collaboration with the Ministry of Instrument Making, Automation Equipment and Control Systems.

Special subdivisions in many academy institutes have been constituted in solving problems of automating scientific research. Specialists on automating scientific investigations at work in these subdivisions must possess the research techniques in their fields, have training in computers, applied mathematics, mathematical modeling and so on. The Council on Automating Scientific Research is holding schools and conferences to exchange experience and upgrade the qualifications of specialists engaged in automating scientific investigations. Still, the specialists are few in number; their training needs to be organized in institutions of higher learning. Some institutions of higher learning have taken these steps, but this is still far from enough. In addition, it is advisable to hold courses on the application of computers to scientific investigations for students who will be future physicists, chemists, biologists and specialists in other sciences.

Carrying out these actions will foster the fastest possible advances in efforts to automate scientific investigations in centers of the USSR Academy of Sciences and other departments, including in institutes specializing in physics.

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CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

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ACTIVITIES AT INSTITUTE OF AUTOMATION AND ELECTROMETRY

Moscow VESTNIK AKADEMII NAUK SSSR in Russian No 1, 1979 pp 3-11

[Article by Yu. Ye. Nesterikhin, corresponding member of the USSR Academy of Sciences and director, Institute of Automation and Electrometry]

[Text] The Institute of Automation and Electrometry, Siberian Division of the USSR Academy of Sciences, was founded in 1957. The institute's scientific activities center on developing and building model problem-oriented systems based on CAMAC [computer-aided measurement, automation and control] standards for automating scientific investigations, study of the theoretical principles of memory and optical processing of information and research into the physics of nonlinear waves.

The Presidium of the USSR Academy of Sciences gave a hearing to a paper by the director of the Institute of Automation and Electrometry, corresponding member of the USSR Academy of Sciences Yu. Ye. Institute, relating the work of the institute.

Paper by Yu. Ye. Nesterikhin

The aim of what the Institute of Automation and Electrometry is doing in automating scientific investigations is greater effectiveness and higher quality of scientific inquiry by the direct incorporation of computers in research procedures and the maximum use of computer potentialities at all stages--from gathering experimental information to constructing a mathematical model of the phenomenon under study. The prime direction of work at the institute in this field is carrying through the program of building model problem-oriented automated systems based on a unified system architecture and unitized general-purpose hardware and software. In other words, solutions are being found to problems of constructing systems in which a model architecture (unified for all areas of experimentation) is merged with a model aggregation of units (unified for a given kind of experiment).

Today an adequate approach to this problem involves broad application of program-controlled highway type modular systems corresponding to the international CAMAC standards. These systems are sets of widely varying autonomous devices--CAMAC modules unified in design and modes of information exchange; using them, it is easy to configure programmable structures for automating sophisticated experimental and process facilities.

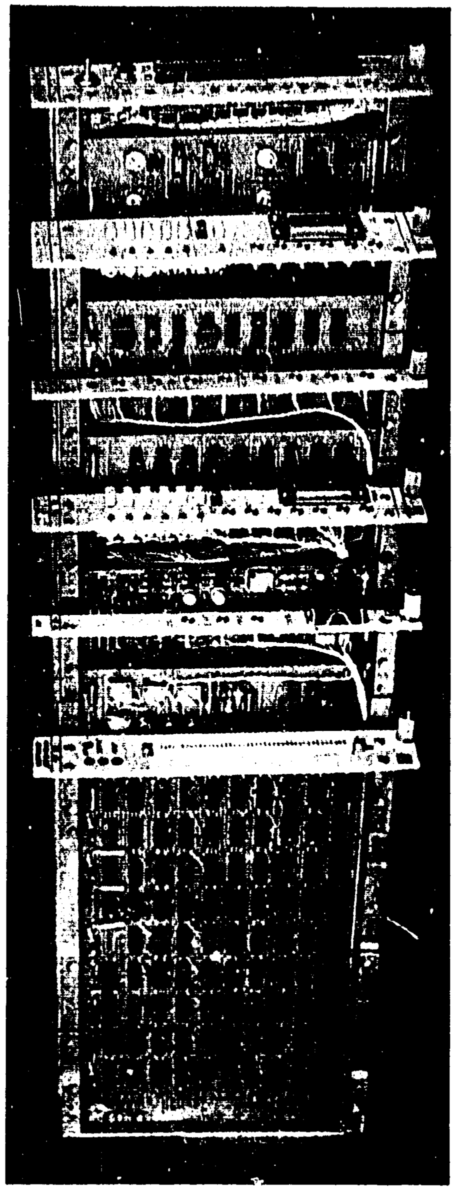
Development of CAMAC equipment, conducted by the institute jointly with the Special Design Office for Scientific Instrument-Making, Siberian Division, USSR Academy of Sciences (the nomenclature of general-purpose CAMAC modules now numbers about 100 designations), served as the foundation for solving problems in automating the most widely varying experiments (from biomedical to nuclear physics)--in a frequency range of tens of kilohertz for continuous type experiments to hundreds of megahertz for pulsed type experiments. And the "orientation" of the system toward a defined class of experiments was achieved by a very limited set of supplementary modules. For example, automating studies of phenomena in the electrical explosion of conductors called for two modules like these: an analog-to-digital converter, for recording a process at a frequency of 200 MHz and a high-speed memory.

Largely, how effective automated complexes are is determined by the "global" system architecture--the character of interaction between the systems that directly serve the experimental setup, the productive computers processing the information and the intelligent terminals--automated work stations of the experimenter, designer and so on. In deciding what model structure to select, one must weigh the state of the art in computer engineering: departmental dispersion in computer manufacturing and, as a consequence, computer standards irregularity; the scattered distribution of "materialized experience" (software support) for computers of different types and so on.

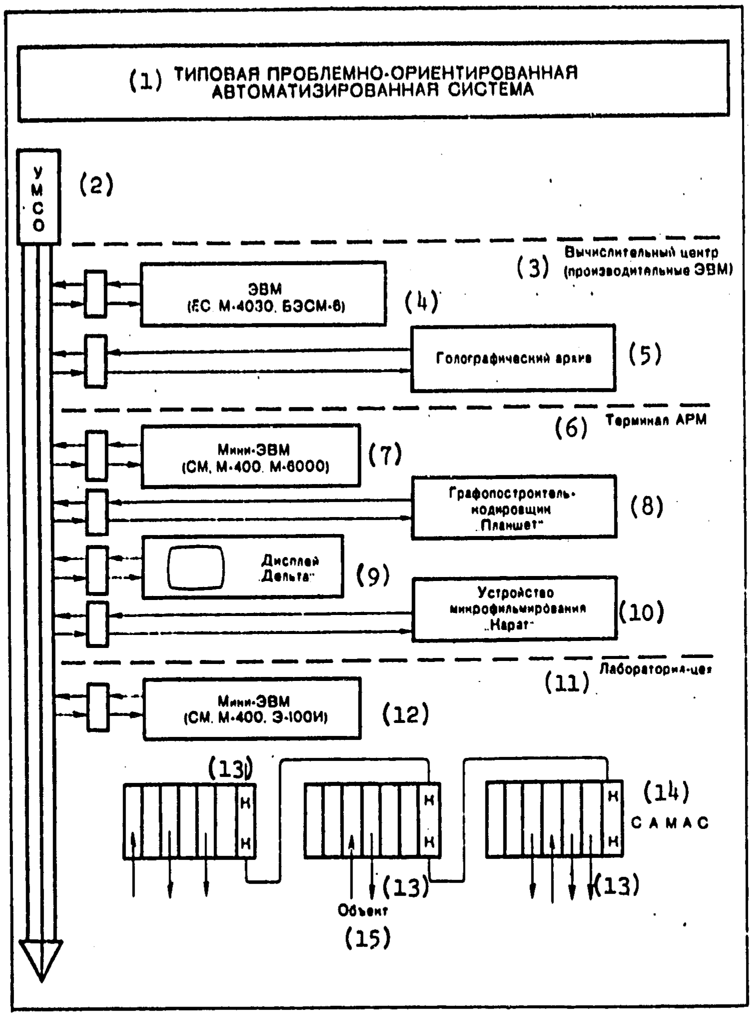
Work by institute scientists into the system architecture of automated complexes led to development of a new type of communication system--a unified highway type interchange system (UMSO [unifitsirovannaya magistral'naya sistema obmena]). This is a high-output machine-independent channel executed under the CAMAC standards. Computers of the principal types built in CEMA countries have been unified in the institute into a single complex, based on the channel: YeS computers, ASVT, M-4030, M-400, M-6000, YeS-1010 and Elektronika-100), along with specialized single-purpose graphics input/output devices and systems functioning in-line with the experimental setup.

