Academy of Sciences USSR, 1960.
20. Gulyayev P. Cybernetics in Physiology. Published by the Society for the Diffusion of Political and Scientific Knowledge. Leningrad, 1958.

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Problems of Communications and Cybernetics

Modern Communication and its Characteristics

In the technical conception modern communication can be defined as an information technique which assures the transmission and reception of messages.

Communication facilities represent one of the most important material conditions for the existence and development of modern society. They are essential for coordinating the operation of all branches of material production, for the control of government, satisfaction of the needs of various public organizations, as well as for taking care of the cultural-domestic requirements of the population.

In the Soviet socialist society with its planned economy and continuous process of expanded socialist reproduction the role of communication is particularly great. It is impossible to conceive of organized operation of Soviet socialistic industry with all its progressively developing cooperation between various branches and enterprises, progressively increasing specialization and well-developed transportation communications as well as highly productive work of agriculture, which is the largest and most mechanized in the world, without the application of various engineering communication facilities, chiefly electric communication facilities. Communication facilities, radiobroadcasting and television are utilized extensively for the formation of social consciousness of people and the mobilization of the masses of workers for premature accomplishment and overfulfillment of the production plans and successful building of communism in the Soviet Union.

Under current conditions of production by society the communication facilities represent an essential factor for increasing the output of social work, the most active factor in saving time. The existence of well-organized communication contributes to improving the work of enterprises and structures, planning and sales organs, reduces unproductive expenditures, accelerates the turnover of facilities which are to be circulated and, as the result of this, reduces the cost of the production output.

V. I. Lenin pointed to this aspect of communication as a most important factor in increasing the output of social work. He wrote the following: "Large-scale production, machines, railroads, the telephone -- all this offers thousands of possibilities for cutting the work time of organized workers by four times, assuring them four times greater welfare than at present" (V. I. Lenin. Works, Vol 20, page 136).

Specific features are characteristic of communication as a branch of material production which distinguish it from other branches of production. One of its characteristic features is the indivisibility of the production process from the consumption process: communication enterprises fulfill not only production functions (functions of transmission and reception of messages) but simultaneously fulfill functions of servicing the consumption process of communication production (a service). By virtue of this, a communication enterprise cannot accumulate orders for messages for the purpose of transmission of them. The production process of communication should be organized so that the inequality of the load, characteristic of the branch of communication, does not cause any delay or slowing in transmission of messages.

Moreover, every communication consumer is always interested in the fact that the communication process be completed as quickly as possible and, as far as possible, immediately. This fact requires the application of the most progressive methods for transmission of communications and the most perfect systems of electrical communication. This is why communication, like none of the other branches of material production, constantly absorbs the latest achievements and discoveries in the fields of physics, electrical engineering, automatics, electronics and radioengineering. The theoretical works of the latest physics which are abstract even at first glance, apparently far from the requirements of life, have exerted an influence upon the development of communication engineering with great rapidity.

The technical basis of electrical communication, which is continuously being perfected, has reached a very high level at present. Modern electrical communication represents a very complex combination of semiautomatically and automatically operating apparatuses and instruments combined into a single whole by a system of wire and radio lines. It is based on the application of multichannel broadband systems of high-frequency telephony, narrow-band systems of voice-frequency telegraphy, semiautomatic and automatic methods of connection in intercity communications, automatic through dialing telegraphic apparatus, telegraph and phototelegraph exchange systems, broad utilization of short-wave and ultrashort-wave radio stations, the use of automatic dial telephone stations for city and rural communication.

In post-war years long cable lines were constructed and put into operation equipped with high frequency apparatus for multiplexing from 24 or 60 to 1,920-channel systems, which made it possible to organize bunched communication channels on the intercity mains, making it possible to transmit a large volume of different information over them.

Coaxial and radio relay communications systems, capable of transmitting simultaneously several thousands of telephone conversations and providing for the transmission of television programs over practically unlimited distances, are being used extensively on the mains of the country. Intermediate amplification and rebroadcasting stations for these systems operate without service personnel, with the use of systems of supervisory control, service and remote control.

On channels with considerable capacity complete automation of intercity telephone communication is being carried out, which makes it possible for the subscriber in one city to call a subscriber in any other inhabited place by simply selecting the numbers on the dial of his telephone.

