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Sampling, Initial Processing, Storage and Transformation of Information about the Course of Production Processes

Introduction

The life of living organisms and the life of man proceeds in a continuous interaction with the environment, adaptation of the organisms to it, in protection against the dangerous effects of the environment and, at the highest level of consciously acting organisms, in actively influencing the environment, transforming it in the necessary direction.

In the world in which the organisms live a multitude of disturbances (external influences) arises which threaten to take the values of the variables essential for normal functioning and life of the organism (for example, the moisture content of the body, the inner temperature of a warm-blooded animal, the glucose content in the blood, acidity and others) beyond certain permissible limits.

Many deviations are incompatible with life. Therefore, as the result of natural selection organisms possessing apparatuses which worked out means of maintaining the values of the essential variables within certain permissible limits in accordance with external disturbances, that is, assured the regulation of these variables, survived. Over the course of ages these apparatuses have been perfected and better ones selected.

A similar problem is encountered in engineering, where it is necessary to assure the maintenance of a number of essential variables within certain permissible limits by means of regulator apparatuses for the normal course of production processes. Deviations of a number of essential variables are incompatible with the existence of production processes, lead to accidents, explosions, fires.

The problem of regulation, of its laws is of much broader significance for the development of production technique, for understanding the activity of living organisms than is customarily imagined in everyday life. The laws of regulation are of significance not only for the autonomic nervous system -- in a manner similar to the way in which provision is made in engineering for the maintenance of the values of various parameters of production processes at a given level, but also for the activity of the organism which is consciously directed outward, for its higher nervous activity; likewise, they are of significance in engineering -- for the automatic control of production processes according to the most advantageous routines.

The recent achievements of information theory, mathematical statistics and cybernetics are uncovering a number of analogies, general laws of regulation both in living organisms and in engineering. The utilization of these laws, an analysis of the analogies between living organisms and automatic control systems for production processes can prove to be useful for the development of both biology and engineering.

Certainly, blind copying of living nature is inexpedient -- mankind would not have gone far on walking locomotives or on ornithopters. However, the fact should not be forgotten that specifically the study of flight of birds assisted the well-known Russian N. Ye. Zhukovskiy in formulating the basic laws of aerodynamics. I. P. Pavlov (Leningrad, 1) dreamed of a deep interpenetration of the exact sciences, particularly mathematics and physiology when he said in a speech in 1902 entitled, "Natural Science and the Brain": "... all of life from the Protozoa to the most complex organisms is a long series of environmental equilibriums which are progressively complexified to the highest degree. The time will come -- even though remote -- when mathematical analysis, based on natural scientific analysis, will cover all these equilibriums, finally including itself in them, with magnificent equation formulas".

We are now much closer to the realization of this dream than I. P. Pavlov could have supposed. A considerable group of reports on these topics given at the First International Congress on Automatic Control in 1960, hundreds of scientific works on the application of cybernetics to biology quoted in these reports, and other scientific discussions published in recent years which were held on these subjects in the entire world and particularly in the USSR (see, for example (Leningrad, 2, 3, 4) and others) represent one of the confirmations of this statement.

For the purpose of providing for the life of organisms, for maintaining the essential variables within physiologically permissible limits, for the activity of higher organisms consciously directed outward it is important to assure timely reception of reliable information about external events, disturbances, threatening the activity of the organism, and storage of the information; processing of it and utilization of it are important also.

In living organisms, for the purpose of obtaining information about the environment sense organs are used: vision, hearing, the sense of smell, touch, and taste. In addition, for the purpose of assuring the normal functioning of the autonomic nervous system, for purposeful activity of the body sources of information are needed -- data units which provide the necessary data.

In the report, "Some Properties of Physiological Regulators" at the First International Congress of the IFAK on Automatic Control in Moscow the American scientist R. V. Jones pointed out: "It is well known that sensory elements which play the part of sensors are associated with a whole series of skeletal muscles; these sensors provide for a low degree of feedback of these muscles. Nerve endings in the muscle send the signal which indicates stretching of the muscle, and Golgi's tendon corpuscle sends a signal indicating compression of the muscle. These two sensory organs and the nerve pathways associated with them are connected so as to assure feedback which includes the whole muscle and, in this way, control the position of the structural organ associated with the muscle in response to appropriate signals coming from the cerebral cortex or other sources" (Leningrad, 5). Similarly, in order to provide for automation of production processes it is necessary first of all to assure the obtaining of the necessary information about the course of the production process, the significance of essential variables characterizing the condition of matter and energy and information about disturbances acting on the process. This information is provided by sensing elements. These sources of information -- sensing elements -- are to gather reliable information about the parameters characterizing the condition and changes in the states of matter and energy: about pressure, temperature, quantity of heat, position and movement of parts, dimensions, density, viscosity, humidity, and composition of the initial, intermediate and end products.