Experience in recent years lent support to the usefulness of the proposed architecture, along with the hardware and software devices of automation that have been built in handling wide-ranging tasks in science and manufacturing.

The proposal of the USSR Academy of Sciences was passed at a conference of presidents of the academies of sciences of socialist countries (1977)--to build model complexes for automating scientific investigations by unified combination of a variety of computers and by interfacing with experimental setups using program-controlled modular systems under CAMAC standards.



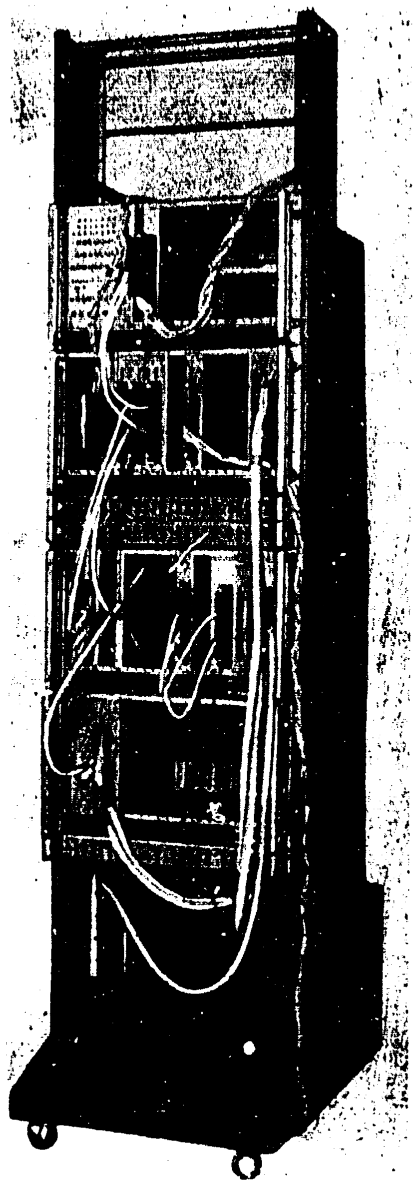
Model CAMAC program-controlled modules



Implementation block diagram for three-level system of automated investigations in the Institute of Automation and Electrometry, Siberian Division of USSR Academy of Sciences

Key:
1. Model problem-oriented system
2. UMSO [Unified Highway Type Interchange System]
3. Computer center (productive computers]
4. Computer (YeS, M-4030, BESM-6)
5. Holographic archives
6. Terminal of automated work station
7. Minicomputer (SM, M-400, M-6000)
8. Planshet graphics plotter-encoder

[Key concluded on next page]



Channel facility of UMSO-interfacer between eight computers of different types

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[Key to Figure on preceding page, concluded]

9. Delta display
10. Karat microfilming unit
11. Laboratory-workshop
12. Minicomputer (SM, M-400, E-100I)
13. Crate...Crate
14. CAMAC [Computer-aided measurement, automation and control]
15. Object

Systems developed by the Institute of Automation and Electrometry, Siberian Division of the USSR Academy of Sciences, based on the model structure, were adopted as base problem-oriented automated systems.

Further, Yu. Ye. Nesterikhin characterized the investigations by the Institute of Automation and Electrometry into optical processing of information.

The scope of interferometric applications grew much larger with the advent of coherent radiation sources and electronic computers. Denis Gabor's discovery of the interference method of image formation helped in the observation of interference effects when light reflects from any scattering objects. Lasers substantially simplified interferometer design; experimentation was fully automated with the aid of electronic methods of information processing.

A laser displacement meter, a laser gravimeter and a laser flowrate meter were designed and built in the Institute of Automation and Electrometry, based on laser interferometers (as part of the program of scientific research "Designing and Building Laser Devices for Information Sensing and Processing, under the Coordinating Plan, Siberian Division, USSR Academy of Sciences). These devices are intended for measuring lengths in physical experiments, determining changes in gravitational acceleration and in studying turbulence.

The IPL-10 laser displacement meter can measure distances to 60 m with a relative error of $5 \cdot 10^{-7}$. The instrument's operating speed is adequate for measurements when a test object is traveling up to 0.3 m/s. The IPL-10 has a digital readout and can function in automated experimental systems. The instrument found application in the assembly and certification of the reference reading system of a machine tool for making parts weighing up to 250 tons. The maximum dimensions of the two control parts, 5 m in length, coincided to a precision of 0.02 mm. The high metrologic characteristics in combination with design simplicity and convenience in operation place the IPL-10 device on a par with the world's best models.

Operation of the laser gravimeter is based on the ballistic method of determining gravitational acceleration. These measurements are taken by computing the path and time of fall of a test mass as the minimum over two intervals. The test mass in the instrument is a corner reflector falling freely in a tube under vacuum. A laser displacement meter is built into the instrument to measure the path intervals. A rubidium standard (whose frequency drift does not exceed $5 \cdot 10^{-11}$ a day) is used as the time reference standard.

Staff members of the Institute of Automation and Electrometry and the Institute of Earth Physics imeni O. Yu. Shmidt, USSR Academy of Sciences, using this instrument, measured gravitational acceleration at the support base of the world gravimetric network in Potsdam, as well as in Singapore and Paris. Similar measurements were made in Novosibirsk, Moscow, Tallin and Tbilisi. The outcome of these measurements was the control tie of the USSR gravimetric network to the world network to a precision of $4 \cdot 10^{-9}$. Work done by the Institute of Automation and Electrometry in laser gravimetry has gained high recognition in our country and abroad.

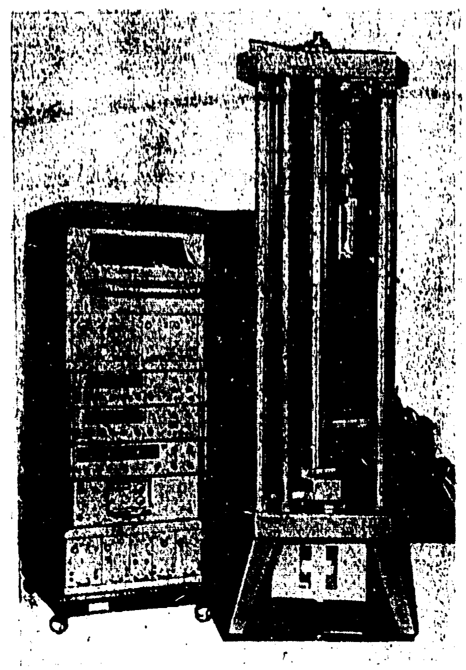
Our measurements in the International Bureau of Weights and Measures (Paris) showed that the laser gravimeter, designed and built in the institute, today is the most precise and most productive instrument of its kind in the world. It turns out continuously up to 5000 measurements a day; they are processed by a minicomputer on a real-time basis with the experimental setup. For comparison, we can state that several tens of measurements a year can be made with the I. Sakumi gravimeter (Paris).

The LADO-1 laser doppler velocity meter was built as a result of scientific cooperation of the Institute of Automation and Electrometry and the Karl Zeiss Jena People's Enterprise (GDR). The determination of the doppler frequency shift in light scattered by impurity particles in a flow of liquid or gas was postulated on the basis of instrument operation. Laser radiation is focussed in a given region of the traveling medium. The doppler shift in the scattered light beam is discriminated by optical heterodyning.

The instrument is built with a two-frequency circuit with shifting of the carrier beam frequency by a known amount; this permits simultaneous measurement of the magnitude and direction of two orthogonal components of the velocity vector. The range of the velocities measured is 0-80 m/s; measurement accuracy is 0.03 percent for an averaging time of 1 s. The volume over which the velocity measurement is averaged is several tens of microns; this affords the possibility of measuring velocity in boundary layers.

This instrument is made up of a laser, optical assemblies, an electronic signal processing block and a precision coordinate-measuring stand. The instrument can position, with precision, the measured volume relative to three orthogonal coordinate axes within the limits 100x100x200 mm. The main area of application for the LADO-1 laser instrument is experimental hydrodynamics and aerodynamics. Manufacture of a series-produced instrument model is proposed for CEMA countries.