New types of phototelegraph apparatuses for the transmission of diagrams, drawings, figures and other pictures do not require the presence of operators at all, because starting and stopping them as well as the supply of blank forms are conducted automatically.

The telegraph exchange, which has been extensively incorporated into the enterprises of the sovnarkhozes [national economic councils] and institutions of the country, operates on principles of complete automation of the connections between different points.

Communication facilities, radiobroadcasting and television are, as they are being packed with the latest electronic and automatic instruments, taking a leading part among the other branches of the national economy, and any achievement in the field of perfection of electrical communication facilities exerts a tremendous influence upon progress in other branches of engineering.

Thus, for example, television on subjects satisfying the cultural needs of the population has become a component part of a whole series of production processes and scientific research. At the present time, not only the so-called "closed" television systems, by means of which observation of a number of technical processes is accomplished, but also television automata based on the utilization of the television method of breaking transmitted images down into their components, are becoming common at the present time. Such automata are utilized, for example, for automatic control of the operation of a rolling mill, for counting the number of parts coming off a conveyer, and in other fields of production. It may be considered that all this is

only the beginning of development of a new branch of engineering -- television automatics -- which in the near future will find extensive application in many fields of human activity.

At the present time, a great effect upon the technical progress of communications facilities is being exerted by semiconductor engineering. As in the past the invention of vacuum tubes exerted a revolutionizing influence on the development of communication engineering, so the application of semiconductor instruments is leading to new qualitative changes in electrical communication engineering, radiobroadcasting and television.

Semiconductor elements are being included on a progressively greater scale in electrical networks of amplifiers and generators, switchboard and call signal apparatuses, radio and television apparatuses, measuring instruments and other apparatuses.

The advantages of semiconductor components and particularly transistors are expressed in a high degree of mechanical stability, extremely small dimensions, practically unlimited longevity and low power consumption. The utilization of semiconductor engineering is opening broad possibilities for increasing the economy and reliability of communication facilities. Thus, for example, the use of semiconductor wide-band amplifiers on cable mains makes it possible to avoid constructing costly equipment at the intermediate repeater stations but rather to set up intermediate amplifiers directly in the cable joints which are supplied at a distance. The utilization of semiconductor transducers for the repeater stations of cable mains and regional communication centers makes it possible considerably to reduce the volumes and lessen the cost of power-supply equipment for electrocommunication agencies and to obtain a greater saving in nonferrous metal and fuel through a reduction in the areas used for production.

Therefore, extensive incorporation of semiconductor instruments into communication engineering assures a high technical level of communication facilities, considerably reduces the cost of communication services and makes them more available for use.

The striving to create a progressively larger number of communication channels on the same circuit for the purpose of most efficient utilization of the costly outside plants will, undoubtedly, lead to the creation of new, more perfect systems of electrocommunication in the future with an even greater capacity.

For a number of years considerable scientific research work has been done on the creation of a long-distance waveguide communication line. A copper tube five-six centimeters in diameter laid at the same depth as the cable will be utilized as a waveguide. With utilization of the millimeter wave range (five-eight millimeters), which

corresponds to a bandwidth of almost 23,000 megacycles per second, such a waveguide line assures transmission of up to 100 television programs and 15,000 telephone conversations to practically infinite distances. With transmission of a frequency band of about 40,000 megacycles along the waveguide it is possible to bring the number of telephone channels up to 200,000. Attenuation, that is, energy losses, in the waveguide communication line is so small that the lengths of the repeater sections can amount to 40-60 kilometers, whereas the modern multichannel K-1920 system requires setting up repeaters on the coaxial cable main every six kilometers.

In the area of radio communications technical progress is associated with work on the creation of long-distance communication systems based on the utilization of scattering of ultrashort radio waves because of the atmospheric inhomogeneities. Utilizing, for example, the phenomena of dispersion in the troposphere it is possible to provide for telephone and telegraph communication on radio links 500-600 kilometers long without repeating, whereby, as work practice has shown on such links, the use of highly effective equipment provides reliability of operation on a level of 99.9 percent or higher. Investigations of long-range ionospheric scattering have confirmed the possibility of obtaining dependable multiplex printing communication as well as radiotelephonic transmission to a distance of 2,000 kilometers or more without repeating.