Without obtaining such information it is impossible to assure automatic regulation and particularly the purposeful control of production processes.

By creating instruments man immeasurably increases his own possibilities of correct knowledge of the laws of nature, expands the volume of information which he receives about the environment as well as about processes occurring in the organism itself to a tremendous degree.

The Significance of Instrument Construction

The history of development of engineering can be divided into two major stages. In the first stage man created tools, machines, which increased the force created by his muscles; for the purpose of accomplishing mechanical work only those sources were utilized which existed in a ready-made form in nature -- the muscle power of domestic animals, water power or wind power. Depending on which materials man used for preparing tools the stone age, bronze age, and iron age are distinguished.

At the second stage, man, based on a deeper knowledge of the laws of nature, created machines which utilized sources of energy latent in nature; the age of steam, electricity, the age of atomic energy began. By perfecting further his machine tools man achieved noteworthy progress in the development of material production.

At the same time, man has gone over to automation, to automatic regulation, to control instead of direct manual control of machines and production producess. In combination with the further perfection of machine tools, a search for new materials, the demonstration and utilization of new types of energy for the needs of production, proceeding along the line of development of automatic control of production processes, man is making even greater achievements in material production and is completely freeing himself for creative activity from monotonous, exhausting work.

For the purpose of assuring automatic control of production processes it is necessary to have facilities for obtaining, processing, storing and giving out information about the course of the production processes, the states of the essential variables determining the course of the production process, about disturbances which can cause these variables to go beyond permissible limits, facilities which accomplish the necessary regulatory effects on the production process. These facilities are provided by instrument construction, for which reason it has become one of the most important branches of material production at the present time.

In the life of a human society, in the development of human knowledge measuring instruments always played a considerable part; even at the dawn of its conscious activity mankind used the simplest methods for measuring weight, time, and the dimensions of bodies. Without instruments, without measuring facilities -- facilities for obtaining information -- neither science nor engineering could have been developed. However, instrument construction is acquiring special importance at the new stage of development of engineering, the stage of incorporation of automatic regulation and control of production processes. No type of activity of human society, whether it be the area of material production, development of science, development of culture, is conceivable without instrument construction, without facilities for obtaining, processing, storing and giving out information.

This is why the development of instrument construction in all the countries of the world is proceeding at fast tempos, which have considerably outstripped the rates of growth of the other branches of material production. The ratio of capital expenditures in instrument construction to the total volume of production is greater than in other branches of industry. From year to year the specific importance of the cost of instruments is increasing in the cost of all the means of production.

According to data published in the literature (Leningrad, 6), the volume of production of scientific and industrial instruments in the United States has increased from $900,000,000 in 1947 by approximately 3.5 times in 10 years, whereas industrial production in the United States during this period of time has increased a total of approximately 40 percent.

Instrument construction in the Soviet Union is developing at a fast tempo. Instrument production in the USSR during the period 1950-1958 increased by more than 7.5 times. The control figures for the development of the national economy of the USSR for 1959-1965 have provided for an increase in instrument production by 2.5-2.6 times in 1965 as against 1958, which predetermines that the average annual developmental tempos for all of instrument construction over the seven-year period will be 13-14 percent. Actually, the production plans for instruments are being considerably overfulfilled. The average annual growth rates of instrument production in 1959 and 1960 amounted to 17-18 percent.

Despite such a fast growth of instrument production in the

Soviet Union, the needs of the national economy for instruments and automation facilities are, on the average, being satisfied only to the extent of 50-60 percent, both with respect to quantity and with respect to nomenclature. This is explained by the fact that the rapid growth and technical perfection of all branches of industry and expansion of operations on automation of production processes which were outlined after the Twenty-First Congress of the CPSU, the June (1959) and July (1960) plenary meetings of the CC CPSU required an increase in the output of instruments and automation facilities in volumes which considerably exceeded the control figures outlined for the seven-year plan of development of the national economy of the USSR. The need for instruments by industry, particularly for the comprehensive automation of production processes, has begun to outstrip the increase in their production considerably.

At the present time, planning and directing organizations are taking measures to eliminate disproportion; it is to be desired that these measures be realized more rapidly and more efficiently. Incidentally, several very important measures should be taken by instrument constructors themselves without any special capital investments:

First -- a marked increase in reliability of the instruments being released, an essential increase in their service periods. As has already been mentioned (Leningrad, 7), specifically a short term of service leads to the fact that several sets of instruments are required per set of basic equipment before it wears out completely or is preventively replaced. Therefore, the increase in the need for instruments is brought about, on the one hand, by a positive factor -- the technical perfection of production leading to an increase in the necessary quantity of instruments to be set up per single set of basic equipment and, on the other hand, by a negative aspect of the matter -- the technical imperfection of the instruments themselves, the need for frequent replacement of units and sets of instruments.

