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# **Science & Technology**

## ***USSR: Engineering & Equipment***

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# Science & Technology

## USSR: Engineering & Equipment

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CONTENTS

19 DECEMBER 1988

### Nuclear Energy

Fuel Balance, Heat Consumption Trends [L. Popyrin, V. Sidorenko; <i>SCIENCE IN THE USSR</i> , No 4, Jul 88] .....	1
Importance of Safety in Ensuring Nuclear Power Prospects [Prof. A. Protsenko; <i>SUMMARY OF WORLD BROADCASTS (BBC)</i> , 23 Sep 88] .....	6
Energodaratomstroy: New Organization Is Proposed To Build Nuclear Power Plants [Rem Germanovich Khenokh Interview; <i>STROITELNAYA GAZETA</i> , 27 Apr 88] .....	8

### Non-Nuclear Energy

Oil, Natural Gas; Future of Power Generation [V. Nalivkin; <i>SCIENCE IN THE USSR</i> , No 4, Jul 88] .....	11
Bureaucratic Obstacles to New Wave Generator Criticized [Yu. Stroginskiy; <i>IZOBRETATEL I RATSIONALIZATOR</i> , No 8, Aug 88] .....	15

### Turbines, Engines, Propulsion Systems

Machine Tool Expo Shows Off Abrasion Tool, New Valve [I. S. Vitol; <i>MASHINOSTROITEL</i> , No 7, Jul 88] .....	17
--	----

### Industrial Technology, Planning, Productivity

50th Anniversary of Institute of Machine Science imeni A. A. Blagonravov, USSR Academy of Sciences [M. K. Uskov; <i>MASHINOVEDENIYE</i> , No 5, Sep-Oct 88] .....	18
Problems of Mechanics; Scientific, Technical Progress in Machine Building [K. V. Frolov; <i>MASHINOVEDENIYE</i> , No 5, Sep-Oct 88] .....	19
GOST Criticized for Overly Rigid Quality Control Specs [A. I. Velednitskiy; <i>TEKHNIKA I NAUKA</i> , No 6, Jun 88] .....	27
Low Pay, Use of Engineers as Unskilled Laborers Criticized [A. S. Sergeev; <i>TEKHNIKA I NAUKA</i> , No 6, Jun 88] .....	32
Cartoon Satirizes Assignment of Engineers as Gardeners, Farm Hands .....	36
In-House Machine Tool Building, Solving Technological Problems [V.F. Rzhavskiy; <i>AVTOMOBILNAYA PROMYSHLENNOST</i> , No 4, Apr 88] .....	36
Determining the Demand for Automated Foundry Equipment [A.A. Panov; <i>MEKHANIZATSIYA I AVTOMATIZATSIYA PROIZVODSTVA</i> , Apr 88] .....	40
Experience in Developing System for Planning, Distribution, Accounting for Ongoing Work in an FMS [L.P. Romanyuk, O.A. Tregulova; <i>MEKHANIZATSIYA I AVTOMATIZATSIYA PROIZVODSTVA</i> , No 4, Apr 88] .....	42
Electrical Engineering: New Forms of Socialist Cooperation [Sergei Samarin; <i>FOREIGN TRADE</i> , Aug 88] .....	46
Integrated Automation in CMEA Countries: Current Problems [Ivan Medvedev, Dmitri Sadovskii; <i>FOREIGN TRADE</i> , No 8, Aug 88] .....	49
Practice, Problems of Conducting State Testing at Industrial Enterprises [I.I. Gerega; <i>STANDARTY I KACHESTVO</i> , No 4, Apr 88] .....	54
First Results of Gospriyemka Discussed [V.I. Kostyuchenko; <i>STANDARTY I KACHESTVO</i> , No 4, Apr 88] .....	55
Results of Gospriyemka Show Improved Technological Discipline [A.S. Grigorov; <i>STANDARTY I KACHESTVO</i> , No 4, Apr 88] .....	55
Results of Gospriyemka Show Reduction in Product Quality Complaints [P.A. Gurov; <i>STANDARTY I KACHESTVO</i> , No 4, Apr 88] .....	56
From Resolution of Scientific-Technical Council of USSR Gosstandart [ <i>STANDARTY I KACHESTVA</i> , No 4, Apr 88] .....	58
Standards, Technical Progress: Reliability Indicates Equipment Quality [ <i>STANDARTY I KACHESTVO</i> , No 4, Apr 88] .....	59

Computer-Aided Design of Technological Processes  
[A. B. Solovey, Yu. A. Privalov; *MASHINOSTROITEL*, No 2, Feb 88] ..... 62

**Miscellaneous**

Improving Quality of Railroad Rails  
[V. A. Palyanichka, M. S. Gordiyenko, et al.; *METALLURG*, No 7, Jul 88] ..... 63

### Fuel Balance, Heat Consumption Trends

18610168a Moscow *SCIENCE IN THE USSR* in  
English No 4, Jul 88 pp 12-18

[Article by L. Popyrin, corresponding member of the USSR Academy of Sciences, expert in heat and power engineering and department head at the Krzhizhanovsky Power Engineering Research Institute, and V. Sidorenko, corresponding member of the USSR Academy of Science, expert in nuclear reactors, and deputy chairman of the USSR Safety Supervision Committee for Atomic Power Engineering]

[Text] Advances in nucleonics and nuclear power engineering during the last thirty days allow the energy balance in the Soviet Union to be restructured so that atomic energy is used not only for the production of electricity, but also of heat where it is economically justified. Such a change will necessitate a large-scale reconstruction of the network of trunk and distribution heat pipelines in cities, along with a modification of the role and operating mode of existing heat supply facilities. Great outlays are inevitable since heat generators using atomic fuel are much more expensive than their fossil-fuel counterparts. Highly topical therefore are all questions of cost-efficiency of building such generators and all major engineering decisions concerning their application.

Naturally, when discussing the future of nuclear power engineering we should always remember what happened at Chernobyl and treat matters of safety with the utmost care and thoroughness. Nevertheless, this does not mean that Chernobyl will halt the development of nuclear power engineering, for without it the national economy cannot be provided with the required amounts of energy.

### USSR Fuel Balance

The Soviet Union is the only industrial power whose prospected reserves of fossil fuels are large enough to take care even of its long-term demands. However, the main fuel consumers are far removed from the areas where power resources are concentrated. Over three quarters of all power generated is consumed in the European Soviet Union (including the Urals), while fossil-fuel production here tends to decline. As a result, great amounts of oil, natural gas, coal, and electric power have to be transported from the east to the west of the country (Table I). At present, fossil-fuel supplies from the east make up nearly two-thirds of the energy balance of the European regions (including export). By the end of this century the absolute volume of all power resources (oil, coal, gas, etc.) transported from the east is expected to increase even further.

Transportation of such amounts of fuels over distances of some 3000-4000 kilometers involves great expenditures on the development of the transport network, hence increases the cost of the fuels.

The most promising way out of this situation is to develop the nuclear power industry. The atomic power plants in the European USSR are capable of producing enough electricity to meet the increasing demand. By the end of this century the share of electricity generated by atomic power plants may rise to 25 or 30 percent, substantially reducing the consumption of fuel oil and natural gas. It should be noted, however, that only a quarter of all primary energy resources are used to produce electric power (Table 1). This means that atomic power plants alone cannot serve as a means of wholly eliminating shortcomings in the energy balance of the European USSR.

Table 1. Some Indicators of the USSR Fuel Balance (in million tons of equivalent fuel\*)

Indicators	1960	1970	1980	1985
Fuel production	760	1270	1960	2250
Fuel consumption, including that in the European USSR	700	1160	1670	1880
(Not counting export)	550	930	1310	1430
Fuel transported from eastern to European regions of the USSR (including exported fuel)	-	130	700	950
Fuel input into electric power generation	110	230	370	450
Fuel input into steam and hot water production	105	260	440	510
Fuel input into high-potential heat generation	130	205	270	320
Fuel Input into other areas (motor transport, etc)	355	465	509	600

\*Ton of equivalent fuel is a unit used in economic statistics to compare the calorific values of various fossil fuels. The combustion of one ton of equivalent fuel produces about 30 million dJ of heat. (Ed.)

The situation can significantly be improved by using nuclear energy for heat generation. More fuel is required to generate steam and hot water, i.e., heat of medium and low potential<sup>1</sup>, than to generate electric power. The generation of high-potential heat (for high-temperature processes in ferrous metallurgy, machine building, construction materials industry, etc.) also requires a considerable amount of fuel.

### Heat Consumption Trends in the USSR National Economy

The development of the power generation complex during the last 25 years has revealed certain important trends in heat consumption (Table 2). One such trend is the stable share of low- and medium-potential heat in the total consumption of end power<sup>2</sup>; a somewhat decreased supply

of heat to the public and housing sectors and services; and an increased consumption of heat by industry. Another trend is a larger share of steam and hot water in the

generation of low- and medium-potential heat, and an increased proportion of low-potential heat in the total power consumption.

Table 2. Some Indicators of Heat Consumption by the USSR National Economy, Percent

Indicators	1960	1970	1980	1985
Share of low- and medium-potential heat in total energy consumption	54	55	55	56
Share of low- and medium-potential heat consumed by:				
Industry	50	56	61	61
Housing and services	50	44	39	39
Share of steam and hot water as heat carriers in low- and medium-potential heat supply	47	63	70	73
End power consumption:				
medium-potential heat	51	45	43	41
low-potential heat	49	55	57	59

There is every reason to believe that these trends will prevail in the future as well. This fact opens up wide prospects for the use of the existing types of atomic reactors to generate heat of a relatively low temperature.

The changeover to "atomic" heat is facilitated by the high concentration of thermal loads typical of the Soviet Union: the share of heat consumption by cities and small towns has reached 80 percent; 70 percent of this amount is consumed by cities with thermal loads above 2000 GJ per hour.<sup>3</sup>

Centralized heat supply provided 50 percent of all heat in this country in 1985 and is expected to reach 60 to 65 percent in the future, with centralized heating in cities attaining 75 to 80 percent.

Thus, there are favorable conditions for building large heat generating facilities, including atomic ones.

#### Atomic Thermal Plants: What Will They Be Like?

To date several versions of an atomic heat production facility based on pressurized water nuclear reactors have been developed.

One of the most promising ones is the atomic power-and-heating plant generating both heat and electricity. The atomic power-and-heating plant (APHP) is designed as a traditional thermal power installation (Fig. 1). After performing its function in the turbine (4) the steam is split into two streams. One is directed to the condenser (6) where it is condensed at a temperature of 20 to 30 degrees C, and the heat it carries is lost. The second stream is conducted to the water heater (7) and its heat is added to the heat supply system. The APHP is therefore more efficient than the conventional atomic power plant in which all steam passes into the condenser (for this reason they are sometimes referred to as condensing plants) and is lost. It is planned to build 2000-Mw APHPs to supply heat to large cities.

Another way to improve the efficiency of a heat generating nuclear reactor is to split heat into two streams (See Fig. 2), one of which will be used for power generation and the other for heating. The first steam is used in the traditional condensation cycle and does not provide any power for heating. Although its heat utilization efficiency is lower than that of the previously described version, it has advantages that become evident when using, say, boiling-water cooled reactors.

The point is that water in the reactor's fuel core is in two phases: as a liquid at the inlet and as a steam-and-water mixture at the outlet. If the water at the reactor inlet is additionally cooled, as is done in this case, it will tap more energy produced during uranium fission, at the same time improving the depletion of the fuel. Calculations show that this scheme provides significant economic gains. To select the best scheme though, it will be necessary to examine all the design versions available.

Engineers are now working on a special purpose generator which will produce heat for some specific need, say, for domestic consumption. A generator of this type, termed atomic heat plant (AHP), is shown in Fig. 3. The current USSR five-year plan envisages the completion of two large AHPs to meet the demand for heat of Gorky and Voronezh.

In the design and construction of any reactor plant special attention is paid to operation safety. But before discussing safety matters involved in AHPs we will have to say a few more words about the APHPs. At present these plants use shell-type water cooled reactors of the same design as those in operation in condensing atomic power plants. A standardized design approach means that all nuclear and radiation safety regulations, as well as safety regulations concerning the siting of atomic plants, are virtually the same.

As far as the atomic heat plants are concerned, they should be located near large settled areas so that the losses of heat during transportation are minimal. The AHPs have therefore to meet stricter operation safety standards which necessitates designs differing from those of the APHPs.