The step that follows in applying interferometry for investigating flows is designing and building a doppler photographic reading correlator. This instrument must function at very weak scattering levels--down to units of photons.



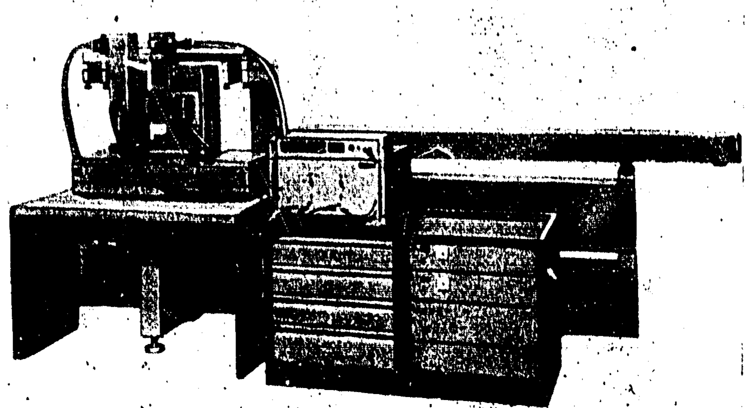
Mobile facility for measuring gravitational acceleration

Broad use of laser measuring devices goes far in ensuring progress in scientific experimentation and in industrial technology.

Concluding his paper, Yu. Ye. Nesterikhin highlighted studies at the Institute of Automation and Electrometry on the physics of nonlinear waves.

Very marked progress in studying nonlinear phenomena was recorded worldwide over the past 10-20 years. This progress was due, in large part, to the general advance in investigating many-body problems and to developments in computer engineering that permit numerical experiments to be conducted with a large number of nonlinear equations.

Studies into problems of the physics of nonlinear phenomena were conducted by a group of theoretical physicists at the Institute of Automation and Electrometry.



LADO-1 laser doppler velocity meter

A study was made into the problem of the parametric turbulence of waves originating when they are excited by an external homogeneous electromagnetic field, for example when magnons are excited in ferromagnetic materials by an electromagnetic field in the UHF range, when sound in crystals is excited by laser radiation and so on.

Decay processes leading to formation of a wave spectrum in terms of frequencies and directions of propagation are fairly strong in plasma, generally speaking. Plasma turbulence was shown, in contrast to hydrodynamic turbulence, to be severely anisotropic and nonstationary; its spectrum is singular and is concentrated at lines and surfaces and even in individual points in wave vector space.

Couette flow serving as the example (flow of fluid between coaxial cylinders, one of which is rotating), a study is underway dealing with the initiation of hydrodynamic turbulence.

As early as 1944, academician L. D. Landau proposed that the initiation of turbulence can proceed stage by stage: as the velocity of laminar flow increases, stability losses occur and a periodic flow with a certain frequency originates; then stability loss again ensues, additional motion at a different frequency not commensurable with the first starts up, then—flow at a third frequency and so on. To verify this hypothesis, in the institute a facility was built; with it, the flow rate of a liquid was measured with the laser doppler velocity meter and in experimental real-time data were fed into a computer operationally performing the statistical processing of the data, for example, computing the pairwise autocorrelation velocity function, the power spectrum and so on.

As the experiments revealed, L. D. Landau's proposal is valid only to the third critical velocity. Beyond that, instead of motion with many periods there ensues motion of an intermediate type, when spatial periodicity is preserved to a significant extent; however, the temporal periodicity breaks down and the frequency spectrum proves to be not discrete, but continuous. Apparently, in this experiment the "strange attractor" effect--intensely under study by mathematicians--was realized. It turns out that regions with elongated trajectories (attractors) not containing stable points and limiting cycles can exist in the phase space of systems with three or more degrees of freedom. At present detailed experimental study of the strange attractor effect in Couette flow is underway.

Discussion of paper

After Yu. Ye. Nesterikhin's paper was delivered, the floor was given to corresponding member of the USSR Academy of Sciences Ye. P. Popov--chairman of the commission of the presidium, USSR Academy of Sciences, that has been looking into activities at the Institute of Automation and Electrometry. The reorganization of the institute some years ago, related Ye. P. Popov, yielded good results: automation was dovetailed in with modern physics, leading to the achievements that were recounted in the paper.

Original general-purpose systems have been developed on the basis of CAMAC standards. The institute's achievements has won world recognition in the area of software support associated with the development of these systems. Particular mention must be made of the graphical display equipment built here, with high resolution and automatic recording devices.

Studies on automation of scientific investigations are going on at the institute at a very high level and can yield an even broader outcome--in the automation of designing in the most wide-ranging sectors of the national economy.

The Institute of Automation and Electrometry has accumulated much positive experience in organizing inter-industry design offices. These design offices are administratively under the enterprise, but as to scientific methodology the institute directs them. This kind of link between institute and industry did much to promote the broad realization of the achievements and the results of investigations into manufacturing.

Academicians A. M. Prokhorov and N. A. Pilyugin and corresponding member, USSR Academy of Sciences A. F. Bogomolov spoke at the session of the Presidium of the USSR Academy of Sciences.

The president of the USSR Academy of Sciences, academician A. P. Aleksandrov, spoke forcefully of the importance of the institute's studies, especially in designing and building systems in accordance with CAMAC standards. This made it possible, he said, to sharply improve the equipping of our institutes engaged in physical, biological and even economic investigations. The systems built by the institute for interfacing experimental facilities and computers, now in production in our country by various departments, make it possible to build very flexible computer structures in Academy of Sciences institutes that have a variety of computers. Here is an example: the system for nuclear studies that were to be conducted in CERN--built in the Leningrad Institute of Nuclear Physics imeni B. P. Konstantinov--proved to be very effective. Soviet devices in accordance with CAMAC standards were interfaced rapidly and without difficulty with Swiss, British and French facilities, so that two days after arriving at CERN, Soviet specialists commenced measurements. Another example lies in the system of automation for RATAN [radiotelescope of the USSR Academy of Sciences].

Summing up the discussion, V. A. Kotel'nikov, vice president, USSR Academy of Sciences, and academician, took note of the contribution of the Institute of Automation and Electrometry to designing and building systems under CAMAC standards. The work that the institute is doing in automating scientific investigations is very vital, in particular, for academy institutes, and this work must go on. Unquestionably, the institute has found its calling and must not change the direction of its investigations.

Resolution

In the resolution passed by the Presidium of the USSR Academy of Sciences, approval was given to the scientific and scientific-organizational activities of the Institute of Automation and Electrometry, Siberian Division, USSR Academy of Sciences. The primary directions of the institute's scientific activities were confirmed: studies on automating scientific investigations based on a model highway type computer system and CAMAC standards; investigations into the theoretical principles of memory and optical processing of information; study of physical effects for developing new principles of measurements and measuring devices; and investigations into the physics of nonlinear waves.

The Presidium of the USSR Academy of Sciences also approved the activities of the institute in developing new, more improved forms of introducing scientific innovations into the national economy.

10123
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GEOPHYSICS, ASTRONOMY AND SPACE

'AIR & COSMOS' REPORTS ON 'SALYUT-6' MISSION OPERATIONS

Paris AIR & COSMOS in French 7 Apr 79 pp 44-45

[Article by Serge Berg: "Observations, Maintenance on Board 'Salyut-6'"]

[Text] Some 40 operations to repair and replace defective materials and equipment were conducted by the "Soyuz-32" crew during the first month on board "Salyut-6", according to IZVESTIYA on 25 March.

Some of the repairs, which were termed "preventive maintenance," were begun as soon as Vladimir Lyakhov and Valeriy Ryumin arrived at the orbital station; the others were made after the "Progress-5" freight transport ship had delivered replacement parts.

Thus, for example, a back-up camera was brought by "Progress-5" because the on-board television system, which had been used extensively by previous crews, showed signs of failure. Similarly, the shower stall curtain was changed.

But the most important operation--and the longest (several days)--consisted of neutralizing a fuel tank in the propulsion system, in which the membrane was damaged: the membrane separates two parts of the tank, one containing nonsymmetrical dimethylhydrazine and the other--compressed nitrogen. The "Salyut" station has three of these tanks, and consequently it was possible to totally empty the defective tank without hindering the functioning of the station.