The increase in reliability of instruments being put out at the present time by two or three times would apparently be almost equivalent to doubling the production power of Soviet instrument construction without special capital investment and would markedly increase the satisfaction of the need for instruments in the Soviet Union.

The next measure for improvement of provision of automation with the necessary facilities for obtaining information is the improvement of methods of sampling information, revision of established methods and of the established nomenclature of the instruments, bolder utilization of analogies and examples from living nature along this line.

An important measure is a revision, in principle, of the methods and apparatuses for storing information about the course of production processes. Actually, at the present time, a very considerable part of production power in instrument construction is utilized for putting out the so-called "secondary" instruments which are to go on central or local control boards. Forcing the incorporation into production of current progressive methods of storing information -- scanning instruments which make it possible, by means of several secondary instruments, to monitor several hundreds of parameters of a production process, the development of more perfect methods of storing and giving out information with utilization, particularly, of components and units of computing technique would make it possible to satisfy the growing needs of industry, with a substantially smaller load on instrument constructing plants, by putting out secondary instruments.

Problems of reliability of instruments, improvement and expansion of methods of sampling and storing information about the course of production processes have been analyzed in detail below with an analysis of the analogies arising in the combined examination of processes of sampling, initial processing, storing and giving out of information in living organisms and in engineering.

Problems of Reliability

It has been mentioned repeatedly that cybernetics deals with the study of both the systems created by man and systems occurring in nature during the course of evolutionary development (living organisms); in the reference (Leningrad, 8) mention is made further about the great benefit which cybernetics can bring to physiology.

In the present discussion I should like to show how the "cybernetic" approach to the analysis of problems, the attempt to demonstrate some of the rules and regulations or at least feel out general pathways in the problem of obtaining information in the production complex and in the living organism can prove to be fruitful for instrument construction.

Along this line, first of all, the fact is very interesting that the living organism provides for the great reliability specifically in the sensing elements for collection of information. Thus, according to data presented by V. D. Moiseyev (Leningrad, 9), the retina of each eye contains about 100,000,000 receptor cells which transmit information to the brain by means of only 1,000,000 nerve fibers, that is, every long distance communication element, nerve fiber, services about 100 sensing elements; according to information from another source (Leningrad, 10) there are 130,000,000 retinal cells and only

800,000 nerve fibers, that is, each nerve fiber is serviced, on the average, by approximately 160 sensing elements. The opportunity of obtaining false information because of "damage" to any of the sensing elements is absolutely negligible. If we use the data of V. D. Moiseyev (Leningrad, 9) as orientation, the probability of erroneous transmission thereby does not reach one in a trillion.

In order to come close to such a probability it is necessary to raise the reliability of modern industrial systems of sampling and transmitting information by many millions of times. It may be said that the visual analyzer of the eye is as much more reliable than the industrial systems for obtaining information as the earth sphere is more stable than a child's top. As has been pointed out, for example, in the report about the very reliable Japanese digital system of controlling machines with transistors at the International Congress on Automatic Control in 1960 (Leningrad, 11), assuming one fault every 100 days from each of the 500 control components, an exceptionally high degree of reliability is required which corresponds, on the average, to only a single breakdown every 20,000 days. This requirement has led to the complete exclusion of vacuum tubes from the system and made it possible to utilize transistors only of increased reliability, selsyns, two-phase servomotors and similar units with a relatively high degree of reliability.

In engineering, in a large number of systems, we make use of "single-line chains of effects", in which the going out of commission of any one element interferes with the operation of the entire setup, and we use automatic reserve considerably less often, whereas in nature parallel circuits, or in a more general sense, "redundant" bypasses are tremendously common, increasing the organism's survival capacity. Thus, Professor Chlenov (Leningrad, 3) points out that for the occurrence of various diseases in man half and sometimes a much greater part of the many millions of cells connected with the corresponding function of the organism must go out of commission.

In telemechanics we are concerned with the problem of maximum multiplexing of one or two communication channels, over which many different messages are transmitted (and in a number of cases of application, like, for example, long distance communication, this is certainly fully justified) while in the living organism a tremendous number of parallel channels is used -- nerve fibers utilized for the transmission of a single message.