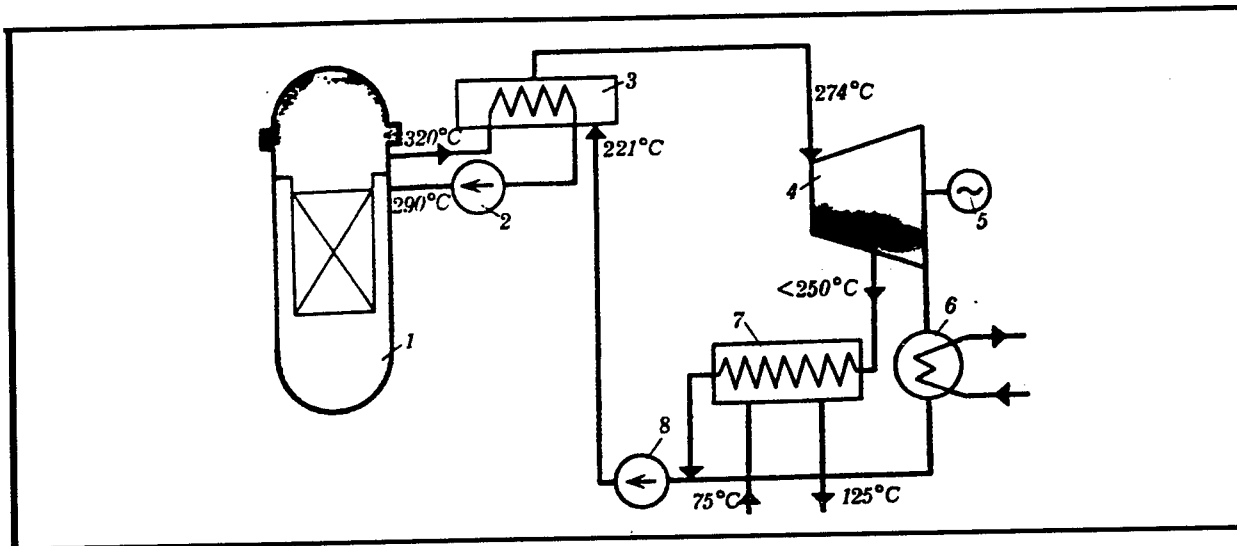


Fig. 1. Thermal APHP circuit with a VVER-1000 reactor

Key: 1)reactor 2)circulation pump 3)steam generator 4)steam turbine 5)electric generator 6)condenser 7)water heater for heating system 8)feed pump

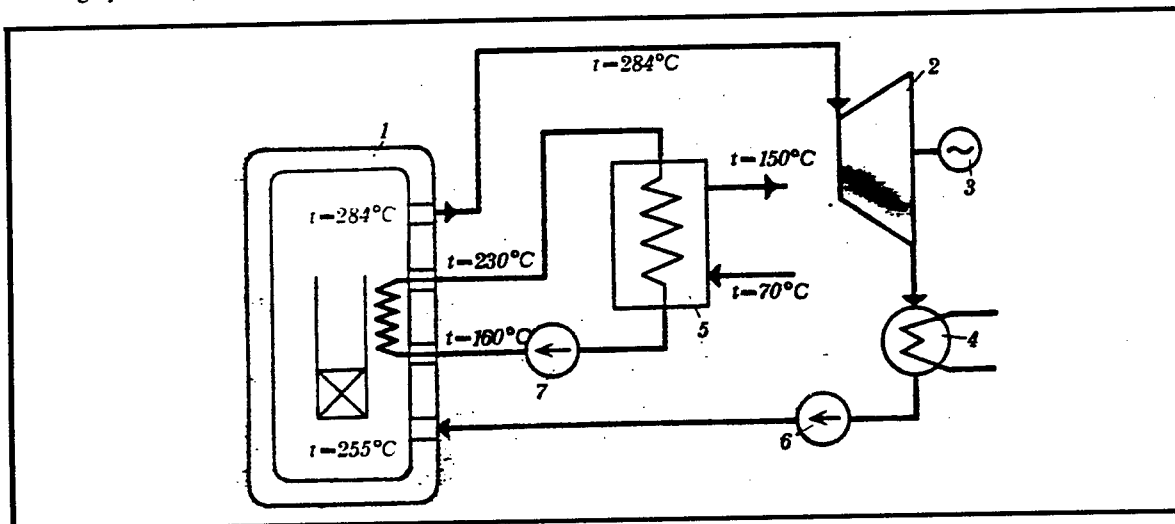


Fig. 2. Thermal circuit of a nuclear power supply with a VK-500 reactor

Key: 1)reactor 2)steam turbine 3)electric generator 4)condenser 5)water heater for heater system 6)feed pump 7)circulation pump

Any nuclear power installation is equipped with hardware providing for radiation safety of the staff and nearby population and preventing radioactive matter penetrating into the heating system or into the technological heat carrier. The safety measures and technical equipment may vary, depending on the type of reactor and its location, but each and every installation should rule out the very possibility of accidents like the one at Chernobyl. The task today is to design a new generation of reactor installations of improved safety, and the AHPs should be included in this category. Operation safety has been considerably improved at a reasonable cost by developing special low-temperature shell-type reactors for use at AHPs oriented to standard domestic heating

system parameters (water temperature of up to 150 degrees C at the inlet).

The very fact that such an installation should operate under moderate conditions (at 200 degrees C which is about 100 degrees lower than usual, and at pressure which is only an eighth of the standard) makes the installation much safer. At the same time a moderate energy intensity in the fuel core improves the reliability of the fuel element.

Operation safety is given priority in designing reactors for the AHPs. Account is taken even of the least probable situations such as damage to the shell, the fall of an

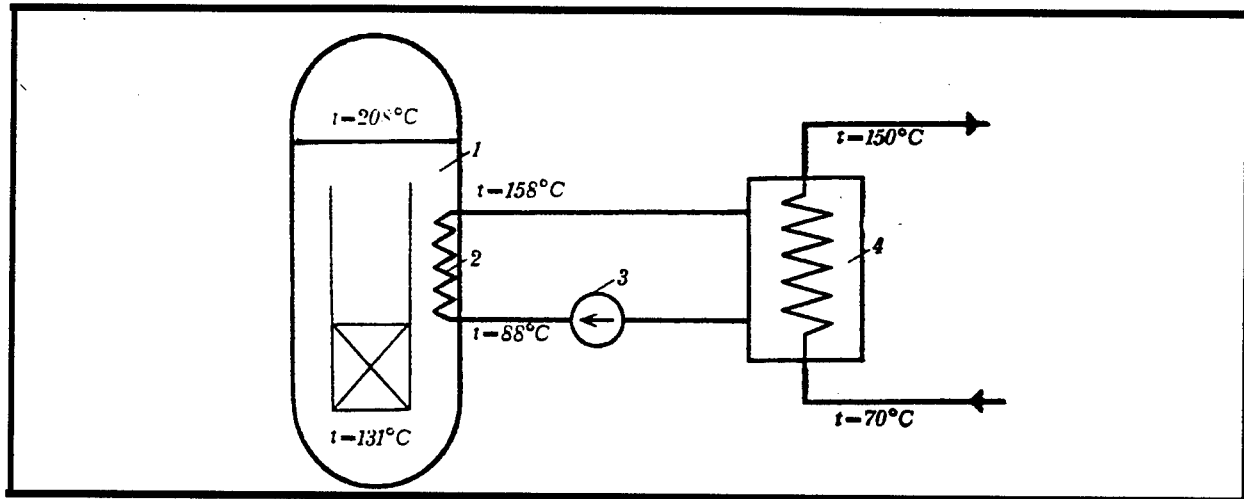


Fig. 3. Thermal circuit of a nuclear heating installation

Key: 1) reactor 2) water-water heat exchanger 3) circulation pump 4) water heater for heating system

aircraft, the impact of a blast shock wave, etc., and every precaution is taken during the removal of solid and liquid radioactive waste materials.

Heat from the reactor is conducted to the user by means of an intermediate heating circuit in which the pressure is lower than in the heating system, owing to which radioactive penetration into the heating system is impossible even in the event of a leakage. In this reactor installation natural circulation of the heat-transfer agent does the work of the pumps. Therefore, the reactor is insensitive to electric power supply failures. Also provided for is an additional safety shell which houses the main shell with a clearance. Thus even if the shell should be ruptured (this is one of the most serious failures) the core of the reactor will not be left without water and a situation fraught with the danger of a radioactive discharge into the atmosphere will be prevented.

Some of these design solutions may be used in the future for special-purpose reactors of improved safety intended for industrial heating supply systems using high-potential heat.

### Optimization of Heating Systems

As a next stage in its development, centralized heating can be provided by several types of installations. These include heat-and-power plants working on fossil fuels, atomic heat-and-power plants, district heating plants using fossil fuels, heating plants using nuclear fuel, including the AHPs and industrial AHPs generating medium- and high-potential heat.

To set up an efficient centralized heating system it is important correctly to define areas of application of its component parts. One of the directions of the study discussed in the present article was related to identifying problems that may arise in the course of optimization of

the heating system. These problems have been formulated and arbitrarily grouped at four hierarchic levels: the power producing system of the country as a whole; the integrated electric power systems and atomic power systems that are its component parts; the heating systems of a specific city or industrial center; and finally, individual heat sources.

For the solution of the problems in each group specific tasks, methodologies and mathematical models have been worked out. The main criterion has been minimum cost for the national economy. Other considerations were the probability that the production of fossil and nuclear fuels will be limited, and that there will be restrictions connected with transportation and with environmental questions. Computations have been carried out by means of powerful computers using modern methods of optimization and decision-making.

At the first hierarchic level (the country as a whole and individual regions) optimization means working out an optimal policy of developing a centralized atomic heating system within the national power system, and deciding the scope of construction of the AHPs, AHPs and industrial AHPs, taking into account the power consumption patterns existing in the USSR.

At the second hierarchic level two groups of problems have to be tackled. The first is related to questions of the power supply: integration of the power generated by AHPs into the power grid and determination of total capacities and operation modes depending on its demands. The second group of problems concerns the development of nuclear heating installations as component parts of a nuclear power generation system. Future requirements and prospects serve as the basis on which major specifications of nuclear reactors for future AHPs, AHPs and industrial AHPs are determined.

At the third hierarchic level dealing with urban heating problems the policy is towards optimal development of heating systems using both nuclear and fossil fuels. This involves optimization of unit power, of the composition of major APHP, AHP and industrial AHP equipment, and of the deadlines for putting it into operation.

Optimization of nuclear heating systems is treated at the fourth hierarchic level. The most efficient arrangement and production schemes, designs and parameters of APHPs, AHPs and industrial AHPs are selected.

A measure of inertia is typical of the development of the power systems, therefore the problems mentioned above are dealt with in advance. Computations precede actual realization by 5 to 7 years, and in some cases by 20 or even 30 years.

### Economic Considerations

The studies carried out indicate that in the European regions of the Soviet Union an extensive use of nuclear fuel in the heat supply system can be efficient if the atomic heat plants are rationally integrated with plants using fossil fuels.

A comparison of the technical and economic characteristics of traditional and atomic heat-and-power plants suggests the latter to be advantageous under heat loads of over 6000-7000 GJ per hour. While having similar economic characteristics, the APHPs provide for greater savings in fossil fuels and thus reduce the need to increase their production in undeveloped regions of Siberia.

At present the area where AHPs can be efficient can be defined only tentatively owing to the uncertainty of some of their technical and economic parameters. What can be stated definitely is that they can compete with the APHPs under relatively low heat loads, that is, loads of 1800 to 3500 GJ per hour, since in this mode (with the VVER-1000 reactor) the latter's technical and economic indicators are reduced significantly.

A comparison of AHPs with district boiler facilities using fossil fuels shows, that in the European regions the former are more efficient under heat loads of 2000 GJ per hour.

As far as the APHPs are concerned, they are most economical when they supply only a regular amount of heat within a heat supply system. Peak loads should be carried by "peak" facilities using fossil fuels. The same is true of the systems using AHPs as the major heat sources.

How will the structure of the supply system be affected by the development of the atomic heat sources? Respective studies taking into account considerations of economic efficiency and recommendations concerning applicability of each type of heating installation show that the share of atomic heat sources has been growing rapidly (Fig.4), and that in future they will produce one-third of the total heat output, thereby reducing fossil fuel consumption by about 400 million tons of equivalent fuel per year.

Gradually building in nuclear installations into centralized heating systems is not only expedient but imperative, since today this is the only feasible way to provide the country with the necessary amount of thermal energy.