The defect in this membrane had already been noted by mission controllers and cosmonauts [Kovalenok and Ivanchenkov] 5 months ago. Only after a number of simulations in ground laboratories could the procedure to be followed in orbit be established.

The operations began on 16 March. First of all, the crew rotated the "Soyuz-32"--"Salyut-6"--"Progress-5" complex along its longitudinal axis in order to create an artificial microgravity; the centrifugal force thus created made it possible to separate the combustible from the nitrogen. Part of the fuel could then be pumped into one of the empty tanks on "Progress." But the complete evacuation required more than a week; the process was based on the property of the space vacuum to "suck" all traces of hydrazine that could be found within the tank (which was vented to open space). With the evacuation complete, the tank was refilled with compressed nitrogen. The operation lasted 10 days; it was completed by ?7 March.

Surveying Over China

Of all the experiments a great deal of attention was given to those taking place in the "Splav" and "Kristall" furnaces, which handled Soviet experiments for 3 days before the French-Soviet "Elma" experiments began (cf. AIR & COSMOS, No 759). The Soviet press has emphasized the interest in obtaining by fusion very pure glass to be used in the manufacturing of optical fibers for telecommunications....

Earth observations continue to occupy an important place, and the Soviet press was particularly pleased to describe the work conducted over the USSR-Chinese border region: observations of the Pamirs, the Lake Baykal area, the region where BAM is being constructed....

Ryumin and Lyakhov know these areas very well. One was borm in Komsomol'sk-na-Amur, and the other did his military service in the extreme Far East. Time and again they flew over these regions in a TU-134 specially equipped for flights of cosmonauts making observations under the auspices of the "Priroda" (nature) program. Responsible for these flights is Soviet test pilot Nikolay Stepanovich Zatsepa. The course usually flown was: Moscow-Irkutsk-Khabarovsk-Vladivostok-Kamchatka-Dushanbe-Astrakhan'-Moscow.

Ryumin and Lyakhov, who have already spent 1 month in orbit, installed on board the station a "Yelena" gamma telescope, which was designed to record the flow of gamma radiation and electrons; they have also conducted the "Fiton" and "Biogravistat" experiments, which dealt with plant growth.

From now on the two cosmonauts can communicate with one another using the "Kol'tso" (ring) walkie-talkie system. And finally, the cosmonauts made possible yet another space "first" on 24 March: thanks to a television receiver delivered by "Progress-5" and installed on board "Salyut-6," the first television pictures from earth were viewed in orbit. From now on there will be two-way communications through television.

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PHYSICS

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GENERATION AND UTILIZATION OF POWERFUL NANOSECOND PULSES, A SCIENTIFIC COMMUNICATION

Moscow VESTNIK AKADEMII NAUK SSSR in Russian No 2, 1979 pp 37-46

[Article by Doctor of Technical Sciences G. A. Mesyats]

[Text] This communication is devoted to the technique of nanosecond pulses, whose output varies from megawatts to terawatts or more with pulse length from tenths to hundreds of nanoseconds. We began investigations in this field at the Tomsk Polytechnical Institute in 1957 to investigate the development of electric discharges in various dielectric media: in liquids, solids, gases and in a vacuum.

At the end of the 1950's and beginning of the 1960's, interest in these investigations increased especially due to the need to utilize powerful nanosecond pulses in a number of new areas of physics: to generate powerful laser emission pulses, for input and discharge of charged particles in accelerators (specifically, in an accelerator with counter beams), for investigations in nonlinear optics, in nuclear physics (to supply power to spark and streamer chambers), in high-speed photography and so on. Investigations of powerful nanosecond pulses, carried out at Tomsk Polytechnical Institute, contributed to a significant degree to rapid development of some of the named fields. For example, methods or indirectly pulsed installations developed by our group were used in creation of powerful ruby lasers, spark and streamer chambers, in investigations on nonlinear optics, in investigation of nanosecond X-ray pulses and so on. A monograph,* devoted to the technology of powerful nanosecond pulses, was published in 1963.

Two factors can be named which aroused the great interest in this field of technology and its rapid progress. First, this was investigation of high-speed processes which occur due to the effect of strong electric and magnetic fields within a very short time; second, the energy of powerful nanosecond pulses can be converted to electron or ion energy, to electromagnetic radiation

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*G. A. Vorob'yev and G. A. Mesyats, "Tekhnika formirovaniya vysokovol'tnykh nanosekundnykh impul'sov" [The Technology of Shaping High-Voltage Nanosecond Pulses], Moscow, 1963.

energy of different range -- from X-ray to infrared -- and also to SHF-radiation energy by using various physical effects.

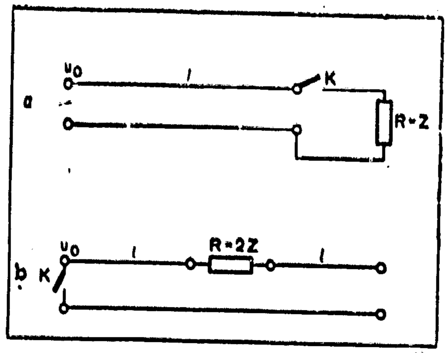

Figure 1. Pulse-Shaping Circuits: a -- diagram of square-wave pulse formation with amplitude $U_0/2$; b -- diagram with double storage line; U_0 -- preliminary voltage of storage lines 1; K -- switching element; Z -- wave impedance of line

The problem generating powerful nanosecond pulses is one of the trends of investigations of the Heavy-Current Electronics Institute (ISE) of the Siberian Department of the USSR Academy of Sciences, recently created at Tomsk. Various physical and engineering problems related to the use of powerful nanosecond pulses are now being solved in many scientific institutions of the country: at the Institute of Atomic Energy imeni I. V. Kurchatov, in a number of laboratories of the Physics Institute imeni P. N. Lebedev of the USSR Academy of Sciences, at the Institute of Nuclear Physics of the Siberian Department of the USSR Academy of Sciences, at the Institute of Automatics and Electrometry of the Siberian Department of the USSR Academy of Sciences, at the Applied Physics Institute of the USSR Academy of Sciences, at the Joint Institute for Nuclear Research at Dubna, at the Khar'kov Physicotechnical Institute of the Ukrainian SSR Academy of Sciences, at the Leningrad Scientific Research Institute of Electrophysical Apparatus imeni D. V. Yefremov, at the Tomsk Polytechnical Institute and so on. Any laboratory involved in plasma physics or laser or nuclear physics essentially now utilizes the technology of powerful nanosecond pulses to one or another degree.

The simplest circuit for generating powerful nanosecond pulses is presented in Figure 1, a. It is formally similar to ordinary pulsed equipment circuits. The storage lines are first charged to voltage U_0. K is a switching element, as which spark gaps are used. If the load resistance R is equal to the characteristic wave impedance of this line Z, a square-wave pulse with amplitude $U_0/2$ and with length equal to double the wave travel time in the storage line can be generated. The energy rise and decay time in the pulse is determined by the transient processes which occur in the switching element.

A circuit with double storage line, which permits generation of a voltage two times greater than in the previous circuit, is presented in Figure 1, b. There are different methods of pulse conversion, specifically, shortening the pulse front and pulse length, since a square-wave pulse with short length and with short front length is commonly used. The device which shortens the pulse front is called a sharpener, while the device which shortens the pulse length is called the cutting element. The cutting element and sharpener are nonlinear resistors whose value is high for some time and then decreases almost to zero very rapidly within a nanosecond and sometimes in fractions of a nanosecond. Various types of spark gaps or ferrite elements are most frequently used as nonlinear resistors.

One of the main problems in generation of powerful nanosecond pulses is the problem of commutation. A discharge in different media -- in a vacuum, gaseous medium, liquid and sometimes in a solid -- is used for commutation. Commutating gas-discharge arresters are widely used. The time during which the pulse energy rise occurs from zero to the maximum value is called the commutation time. This time determines the minimum possible pulse front.

For gas-discharge commutators with low current value in the pulse (up to 10^4 A), the commutation time t_k is calculated from the Rompe-Weizel spark model:

$$pt_k = \frac{A}{(E/p)^2},$$

where p is gas pressure, E is the electric field intensity and A is a constant which characterizes the gaps. With fixed voltage in the spark gap, the value of E_p is constant; therefore, the time t_k will decrease with an increase of pressure. Because of this, the nitrogen, air or other pressure in these spark gaps should not be less than 10 atm with pulse front length beginning at nanosecond.