In a work mentioned in the bibliography (Leningrad, 12) a detailed analysis is given of the problem of the connection between the "number of lines in a connection", N, and the probability of improper operation ρ (N) with a given probability of breakdown of a single component E; for the probability of incorrect operation of a single element E equal to $5 \cdot 10^{-3}$ we have the following:

$$\rho(N) = \frac{6.4}{\sqrt{N}} \cdot 10^{-\frac{8.6N}{10\,000}}.$$

According to this formula we obtain, for example, for N=2,000 only a low degree of reliability corresponding to $\rho(N)=2.6 \cdot 10^{-3}$; for N=20,000 we have a very good reliability, corresponding to $\rho(N)=2.8 \cdot 10^{-19}$, that is, an increase of N by only 10 times increases the reliability by approximately 10^{16} times!

The loss of reliability in industrial control systems increases further as the result of a large number of elements participating in the single-line action chains mentioned above. Thus, for the purpose of control of the turn of a slide valve under the influence of a change in temperature some place in the production process the use of about 20 amplification components is necessary in the regulation system: thermocouple, vibrapack, 3-4 stage amplifier, a servomotor of the secondary instrument, a rheochord of the regulatory attachment, several stages of electronic and sometimes magnetic amplification, and a servodrive for the slide valve. As a rule, no parallel circuits are provided in such apparatuses.

Nevertheless, as has been pointed out in the work mentioned above (Leningrad, 12), "the logical depth" of operation of our nerve cells, that is, the total number of basic operations from the input (perception) to storage (memory) or to output (the control of motor centers) is apparently much less than in the artificial automat which might be able to cope with problems of such complexity. "More specifically: the number of neuron synapses from peripheral sense organs along centripetal nerve fibers through the brain and back along the centrifugal nerves to the motor system does not exceed 10. A parallel complexity in the neuron system is indisputable" (Leningrad, 12, page 135).

In engineering at the present time a problem of exceptional importance has been posed of constructing reliable systems from unreliable components -- more accurately, synthesis of systems of a given reliability from components which do not permit obtaining the required reliability of the system with a single-line construction.

The exceptional part played by vacuum tubes in modern engineering is well known. We can point (Leningrad, 13) to the following problems of electronic apparatus, which explain its extensive incorporation into all fields of knowledge, industry, medicine, and biology:

high degree of sensitivity; possibility of amplification of very weak voltages and currents; convenience in transformation of energy; flexibility of control, including long distance control; high speed; possibility of recording and observation of the most varied processes with a high degree of accuracy. These properties of electronic instruments are being progressively perfected. Thus, for sampling of information about small and supersmall displacements in engineering and in biology mechanotrons -- vacuum tubes -- sensing elements for displacements (Leningrad, 13, 14) are finding application; for sampling of information about the quality and composition of a product -- photoelectronic sensing elements; ionic instruments are used for vacuum detectors; for the purpose of measurement of temperature semiconductor resistors (thermistors) are used.

The very much limited reliability of electronic instruments is frequently considered an essential obstacle to their use in complex systems of monitoring and control requiring a high degree of reliability of action. Emphasis of this fact is fitting in all those cases where we are dealing with an urgent need for a marked increase in reliability of electronic components of automatic systems. However, along with work on increasing reliability of the components work should be done on the problem of creating efficient structures of automatic systems with broad utilization of analogies arising from analysis of nerve nets in living organisms, particularly the creation of parallel, collateral, reserve, in a general sense "redundant" circuits which can markedly increase the reliability of the system made up of components of limited reliability.

Everything which has been stated certainly applies to industrial systems made up of any elements. It is essential to direct the greatest attention to a marked increase in reliability of these systems not only because their reliability is, for example, millions of times less than the corresponding information systems in living organisms, as has already been mentioned, but also because of the fact that they are absolutely, inadmissibly low. For on the average, one fault every 100 days is not permissible for any production process. Such reliability has been mentioned above as a limit which is difficult to achieve at the present time for the complex system which has been analyzed (Leningrad, 11). Therefore, means of increasing reliability should be developed such as the introduction of noncontact principles or at least a marked reduction in the application of sliding contact in industrial information and monitoring systems. Cases where, because of a poor selection of the individual relatively small components of one instrument or another the warranty service period of the instrument is reduced by tens and hundreds of times are absolutely inadmissible.

Thus, according to the certification data, "noncontact selsyns should operate synchronously for 3,000 hours", the service period which is usually accepted for this machine, which in principle is no less reliable than the short-circuited induction motor and is quite similar in its reliability to such a long-lasting apparatus as a transformer, because under ordinary working conditions the noncontact selsyn makes only several revolutions a day.