In the United States, much attention is given to the problem of organization of communication with the utilization of artificial earth satellites. (We have in mind the utilization of satellites as passive repeaters of signals sent by ground radio stations). The setting up of sending-receiving stations on satellites will provide high speed reliable communication which is practically not subject to the influence of natural interference. Artificial earth satellites can also serve for covering large territories with television broadcasting.

In connection with the era of space flights which has been initiated the technique of long-range radiocommunication will be developed more precipitously than heretofore. It is necessary to assure dependable communication with spaceships at distances of tens and hundreds of millions of kilometers. Here, aside from the use of low-noise amplifiers, which increase the sensitivity of modern radio receiving apparatuses by tens and hundreds of times, it is necessary to create a technique of receiving superpower impulses of superhigh frequency as well as to solve a number of complicated problems of remote control and distance regulation engineering.

Characteristic of the branch of communication is the close interaction of all its components and agencies. No single communica-

tion agency renders full and complete service without participation of the others. Usually two, three or more communication agencies participate in the transmission of messages. Associated with this is the need for organization of a communication system which would assure the possibility of linking each point with any other point both within administrative and economic regions as well as within the limits of the entire country. This is required by the steady growth of the need for communication in all branches of material production and the fast growth of the cultural-domestic needs of the population.

The Role and Place of Communication Facilities in the Automation of the National Economy

The development of modern engineering is characterized by extensive automation of all branches of the national economy. The automation process is inevitably associated with the organization of centralized monitoring and automatic control and utilization of technical communication facilities for the transmission of television, remote control, distance regulation and telemetering signals.

By means of modern communication facilities at the present time a centralization of dispatchers on railroads, the control of a standard power system, supervisory control of the courses of technical processes, long-distance observation of processes of drilling wells and production of petroleum, remote control and supervisory control of the operation of oil- and gas-lines, telemechanization of rolling mills, etc. are being carried out.

With the accomplishment of comprehensive automation, enlargement and unification of separate apparatuses, shops and entire production systems into powerful and complex systems with centralized monitoring and automatic control the technical communication facilities will be included to a progressively greater delay in automatic control of production and will become an inseparable part of it, and in a number of cases will also determine the possibilities of carrying out the production itself.

Only by means of the apparatuses of industrial television can observation be made of technical processes occurring in premises with high temperatures or harmful gases, to see what occurs in atomic or chemical reactors, to carry out under-water investigations at great depths, to monitor a number of other processes. With the aid of television, as is well known, the Soviet cosmonauts Yu. A. Gagarin and G. S. Titov were observed.

Modern automatics organically includes communication facilities as a component and inseparable element without which it

cannot operate. For example, would it be possible to conceive of the normal operation of a modern gas or oil main going over a long distance without centralized control by automatic apparatuses by means of communication facilities? Would it be possible to control a modern power system consisting of a number of stations, substations and transmission lines or exercise control and monitor a large water- or gas-supply system without the use of communication and telemechanics facilities? Without technical communication facilities it is impossible to control complexly automated enterprises or any type of modern transportation, particularly railroad, where problems of capacity and safety of movement of trains are solved by means of communication facilities, automatic signalling and block systems, centralization of dispatchers, automatic stops and other automatic devices. With the accomplishment of comprehensive automation, utmost cooperation and specialization of production technical communication facilities will progressively expand the size of the group of problems which may be solved with their aid.

In connection with the accomplishment of new production functions by communication the generally accepted interpretation of the role and significance of communication is essentially changing at present. While previously, we meant mail, telegraph and telephone with their quite limited functions of sending and receiving messages by communication, now, speaking about communication facilities we should understand the large combination of electronic instruments, switchboard devices and communication channels which make it possible to effect the exchange of all types of information, including automatic information, without which it is impossible to assure normal production and social activity of a modern society.