Processes related to the inertia of channel expansion begin to play a significant role with a large increase of current. The channel is unable to expand rapidly within a short time and to increase its conductivity. Therefore, the problem arises of how to achieve high values of current with short rise times. Two methods of solving this problem were proposed at ISE SO AN SSSR.

The first method, called avalanche commutation, consists in the fact that a large number of electrons is created simultaneously in the spark gap upon application of an electric field. Each of these electrons, located in a sufficiently high electric field, creates an electron avalanche within a short time: one electron leads to formation of millions and even hundreds of millions of electrons within a very short time and the current in the gas increases very rapidly. Thus, the spark channel is eliminated and, moreover, extremely rapid processes occur which permit a reduction of the rise time to tenths of a nanosecond. Experiments showed that current rise rates up to 10^{14} A/s can be achieved during avalanche commutation. Moreover, higher pulse recurrence frequencies (up to 10^4 Hz or more) are achieved with avalanche commutation.

The second method proposed during development of the avalanche commutation method consists in injecting electrons from an electron source directly into the gas. If the value of the injected electron current is high, the short commutation time and the high rate of current rise are achieved even without avalanche multiplication of electrons under conditions of an independent space discharge. The device which operates on this principle is called an injection thyratron. As is known, the electrons of ordinary thyratrons appear due to cathode heating. Here the electrons are injected through the cathode from the outside. This permits total control of the device: not only of switching it on, but also of switching it off rapidly and stopping electron injection.

This device, proposed in 1969, was very useful for different purposes, specifically, in powerful gas laser equipment. However, there is one deficiency in the injection thyratron. As soon as the electric field in the gas decreases, the electron drift rate decreases during commutation and the commutator will have high residual resistance. This same problem exists in spark gaps with avalanche commutation. To correct this deficiency, a gas must be used in which high electron drift rate is maintained in low electric fields. For example, methane has this property. The dependence of the electron drift rate in methane on E/p (Figure 2) is similar in nature. At $E/p \approx 1\ V \cdot cm^{-1}\ mm\ Hg^{-1}$, this rate is maximum (on the order of 10^7 cm/s), although it is considerably less than 10^6 cm/s in ordinary gases. This effect permits a reduction of the residual resistance of the injection thyratron by several factors.

Low residual resistance and high current rise rate may also be achieved in spark gaps with large number of spark channels. Many channels can be formed in solid-state, liquid and gas spark gaps. A commutator with six spark channels, developed at TPI, in water which commutate current of 150 kA within 8 ns, is shown in Figure 3. Methods of igniting up to 10 channels in a gas at voltage from 0.5 to 3 mV have been developed at ISE SO AN SSSR. In this case the time between ignition of individual channels comprised units of nanoseconds.

Storage lines are used to store energy. Two types of lines are usually employed: strip lines -- two strips between which a dielectric is placed, and coaxial lines -- two coaxial tubes between which a liquid dielectric is usually located. One can show that the current related to the width of the strip or diameter of the tube is proportional to $E\sqrt{\varepsilon}$, where E is the electric field intensity and ε is the dielectric permeability of the insulation. Consequently, ε and E of the insulation must be increased to increase the current (by using, for example, distilled water in which $\varepsilon = 81$) and the dimensions of the storage elements must also be increased. When the energy of the storage elements reaches millions or tens of millions of joules, the storage devices acquire enormous dimensions and their cost increases sharply. Moreover, difficulties related to generation of short pulses appear (the larger the dimensions, the more difficult it is to generate short waves).

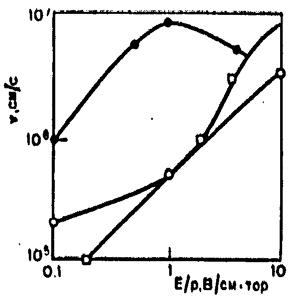

Figure 2. Dependence of Different Gas Drift Rate on Ratio of Electric Field Intensity E to Gas Pressure p: O -- Ar; ● -- CH_4; ◻ -- CO_2

Figure 3. Multichannel Discharge in Water

Therefore, the problem of finding new storage devices arises. The importance of this problem is illustrated by the following example. It is known that 1 kW·hr (3.6 MJ) of ordinary electric energy costs several kopecks. Not less than 1 million rubles must be spent to produce the same power in a nanosecond generator. Therefore, a search for methods for most efficient conversion of ordinary electrical energy to powerful short energy has been conducted for a long time in the most diverse laboratories.

One of the solutions to the developed situation is to use inductive energy storage devices and current cutoff in them. These investigations are being conducted actively and successfully at the Institute of Atomic Energy imeni I. V. Kurchatov under the supervision of Academician Ye. P. Velikhov and at the Scientific Research of Electrophysical Apparatus imeni D. V. Yefremov at Leningrad. The problem of producing very high pulsed energy in the milli- and microsecond bands has been solved there. The ISE SO AN SSSR jointly with the Tomsk Polytechnical Institute is solving the problem of energy storage in inductance and conversion of it not only to microsecond, but also to nanosecond electron beams. It is not yet possible to completely solve this problem, but pulse generators have already been developed which permit energy storage in capacitors at low voltage, then pumping it to the inductance, after which the current is sharply cut off, usually due to explosion of the conductors. Solution of this problem became possible due to development of new current choppers, as which a set of a large number of copper micron conductors is used instead of the metal foils used previously. The use of these conductors permits a multifold increase of the current cutoff speed and consequently of pulse amplitude. These effects are used to develop small pulse generators with voltage of 0.6-1.5 MV. Electron accelerators are being developed on the basis of these generators.

A pulsed accelerator with electron energy of 1 MeV and current up to 20 kA, developed at ISE SO AN SSSR and the Tomsk Polytechnical Institute, is shown in Figure 4. Several of these accelerators are operating at institutes of the USSR Academy of Sciences.

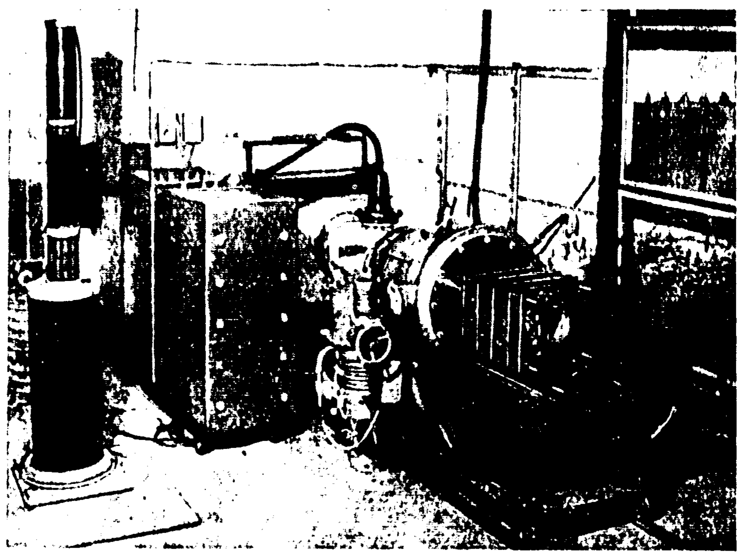

Figure 4. "Puchok 1M" Electron Accelerator With Inductive Intermediate Energy Storage Device and Microconducting Current Chopper

The disadvantage of current choppers in the form of exploded conductors is their one-time use. A new conductor must be inserted to generate a new pulse. Usually several minutes are required for preparation and replacement of the chopper. Therefore, these generators are not yet able to operate in the large-frequency pulse mode. In this regard the injection thyratron which was discussed above opens up interesting possibilities. Current cutoff in it may occur due to stopping electron injection.

The following experiment was conducted to check the possibility of current cutoff. A voltage of 330 kV was fed to an injection thyratron. The current of the injected electrons comprised 18 kA. The current in the thyratron itself was 150 kA. After the electron current was stopped in the injector, the current in the thyratron was stopped as well. The cutoff time of current of 150 kA comprised approximately 200 ns.