The main limitations on the service periods of these machines and a number of other electrical mechanisms are usually made by inadequate bearings, and in a number of cases unsatisfactory production technique, particularly in the preparation and utilization of insulating materials. Nevertheless, as the practice of utilization of the first batch of Soviet noncontact selsyns (which were considerably less well worked out technically than those being produced at the present time) on the channel imeni Moskva, has shown, 15-20 years of operation is not the maximum limit for these machines. And this amounts to 120,000-160,000 hours rather than 3,000.

The situation is even worse with regard to the established service period of numerous automatic components, developed, for example, in the aviation industry but fully suitable in their function and construction for utilization in general industrial systems. In the technical assignments for workup given by airplane constructors, requirements are mentioned for the service period which only a little exceed the service period of the main assemblies of the airplane -- usually several hundreds of hours. Therefore, in the certificates of such long-lasting automatic components as, for example, rotating transformers, relays and switches, a service period of several hundreds of hours is indicated, which does not permit the one planning and designing an industrial system to utilize them. In many cases, the actual service period of such a component is actually close to that on the certificate, because in the construction and release of the article absolutely inadequate attention is given to problems of longevity.

When thinking about problems of reliability of cybernetic apparatuses will lead constructors and technologists to develop measures for increasing the service periods of automatic components by several times (for a number of articles increasing the service period by even tens and, in various cases, by hundreds of times is practical with the taking of relatively simple measures), they will provide not only for an essential improvement in reliability of monitoring and automation systems but also will coordinate their results, as has already been mentioned, with marked increase in the output of the instrument construction industry of the Soviet Union.

Work on increasing the reliability of components and systems in automatics should be carried out and stimulated on the same level as the most important problems for the Soviet Union.

The development of parallel series of instruments with increased longevity (thousands and tens of thousands of hours) in special branches of instrument construction, which may be of importance not only for industrial systems but also for objects with comparatively short service periods would be of considerable benefit. Theoretical and practical development of methods of constructing highly reliable systems from components of relatively low degrees of reliability should constitute the necessary steps along this line, with creation of a large nomenclature of noncontact instruments for sampling, transmission and storage of information of multipath long distance transmission systems which make it possible markedly to increase the power of a signal with a high degree of accuracy. It is time also to proceed from well organized popularization of the merits of semiconductor components to an equally well organized mass output of these components with stable characteristics and the necessary nomenclature.

Problems of Improvement of Methods of Sampling Information About the Condition of the Main Parameters of Production Processes

In practice, all physical parameters by which the production process is characterized are utilized for sampling useful information. Thereby, extensive use is made not only of the direct phenomena accompanying the course of the process -- change in the temperature, pressure, color, chemical composition, etc., but also auxiliary apparatuses which contribute to obtaining information about the condition or properties which are not available to perception or are less conveniently perceived. Thus, for a large number of fluids which are in closed containers and which possess aggressive or other properties which make utilization of ordinary float gages difficult for measuring the fluid level, radioactive apparatuses are used (for example, the "Teplopribor" level gage worked out by the NII [Scientific Research Institute] which utilizes radioactive isotopes of the UR-4 type and similar ones) consisting of a radioactive emitter and a radiation receiver placed outside the vessel containing fluid and moved synchronously along the top of the vessel in accordance with the fluid change in the vessel; certainly, in this case the source of information is constituted by the properties of the fluid itself, specifically various absorptive properties of the fluid layer and of the corresponding layer of air or other vapors or gases which occupy the volume over the fluid level.

The same situation exists with regard to the capacitance detector of the fluid level, which has found very extensive application recently; this consists, in its simplest form, of a rod which is to be dropped in the fluid being measured; this rod is covered with a thin insulated film with a high dielectric constant (for fluid which conducts the current) or two electrodes insulated from one another if the fluid does not conduct the electric current and has a dielectric constant which is essentially different from air. In these cases the information is also obtained, naturally, from the properties of the fluid itself.

At the present time, the nomenclature of primary elements and detectors is divided into several large groups. We shall not deal with the special large group of instruments which measure electrical variables: current, voltage, power, frequency, phase shifts, and others, but we shall rather concentrate on the group of instruments which include the most common general industrial production processes, on the so-called "division of heat energy or heat engineering instruments".

These instruments can be divided into five groups: 1) pressure and vacuum detectors; 2) detectors for the consumption and quantity of fluids and gases; 3) detectors of fluid levels; 4) temperature and quantity of heat detectors and, finally, 5) a group of instruments with a tremendous nomenclature and of tremendous importance for measuring the condition and composition of substances; this includes gas analyzers, mass spectrometers, chromatographs, pH-meters, redox meters, concentration meters of various types, instruments for measuring viscosity, dust content, smokiness, moisture content, color, and others.