Characteristic of the current tendency in the development of communication facilities is the fact that automatic apparatuses and machines which carry out a given technical process or process data on electronic computers are the direct sources and receivers of information, aside from people. At the present time, in the branch of communication a new concept has been accepted based on the accomplishment of production functions by communication facilities -- the so-called "technical communication", by which is meant the combination of technical communication facilities which provide for technical monitoring and control of automated production. Along the channels of this communication information comes in continuously about the course of the technical process, and supervisory control and remote control signals are transmitted which act on the motor stages or mechanisms which carry out set routines of operation.

The organizational problems of technical communication,

like the utilization of technical communication facilities for automation and telemechanization of production processes, have recently been acquiring progressively greater importance.

Problems of organization of technical communication are of particularly great current importance on railroad transportation, where in accordance with the seven-year plan of development of the national economy an increase of freight turnover of 40-50 percent has been planned with increase in the length of the railroads by only 7.5 percent. This problem can be solved only by means of electrification of the lines carrying the most freight and incorporation of the facilities of automatics, telemechanics, dispatcher centralization and modern communication facilities.

At the present time, all types of wire communication facilities, ultrashort-wave radio stations of different functions, television apparatuses and computers which make it possible to assure the safety of train movement, increase the handling capacity of stations and junctions, and improve the operational indices of railroad transportation work are included in the automation complex of railroad transportation.

The great development of pipe-line transportation, the freight turnover of which is to increase by 5.6 times in the seven-year period and the length of the mains, by three times, has been provided for by the seven-year plan of development of the national economy. In the seven-year period 56,000 kilometers of pipe lines of all types and for all purposes are to be constructed, as the result of which at the end of 1965 the network of gas lines, oil lines and product lines will exceed 75,000 kilometers in length. Modern pipe lines are complex engineering structures. Their capacities are very great, and in the case of large pipe diameters exceed the handling capacity of railroads. The lengths of mains is measured in thousands of kilometers. The total length of the product line and oil line from Bashkiriya to Irkutsk is greater than 4,000 kilometers.

It is easy to conceive of the importance of centralized telemechanic supervision and control, assuring the normal operation of pipe lines of such extent. By effecting centralized control of the flow of gas or oil along a pipe line from a dispatch station, by regulating the operation of compressor stations, pumps or gates, it is possible to assure the optimum routine of operation of the pipe line over its entire course and to take immediate measures for eliminating faults which arise.

Furnishing pipe mains with modern communication and telemechanic facilities not only solves problems of operational control of pipe-line equipment but also markedly increases the trouble-free operation, reduces the number of operations personnel on these mains

(line walkers, skilled workmen, personnel on duty and others), making it possible to reduce expenditures through a reduction of the construction of living and subsidiary quarters.

Overhead communication lines at railroads and pipe lines do not assure the reliable operation of telemechanic monitoring and control systems. Such communication lines, as is well known, are unreliable in their operation, depend on climatic and atmospheric factors and do not assure obtaining the required number of channels. At the present time, radio relay systems and cable communication lines are being set up along the routes for the telemechanization of the main pipe lines and railroad transportation.

In the United States, in the construction of gas lines the most modern and reliable communication facilities are set up, without regard for expense for the communication and telemechanic equipment, because in the final analysis this will save considerably on funds during the process of operation. The total extent of radio relay systems servicing pipe lines in the United States amounted to more than 100,000 channel-kilometers by 1957.

In the USSR, recently great work has been done on comprehensive automation and telemechanization of oil-producing enterprises with coverage of the following production systems: oil wells, group collecting stations for oil and gas, pump stations, diemulsification apparatuses, compressor stations, air-gas distributing stations, facilities for water and power supply of the oil fields. For supervisory control and long distance monitoring and control of production facilities for petroleum scores of telemechanical systems have been worked out now with the use of wire and radio channel communication.

At the present time, there is an acute need in the coal and mining industries for the application of telemechanic and communication facilities for the accomplishment of comprehensive mechanization and automation. They are essential in all branches of the coal and mining industries, particularly for long-distance control of combines and cutting machines, underground transportation, assembly lines, ventilation apparatuses, pumps and other mechanisms. The incorporation of telemechanic control systems into the coal and mining industries will improve work safety and will considerably increase the work output of miners.