However, it is difficult to use an injection thyratron as a current chopper in the presence of an inductive storage device due to development of instability in the thyratron plasma. The electric field in the space gas discharge plasma of the thyratron increases strongly during current cutoff. It also leads to instability of the space discharge and formation of a discharge channel. To eliminate this instability, the electric field must be reduced, for example, by increasing the distance between the thyratron cathode and anode with fixed voltage. But this leads to a decrease of current which pumps the inductive storage device. Therefore, gaseous media must be found in which the discharge current, proportional to the electron drift rate, will be greater in small electric fields. It was noted above that methane, the use of which may be very useful, has this property.

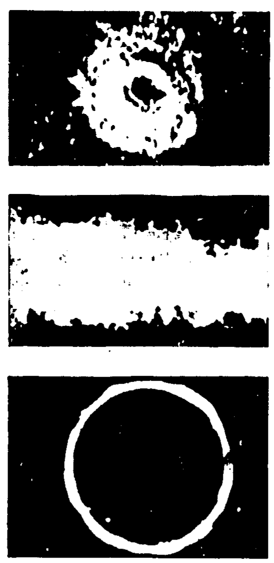

Figure 5. Prints of Electron Beams of Different Type

One of the most significant trends in the use of powerful nanosecond pulse equipment is ..its use in heavy-current nanosecond electron accelerators. The first investigations in this direction were conducted independently in the USSR and in the United States. A group of research associates at ISE SO AN SSSR developed the first heavy-current nanosecond electron accelerator in the USSR in 1967. This was preceded by almost a decade of investigations on powerful nanosecond pulse technology and study of the discharge in a vacuum due to the effect of high-voltage nanosecond pulses. The investigations led to the discovery of the phenomenon of explosive electron emission, consisting in the fact that the microscopic points on the cathode explode due to the effect of the autoelectron emission current. A metal-plasma transition is formed in this case which contributes to sharp amplification of electron current. The electron currents may be extremely high -- up to hundreds of thousands and even millions of amperes.

Explosive electron emission is used in heavy-current electron accelerators. There are three types of these accelerators. First, an accelerator which permits generation of a focused electron beam. For example, current density up to 10^7 A/cm^2 has been achieved at the Institute of Atomic Energy imeni I. V. Kurchatov and at FIAN [Physics Institute imeni P. N. Lebedev of the USSR Academy of Sciences].

Second, an accelerator for generating large-area beams. A wide electron beam can be produced and discharged into the atmosphere with the existence of many emission centers on a large surface. For example, beams with current up to 20 kA and area up to 1 m^2 for CO_2 laser pumping have been achieved at ISE SO AN SSSR.

Third, beams of tubular shape can be produced in accelerators by using diodes with intersecting electric and magnetic fields. Prints of three different types of beams produced in accelerators of ISE SO AN SSSR: a -- an annular beam 6 cm in diameter with current of 10 kA and electron energy of 600 keV; b -- a flat beam 10 cm wide with current density of 10 A/cm^2, t_k = 25 ns; and c -- a focused beam with current density of $5 \cdot 10^6$ A/cm^2, are shown in Figure 5.

Development of powerful nanosecond electron beam equipment strongly stimulated the possibility of using them in thermonuclear fusion. These investigations are being conducted at a number of organizations in the USSR and primarily at the Institute of Atomic Energy under the supervision of L. I. Rudakov and at the Institute of Nuclear Physics of the Siberian Department of the USSR Academy of Sciences under the supervision of Corresponding Member of the USSR Academy of Sciences D. D. Ryutov.

Three high-voltage stands of the ISE SO AN SSSR for production of nanosecond pulses having voltage greater than 3 MV and current up to 500 kA, which will be used to conduct various types of investigations related to the effect of these pulses, are shown in Figure 6.

The use of high-voltage nanosecond pulse equipment permits solution of the problem of miniaturization of high-voltage devices. It follows from Figure 7 that the electric strength of insulation increases strongly with a decrease of pulse length, that is, high electric field intensity can be achieved with

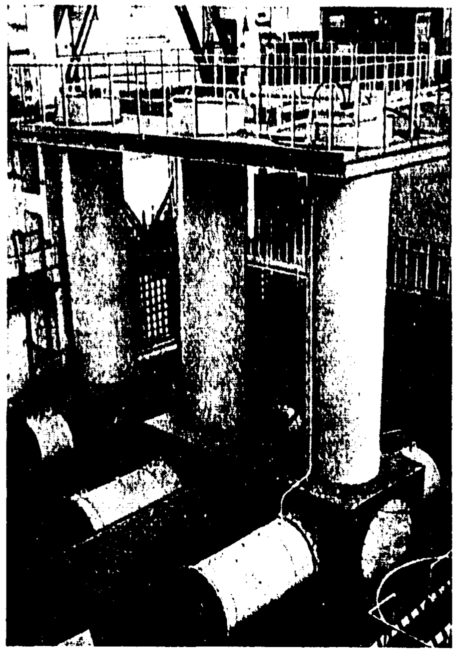

Figure 6. High-Voltage Stands for Nanosecond Pulse Tests

short length. This permits solution of the problem of miniaturization of high-voltage devices. On this basis, a series of essentially new X-ray apparatus has been developed under the supervision of V. A. Tsukerman and N. I. Komyak during the past few years at the NPO Burevestnik. Explosive emission cathodes are used as the electron source in them. The fundamental research of explosive electron emission and the autoemission processes which stimulate it, carried out by out group at Tomsk, by G. N. Fursey at Leningrad University, and also by M. I. Yelinson at the Institute of Radio Engineering and Electronics of the USSR Academy of Sciences and by V. N. Shrednik at the Leningrad Physicotechnical Institute imeni A. F. Ioffe of the USSR Academy of Sciences, contributed to the success of this work.

The weight of the X-ray apparatus now produced is 8-10 times less than ordinary apparatus. These X-ray devices are used actively in flaw detection, specifically, to X-ray gas and oil pipelines, to calibrate radiation detectors, in medical practice and so on. Development and introduction of these nanosecond X-ray apparatus denotes a real revolution in X-ray technology. They are now being sold in all CEMA countries and also in the United States, West Germany, England, Japan and other capitalist countries.

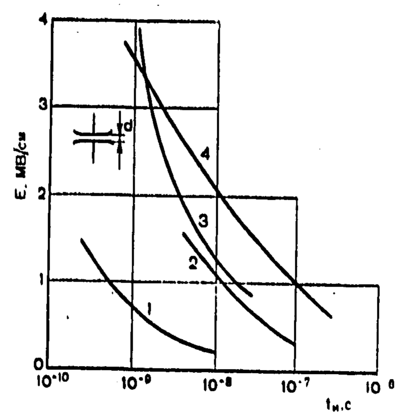

Figure 7. Dependence of Electric Strength of Different Media on Pulse Length: 1 -- air, p = 10 atm, d = mm; 2 -- dielectric water surface, d = 3 cm; 3 -- vacuum, d = = 0.5 mm; 4 -- transformer oil, d = 1.2 mm

The small overall dimensions and the possibility of producing high outputs make powerful nanosecond electronic accelerators exceptionally promising for production purposes. Experiments conducted at ISE SO AN SSSR showed that such processes as hardening polyester paints and sterilization of microorganisms proceed with identical success upon exposure to both continuous and nanosecond pulse beams with high pulse recurrence frequency.

The "Sinus-4" accelerator, which has average output of 6 kW, pulse recurrence frequency of 100 Hz and pulse length of 20 ns, is presented in Figure 8.

An installation for using powerful SHF pulses with recurrence frequency of 100 Hz has been developed in joint work of FIAN, the Applied Physics Institute of the USSR Academy of Sciences and ISE SO AN SSSR. It includes a powerful nanosecond pulse generator, a diode for shaping a tubular electron beam, a resonator and solenoid. Investigations to produce powerful SHF emission pulses using heavy-current electron beams were begun jointly in the 1970's by the Applied Physics of Institute of the USSR Academy of Sciences and by FIAN. These investigations laid the basis for the large cycle of research which has now received international recognition.