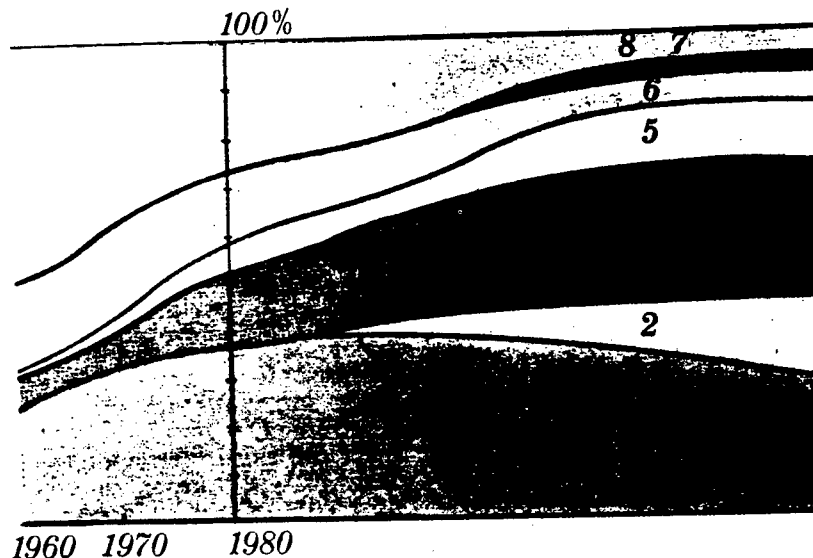


Fig. 4. Structure of heat sources

Key: 1)heat-and-power plants 2)atomic heat-and-power plants (APHP) 3)district boiler facilities 4)atomic heat plants (AHP) and industrial AHPs 5)secondary sources 6)small boiler installations 7)new heat sources 8)other sources



### Footnotes

1. The heat supply service distributes low-potential (up to 100°C), medium-potential (up to 300°C) and high-potential (above 300°C) heat. (Ed.)
2. End power is the mechanical, thermal and other types of energy supplied to the national economy upon deduction of losses. (Ed.)
3. One GJ per hour is equivalent to 0.28 Mw; thermal loads are usually evaluated in GJ per hour, power—in Mw. (Ed.)

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### Importance of Safety in Ensuring Nuclear Power Prospects

18610070 London SUMMARY OF WORLD BROADCASTS (BBC) in English 23 Sep 88 pp 7-9

[PRAVDA 6 Sep 88 second edition—Excerpts from article by Prof. A. Protsenko, Chairman of the USSR State Committee for the Utilisation of Atomic Energy: "Nuclear Energy After Chernobyl"]

[Excerpts] The general public is concerned about problems of the development of nuclear energy. Various views have been expressed in PRAVDA. Today it is a specialist's turn. It must be said that the incompetence and conservatism that led to an imbalance in the development of industry and neglect of the development of the latest progressive technologies during the years of stagnation [Brezhnev era] inhibited technical progress. In these conditions serious malfunctions began to occur in various spheres of industry. Numerous accidents in industry, on railway transport, on ships and in aviation were largely the result of lagging in technology and increasing irresponsibility. Chernobyl was one of them.

Many difficult problems are now determining the way in which nuclear energy is developing: at one end of the spectrum you have a very severe shortage of energy for the national economy and at the other end you have the accident at the Chernobyl nuclear power station.

It may seem strange to claim that one major accident has influenced the development of the entire nuclear power industry, but it is so. Chernobyl required such great efforts from the national economy when it came to eliminating the consequences of the accident, so shook the public and showed up so clearly many shortcomings in the nuclear power industry that for a long time to come it will be the starting point for the adoption of many decisions. Industrial specialists and leaders and the public have different perceptions of the situation. It is discussed in various ways in the press. As well as a sober approach one often finds a great deal of emotion and a lack of objectivity and professionalism.

The development of the modern nuclear power industry was preceded by decades of scientific and technical research, testing of technology at experimental power stations and the creation of the country's nuclear industry. Scientists, engineers and industry did not have modern nuclear power stations of that capacity immediately. The first nuclear power station was built in our country more than 30 years ago. It was followed by several more stations and nuclear reactors of various types. Scientists were looking for the best. This extensive quest enabled them to identify and begin to develop the most suitable types of nuclear power stations for our country. Similar decisions were made in other countries.

Nuclear science and technology and the nuclear industry and nuclear power sector were set up in a relatively short time. Although requiring considerable capital outlay and effort on the part of society, the development of the sector provided benefits which are not fully appreciated and which contributed to the progress of science and technology throughout the country. Nuclear science and technology was and is a most effective catalyst, one of the key avenues of scientific and technical progress. The entire history of the development of nuclear science and technology is associated with a constant quest and the exploration of new avenues. And then, against the background of this mounting technological progress, there came Chernobyl.

What comes after it? What path is to be followed? There are many opinions on this: a variety of opinions, to say the least, often diametrically opposed. Some say: close down the nuclear power industry and all the difficulties will be eliminated. Some believe that it is necessary to take a super-revolutionary path: dismiss everything in the past as worthless and create something new as soon as possible.

Take the first point of view. It is most vigorously and most frequently put forward by representatives of the humanitarian professions, by academics involved with various "non-nuclear" specialties and people living near nuclear power stations that are in operation or are in the process of construction. Sometimes its advocates start talking not only about nuclear science and technology, but about technology in general, about its dominance. In the history of the development of science and technology there has been more than one period when very important scientific avenues have been closed or the wrong avenues have been explored in technology or the national economy, generally when decisions have been taken arbitrarily, bureaucratically or as the result of an "outcry". In science there was the well known persecution of cybernetics and genetics. In industry there was the brake on the development of machine building and coal power. There were also unwarranted and undiscussed decisions on urban development (the five-storey blocks in Moscow) and agriculture (maize, the clearing of vineyards). Such things must not be allowed to happen again.

One can appreciate and understand the excessive emotion, because by and large they are committed people who are sincerely trying to help. But one cannot accept ignorance. Obviously, decisions must be prepared and adopted by professionals, experts. Knowledge is needed to make public discussions and debates useful and not harmful in terms of adopting decisions, which means vigorous educational work.

Specialists and academics in nuclear science and technology are doing this work with the public. But it is not yet being carried out on a large scale. A certain difference about the topic in the past is a factor here. The nuclear age needs its own education, its own thinking. Clearly this is a broader problem than the mere adoption of correct technical decisions.

There appeared and still crops up occasionally another, also, perhaps, extreme view of the future development of nuclear power. Perhaps in a somewhat exaggerated form it appears as follows: forget about the reactor technology and nuclear power stations created and developed over decades because they are no good and quickly create, with the help of new specialists who are not encumbered by past experience, new reactors based on entirely different principles and technology. This hastily concocted, pseudo-revolutionary development strategy is non-viable, like similar proposals in other areas of human activity which reject past experience. The inevitable failures of this approach often lead to distrust of new technology, operating failures and even tragedies involving collectives or individuals.

These matters cannot be solved at a stroke; what is required is painstaking, persistent planning work in all areas. First, the improvement of the first-generation nuclear power stations of the 1970s... The operation of nuclear power stations, including shutdowns and accidents, has provided and will provide invaluable experience which enables one to judge their reliability and safety and find and apply new technologies. This work to improve safety was being conducted here and throughout the world long before the Chernobyl accident. Unfortunately, the work was slow.

The specific causes of the Chernobyl accident have been rather extensively covered in the press: the grossest violations of station operation rules, in which certain station design faults also played a part.

The Chernobyl accident also set a number of new tasks. Many of the country's leading scientists and technical experts took part in eliminating its consequences, in the analysis of the causes and in stating the conclusions. Dozens of specialists were operating under their guidance. Their collective mental effort made it possible to find the requisite solutions during the elimination of the consequences of the accident at the Chernobyl AES.

The results of their work and analysis have been used by designers and physicists to improve safety at existing nuclear power stations. A great deal has now been done on systems for safely extinguishing a fission chain reaction, diagnosing the condition of a reactor and improving the performance of the reactor and its heat removal systems.

It must be said that this improvement has been carried out not only at nuclear power stations with reactors like the one at Chernobyl, but also at other stations in the country with reactors of a different type. Nuclear power stations are substantially safer as a result. Chernobyl signifies human lives and destinies, it signifies hundreds of square kilometers of territory temporarily lost. It is a colossal waste...

Safeguarding and improving safety is a constant process that requires special attention and a powerful scientific base. Unfortunately, the experimental base is poor and there are not enough equipment testing units.

Long before the Chernobyl accident, work began in design bureaus and scientific research institutes on creating a new type of high-safety reactor, in particular a high-temperature helium-cooled reactor, a new type of water-cooled reactor and so on. But the work was delayed because the experimental and testing facilities were lacking. The leadership of the sectors responsible for this did not pay due attention to the problem. It can be said that it is a problem for many industrial sectors, but in nuclear power, a relatively new sector, it is particularly important. I and my colleagues have spent a year drawing up and getting approval for a draft government resolution on creating these reactors and providing the requisite experimental and test facilities and computers. And here are the results. The draft was sent to 55 ministries and departments for their approval. It was rejected by 50. What was the problem? Was it just the leaders of the departments? Hardly. The manufacture of experimental and series equipment for research and the development of new technology is very unprofitable for plants and for sectors in general. And this is a disease of all industrial sectors.

All-round incentives for work on new equipment must become a very important component of the development of technology and industry. This problem may be solved automatically once we have been through the first stage of restructuring in management and industry. but it must be tackled now, within the framework of the present structure and potential. The USSR State Planning Committee, Ministry of Finance, and State Committee for Science and Technology must look into these new methods of stimulating the creation of new equipment—priority provision of resources and preferential credit, including foreign currency. Perhaps state orders, free from conventional planned supplies and geared solely to the solution of very important state tasks, will help to solve this problem.

Foreign experience indicates that state funding of and incentives for major work on new technology are an established and tested practice. Industrial and power engineering development is a very difficult and painful process at the moment. The point is that they have grown so much that their effect on nature is comparable to natural mechanisms and phenomena.

Opponents make the reasonable observation: How can one talk about the ecological advantages of nuclear energy after Chernobyl? There was damage amounting to R 8,000 million—enormous damage, indeed. These billions are an appreciable sum even compared with the damage to the country as a result of the entire annual effect of industry and power engineering on nature. According to the experts, that figure is about R 50,000 million a year. A glance at the past will tell you that accidents in industry and in the transport sector result not only in economic damage, but also deaths and the temporary resettlement of many thousands. Nevertheless, society does not make hasty decisions, does not close off these areas of its activity, does not ban aircraft, river and sea-going ships, and motor vehicles, and does not close down industry, but demands that specialists and engineers find solutions which will reduce to a minimum the harm inflicted on nature and people by technology. Society knows one cannot live without this, just as it cannot live without electricity. For nuclear power stations, which when they operate have virtually no effect on the environment and human beings and are therefore the most acceptable source of electricity, the way to bring about improvement is to increase their safety.

Non-traditional, including renewable, sources cannot solve the energy problem. They can be a substantial help but no more. In view of the overall power engineering situation at the moment, the issue of making nuclear power safer is of great importance and the work is being carried out vigorously. A reliable solution to this problem will make nuclear energy the sector that has the least effect on the environment.

Nuclear energy offers other opportunities for solving ecological problems. For many years now the USSR Academy of Science has headed work on the development of an area of science and technology which comes under the blanket heading of atomic-hydrogen power engineering. Using nuclear energy to enrich organic fuels or using it to obtain hydrogen or energy sources containing hydrogen will make it possible to introduce ecologically clean technology in industry and the energy sector. The problems of interaction with the environment that arise in connection with the large-scale development of industry and the energy sector are so complex that they cannot always be solved by conventional methods. New ideas are needed.

Ultimately, the "human beings-technology-nature" problem can only be solved on the basis of the development and utilisation of the latest technology and scientific and technical achievements. This makes it clear that it is the work of highly skilled specialists which now

determines the progress of our society, and this work must attract the maximum pay. It is not the first time we have talked about this, yet this abnormal situation has persisted for decades. The partial measures that were adopted recently to regulate the pay of scientific workers and the staff of design and planning organisations are a very small step in the right direction. Specialists earn less than a very large number of less qualified working people. An operator in charge of a reactor like the one at the Chernobyl AES gets paid less than a city bus driver. That is our evaluation of their degree of responsibility and usefulness.

The issue often arises of how economical nuclear power is... You cannot talk in isolation about how economical nuclear power is. It has to be compared with electricity generated from coal, gas and oil. And that is where the problems start. All these fuel sectors are state-subsidised—tens of billions of roubles per year. Fuel prices do not correspond to the real economic costs of fuel production. A reform of prices, including fuel prices, is envisaged, but doubts are already arising: prices must not be raised too sharply—it would lead to a heavy increase in the cost of materials and equipment. Let us do it cautiously and gradually, otherwise we will not be able to establish a normal economic mechanism. However, this must not be allowed—prices must reflect the socially necessary labour and material costs. Life has very often corrected us—half-measures are as a rule deceptive, aggravating a problem while giving the impression of tackling it.

In reality, prices [should] reflect the fact that organic fuel is becoming less and less accessible both in geological and territorial terms. Oil extraction is essentially no longer increasing. Gas extraction will stop growing by the end of the century. An ecologically acceptable way of using such fuel as coal on a large scale has not yet been found. We should rely on nuclear power. The measures now being adopted to improve society will improve nuclear power too. The only alternative to the retarded growth of nuclear power is its accelerated development.