A great demand for communication and telemechanic facilities is being made by agriculture, which needs chiefly internal communication and telemechanic systems capable of controlling territorially separated assemblies and apparatuses, particularly driverless tractor units for plowing or harvesting (the suggestion of Comrade Loginov and others). The total area of land which is only being irrigat-

ed in the USSR amounts to 10,000,000 hectares, while the length of irrigation channels in a short time will reach a half-million kilometers. On such a scale, telemechanic control is necessary for irrigation systems also, which will free a considerable number of workers occupied in operation of irrigation equipment and will considerably improve the utilization of irrigation channels.

Work has been begun on the incorporation of communication and telemechanic facilities into the municipal economy. Communication channels here are required for centralized control of water supply, sewage, electrical supply, gas supply systems, as well as for the regulation of city traffic.

In power systems for the organization of telephone and telemechanical communication transmission lines are utilized directly. However, in connection with the creation of a standard power system for the European part of the Soviet Union (and subsequently for the entire country) which operates on transmission lines, high frequency channels cannot be considered the main type of communication channels. For the control of the standard power system considerably more communication channels, greater extent, with a large number of intermediate stations which should operate completely independently without connection to transmission lines, are required. Such communication channels can be created only on cable mains and radio relay systems. It is quite natural that setting up these lines over great distances is economically expedient, with comprehensive utilization of them not only for energetics but also for the general needs of the nation.

The use of communication and telemechanic facilities is not limited to complex technical systems which cover large areas. They are essential also within the limits of separate enterprises and combines of metallurgical, chemical and other branches of industry.

The mechanization and automation of production processes are inseparably connected with their intensification, and the latter in many cases is impossible without the corresponding improvement in the production and control organization. Hence, problems of mechanization and automation of operational control of production by means of technical communication facilities, computers and cybernetic machines assume very great importance.

Enterprises need the use of dispatch stations and production loudspeaker communication apparatus, the organization of dial telephone and automatic telegraph communication, the utilization of radio stations for communication with mobile units, and different industrial television apparatuses.

Experience in the use of phototelegraph apparatuses of the FTAP, "Rekord" and other types at a number of enterprises (for two-

way communication between shops and laboratories, design bureaus, etc.), has shown that these all-purposes apparatuses, which permit the transmission of the most varied documents (hand-written and typed materials, figures, drawings, diagrams, etc.) and which automatically convert the elements of the message into electrical signals and back are very promising and should find extensive application in communication within the plant and between plants.

The automatic telegraph exchange has merited general recognition in administrative organizations, enterprises and institutions as the most convenient and efficient type of documentary communication between enterprises, sales and administrative organizations and of the latter with the sovmarkhozes.

For the purpose of automatic communication with moving systems the radiophone has been worked out; this represents a dial telephone with a dial for calling a subscriber of a dial telephone station or a subscriber on a moving object. Radiophones will find extensive application in places where, for a number of reasons, it is impossible or inexpedient to lay cables or overhead lines (on moving transport between shops, travelling cranes, construction platforms, and others) in the case of heavily broken terrain.

Of no less importance is communication in industrial construction, in the utilization of new ore deposits, reclaiming of new territories and regions. The erecting of large industrial enterprises, hydrotechnical, transport, civilian housing and other structures is accomplished, as a rule, by many general construction, specialized and assembly organizations. The coordinated and smooth-running operation of all these organizations is possible only in the presence of modern communication facilities. They are necessary not only for bringing equipment and materials in a timely way from suppliers and supply centers but also for the operational linkage of all the production organizations and service agencies participating in the construction as well as for operational supervision of the construction in all areas of production.

The organization of communication operations for the entire system of structures being erected is of essential importance for the coordinated operation of all links and therefore for the acceleration of construction and reduction of its cost. Communication facilities should be provided at the initial stage of construction along with the first provisional structures so that no unproductive delays occur during the construction of the main installations.

A special place in the solution of the problem of comprehensive automation and in the acceleration of technical progress in all fields of production and science is played by computing equipment.

Electronic computers have appeared comparatively recently, but their field of application is being expanded very rapidly. At the present time, computers are used for processing data in the planning and accomplishment of complex engineering calculations, for the control of assembly lines, rolling mills, for monitoring and recording the numerous technical parameters in the oil-processing and chemical industries (nitrogen, sulfuric acid, soda and polymer) and other branches of the national economy, including for the processing of data received from spaceship satellites.