In this group the difference between industrial instruments and sense organs can be seen most readily. Thus, for example, in the food industry there are practically no instruments which might properly determine taste -- in the great majority of cases the taster is man; in a considerable number of cases the same applies to smell in the perfume industry. As a whole, such sense organs as taste and smell, I daresay, have been least modelled by automatic apparatuses.

The group of instruments for measuring the condition and composition of substances will in the very near future obtain essential and preferential development, outstripping the growth tempos of other general industrial instruments by 1.5-two times.

Primary elements and detectors which sample information about the course of a production process are analyzed in the very abundant general and reference literature (see, for example (Leningrad, 15, 16)). Elements for the initial processing of this information for the purpose of transmission of it for storage or other uses -- elements of general industrial long distance transmission are also extensively analyzed in the literature (see, for example (Leningrad 17, 18)).

We should like to point out only certain basic directions along which the development of instruments in this category should progress in the current seven-year period. These main directions include not only the problems which are new in principle but also the very important matter of putting a certain order into the development and production of these instruments for this nomenclature division, the development of types, normal series, the introduction of the greatest unitypicality of the information being transmitted, standardization of the output signals of the primary elements which are different in their construction and purposes and others. Great importance is ascribed also to increase in the reliability of sampling and transmission of the information; along this line the so-called "systems with power compensation", otherwise known as "local compensating systems", in which amplification of the signal occurs directly at the place of sampling the information and signals are put into the transmission line which essentially exceed the possible level of noise, will be considerably developed.

In the very methods of information sampling in a large number of cases a transition is being made from taking samples (at the present time, the basic method of sampling information at many factories of the chemical, food and similar branches of industry) to continuous information sampling, which best satisfies the current continuous production processes, on the one hand, and methods inherent in living organisms, on the other.

Considering the size of the present work it is neither possible nor advisable to analyze the specific main trends of the present development of the types of detectors mentioned in greater detail. We can point out only the great development which, on the one hand, is being given to new instruments for measuring the condition and composition of substances and, on the other hand, new methods of sampling information which utilizes neutron radiation, for example, for determining the level, moisture content, concentration of various materials, reflection of beta- and gamma-rays, ultrasonic waves, reflection of centimeter waves, various semiconductor converters and other achievements of modern physics.

Along with the methods listed it is apparently advisable, by using the "cybernetic" approach, to perform research work in the field of seeking out methods and development of instruments which simulate such important sources of information as taste and smell organs in our bodies. Here, apparently, considerable coordinated work is needed not only by scientists and investigators in the field of instrument construction but also biologists, because, as far as we can judge from known material, the degree of study of these sense organs along the line in which we are interested is still lagging behind the study of the visual analyzer, the eye. Incidentally, a considerable group of instruments, corresponding in their nature to the sampling of information by the visual analyzers, also awaits development.

The important branch of instrument construction which directly services scientific investigations -- the so-called "scientific instrument construction", where the latest achievements of all branches of knowledge, including cybernetics, should be used to the greatest degree is being developed absolutely inadequately. In the construction of systems for sampling information for purposes of monitoring and regulation it is advisable to pay attention to the nature of the signal transmitting the information.

For a long time now attention has been directed to the fact that in the nervous systems of the higher animals the optimum frequency modulation, in the sense of noise-proofing, is used rather than the optimum pulse amplitude (in Fig 1 we are presenting the characteristic graph taken from (Leningrad, 5) which illustrates this principle), but in parallel there is a continuous transmission of information through the blood and chemical substances.

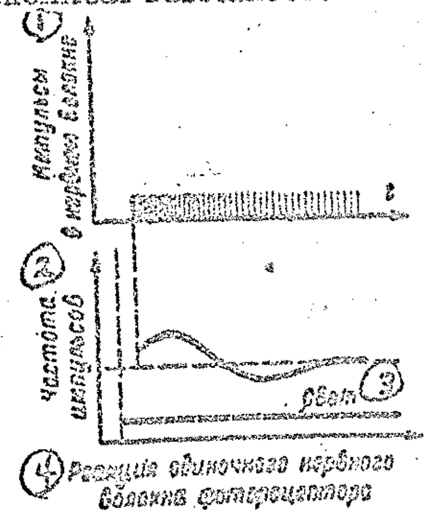

Fig 1.