**Energodaratomstroy: New Organization Is Proposed To Build Nuclear Power Plants**  
*18610421 Moscow STROITELNAYA GAZETA in Russian 27 Apr 88 p 1*

[Interview by I. Bilyk, editor of SLAVA TRUDU, Energodar, Zaporozhye oblast, with Zaporozhye AES construction manager Rem Germanovich Khenokh: "A Firm for AES: Zaporozhye Power Plant Builders Propose an Efficient Structure of Management"]

[Text]The achievements of the Zaporozhye power plant builders are well known. In 1986 they put in service the 1,000 MW No 1 power generating unit of the AES, and since then, after another year, they finished construction of three more nuclear giants. Due to reduction of scheduled construction time, an economic effect of R100

million was obtained and an additional 21 billion kWh were produced. The construction site became exemplary for a series of AES being built using the standard design.

It seems that they should strengthen the established structure and improve the work organization within the framework of proven decisions. However, recently, Zaporozhye builders came up with an idea of creating a firm, new in principle, namely the association Energodaratomstroy and brought it up for discussion by the whole collective of construction and assembly workers.

"Why would one look for better when he has it good?" That was the first question the free-lance correspondent of STROITELNAYA GAZETA [SG] asked the manager of the general contractor department for construction of Zaporozhye AES, R. Khenokh.

[Answer] It is known that our achievements were made possible, firstly, thanks to a strong and stable collective of construction and assembly workers and their high qualifications. However, under conditions of the economic reform, the use of accumulated experience is hampered by the existing structure and departmental ties. From outside, it appears that even after we went to a collective contract system, everything remained as before and depended on the relations between the general contractor and subcontractors. But it only appears this way from the outside. The general contractor has a more difficult time of solving prospective problems. For example, let us take any specialized assembly administration. Its direct boss is a Trust located far away from Energodar that is at the same time dealing with dozens of other problems based on its own departmental needs, shifting manpower and resources. Under conditions of full cost accounting [khozraschet], the differences will definitely increase. And this is, of course, unprofitable for all parties. Today, for example, we have one administrator for eight construction workers at the site. The apparatus is cumbersome, inflexible, and, therefore, reacts slowly to new concepts. The creation of the association will, in my opinion, remove this problem. . .

[Question] How do you view the future association?

[Answer] It may be based on plants manufacturing special structures and KPD [industrial construction parts], and construction and assembly divisions. United in one organization and "removed" from their departments, they will specialize in the two following directions: construction of AES reactor buildings and their auxiliaries, and construction of residential and social life buildings in Energodar and other sites where AES are built. It will be something like a specialized firm for AES construction.

By the way, such firms are operating successfully in a number of countries.

[Question] What are the social consequences of realization of this proposal? What is a simple laborer to expect? Will he not lose income? There are already rumors at the

site that creation of the association will take away employee benefits from a number of large organizations and will create additional difficulties in construction and distribution of housing. . .

[Answer] We have also assessed this side of the project. I will start by noting that the main part of the collective will work in Energodar. Here is the future industrial and social base of the association. For example, we propose to carry out the pre-assembly of large structures using the available capacities here, and then ship them using inexpensive waterways to other sites. Today, powerful industrial bases are built from scratch at practically all AES sites. These bases after completion of the complexes are being closed because they are not needed anymore. It is not difficult to calculate the savings that the association may bring if we eliminate only the large bases at each AES. As to work at other plants, for example, at Rostov AES, our people will be able to do it in limited numbers by using either a short-term assignment method, or being sent on a long-term business trip. We calculated that workers on short-term assignment will earn R600-800 a month. They, as well as the people on the business trip, will be provided with the necessary living conditions.

If our project becomes a reality, we are scheduled to spend one year in preparatory work at the construction site and the residential townships. We will be able to build small-family dormitories and housing, using industrial methods. First of all, the housing will be built for the construction workers and, later, for the plant operational personnel.

For those who would go on a business trip with their family, housing in Energodar will be reserved, and at the work place they will receive temporary apartments. At the present time, the assembly workers lead a nomad's life together with their families or alone all over the country. They either do not have a permanent home at all, or very seldom stay there. The sad consequences of such practices are well known.

**Commentary of the Manager of USSR Glavstroy [Main Authority of Construction] at the USSR Ministry of Power, A. Andrushechko**

The desire of Zaporozhye AES construction workers' collective to surpass at the achieved level, to work better, and, of course, earn more, is quite understandable, and I personally approve it. Unfortunately, based on the text of the interview, it is difficult to make any concrete conclusions concerning the proposal of the Zaporozhye workers. First, it is necessary to receive the project being discussed itself, and, second, to examine it in detail.

I can quite authoritatively assure the readers of SG that as soon as we receive the complete proposals, we will carefully examine them with the help of scientists and construction organization specialists. Under the conditions of the first steps of radical economic reform, it is

not prudent to make hasty decisions and jump from one extreme to another, and start changes for the sake of change. It is necessary to examine the problem not only from the standpoint of Zaporozhye AES and construction workers' interests, but also from the standpoint of the whole ministry. I think it will be both correct and fair.

Now, don't think of me as dragging my heels, a man who is too cautious. I know well the Zaporozhye power plant builders. They are highly qualified, respectable, and

thinking people. Their manager, Rem Germanovich Khenokh is without any doubt an extraordinary man, outstanding organizer, and a soberly thinking manager. Of course, neither he, nor the other like-minded people around him, would come up with a proposal of radically changing the existing structure without good reasons. And, therefore, I repeat that we will carefully examine their proposal when we will receive it. **From the board of editors: We will definitely inform our readers on the results of the ministry's analysis.**

**Oil, Natural Gas; Future of Power Generation**  
*18610169 Moscow SCIENCE IN THE USSR in  
English No 4, Jul 88 pp 58-67*

[Article by V. Nalivkin, corresponding member of the USSR Academy of Sciences. First four paragraphs are introduction by SCIENCE IN THE USSR]

[Text] There were heated debates at the 27th International Geological Congress<sup>1</sup> on what is probably one of the most acute questions of our time: how much oil is left in the world?

The question came up at the colloquium on the world's energy resources. The reserves of hydrocarbons in the earth's crust are not unlimited. Today they provide for more than 60 percent of our energy requirements.

To prepare a reliable forecast one needs to have a good knowledge of the geology of oil and the methods used to extract it. One should also be familiar with the economic aspects of the problem. The complexity of the problem can be seen in the fact that estimates by experts from different countries vary widely.

We have asked V. Nalivkin, Corresponding Member of the USSR Academy of Sciences, a foremost Soviet expert in the geology of and prospecting for oil and gas, to tell our readers what he and his colleagues think about the energy future of mankind.

**Oil Industry: From Birth to Old Age**

Man has been familiar with oil and natural gas for millennia. The first mention of oil occurs in cuneiform tablets of ancient Babylonia. Approximately 6000 years ago oil and asphalt were recovered near the banks of the Euphrates. The first "tankers" were also built there. They had a capacity of up to 5 tons and comprised asphalt-daubed baskets in which oil was floated down the Euphrates. The oil was taken from places where it oozed out from the ground or from natural oil lakes and dug wells. The location is not surprising: today we know that the world's largest oil and gas fields are in Mesopotamia and the Persian Gulf.

In our country, too, specifically, in Azerbaijan, oil has been known for thousands of years. There were also shows of natural gas in this region in ancient times, which apparently gave rise to fire worship. Near Baku there is a mountain which glows in darkness, lit by burning streams of gas penetrating through its crevices. Not far from the site stands an ancient temple of fire worshippers.

A small oil refinery using local oil was built in 1745 on the Timan mountain ridge north of the Urals.

Oil began to be considered as an energy source only in the first decade of the last century when various mechanical devices appeared which required fuel and lubricant.

A need also arose for lighting the streets in growing cities. This led to a rapid rise in the price of oil. More efficient methods for extracting oil were worked out. This marked the end of the "childhood" of the oil and gas industry.

A big stride was made in 1859 when an oil well in Pennsylvania (USA) began to produce considerable quantities of oil. Oil production grew especially rapidly in the 1920-30s. The gas industry lagged somewhat behind: its intensive development began only in the 1940s.

It seems that oil and gas will remain the prime energy source till the 21st century. According to geologists, the earth still contains large reserves of these valuable hydrocarbons. Nevertheless, the period during which they will continue to play the dominant role in the energy balance is relatively short. In about 90 to 120 years' time their production will fall owing to the dwindling reserves, and coal will come to the fore. By then an intense search for alternative energy sources will no doubt be under way.

Of course, the decline in oil and gas production will be gradual and the chemical industry will become the main oil user instead of the power industry. Already today about 8 percent of the total oil output goes for the manufacture of plastics, rubber, asphalt, etc. According to forecasts, by the year 2000 the chemical industry will consume twice as much oil as it does now. It is obviously more advantageous to manufacture plastics and fibers than to burn such a valuable mineral. The petrochemical industry has been developing at a rapid rate as demands for its products grow steadily, and this process is irreversible.

The high value of petrochemical products will warrant the large investments to be made to extract oil from impoverished deposits. The remaining hydrocarbons will be available in small amounts. To expand oil production deep wells will have to be drilled. This period may be considered the "old age" of the oil industry.

Today we have a panoramic view of the history of the use of hydrocarbons, including its final stage. The period during which the uses of oil and gas were not yet clearly defined or established lasted six thousand years (more than 90 percent of the entire span). The epoch of the formation and growth of the oil and gas industry covered 90-100 years (1.5 percent); the industry flourished for 100 to 200 years (about 2 percent). The period of decline will be a long one, probably stretching over several centuries (5.78 percent of the entire span of the use of oil).

For many countries it is becoming increasingly difficult to find new oil deposits. There are ever fewer continental deposits whose development would be profitable.

Geologists began to explore continental shelves. But although offshore oil now accounts for about 25 percent of the world oil output, in 30 out of 62 oil-producing

countries its recovery is falling (these do not include the eleven oil-rich Middle East countries, because the amount of oil produced there is governed mainly by market and political considerations).

#### Are There Any New Reserves?

The mineral wealth lying in the depth of the earth has been explored for 40-45 percent. New rich oil and gas fields will hardly be found as there are few land areas left that have not been explored. Specialists believe that the total oil reserves vary from 220 to 400 billion tons. The main mass of hydrocarbons lies in large depressions of the earth's crust at a depth of more than 2 to 4 km. They are filled with sedimentary rocks containing strata rich in organic matter. Porous strata which can contain oil and gas are interleaved with "screening" strata protecting the underlying deposits. These depressions are called sedimentary basins and hold isolated oil and gas deposits.

The least explored areas for oil and gas are Antarctica and the shelves of the northern seas hidden under floating ice. Available geophysical data indicate, however, that rich deposits such as those discovered in the Middle East or the Gulf of Mexico are not likely to be found there.

It is quite possible that oil and gas fields with reserves of several billion tons can still be found. But how long will they last at the present rate of production which runs into three billion tons a year? So, the search for small deposits must continue despite the difficult natural conditions. This is important since the time is fast approaching when all the large deposits will be exhausted. This means that certain transport problems must be solved; settlements and towns must be built in uninhabited regions; and for the exploration of the Arctic shelf, new machinery and equipment must be designed.

New deposits may be found at great depths (exceeding 4-5 km) of the earth's interior. It should be kept in mind, however, that the amount of oil begins to decrease from a depth of 3-5 km. At any rate, that is what the findings of geologists suggest.

Some oil deposits are undoubtedly contained in unusual traps about whose existence geologists know nothing. Besides, in the earth's crust there are many small and tiny deposits which are overlooked during large-scale geophysical surveys of oil and gas fields. For all we know, they may contain more than 20 percent of the total reserves. Their development takes much time and money: the extraction of one ton of oil from deposits containing less than one million tons costs 10-15 times more than that from ten-million-ton deposits. Therefore, small deposits will contribute little to the total oil production, but they can slow down its decline.

After an oil field has been worked out, some 50 to 70 percent of the oil remains underground. It covers the walls of hollows or is trapped in closed pores in rocks and

strata that do not communicate with the well. How to extract this remaining oil is a subject of intensive research. Various experiments have been carried out involving the heating of the bed with steam, the burning of oil directly in the bed, the use of surface-active substances, explosions, etc. None of the methods has proved very successful. Still, there must be a way, an entirely new approach whereby at least half of the oil that remains underground could be extracted. This would immediately double the recoverable reserves of oil.

What can replace the diminishing energy sources?

This problem is in part being solved by physicists: the share of nuclear energy in total energy output is rising steadily.

Sun, wind, rivers, tidal waves and geothermal energy can supply some of our energy needs. But it is extremely costly to tap such exotic energy potentials. To a certain extent the problem of energy supply is being tackled by geologists. For there are large reserves of fuels other than oil and gas. Thus, coal reserves exceed those of oil and gas 10-15 times. There is as much shale oil as there is oil, while reserves of bituminous sands are about one half as large. The biggest deposits of coal are found in the USSR, the USA and China; of oil shale, in the USA, Brazil, China and the USSR; and of bituminous sands, in Canada and Venezuela.