Efficient utilization of electronic computers is associated with the organization of a system of electrical communication adapted for transmission of any quantity of information immediately to computation centers.

According to tentative calculations of specialists in the United States it is expected that after 10 years "machine information" (that is, data which is transmitted for machines and from them) will exceed all telephone and telegraph information now transmitted over the entire telephone and telegraph systems of the country. This naturally requires the expansion and improvement of the communication system.

On the basis of computation centers and general telephone and telegraph systems local networks are being formed which solve a large number of various problems on a rental basis. Such utilization of computers in combination with well-developed systems gives a great saving, increases work output and makes it possible essentially to reduce expenditures for maintenance of service personnel and accelerate production processes.

Major scientific research work is being conducted actively on the development and adaptation of communication systems for the transmission of data also in the FRG, England, France and other countries.

From everything stated above it follows that the problem of creating a large number of continuous-action and high-speed communication facilities is now becoming a key problem, and future progress in many fields of engineering and production organization depends to a considerable degree on its successful solution.

Cybernetics and Communication Problems

As applied to communication problems three divisions of cybernetics are of the greatest importance: information theory; automatic control theory and feedback theory; the theory of cybernetic machines, the operation of which is based on the production, transmission and transformation of information.

Among the first attempts scientifically to generalize on experience accumulated in the field of telephone communication service to the population and to enterprises were the works of the Danish scientist, Erlang, who in the 1920's created the so-called "mass service" theory. Erlang divided mass service systems into two categories: systems with refusals, where the request for service (call) receives a refusal when all the instruments at the station are completely busy, and systems with waiting, where in case all the instruments are busy the person making the request is placed next in turn. On the basis of the methods of the probability theory Erlang worked out a number of the initial principles for calculation of the necessary number of instruments which will provide for a certain quality of service.

A great contribution to the information theory was made by the works of Soviet scientists: Academician V. A. Kotel'nikov, Corresponding Members of the Academy of Sciences USSR A. A. Kharkevich, V.I. Siforov and others. In the work, "The Capacity of the 'Ether' and of a Wire in Electrocommunication", written by V. A. Kotel'nikov in 1933 a system was first developed for classifying signals into discrete (telegraph) and continuous (speech, television). In this work it was shown that methods of transmitting information being used at present far from completely utilize the capacity of communication channels, and there are great possibilities for further improvement in the quality of communication and increase in the quantity of information which can be transmitted over communication channels. Specifically, it was pointed out that a continuously changing signal can be represented in the form of a sequence of discrete values which are to be transmitted at certain intervals the duration of which is determined by the frequency band of the signals being transmitted. On the basis of this principle practical methods of so-called "quantising" of the signal were worked out, that is, for the transmission of a continuous signal in the form of a sequence of descriptive ordinates, which at the present time is used widely in various types of pulse modulation.

The information theory is of tremendous importance for the development of communication engineering. It uncovers possibilities which are new in principle for increasing the capacity of electrical communication systems. On the basis of its theoretical principles it is possible to create apparatuses which make it possible to organize telephone communication, radiobroadcasting and television in a narrower frequency range. Such a possibility is based on the fact that any transmission will contain a certain share of redundant information, the exclusion of which in transmission and artificial restoration of it at the time of reception make it possible to reduce considerably the operating frequency range. Investigations have shown that by means of

synthesizing apparatuses it is possible to compress by 10 times the frequency band necessary for transmission of a telephone conversation. In practice, the realization of this method will make it possible to assure a tremendous increase in such necessary communication channels and obtain a very considerable saving in monetary outlays.

In connection with the utilization of electrical communication facilities for telemechanization and for transmission and for the purpose of obtaining data from electronic computers the problem of reliability is acquiring particular current importance. Errors in transmission are conditioned chiefly by the influence of noise, of which the so-called "external" noise is created by interfering signals transmitted over nearby channels or by all-possible electrical apparatuses which are in the vicinity of the communication channels (in radiocommunication a great part is played by atmospheric disturbances); internal interference occurs in the systems themselves, as the result of random electrical phenomena, for example, electrical fluctuation brought about by thermal movement of electrons.