Powerful nanosecond electron beam equipment made it possible to obtain new fundamental results in nuclear physics, solid-state physics, in gas- and vacuum-discharge physics and so on. For example, the first investigations of the effect of powerful beams on ion crystalline dielectrics and glass were performed at the Tomsk Polytechnical Institute and the ISE SO AN SSSR due to the use of heavy-current accelerators of ISE as early as 1969. These investigations permitted the detection of such phenomena as brittle failure of ion crystals, semiconductors and glass; fundamental plasma luminescence having temperature independence; high-energy conductivity during the effect

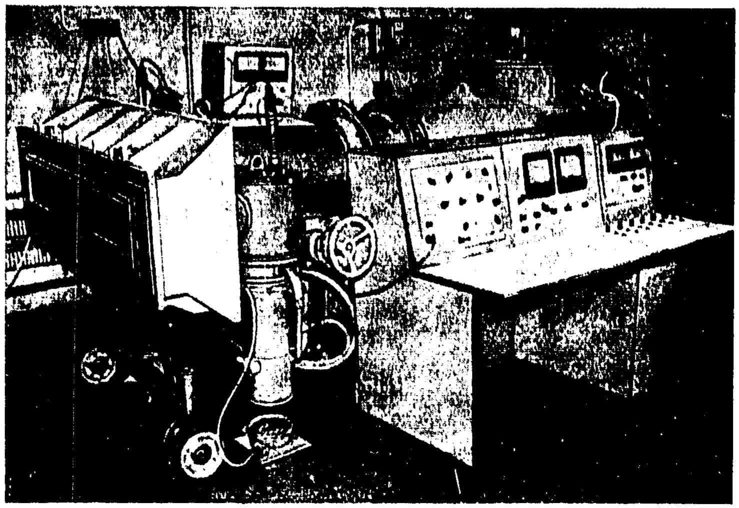

Figure 8. "Sinus-4" Electron Accelerator of ISE SO AN SSSR

of an electron beam and so on. One can state that a new trend related to study of phenomena caused by formation of a degenerated electron-hole plasma whose density is up to 10^9 times higher than that in stationary irradiation in ordinary accelerators, occurred in irradiation physics of dielectrics.

Thus, powerful nanosecond pulse equipment now finds application both in various physical investigations and in solving a number of production problems and its capabilities are far from exhausted.

A discussion was held after G. A. Mesyats's report.

Academician A. V. Gaponov-Grekhov pointed out the unique capabilities of superhigh-power pulse generators to create high-frequency emission. Talking about the scientific trends developed at the Institute of Heavy-Current Electronics of the USSR Academy of Sciences, A. V. Gaponov-Grekhov emphasized that main efforts are concentrated here in development of purely electron beams and, moreover, development of accelerators is being carried out for specific applications. The Applied Physics Institute of the USSR Academy of Sciences is cooperating effectively with the Institute of Heavy-Current Electronics, specifically in the field of SHF-emission application.

L. I. Rudakov emphasized in his talk the importance of extensive development of the problem of producing superpowerful emission pulses, being carried out under the supervision of G. A. Mesyats at the Institute of Heavy-Current Electronics of the Siberian Department of the USSR Academy of Sciences.

M. S. Rabinovich noted the important role which the investigations of the scientific collective headed by G. A. Mesyats played in the work of FIAN in laser technology and development of powerful SHF generators. Approximately 100 different accelerators developed at different institutes are now operating in the USSR. There is already an acute need for industrial production of accelerators for various purposes.

Academician Ye. P. Velikhov talked about the cooperation of the Institute of Heavy-Current Electronics of the Siberian Department of the USSR Academy of Sciences and the Leningrad Scientific Research Institute of Electrophysical Apparatus imeni D. V. Yefremov in development of a series of accelerators for different purposes. One of these accelerators is already produced by industry.

The President of the USSR Academy of Sciences Academician A. P. Aleksandrov summarized the discussion. He turned attention to the fact that almost identical accelerators are now being developed at different institutes for different production purposes and expressed the opinion of the need to coordinate efforts in this field. Having noted the great successes of the recently created Institute of Heavy-Current Electronics of the Siberian Department of the USSR Academy of Sciences in working out the problem of superpowerful nanosecond pulses, A. P. Aleksandrov wished them further success in development of this important trend.

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PUBLICATIONS

ORGANIZING THE OPERATION OF A COMPUTING CENTER

Moscow ORGANIZATSIYA RABOTY VYCHISLITEL'NOGO TSENTRA (Organizing the Operation of a Computing Center) in Russian 1978, signed to press 11 Jul 78, pp 1-6, 186-191

[Annotation, foreword, introduction, Appendix 5, bibliography, and table of contents from book by I. A. Orlov, Izdatel'stvo "Energiya," 28,000 copies, 192 pages]

[Text]

ANNOTATION

The purposes for forming computing centers, their functions, and organizational structure are discussed in the book. Also discussed are questions of standardizing methods, procedures, and the operations sequence at the computing center, which all turn out to be basic for achieving smooth and systematic computing center operations. Processes of preparing, controlling, and processing information are reviewed, as is the principle of organizing computing center operations.

Much attention is devoted to the means and measures instituted to create conditions for most effective computer utilization. In this context, questions of the temperature range within which computers operate, distribution and supply of clean air in the computer room, control of noise and vibration, and power supply of the computer are considered.

The book is intended for students of technical high schools who, through their vocation, are tied to the servicing and utilization of computers that form part of a computing center.

PREFACE

The present text for students of technical high schools is intended for the course on organizing the operation of a computing center, which comes under the specialty area of electronic computers, instruments, and devices. Considering the size of the book and the general direction of the course, the author did not undertake to turn this book into a reference volume with detailed explanations of all possible methods and procedures of organizing and carrying out operations of a computing center. Nor did he delve deeply into the area of using the equipment and methods for assuring its effective utilization. The purpose of the book is to discuss the solution of all questions from a general (and sufficiently complete) point of view and, above all, to create in the reader a proper understanding of how all basic work of a computing center should be conducted in principle and what the general forms and rules are for its organization and execution. Many of these forms are now practiced at our leading computing centers, although there are also those ingenious and useful methods found in the practice of foreign computing centers recommended in the book for our acceptance.

The level of development reached by computer technology demands a corresponding level of organization in its utilization. Only in that case will it be possible to obtain a truly well-adjusted and efficient operation of a computing center in all its branches. It is thus even more important to train young specialists into whose hands the future of our technology will be placed.

INTRODUCTION

The urgent tasks of further developing science and technology in our country and of finding the fastest (and the most efficient) solution of scientific, engineering, and economic problems arising as part of these tasks gave rise to the formation of computing centers, rather than a simple desire to increase the efficiency of using digital computers and to improve the conditions of servicing them. National and foreign experience in manufacturing and applying computing technology shows that the most promising direction in solving such problems is the integrated utilization of a large number of digital computers used within the framework of a computing center, which in final form represents a unified network of computing centers.

The complexity and multifaceted nature of the problems posed leads to the necessity for maximum utilization of digital computer capabilities and to an intimate, creative collaboration of specialists in a whole line of disciplines. The most favorable conditions for such cooperation and effective utilization of digital computers are possible within the framework of computing centers equipped with digital computers of various classes, and by concentrating large numbers of specialists with appropriate qualifications in a single place.

But the computing center is not just a collection of computers and experienced specialists; it is a complex mechanism, where there should not be separate categories such as computers, programmers, modelers, and so forth, but instead should be a unified, functional team, with a common plan, rule, and rhythm directed toward an effective implementation of the link between customer and computer.

Nevertheless, today, when computers are equipped with a well-developed library of subroutines and a system for automated programming, preparation of problems for solution on the computer still remains a laborious and costly process. One of the reasons for this is that the necessary forms and rules for regulating the work of the basic work groups at the computing center and for assuring mutual understanding among them (and with the customers) in working out complex programs have neither been sufficiently worked out nor are they being enforced rigidly enough. It is easy to imagine how, under these conditions, the chain linking customer and computer, whose links are precisely modeler, programmer, and operator, is lengthened. It is therefore necessary to establish stricter control of the entire process of preparing and processing information in a computing center, for which there should be provided at each of the centers an appropriate digest of rules and procedures, that is, an established form (standard) for organizing the work of the modeler, programmer, operator, and so forth, down to the mechanical utilization of the computer itself. Only in that case will a computing center become an integrated, well-balanced mechanism.

By standardization is meant the establishment of strictly defined forms for documentation, general rules and order for the execution and submission of work in all subdivisions of the computing center. This is a necessary prerequisite for realizing control over the operation of the computing center, and consequently also for the opportunity to increase its efficiency.

Lacking such standards, the leaders of the computing center find it is impossible to evaluate precisely the time for execution of one or another operation, and those who perform an operation frequently have only a vague idea about this matter, carrying out their obligations in accordance with their own conception of methods and spheres of operation.