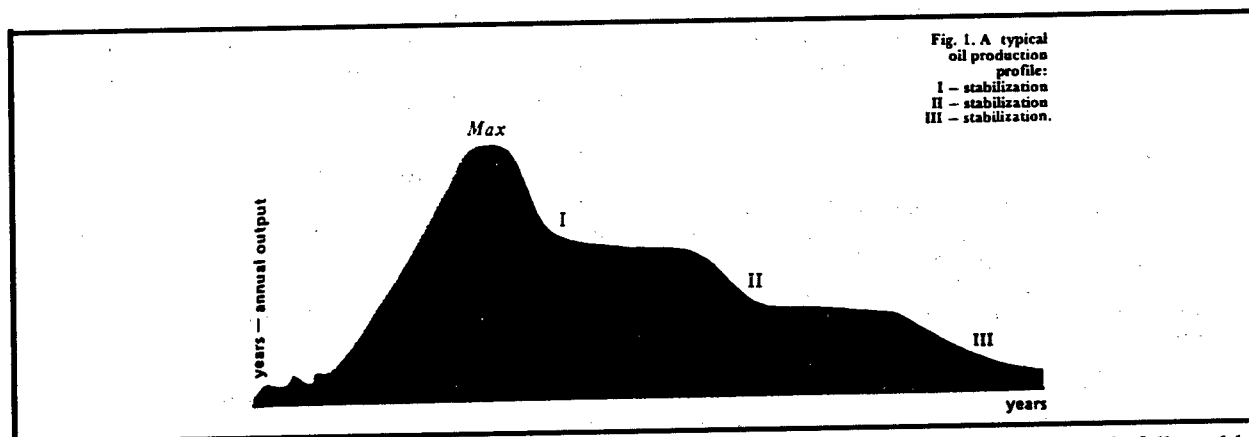
To work these fields a number of problems must first be solved. For example, in order to expand coal mining we must begin building cities and roads in uninhabited areas. As for the processing of bituminous sands, its cost is too high at present to make it economically worthwhile.

The use of natural gas, too, poses certain difficulties. The main problem here concerns transport. We can convey gas by pipelines or liquefy it for haulage, but this is costly. And much gas is consumed by compression stations.

#### Two Theories, One Prospect

The prospects for finding deposits of oil and gas would look quite different if it turned out that large amounts of these hydrocarbons are of an inorganic origin<sup>2</sup>. At present there are two diametrically opposite views on this subject.

According to the inorganic theory hydrocarbons are formed at great depths of the earth's interior, as deep as its mantle. From there they periodically rise along cracks and fractures and accumulate in porous igneous and volcanic rocks besides sedimentary ones. In that case oil and gas are not necessarily restricted to deep sedimentary basins and accumulate in any porous rock overlaid with close-grained rock strata that hinder further movement of oil to the surface. Such conditions exist in basins that do not lie very deep in the earth's interior and in



magmatic rocks, where no prospecting for oil has so far been made. In other words, if the inorganic theory of the origin of oil is correct, the areas where oil can be found are much more extensive than hitherto thought. The theory seems to be confirmed by the presence of methane in volcanic gases and of oil-resembling liquid inside whole mineral crystals in volcanic rocks.

However, thorough geochemical investigations show that there is a direct relationship between oil and organic matter. These findings form the basis of the organic theory of the origin of oil. It has been established that oil is generated only after organic sediments are heated to 80-120 degrees C. Usually such temperatures correspond to depths of 1.5-2.5 km. When rocks sink deeper into the earth's interior (and thus become hotter) natural gas begins to be generated on a large scale. The geochemical analyses are backed up by data on the actual occurrence of oil-bearing formations. In the areas where the temperature of formations reached 80-120 degrees C, oil predominates; where the temperature is higher mostly gas is formed. At permanently low temperatures and in the absence of organic matter in rocks no hydrocarbons are normally formed. Neither are they formed in shallow-lying basins.

As to the question of when oil and gas will cease to be recovered, the answer depends on the purpose for which these minerals are extracted. Oil and natural gas will probably cease to be used, first, for generating electrical energy, and then as a motor fuel. But oil will continue to be used in the chemical industry for a long time. And even when that comes to an end, there will be no need to include it in the RED DATA BOOK of mineral resources. For there will still be a great number of small oil deposits.

#### What the Graphics Tell Us

In order to determine, if only approximately, the times when the role of oil and gas undergoes a substantial change, let us turn to a graph showing averaged oil production in an individual country (Fig. 1). From the graph we can identify the following tendencies.

A period of steady rise in oil production is followed by stabilization lasting six years on the average (ranging from 2 to 10 years). This period can be shorter if measures are taken to stimulate production. The rate of decline in production is, as a rule, the same as that of the preceding rise.

After 4 to 5 years of rapid decline in production there usually follows a second period of stabilization or a sharp drop in the rate of decline. This period last 10-20 years (ranging from 5 to 30 years). After that the production curve again shows a rapid decline, more gradual than the first. Then follows a third period of stabilization. This stage has so far been reached only by a few countries or regions. Therefore, we have no precise data on the duration of this period.

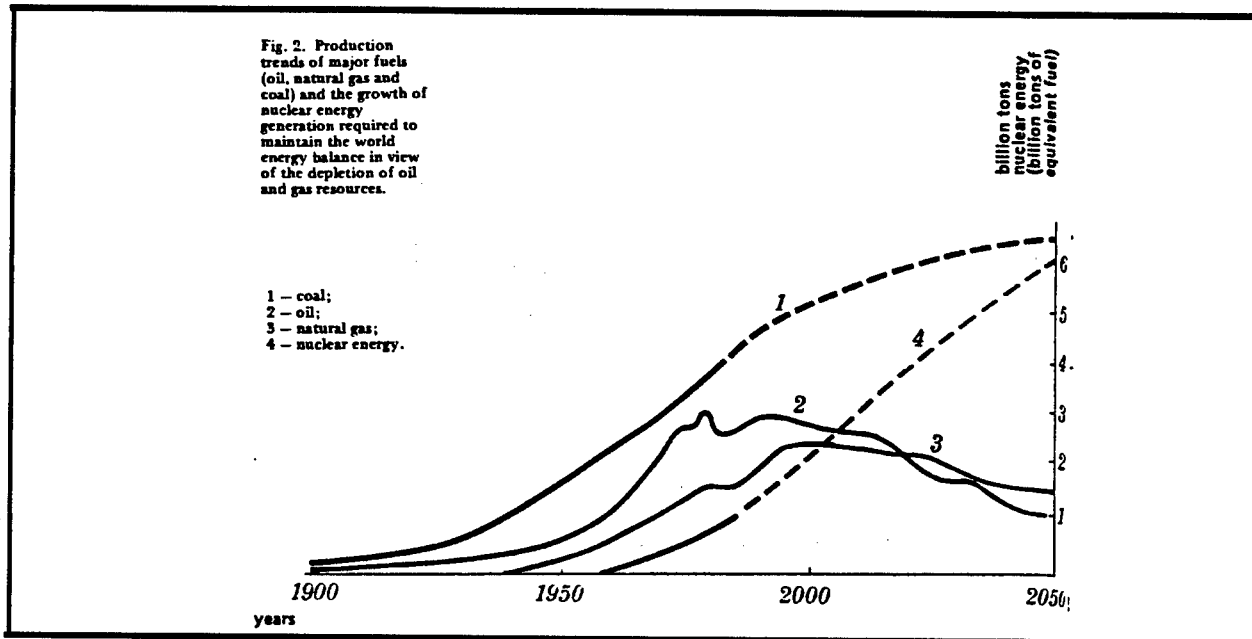
On the basis of this pattern one can forecast the production of natural hydrocarbons for any country. Summing up the projected annual outputs of all countries we can plot the world oil production (Fig. 2). It does not show any clear-cut periods of stabilization since they occur at different times in different regions of the world. Similar curves can be produced for coal, gas and nuclear energy.

The major peak in oil production will apparently occur at the very end of this century, or, better for us, during the first decades of the 21st century.

The maximum production will then exceed 3 billion tons per year, which is one percent of the geological resources. However, if the initial potential reserves are underestimated (at present they are estimated at 300 billion tons), the maximum will be somewhat higher, and the general decline in production will proceed more slowly.

Gas production apparently obeys the same law since the methods of exploration and development of natural gas fields are similar to those of oil. However, gas fields are developed more slowly because of the transport problem and the lower demands.





The maximum world output of natural gas (2.5 trillion cu.m per year) will probably occur early next century. During that time 25-30 percent of the initial potential gas resources (estimated at 300 trillion cu.m) will be recovered.

The rate of increase in coal output is slower than that in oil. This is due to the inertia inherent in the coal industry: before coal can be brought up to the surface, it is necessary to excavate open-cast or underground mines, and this takes time.

The production of coal, unlike that of oil and gas, will not be limited at least in the foreseeable future by its reserves. By 1980, some 114 billion tons of coal had been mined in the world, or 0.8 percent of its total reserves. If this rate of production is preserved through the year 2000, by the turn of the millennium only 1.3 percent of its reserves estimated at 14.3 trillion tons will have been mined. The annual output of coal will then be about 6 billion tons.

However, the development of most of the coal fields is a complex task. The main deposits (about 44 percent of the world's reserves) are found in the regions of Siberia that are not easily accessible. At present it is not profitable to develop coal mining there. Huge open-cast mines would damage the environment. Besides, the burning of coal produces much ash and sulfurous compounds. Any forecast concerning coal mining must take due account of environmental restrictions and economic considerations. Therefore, it is hard to predict how much coal will be mined in the future. Progress in science and technology will no doubt make it economically profitable to develop all coal fields. In that case coal mining will keep on increasing till the middle of next century.

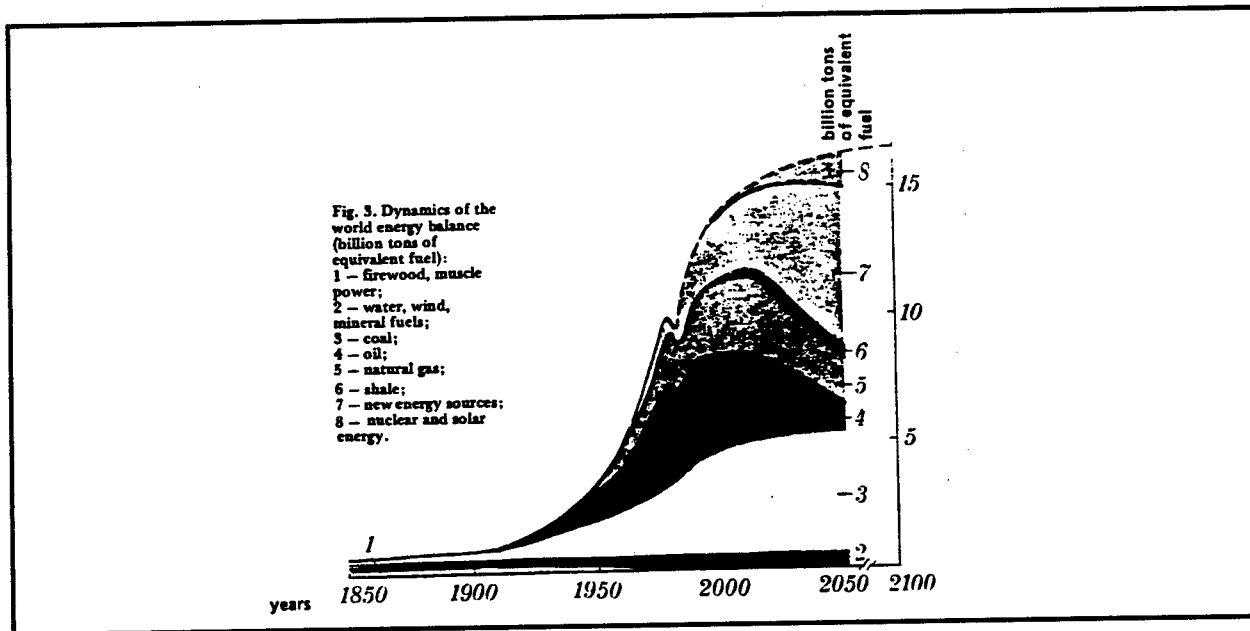
Bitumen is mined together with the enclosing rocks and then separated by heating, which is very costly and labor-intensive. Even the richest fields in Canada and Venezuela are barely profitable. In the future, however, bitumen will undoubtedly become an important feedstock for the chemical and power industries. Its reserves are immense—about 150 billion tons.