1. Impulses in the nerve fiber; 2. Pulse frequency; 3. Light; 4. Reaction of a single nerve fiber of a photoreceptor.

This combination of impulse transmission of information and continuous action upon the sensitivity of the perceiving cells (on the gain of the system) in the visual analyzer -- in the adaptation system of the retina of the eye is very interesting. In (Leningrad, 5) material is presented indicating that if the illumination falling on the photoreceptors of the eye is markedly changed, first pupillary reflexes occur for one-two seconds under the influence of the impulse information which make it possible to create a regulatory influence approximately within a range of 1:25, but after the prolonged effect of light the continuous process of change in the sensitivity of the photoreceptors occurs which provides for a regulatory effect, slower (several minutes) but now in the range of $1:10^7$ times; after the completion of the process of adaptation the pupil returns almost to the original diameter. The possibility has not been excluded that in a number of industrial systems the combination of high-speed impulse line of information in a narrow range of regulation with another, relatively slower continuous action over a considerably broader range of regulation would be expedient under conditions of the prolonged effect of the disturbance.

Finally, the fact attracts attention that only a small number of modern industrial regulators operates from sensing elements which react to illumination, color or similar parameters. Among these regulators we may mention, for example, the well-known regulators of the course of smelting in converters in accordance with the color (or more accurately, an indicator of the end of smelting by a blue-red relationship); photorelays of different types, particularly for turning artificial lighting on and off; a number of photoelectric regulators, depending on the color (for example, the whiteness of flour), transparency, reflecting properties of various substances and surfaces, smoke and dust content in certain areas, etc. However, the main, predominant part of the modern industrial regulators operates from detectors of pressure, consumption of fluid and gases, temperature, movement of mechanical elements (particularly, in measurement of a fluid level and its density with the utilization of floats), and others. In man, of approximately 4,000,000 nerve fibers which transmit information half of them are for vision (about 2,000,000 nerve fibers); only 60,000 nerve fibers serve the organs of hearing, and all the other detectors are fewer in nerve fibers than vision, which is the "dominant sense for relation with the outside world" (Leningrad, 5). It is possible that this fact will be able to emphasize the number of useful associations for the scientific instrument constructor and the research technologist.

Problems of Storing and Giving out Information

In completely automated systems the flow of information from the primary elements as well as from feedback elements takes place largely in the computers of the regulators. However, in these systems the storage of a certain part of the information is required both for the possibility of subsequent monitoring of the course of a production process as well as, in a number of cases, for assuring the accomplishment of the optimum regulatory process, particularly the so-called " learning" process, in which it is necessary to compare the results of production operations with the values of variables which exist during the operation.

In systems which are partially automated or with the accomplishment only of running monitoring of the course of the production process the flow of information proceeds through long distance transmission to the so-called "secondary" instruments which serve for the direct reading of the current value of the variable being monitored from a dial or for remembering the values of the parameter for a certain period of time, which is accomplished by and large by automatic recording instruments on a disc or strip chart; recently, a memory system in the form of figure recording machines has been developed, which record the values of the variables in a numerical code. There are also various developments in which the current values of the parameters are recorded on magnetic tape or on punch cards, particularly for systems which operate in a cyclic process. Thus, in the report to the First International Congress of the IFAK on automatic control (Leningrad, 19) a report was given on the utilization of a three-stage selsyn system for these purposes, which assured control of a machine with an accuracy up to 0.001 percent, and the use of punch tapes with eight rows of perforations for each support. In a report already mentioned (Leningrad, 11) information coded according to a binary calculation system is also recorded on the punch tape; a photoelectric coding apparatus converts continuously acting factors (turns and movements) into numerical factors. An apparatus is also known with selsyns and magnetic tape, in which after processing of the first item the selsyns record the information concerning the principles of all operating organs on the magnetic tape; then, the control is switched to the magnetic tape, and the selsyns serve as feedback elements checking on the correctness with which the commands are carried out. However, such methods of storing information have not yet found extensive application outside of the metal-working industry, and, even in this field they are utilized inadequately. (Incidentally, it should be pointed out that the tendency toward extensive development of these methods is expressed in a very clear-cut manner in modern world instrument construction, which found its expression, particularly, at the International Exhibit in Düsseldorf in October 1960 ("Interkama", 1960)).

The main types of apparatuses for the transmission and storage of information at a modern enterprise, as has already been mentioned, are long distance transmission and a secondary indicating or recording instrument. Thus, in 1958, at the beginning of the seven year period, the annual output of general industrial secondary instruments of all types amounted to approximately 25 percent of the output of all general industrial instruments in the USSR, including detectors and regulators of all types. At the end of the seven-year period an increase was outlined in the output of secondary instruments by approximately 3.2 times, that is, by only 30 percent less than the planned average increase in output for primary elements. While practice will correct these figures somewhat, the decisive importance which specifically this system of transmission and storing information has at the present time and will preserve in the next few years is evident.