The existence of appropriate standards for the work of personnel and equipment makes it possible for the leadership to estimate properly the levels of expenditures, dates, and specialist staffing necessary for the efficient operation of the computing center, and to introduce changes into the existing system of programs in order to establish appropriate control. Leadership has to have the opportunity to evaluate the true loading of the equipment and personnel and, consequently, determine the most efficient mode of operation of the entire computing center in view of available resources.

Of course, the task of precise standardization of the entire operation of information processing in a computing center is complicated and collides with a whole number of problems, which makes it impossible to solve it exactly. The current incomplete change of computer generations, the appearance of minicomputers that have considerable capabilities, the introduction of multiprogramming computers and computers with time division operation, and, finally, the successful development of devices that receive information directly from text or as the spoken word, these all prove and will continue to prove to have a significant influence on the form in which computer operations are organized at a computing center. In view of the lack of adequate experience in the utilization of all these modern computers, a certain amount of time will be required in order to crystallize a more efficient structure for computing centers and for the forms for organizing the work in these centers before it will be possible to speak of truly standard forms and structures.

At the same time, operational experience at leading computing centers under all these conditions shows that it is not only possible but necessary to base all work on strict and completely defined rules for organization and procedure, which make possible not only shorter time spans for certain operations but also substantial increase in the quality of execution. It is precisely the stricter standardization of the current operating forms at a computing center that has to be the basis for more efficient utilization and the platform for more successful development and assimilation of future developments. In this, the standardization of the operating side of information processing has to be based on a technological foundation which, in its turn, demands the implementation of absolutely precise and detailed rules. Only the simultaneous existence of standardized methods for using equipment and provision of an effective operation make possible the creation of a truly integrated, well-balanced mechanism, the most efficient form of implementing the link between customer and computer, both in the present and in the future.

APPENDIX 5

REFERENCE DATA FOR HARDWARE OF COMPUTERS
IN THE UNIFIED SYSTEM

Шифр устройства (1)	Тип и состав устройства (2)	Потребляемая мощность, кВт (3)	Тепловыделение, ккал/ч (4)	Расход воздуха через устройства, м³/ч (5)	Габариты, мм (6)	Площадь зоны обслуживания (сервисная зона), м² (7)
ЕС-2020 (СССР) (11)	Процессор: (8)				3787×740×1600	18,4
	ЕС-2420	1,7	1500	1100		
	ЕС-0821	1,2	1000	800		
	ЕС-3220	0,6	1500	400		
ЕС-2030 (СССР) (11)	Процессор: (8)				6523×750×1500	22,9
	ЕС-2030	1,0	860	1200		
	ЕС-3203.1	1,5	1290	1200		
	ЕС-3203.2	1,5	1290	1200		
ЕС-2040 (ГДР) (12)	Процессор (8)	19	14 500	7400		
ЕС-2050 (СССР) (11)	Процессор (8)				3318×1600×1600	20,1
	ЕС-2050.1	5	4300	1200		
	ЕС-2050.2	1,05	903	1000		
	ЕС-2050.3	3,9	3350	1200		
	ЕС-2050.4	1,05	903	1000		
	ЕС-2050.5	0,7				
	Кросс-шкаф (9)					
ЕС-3205 (СССР) (11)	Устройства оперативной памяти:				2425×750×1700	9,1
	ЕС-3205.1	1,5	1290	2000		
	ЕС-3205.2 (10)	2,0	1720	1200		

[Appendix continues on following page]

[Appendix continued]

Шифр устройства (1)	Тип и состав устройства (2)	Потребляемая мощность, кВт (3)	Тепловыделение, ккал/ч (4)	Расход воздуха через устройство, м³/ч (5)	Габариты, мм (6)	Площадь зоны обслуживания (сервисная зона), м² (7)
	ЕС-3205.3	1,5				
	ЕС-3205.4	2,0				
ЕС-4012 (СССР)	Мультиплексный канал ЕС-4012.1	2,0	1720	1200	2934 × 860 × 1600	11,33
ЕС-5010 (СССР)	Накопитель на магнитной ленте	1,4	1204	700	705 × 745 × 1786	2,2
ЕС-5033 (СССР)	Накопитель на магнитном барабане	1,5	1290	400	750 × 1200 × 1600	4,5
ЕС-5050 (СССР)	Накопитель на сменных магнитных дисках	0,8	690	160	780 × 688 × 890	2,1
ЕС-5051 (СССР)	Накопитель на постоянных магнитных дисках	3,0	2580	1500	1200 × 950 × 1630	4,72
ЕС-5071 (СССР)	Накопитель на магнитных картах	2	1720	1600	750 × 1300 × 1600	12
		3	2580	100	750 × 1200 × 1600	
ЕС-5511 (СССР)	Устройство управления накопителем на магнитной ленте	1	860	800	750 × 1200 × 1600	4,5
ЕС-5551 (СССР)	Устройство управления накопителем на магнитных дисках и барабанах	1,66	1290	1400	750 × 1200 × 1600	4,5
ЕС-6012 (СССР)	Устройство ввода с перфокарт с БССК	1	345	200	550 × 1200 × 1245	3,9
ЕС-6121 (ПНР)	Устройство ввода с перфоленты	—	—	—	—	—

[Appendix continues on following page]

[Appendix continued]

Шифр устройства (1)	Тип и состав устройства (2)	Потребляемая мощность, кВт (3)	Тепловыделение, ккал/ч (4)	Расход воздуха через устройства, м³/ч (5)	Габариты, мм (6)	Площадь зоны обслуживания (сервисная зона), м² (7)
ЕС-7010 (СССР) (11)	Устройство вывода на перфокарты с БССК (24)	1,35	860	300	550 × 1385 × 1285	6,1
ЕС-7030 (СССР) (11)	Алфавитно-цифровое печатающее устройство с БССК на базе АЦПУ 128-5 (25)	2,6	2000	800	1568 × 1183 × 1425	4,9
ЕС-7051 (СССР) (11)	Графическое регистрирующее устройство планшетного типа с БССК (26)	2,9	1720	600	1462 × 1644 × 1630 500 × 1200 × 1050 500 × 1200 × 1050	24,03
ЕС-7052 (СССР) (11)	Графическое регистрирующее устройство рулонного типа (27)	1,2	1032	300	1200 × 500 × 1382	3,48
ЕС-7064 (СССР) (11)	Устройство ввода и вывода алфавитно-цифровой и графической информации на ЭЛТ с БССК (28)	2	1270	1300	1200 × 750 × 1600 1500 × 1103 × 1200	7,2
ЕС-7066 (СССР) (11)	Выносной пульт для ввода-вывода алфавитно-цифровой информации на ЭЛТ (29)	0,25	215	—	743 × 470 × 465	1,02
ЕС-7070 (СССР) (11)	Пишущая машинка с БССК на базе „Консул-200" (30)	0,2	103	—	1000 × 620 × 930	2,63
ЕС-9010 (СССР) (11)	Устройство подготовки данных (31)	0,7	430,0	—	366 × 880 × 1000 1062 × 653 × 970	7,72

[Key on following page]

Key to Appendix 5

1. Equipment code number
2. Type and composition of equipment
3. Power required, in kilowatts
4. Heat generated, in kilocalories per hour
5. Flow of air through equipment, in cubic meters per hour
6. Overall dimensions, in mm
7. Area required for servicing, in square meters
8. Processor
9. Interconnect switching cabinet
10. Operating memory equipment
11. USSR
12. GDR
13. Polish People's Republic
14. Multiplex channel
15. Magnetic tape storage
16. Magnetic drum storage
17. Dismountable magnetic disc storage
18. Permanent magnetic disc storage
19. Magnetic card storage
20. Control device for magnetic tape storage
21. Control device for magnetic disc and drum storage
22. Input device for reading punched cards with BSSK
23. Punched tape reader
24. Punched card output device using BSSK
25. Alphanumeric printer using BSSK and based on an ATsPU 128-5 device
26. Graph-plotting device using a plotter with BSSK
27. Graph-plotting device of roller type
28. Input-output device for alphanumeric and graph information using a cathode ray tube with BSSK
29. Remote terminal for input-output of alphanumeric information using cathode ray tube with BSSK
30. Printer with BSSK based on the KONSUL-200 device
31. Data preparation equipment

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