#### Looking Ahead

The trends currently taking shape suggest that in the 21st century the share of oil and natural gas in the world energy balance and their production will continue to fall. The share of coal will also decrease, although its absolute output will somewhat increase. The share of shale oil, bitumen and synthetic oil will increase very little, if at all. The proportion between the different energy sources will depend on consumption, of course. If the world population becomes stabilized (this is thought to happen approximately in the year 2030), the energy consumption growth will slow down drastically.

Without question, nuclear energy will be of great importance in the future. It is possible that solar energy, too, will come to play a leading role. Besides, new abundant energy sources may be found. In other words, there is no ground for pessimism so far.

Geothermal energy is practically inexhaustible. To tap this energy source we need a heat transfer agent, for example, water. But rocks have low thermal conductivity, and so considerable amounts of heat can be picked up only when the water-rock contact area is sufficiently large. Furthermore, the heat transfer agent must be circulated. Hot porous strata on the bottom of sedimentary basins meet these requirements. Of course, they can be used for this purpose only in areas where there is no



oil. Usually, water in such localities is rich in dissolved salts, hence the equipment should withstand corrosion. Natural hot springs in the areas of active volcanism can be used too.

Most likely by the year 2050 nuclear, solar and geothermal energy will account for about half of all energy used by man (Fig. 3). This is more than the total amount of energy obtained from oil and natural gas during the years of their maximum production.

The seemingly fantastic forecasts of scientists will become a reality in the 21st century. And today physicists, geologists and engineers are laying the foundation of all energy-sufficient future for all.

V. Nalivkin, Corresponding Member of the USSR Academy of Sciences

**Footnotes**

1. See: V. Drouyanov. "Geoscientists Face New Problems", SCIENCE IN THE USSR, 1986, No 4.
2. See: V. Alexeyev, V. Pototsky. "Oil from Sedimentary Rocks", SCIENCE IN THE USSR, 1987, No 3. (Ed.)

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**Bureaucratic Obstacles to New Wave Generator Criticized**

18610025 Moscow IZOBRETATEL I  
RATSIONALIZATOR in Russian No 8, Aug 88 p 8

[Article by Yu. Stroginskiy, correspondent, under the "Ideas and Decisions" rubric: "Use of Sea Surf and Wave of Replies Written for Sake of Form: Device That Makes It Possible To Use Energy of Breaking Sea Wave Is Nearly Drowning in Bureaucratic Depths"]

[Text] Wave electric power plants, in all the diversity of their designs (in England, for example, more than 350

patents have been issued), are designed to utilize the energy of the rising and falling wave. S. D. Persman (Moscow Machine Tool Technical School) decided to also use the energy of the surf—the water of a breaking wave (author's certificates No. 1 105 683 and No. 1 355 754).

While observing the behavior of a wave on the surf line, the inventor noted that in the upper layer of water the flow was toward the shore, in the bottom layer it was directed away from the shore, and in the middle layer there was no current at all. He got the idea of mounting a ratchet wheel with teeth in the form of pockets in a stretch of the horizontal axis, approximately parallel to the shore. The lower part of the wheel is in the bottom layer and the upper part protrudes over the level of the calm (still) water. The upper pockets should be turned toward the sea and the lower toward the shore. The approaching wave makes the wheel turn.

Sometimes, however, waves do not break simultaneously along the entire surf line. Indeed, they approach the shore at some constantly changing angle: the breaker "runs" along the shore. It is therefore best to use not a wheel but rather a drum consisting of many wheels in which, depending on the required power, the wheels are interconnected with an electric generator by flexible couplings. To control the energy more completely in any weather when the height of the waves and location of the surf line change, it is necessary to place several strings consisting of different diameter drums along the shore.

Persman rejected the "purely" inventor's route: an announcement, copyright, arguments with opponents over whether the design will or will not work, insults, etc. He acted like an engineer. He measured the water pressure in a breaking wave with spring scales, and

knowing the period of the waves, he determined their power rather precisely. Next he built a small model. He was not able to find a laboratory in which swelling is reproduced in shallow water. Then, the author began simulating a wave by using a stream of hose rocking in the vertical plane. The model works. In principle, the problem appeared solved. "In principle" cannot satisfy an engineer, however. Evaluation tests were conducted. They gave a justification for assuming that the work should be continued, but with other means and on a different scale.... You cannot get by without developing a theory.... In a word, the sort of comprehensive and basic scientific research work that is conducted in the system of the USSR Academy of Sciences was needed. From the Department of Physicotechnical Problems of Power Engineering came the reply that in-depth economic analysis of the device is necessary. In other words, a collective of specialists having different profiles and having at their disposal the information and technology that is needed here should be convened for such a task. After this, a high evaluation of the invention overall is given, and a proposal is made to send representative materials somewhere to a specialized organization, for example, to the All-Union Scientific Research Institute for Design and Exploration imeni S. Ya. Zhuk [Gidroproyekt]. The reviewer pretended that he does not know (and perhaps he really does not know) that the Gidroproyekt only deals with the calm waters of reservoirs.

The response of K. M. Dyumayev, the deputy chairman of the State Committee for Science and Technology, included comments like the device may only work under specified conditions and it "is one of many in the field of utilization of the energy of the sea's swelling" but that it "cannot be put to practical use since our country and most countries throughout the world do not have seas with constant stormy swelling."

But where did the idea of constant swelling come from?! There were no such preposterous words in the decision of the State Committee for Inventions and Discoveries. Of course the power of a wave electric power plant is greater in a storm than during calm weather. But this is hardly grounds for eliminating systems to extract dispersed energy from the environment, particularly windmills, solar electric power plants, etc. V. P. Goloviznin, head of the Main Technical Administration of the Ministry of Power Machine Building, and V. V. Nechayev, chief engineer of the Main Technical Administration of the Ministry of Power and Electrification, informed the inventor that they do see the possibility of introducing his proposal if design analyses and technical and economic calculations are not presented soon. Why, they ask, has the author failed to make a full-scale model, develop conceptual and detail designs, and perform calculations?! If only some institute of one of these ministries could for once be under the power of the collective.

As often happens, it was not the "regular army" but rather a group of volunteers who showed interest in the invention. Working sketches of a section of the wave power-generating unit were developed here at the initiative of Yu. I. Kirillov, general director of the machine tool association "Red Proletariat," and his deputy L. S. Kheyn. This year the unit is being manufactured and tested directly in nature.

Photocaption: [photo not reproduced] Section of the wave power-generating unit (model). Tests have shown that after the impact of a wave the wheel turns around in water in 15 seconds. A full-scale section will be 30 to 50 times larger than the model.

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**Machine Tool Expo Shows Off Abrasion Tool,  
New Valve**

18610083 Moscow MASHINOSTROITEL  
No 7, Jul 88 pp 37

[Article by I. S. Vitol under the "Exhibition of USSR National Economic Achievements" rubric: "Functional Cost Analysis Reduces Production Expenses"]

[Text] An interbranch exhibition entitled "Functional Cost Analysis—Intensification of Production" took place in the machine building pavilion at the USSR Exhibition of National Economic Achievements. More than 150 industrial and agricultural enterprises and scientific research, design, and planning organizations took part in the exhibition. Included among the 220 exhibits were machine tools, machines, automatons, installations, attachments, instruments, and tools.

Functional cost analysis is a highly effective method of reducing production expenses. It is based on the development of the most economical versions of a design, production process, and manner of organizing production that fully meet all of the functions that have been specified for the object being analyzed while keeping expenditures to a minimum. One of the first branches of the national economy to use the method, back in 1977, was the electrical engineering industry. Its positive experience with the method was noted in the CPSU Central Committee decree entitled "Concerning the Work of the Ministry of the Electrical Engineering Industry Related to Economizing on Physical and Labor Resources in Light of the Requirements Established by the 27th CPSU Congress."

The functional cost analysis method has been widely disseminated at enterprises producing electric current converters since their production entails the use of a

great quantity of materials that are both expensive and in short supply and since the method makes it possible to reduce the amount of materials used in manufacturing the converters, reduces wastes significantly, and increases the converters' quality and reliability.

An abrasive tool for vibratory machines (author's certificates 1068245, 1181855, and 1202826) manufactured by the Leningrad Turbine Blade Plant imeni the 50th Anniversary of the USSR Production Association was among the most interesting exhibits presented by enterprises in the electrical engineering industry. The tool is intended for abrasive machining of products in VUT-250 units and for machining components having a complex configuration. The functional cost analysis method makes it possible to select the optimum version of a tool having increased hardness (by 20 percent) and durability (by 50 percent). A 1.5-fold reduction in the amount of materials used in each unit of product produced has been achieved. The yearly savings from the tool amounts to 35,000 rubles.

The Moscow Machine Building Plant imeni M. I. Kalinin Production Association manufactured a hydraulic valve (author's certificate 918622) to protect hydrostatic power drives from pressures exceeding the established pressure (1 to 50 MPa) in the hydraulic systems of construction, road, and municipal machines. As a result of functional cost analysis, the valve was discharged in an axial direction, and its life was increased.

More than 500 resource conserving products, technologies, and materials resulting in a savings of 325 million rubles—including 159 million rubles thanks to a reduction in production costs—have been developed and introduced since the functional cost analysis method has been in use. The following savings have resulted: 52,700 tons of ferrous metals, 20,300 tons of nonferrous metals, and 63,700 tons of silver. The labor savings have amounted to more than 7,000 workers.

**50th Anniversary of Institute of Machine Science  
imeni A. A. Blagonravov, USSR Academy of  
Sciences**

*18610109b Moscow MASHINOVEDENIYE in Russian  
No 5, Sep-Oct 88 pp 103-104*

[Article by M. K. Uskov under the rubric "Chronicle":  
"For the 50th Anniversary of the Institute of Machine  
Science imeni A. A. Blagonravov, USSR Academy of  
Sciences"]

[Text] The Institute of Machine Science was formed within the system of the USSR Academy of Sciences in November 1938. The organization of the institute was defined by the need to rapidly solve a problem of national importance: changing, under conditions of the industrialization of the national economy, from copying models of foreign machinery to the development of modern machines of our own design responding to the requirements of developing the socialist economy and of strengthening the country's ability to defend itself.

A scientific team that began to work on the development of machine building's scientific base was formed at the institute in the prewar years.

During the years of the Great Patriotic War the institute successfully solved a number of very important problems by having ensured the reliability and survivability of military materiel, the improvement of bombing accuracy, the improvement of aircraft and motor vehicle engines and of artillery weapons, and the automation of small arms.

In the postwar years the institute has become a leading science center at which basic and applied research have been launched in the area of the scientific principles of the development of present-day and prospective machines, production processes and machine building materials. The results of the research performed have won wide renown in our country and abroad. The institute, in close cooperation with scientific research institutes and design bureaus of a number of branches and the largest machine building enterprises, has solved very important problems and tasks relating to research on the stressed-strained states of complex structures, the development of methods of designing and testing for reliability, strength and wear resistance, and the provision of the appropriate methodological-and-equipment and technical standards base. This was conducive to the development of unique power engineering systems having enhanced operating parameters, such as high-pressure steam turbines for GRESs [state regional electric power stations] and powerful hydraulic turbines for the Volga and Bratsk GESs [hydroelectric power stations]. The institute's developments have been used in the designing of water-water reactors and fast reactors for a number of nuclear power plants in operation in the USSR and a number of foreign countries.

Highly effective antifriction materials of the VAMK, AMAN, etc., type developed at the institute, that have made it possible to ensure the serviceability and extend considerably the life of rubbing components of up-to-date machines and models of special machinery, have become widely used in various branches of machine building. In particular, such materials were used for the first time in the world in the design of an unmanned space vehicle—the Lunokhod [Moonwalker]—which made it possible to extend substantially its operating life.

After a 20-year stay in the USSR Academy of Sciences system, in 1961, in association with the elimination of the department of technical sciences, the Institute of Machine Science was transferred to the Minstankoprom [Ministry of the Machine Tool Building and Tool Industry] system with the retention of scientific methodological guidance from the USSR Academy of Sciences. A number of developments that got to be introduced at the branch's enterprises were carried out in the interests of the development of machine tool building at the institute.

The institute, as a major scientific institution solving basic problems of interbranch importance, was returned to the USSR Academy of Sciences system in 1978. Now it is a head organization doing research aimed at the establishment of new principles and laws whose use in branches of the country's machine building complex is contributing to the development and creation of new generations of machines, materials and technologies that are of revolutionizing importance for improving the economy's efficiency and coming to the forefront in the world. From this time the institute has been given considerable development and has achieved definite successes in the area of the solution of machine building's basic problems, in particular, in the development of new principles for the designing of machines and structures having a specific level of reliability with ergonomic and environmental requirements taken into account. Effective methods have been developed for reducing the level of the harmful influence of vibration and noise.

For the first time the institute has developed scientific criteria for setting standards for vibration influences and active vibration proofing, taking into account the human operator's functional and physiological characteristics.

In the current five-year plan period the institute is solving the very important problems of the development of highly reliable and economically efficient machines.