Of considerable increase is a comparative analysis of apparatuses for storing information in engineering and in living nature. While the modern central control and monitoring panel, which consists, for example, of several hundreds of automatic recording instruments and which stores information about changes in hundreds or several thousands of elementary variables in a process, occupies a volume of hundreds and thousands of cubic meters, the entire hereditary information which determines the main course of development of numerous very complex human organs in space and in time and which contains an immeasurable number of times more information is coded in a physical volume of the order of several cubic microns. The storehouse of the hereditary information not only of all people on earth but also of all the animals could readily fit in the framework of a single so-called "programming reference input element" measuring approximately 0.15x0.15x0.4 meter, that is, with a volume of about 9,000 cubic centimeters.

For the purpose of assigning the program, for example, change in the temperature at a single point in an industrial setup a volume of several thousand cubic centimeters is required on such an instrument, 10^{15} times more than the volume of all the hereditary information in man indicated above; these two information storehouses are remote from one another not only quantitatively but also qualitatively.

Above, we have presented several examples of the storage of information on a punch tape and magnetic tape. It may be supposed that this method of storing information, particularly for cyclic production processes, deserves extensive application in all branches of industry. The so-called "scanning" systems, in which information from a large number of primary elements is collected in turn by one apparatus for storage (usually by means of recording the corresponding numbers on the tape) and utilization are being developed considerably.

Information sampling which is relatively closer to biological systems apparently is done by scanning systems in which the values of one parameter or another are remembered only if they go beyond permissible limits; these systems are also technically more economical with respect to information utilization, possessing a greater density of information reserve than the other systems.

Less promising is the route of creation of the ordinary type of secondary instruments with a large number of curves or points recorded on the same strip. Thus, an automatic potentiometer of the Cambridge company with 400 record points and a special coding area which facilitated the determination of whether one point or another belonged to a corresponding primary element, demonstrated in Moscow in 1960 at an exhibit of English instruments, is, despite its clever and well-planned construction, not capable of competing with the far more flexible scanning systems mentioned above. However, the storage of information on the strip of a figure-printing machine, punch card or even magnetic tape still seems to us to be only one of the first steps in the direction of increasing the density of reserve information within a given volume.

The next step may be a system which utilizes compact ferrite, capacitance or analog memory elements of modern computers for storing information about the course of a production process; in such a system methods of sampling and storing information borrowed from living nature, such as the remembering of only the repeated deviations from the permissible values of the variable, increase in the "contrast" of information by introducing a set effect of the excited elements upon the sensitivity of the others, for example, the neighboring unexcited elements, as occurs in the visual analyzer of the eye (Leningrad, 5), and the assurance of prolonged storage and production "on demand" or automatically only of those volumes of information which correspond to the best, worst, or other previously designated results of production operations may be realized.

The situation is not only that the physical volumes of storehouses in which the reserve information is kept are large; perhaps even more serious is the fact that even under current conditions this information ceases to be capable of survey and, therefore, available for operative utilization. Study of all the rules and regulations of production processes and the improvement of their control require further quantitative and nomenclature expansion of the network of primary elements. In the course of time the progressively increasing stream of information will swamp man if he does not organize this stream properly. Apparently, it is necessary to a considerably greater degree to attract the attention of the leading instrument construction institutes and KB [design offices] to the solution of problems of transmission and storage of information; the development of a system of storing production information according to current principles of cybernetics with the use of technical facilities which are being applied in computation technique and various methods which have been critically borrowed from living nature should become one of the leading topics of scientific research in instrument construction and automatics. This topic is not only of tremendous direct economic and technical significance but is also the key to the creation of automated production complexes of the future.

In addition, it would be quite opportune, perhaps at the Academy of Sciences USSR, to pose the problem of seeking out qualitatively new methods of storing production information, for example, by means of acting on molecules of a substance, etc. as the most important research problem topic for a number of institutes working in cooperation.

The examples presented above of the "cybernetic" approach to problems of instrument construction in the field of sampling and initial processing and storage of information about the courses of production processes, naturally, do not in any way exhaust the topics and represent only some tendencies along this line. Future development of this topic, study of the dialectical interrelationship and useful analogies between such systems in engineering and living nature is timely and expedient.

The resolutions of the Twenty-First Congress of the CPSU and the July (1960) Plenary Meeting of the CC CPSU concerning the extensive application of automation of production processes to the industry of the Soviet Union, the incorporation of comprehensive automation of shops and plants, the utilization of all the latest achievements of science and engineering for purposes of accelerated completion of the building of communism in the Soviet Union confront Soviet science with honorable and difficult tasks. The considerations presented in this work have the aim of attracting the attention of instrument constructors, investigators and other specialists in the field of construction of such important elements in systems of monitoring and automation as facilities for sampling, initial processing and storage of information to a certain combination of ideas and principles of cybernetics which can prove to be useful in their work.

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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.