Along with the problem of reliability the problem of rapid action should be solved also. Increase in the speed of action can be accomplished only in those channels where the interference level is low and the distortion of the signal has no great effect during its transmission.

Information theory shows that it is possible to bring about an essential increase in the speed of transmission of messages by means of the use of the optimum code, that is, the most dependable code capable of withstanding the effect of noise.

The problem of the simplest, most convenient and perfect methods of coding, that is, methods for converting the message into signals which can be distinguished successively is the main problem in the information theory. In connection with the precipitous growth of computing technique it has acquired particularly great current importance, because the application of effective methods of coding will considerably increase the utilization factor in electrical communication channels as well as the reliability of information transmission.

Further development of the information theory will contribute to the solution of a number of complex and important problems both in the field of communication engineering and in the field of creating better and more economical computers and remote control and distance regulation systems. The use of its principles will make it possible considerably to simplify, reduce the cost and make more reliable the transmission of signals over communication channels as well as to solve a number of important problems in the field of planning and designing of automatic machines.

In connection with the rapid growth in the volume of numerical information which at the time of transmission assumes the appearance of a train of discrete signals, recently the very attractive idea has been advanced of creating a universal communication system on the basis of the transmission of discrete signals. The proponents of this idea point out that the volume of automatic numerical information in the near future will exceed the volume of spoken information and that the capacity of the system designed for the transmission of discrete signals will be greater than that of systems adapted for the transmission of spoken signals.

Undoubtedly, many circumstances indicate the benefit of a system for the transmission of numerical data, but so far it is impossible to accomplish this for a number of reasons. A universal communication system is in a certain degree of contradiction with the main electrical communication equipment being used at present in world practice, which for a long time was perfected along the line of transmission of spoken signals specifically. The transition to this system in itself is associated with an abundance of research and requires the solution of a number of problems.

In order actually to provide for the needs of electronic computing technique it is necessary first of all to adapt the existing communication systems in the best possible way for the transmission of automatic numerical information. For this purpose the investigation of a number of problems pertaining to the structural network theory, switching theory, automatic control theory, code theory and others, is necessary.

In the United States, for the transmission of automatic digital information, standard telegraph channels are used designed for work at a speed of 50-75 bauds. Start-stop telegraph apparatuses adapted for this communication are supplied with special functional mechanisms which make it possible to connect various control, signalling and other automatic devices to the apparatus.

The transmission of the data at a speed of 1,000-1,600 bauds is accomplished over ordinary telephone channels, for which special terminal equipment has been worked out.

The connection of the subscriber with the telegraph station is accomplished by two methods: by means of prolonging the voice-frequency telegraphy channel or by means of the so-called "cable pairs", two-wire circuits adapted for transmission of data at a speed of up to 1,000 bauds. Three types of adapters have been worked out -- transceivers: for 75-180 bauds, 1,000 bauds, and a loop transceiver built completely around transistors.

Therefore, through the development of comparatively simple

apparatuses the problem of the organization of a widely branching communication system has been solved; this is quite flexible with respect to switching and does not require great outlays of funds when a ready-made voice-frequency telegraphy system is available.

Problems of communication and cybernetic engineering are closely connected with one another, and they should be solved in combination. Such an approach will assure the most efficient extensive automation of all types of activity of the socialistic society which are to be automated.

Being an inseparable component of cybernetic technique and exerting a great influence upon the development of the automatic control theory and the cybernetic machine theory, electrocommunication engineering in its turn needs the application of a number of principles of theoretical and technical cybernetics. Based on the developmental tendencies of communication engineering it may be claimed that the future development of technical communication facilities will be very largely dependent upon the development of modern cybernetics. Even now, in connection with complexification of apparatus which has occurred and the putting into operation of multiple-unit electronic communication systems which to a considerable degree are automated, difficulties have arisen in maintaining the apparatus in good condition. While in the year 1957 periods of idleness because of maladjustment of the apparatus on intercity cable and overhead communication lines operating out of Moscow amounted to 45.8 percent with respect to the total number of faults, and the number of station faults was found to be 1.2 percent, in 1959 they increased to 52 percent from maladjustment of the apparatus and 1.6 percent because of faulty station equipment. The proportion of the duration of idleness of radio relay systems brought about by faulty equipment increased from 30 percent in 1958 to 40 percent in 1960.