The institute is doing promising work on the pressing problems of machine building in accordance with the decrees of directive organs, state special-purpose scientific and technical programs, the USSR Academy of Science's problem plan for 1985-1995, and the integrated plans for research, development and experimental work of the Machine Reliability interbranch scientific and technical complex (MNTK).

As the head organization of the Machine Reliability MNTK, the institute is coordinating the work and uniting the efforts of more than 40 enterprises and organizations: academic scientific institutions, branch scientific research institutes and VUZs. The complex's goal is to implement a unified scientific and technical policy in the area of ensuring the reliability of equipment based on an interbranch systems approach to solving the problem that calls for finding and implementing fundamentally new design, equipment-and-process and other solutions at all stages of the life cycle of machines. The Machine Reliability MNTK is doing work on the development of a set of improved technical standards documents, is developing and introducing progressive resource-saving technologies, is introducing new calculation methods and methods of physical and mathematical modeling in machine building, and is bringing to series production models of diagnostic and testing equipment conforming to the top scientific and technical level.

As the head organization of the Machine Reliability MNTK, the institute has highly developed creative and business contacts with numerous leading enterprises of various ministries and departments, both directly and through its branches in Leningrad, Sverdlovsk, Saratov, Gorky and Kuybyshev.

The Institute of Machine Science's activities relating to the preparation and publishing of scientific works and to the propagandizing of scientific and technical achievements here in the country and abroad are multifaceted. Many scientific and reference publications have become guidelines for design engineers developing new generations of equipment.

The institute is rightfully regarded as a molders of highly skilled scientific personnel. It has close ties with many of the country's VUZs, branch scientific research institutes and design bureaus in the area of retraining and improving the skills of specialists. The institute is making a large contribution to the training of scientific personnel for the academies of sciences of union republics.

The highly skilled personnel, the constantly developing testing and experimentation base, and the strong ties to industry ensure the high scientific level of the research done that is aimed at the hastening of scientific and technical progress in machine building. In this way a contribution is being made to the fulfillment of the plans for the development of science and technology stipulated by the priority assignments of the integrated programs for scientific and technical progress of the USSR and CEMA member countries. In particular, in accordance with the second priority assignment of the CEMA KP NTP [integrated program for scientific and technical progress], the institute was actively involved in the development of methods, algorithms and automation systems for research on the strength of machine elements with the use of new materials and technologies for the purpose of improving reliability characteristics and reducing materials intensiveness.

The institute and its team are enjoying international prestige. The institute is engaged in extensive and fruitful scientific cooperation with many foreign academies, scientific societies and centers.

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### **Problems of Mechanics; Scientific, Technical Progress in Machine Building**

*18610109a Moscow MASHINOVEDENIYE in Russian No 5, Sep-Oct 88 (manuscript received 18 May 88) pp 1-13*

[Article by K. V. Frolov, Moscow: "Problems of Mechanics and Scientific and Technical Progress in Machine Building"]

[Text] The most significant achievements in machine building have seldom been the result of the gradual improvement of designs developed earlier. Technical progress is determined by fundamentally new solutions based on fundamental achievements gained in various fields of science. This dependence of the level of the development of technology on the rate of introduction of new scientific achievements is becoming stronger and stronger. Now research on fundamental problems is being performed ever more often according to industry's requests with the rapid and efficient use of completed developments. At the same time many useful scientific developments are awaiting introduction or are being used to a limited degree. There are various reasons for this: the insufficient acquaintance of industry personnel with new scientific ideas; industry's unpreparedness to take in fundamentally new designs, especially when it is necessary to unite the efforts of several branches; lack of interest in departing from traditional approaches and methods; and the insufficient involvement of scientists in taking developments to the point of experimental models and in propagandizing their achievements. The most important problems from various divisions of mechanics whose solution is determining to a significant extent technical progress in machine building<sup>1,2</sup> are discussed below.

### **Mechanics of Deformable Rigid Bodies**

Achievements in the area of the basic and applied divisions of the mechanics of deformable rigid bodies, as well as of experimental mechanics, the physics of metals, and the mechanics of composites, are becoming the basis for solving pressing problems relating to the strength and life of machines (fig 1) with a simultaneous reduction of their power intensiveness and materials intensiveness<sup>3,4</sup>. These problems include the obtaining of engineering calculation estimates of stressed-strained and limiting states, model and full-scale studies in various environments (under high and cryogenic temperatures, in magnetic fields, under radiation conditions), determination

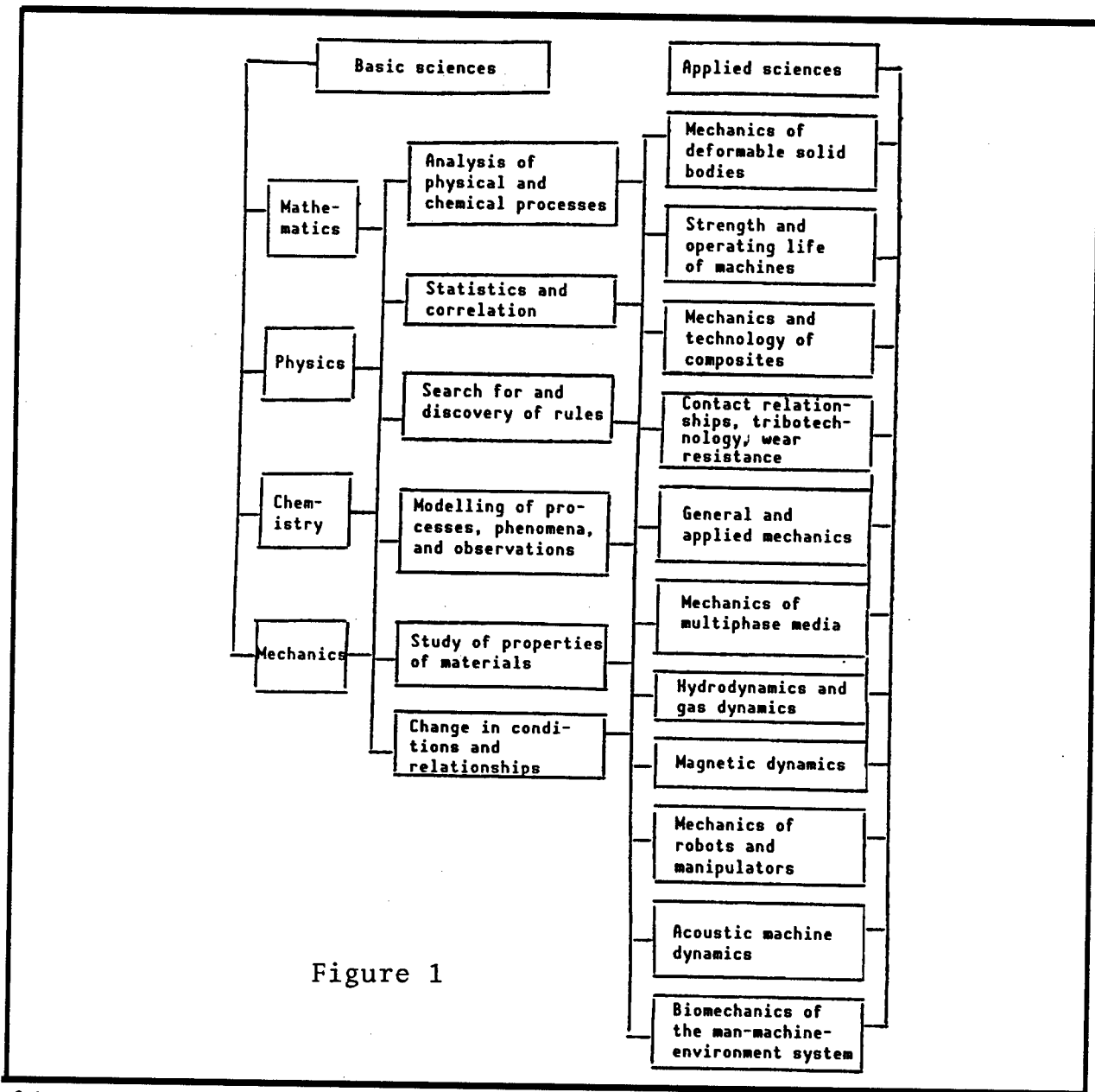


Figure 1

of the remaining life of individual machines with continuous monitoring of the loading history by means of machine-borne computers with an analysis of condition, and the use of criterion approaches to the determination of life by taking into account actual operating conditions. Work on the development and application of new methods of hardening and treating materials is of great importance, such as magnetic-impulse, explosion, ultrasonic, electrophysical, laser, diamond, plasma-beam, cladding, reinforcing, etc., methods.

**Strength and Service Life**

One of the main problems at the design stage (fig 2) is providing grounds for the design safety margin, which

determines the starting service life. Calculations are performed by using a computer for the determination of forces, temperatures, stresses and strains taking operating influences into account. They are supplemented with mechanical tests of laboratory specimens on universal testing machines over a wide temperature range. Tests are made of models for the most complex units and loading conditions. The amount of work relating to providing grounds for the safety margin and service life can reach 15 to 25 percent of the total amount of design work, and these expenditures must be acknowledged as justified.

At the stage of the manufacture of machines and construction much attention is paid to the incoming and

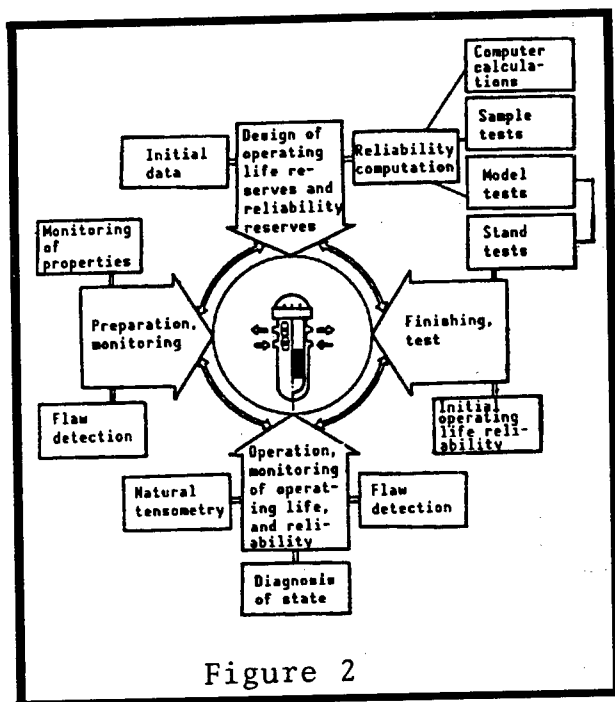


Figure 2

periodic control of the mechanical properties of materials and of joints of construction elements from the viewpoint of their conformity to strength specifications. The actual presence of defects in bearing elements is monitored at the same stage for the purpose of obtaining initial information for assigning the service life and the extent of and time intervals for nondestructive testing under operating conditions.

With the entry of machines and constructions into service monitoring of their current condition for the purpose of revealing current damage and estimating their remaining service life becomes ever more important.

A number of studies have been performed relating to the establishment of criteria for limiting states and studying the mechanics of the loading of standard machine elements, for the purpose of ensuring the strength and service life of machines. Comprehensive studies of the stressed states and strength of heavily loaded constructions and their elements under static, dynamic and thermal loads are continuing. Studies are being launched on determination of the strength of bearing parts of machines and construction elements fabricated from new composite materials. Experimental methods and facilities have been developed for studying stresses and strains at variable and elevated temperatures. Calculations of the long- and short-time fatigue of machine elements and constructions and of the crack resistance of materials and construction elements are especially important. A major role in the ensurance of reliability is being played by the development of modern experimental methods of studying strains by means of brittle and

light-sensitive coatings, dividing reticles, replicas and moire, holography and strain measurement.

The role of the technical diagnosis of machines and construction and of the parameters of technological and working processes is increasing sharply in association with the necessity of the ensurance of reliability and service life and safe operation. It can be considered normal for today's heavy-workload machines if the cost of diagnostic facilities equals as much as 10 to 15 percent of the cost of the machines themselves. In especially critical cases, as it applies to power-generating equipment, for example, methods for the combined diagnosis of the technical condition of the subject are employed, including the measurement of vibration and pressure and temperature fluctuations; multipoint full-scale strain measurement; nondestructive testing based on ultrasonic, magnetic, electrical, radiation and acoustic operating principles; the computer analysis of acoustic emission parameters; and continuous and pulsed holographic systems.