For the purpose of increasing the reliability of communications and reducing the time necessary for seeking and eliminating faults there is an urgent need for the development of special apparatuses and automatic monitoring and regulation systems capable of predicting the possible going out of commission of various units and components of the communication systems and immediately determining the locations of the faults initiated.

Such automatic systems and monitoring and control apparatus are essentially cybernetic. They should be created on the basis of the automatic regulation and feedback theories, the game theory information theory and cybernetic machine theory, etc.

Automatic monitoring, measuring and regulatory apparatus will make it possible to eliminate completely the causes of corommunica-

tion apparatus' going out of commission and will make it possible to convert emergency repair of equipment into preventive maintenance.

For the purpose of assuring the continuous operation of automated electrocommunication systems cybernetic apparatuses are needed which will provide for an automatic search for free operating channels, in the event of an operational disorder in communication channels, as well as preferential transmission of very important operational information.

The need for the development of cybernetic apparatuses is determined not only by the requirement of insuring continuity of communication but also by the requirement that the quality of communication be increased and that communication systems be further perfected. Specifically, they are necessary for optimum regulation of the parameters of repeaters, based on conditions of minimum nonlinear distortions, automatic search for the optimum wave in automated short-wave communication lines, etc.

Cybernetic apparatuses make it possible considerably to increase the volume of information being transmitted per unit time. In the foreign press a computer has been described which makes it possible to double the number of telephone conversations being transmitted over the trans-Atlantic submarine cable. In the case of an ordinary two-way telephone communication each subscriber, for practical purposes, speaks only half of the total time that the channel is occupied and there are also pauses. In the case of multichannel communication on intercity mains at any moment a great probability exists that there will be a free channel present which can be utilized for increasing the number of simultaneous conversations. When the number of persons conversing exceeds the number of channels, such an apparatus connects automatically to the channels of the persons [of the pairs] who are speaking at the time and disconnects those who are silent at the given moment. As soon as a subscriber begins to speak he is instantaneously connected to the necessary channel.

Postal telegraph communication enterprises are carrying out great and laborious work for the processing of letter correspondence and publications. The Moscow Post Office every day receives and sends more than 2,000,000 letters and parcels and 4,000,000 newspapers and magazines.

The processing of mail shipments and publications and, particularly, the sorting of letter correspondence is at the present time based on manual work with partial mechanization. Semiautomatic letter-sorting machines have considerably facilitated the work of sorters and accelerated the process of processing the correspondence but have not relieved the operators of these machines from the need for reading

the addresses on all the letters and distributing them by means of pressing on keys of the necessary directions.

For the accomplishment of comprehensive mechanization and automation of all operations of processing written correspondence machines are necessary which automatically identify stamps, distinguishing them from other objects, which sort and categorize letters according to size and which also read the addresses and sort the letters in accordance with the places to which they are being sent.

The development and planning and designing of modern electrocommunication systems are associated with large-scale laborious calculation and the solution of a number of complicated problems of synthesis and analysis. For finding the optimum variant not uncommonly it is necessary to make a large number of tests, select parameters which assure given technical conditions or, conversely, with an impossibility of changing the parameters, to determine the initial conditions under which the processes should proceed normally in the system being planned, that is, colossal calculation work needs to be done which takes away considerable time from planners.

The development and application of special cybernetic instruments constructed through the unification of analog and digital computation principles will relieve workers of scientific research and planning institutes of a large number of laborious calculations which do not require creative elements and, at the same time, which is very important, will considerably reduce the period necessary for planning, designing and creation of new communication systems. Under conditions of a continuously increasing volume of scientific research and planning work the solution of this problem is acquiring great and current importance.

The far from complete list of practical application of modern cybernetics to communication presented above permits us to conclude that cybernetics is the basis which will make it possible to solve a number of complex and laborious problems occurring in communication engineering.

Cybernetics is the method which will give a new basis, in principle, for solving problems of comprehensive automation of modern production. Cybernetic machines will find extensive application in many fields of activity of modern society which will signify a colossal facilitation of labor processes, further increase in material production and, therefore, increase in the material welfare and cultural standard of the working class under conditions of a socialistic system of economy.