#### Mechanics and Production Engineering of Composites

The main task of the mechanics and production engineering of composites is scientific support for work on the development and introduction of composite materials. This is laying the scientific foundations for understanding, describing, predicting and monitoring the construction properties of all the many kinds of composite materials. It is important that the results of this research reach the user not only in the shortest time, but also in the form most convenient for practical application. Here it is necessary to take into account the fact that up to now composites have been used relatively little for the fabrication of standard machine building parts. Their use has been restricted mainly to frame and flat parts typical of aircraft and spacecraft. Therefore, a condition for the broad application of composites in machine building is the prior solution of a number of new problems associated with the production of precision working surfaces having specific properties (antifriction, for example) and precision constructions based on a combination of frame elements made of composites and metal supporting assemblies built into frames, and with the application to the surfaces of composites of wear-resistant and other metallic coatings, etc.

There are a great number of items in machine building in which the reduction in the weight of individual elements of machines achieved by the change to composites can improve considerably the properties of machines. For example, the reduction provided by composites in the weight of the moving parts of robots and manipulators, with the preservation of structural rigidity, results in a reduction in the power and, accordingly, the weight of drives. The gain from the reduction in moving masses grows progressively in the direction from higher degrees of mobility to lower, whereby the higher represent mass loading. The reduction in moving masses is opening up opportunities for an increase in the speed, i.e., the productivity, of robotic equipment. The saving from the use of composites in transport vehicles, agricultural



equipment and in many other areas is similar. A fundamentally new level of technical and economic indicators is being reached by the use of composites for the fabrication of high-pressure gas cylinders, bearings, chemical reactor vessels, aircraft, the hulls of submarine equipment and superdeepwater devices, the cases and parts of internal combustion engines, and large-scale vessels for storing and transporting liquid and gaseous products.

The fact that many hopes for composites have been unrealized thus far is explained by the underestimation by designers of the particular features of the mechanics of composite media and of the danger of the appearance of manufacturing defects. In spite of the considerable deepening of basic knowledge in the area of the mechanics of composite materials and the solution of a wide range of application problems, it is necessary to increase considerably the amount of theoretical and experimental research, to bring it to the point of the development of standard procedures and application software packages for the calculation of manufacturing and operating stresses and strains, of the optimization of manufacturing and design parameters, and of the establishment of permissible defects in standard constructions under various kinds of static and dynamic loads, taking into account physical fields of various natures.

#### **Mechanics of Contact Interactions and Tribological Problems of Wear Resistance of Machines**

The solution of basic and applied tribological problems is aimed at improving the wear resistance and reliability of rubbing components, which is especially important under conditions of the intensification of loads and speeds in machines. Of course, an appreciable percentage of the world's energy resources is spent on overcoming frictional forces, and for this reason the reduction of friction losses is one way of improving the energy characteristics of machines. Eighty to 90 percent of failures in the moving joints of machines are the result of wear.

In studying the surface failure of rigid bodies at points of friction, the physical, chemical and mechanical aspects must be taken into account, as well as the distinctive features of contact, the change in the geometry of the contacting bodies over time, kinematics, the structure and composition of the surface and near-surface layers and the state of the lubrication layer. A reliable description of such a complex phenomenon can be based only on a combination of an experiment and mathematical modeling, utilizing the theory of physicochemical processes, continuum mechanics, thermodynamics and materials science methods.

The following basic directions of basic research in the field of tribology can be distinguished. First there is the study of the mechanics of contact interactions at points of friction, as well as of the accompanying processes, taking into account the sharp change in the physical state of materials under conditions of friction, the presence of

a lubricant and other factors. This work direction is making it possible to develop new materials for rubbing pairs and to select rubbing pairs as applied to specific conditions.

The second direction is the experimental and theoretical study of the thermal physics of rapidly occurring friction processes, which is required for the development of brakes, clutches, guiding supports and other components for similar purposes.

The third direction is the study of processes occurring in the boundary layer of a lubricant in all their complexity.

Work in the field of tribology has resulted in the solution of many practical problems. New lubricating materials and methods of supplying lubrication have been developed, such as water-based lubricants, gas lubrication and lubricants based on magnetically active liquids and magnetic powder materials. The latter can be fed to the friction zone by a fairly simple method: varying the characteristics of the magnetic field in the friction zone. The selective transfer effect is beginning to be used, which is produced by a sharp reduction in the friction coefficient, which is accompanied by the same sharp reduction in wear. New wear-resistant antifriction coatings are being developed that can be applied by modern physical methods, such as vacuum, ion-plasma, laser, detonation, electron-beam, etc. Special composite materials, ceramics and materials produced by powder metallurgy methods are beginning to be used in rubbing pairs.

Bearing units with a gas lubricant are distinguished by enhanced service life and are able to operate in the temperature range of -260 to +1000o, under conditions of elevated radiation, and at rotational speeds of up to 700,000 rpm. Changing to a magnetic power lubricant makes it possible to increase by a factor of 10 to 20 in terms of the wear criterion the service life of toothed gearings and to increase by a factor of 1.5 to 2 the power-to-load ratio of rubbing assemblies. The task of tribology also includes the ensurance of the serviceability and reliability of sealing devices, which in many instances determine the service life of and failures in machines. New sealing materials are being developed, as well as finishing and hardening processes and methods of choosing optimal designs for sealing units and sealing forces taking into account the distinctive features of the work of seals.

The solution of the problem of developing an efficient design for a stepless power transmission and of its introduction in industry depends to a considerable extent on research being conducted on frictional fluids that raise the friction coefficient in rubbing contacts with minimal wear.

Research is being conducted on many different methods of spraying onto a rubbing surface various coatings that improve the wear resistance of units. These same methods are finding extensive application also in the repair (restoration) of worn parts.

### General and Applied Mechanics

Research in terms of vibration theory must be singled out first of all in the field of general and applied mechanics. New divisions of the theory of nonlinear vibrations have undergone intensive development recently. A technique has been developed for using asymptotic methods of nonlinear mechanics and the theory of Markov processes for the analysis of random vibrations in viscoelastic systems subjected to the influence of random forces of the white noise type. Methods have been developed for studying nonlinear vibrations of a liquid with a free surface and of bodies containing cavities partly filled with a liquid. A theory has been constructed for the effect of an external vibration on nonlinear mechanical systems. The following have made important advances: the theory of vibrational displacement, the theory of vibrations of a system with limited excitation, the theory of structural damping, the theory of vibration conduction, vibrorheology, and the theory of the effect of vibrations on pulps and suspensions. These developments have been conducive to the appearance of a number of fundamentally new design and technology developments in the field of vibrating machines and processes—vibrating separators, vibrating conveyors, vibrating mills, crushers, vibrating propulsion engines, etc.—many of which have been introduced in industry<sup>5,6</sup>.

In particular, vibrating transport systems have been developed for moving loads along horizontal or slightly inclined surfaces and along a helical load-carrying surface that performs only small-amplitude vibrational motions. Vibrating conveyors operating according to the same principle have found application as intrashop materials handling facilities and in equipment for the automatic assembly and sorting of parts. A conveyor furnished with additional uncomplicated devices, when operating in a certain mode, can reject and orient parts while moving them at the same time, which considerably simplifies the mating of a conveyor with robotic systems. The transporting process can be combined with drying, granulation and other production operations when vibrating conveyors are used for transporting free-flowing materials.

The heat treating of products in a vibrating fluidized bed of a specially selected finely ground material (corundum, sand, etc.) is highly effective. This technique not only

intensifies the process but also makes it easily controllable. Vibrating molds are used in plants for the continuous casting of steel. The vibrational effects produced in them make it possible to reduce sharply the material's tractive resistance in the mold, to improve heat and mass transfer conditions, and in the final analysis to increase the plant's productivity with a simultaneous improvement in the metal's mechanical properties.

Vibrating equipment is finding application for the intensification of the operations of turning, drilling, machining by means of abrasives, crushing, milling, breaking rocks and frozen ground, etc. The following operations are being performed by means of vibration processes: the removal of corrosion, the removal of burrs, the rounding off of sharp edges, three-dimensional grinding and polishing, the hardening of surfaces, the compensation of stresses in surface layers, the preparation of surfaces for electroplating and lacquering and painting, and decorative finishing. For this purpose, parts or blanks are moved in a free or secured state into a chamber with a filler and working fluid that are strongly agitated under the effect of vibration.

A considerable (severalfold) increase is achieved in the efficiency of heavy-duty manufacturing-process vibrating machines working under great loads (that have pronounced elastoplastic or viscoelastic rheological characteristics) by changing to the resonance mode of operation. The existence of such modes and estimates of their effectiveness first received theoretical substantiation, as also recommendations on the selection of design and process parameters making possible the tuning of a system to resonance. Resonance modes of operation were implemented in practice in machines for crushing rocks, in ultrasonic machining machine tools and in shakers, for example.

An oscillogram of the process of crushing a portion of a rock mass by means of a vibrating crusher is presented in fig 3 ( $x$  is the amplitude of the vibrations of the crushing members,  $t$  is time and  $t_p$  is the section of the cycle corresponding to the resonance mode). It is obvious that when the resonance mode is implemented in the system then the amplitude of the vibrations of the crushing members grows severalfold in relation to no-load running. If the rock mass's level is held at a constant optimal level the resonance mode, or one close to it, is maintained stably. However, it is more effective to use for

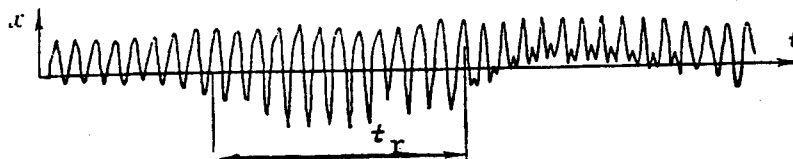


Figure 3

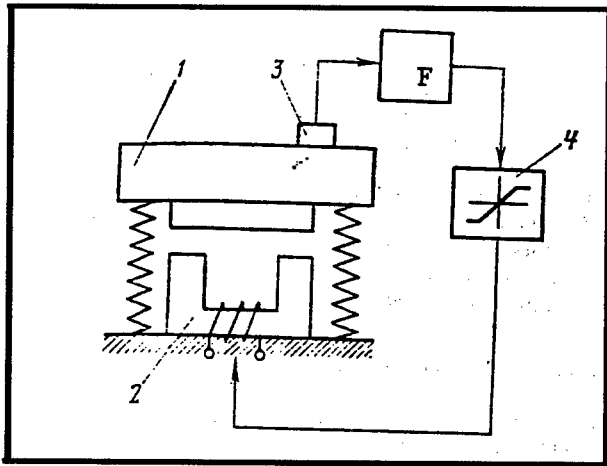


Figure 4. Autoresonance Vibrating Machine With Electromagnetic Exciter

Key: 1) vibrating system 2) exciter 3) vibration sensor 4) nonlinear amplifier, F-phase-shifting element

stable maintenance of the resonance mode control systems having a feedback loop that implements autoresonance excitation (fig 4).

A new class of vibrating machines having self-synchronizing vibration exciters has appeared, developed on the basis of the theory of the self-synchronization of unbalanced spinning rotors installed on a common base. Machines of this type are not only simpler to construct and control but are also more advantageous energywise. Licenses have been sold by firms in the USA, Japan and other countries for a number of machines having self-synchronizing vibration exciters. Nevertheless it can be stated that the capabilities of these machines are as yet being used far from completely, as is the self-synchronization effect itself.

#### Mechanics of Multiphase Systems

One new direction in the mechanics of multiphase systems is the study of the mechanisms of the excitation of wave motion in suspensions of solid particles, drops and bubbles in a liquid, as well as in streams of a liquid, gas or vapor bounded by compliant walls. A number of basic effects quite useful for practical work have been discovered within the framework of this direction up to the present.

It has been established that, under the influence of external vibration under certain conditions, unidirectional movements of inclusions relative to a liquid can originate, as well as stable periodic movements of inclusions along closed paths and a concentration of inclusions in certain limited regions. The conditions for the existence of these forms of motion and their stability are determined by the amplitudes and frequencies of the external influence and by the geometrical and physical parameters of the system. Of particular importance is the

fact that in the process of motion the self-tuning of the system's parameters to resonance values takes place, with which the sustaining of wave motion requires a minimum input of energy.

The forms of motion discovered have been implemented in industrial plants in the form of fundamentally new highly efficient methods for transporting, separating and stirring suspensions, emulsions and gas-saturated liquids. These methods surpass in terms of their efficiency the well known ultrasonic and vibration methods and a group of special machines and equipment has been developed at IMASh [Institute of Machine Science] for the purpose of introducing them in the national economy.

Wave processes can be created in streams of multiphase media (in pipelines, for example) by means of external influences, but they can also be of a self-oscillating nature, i.e., originate as the result of the loss of stability of steady flows of a liquid, gas or vapor. In particular, a determination has been made of the parameters determining the elastic damping properties of pipeline walls with which disturbances are stabilized or, on the other hand, damped. In the course of a study of the mechanism of the propagation of acoustic disturbances caused by the operation of pumps or originating in the shutting off of a section of a pipeline, wave process stabilizers were suggested as general-purpose devices for lowering the level of pressure and flow rate fluctuations in pipelines for various purposes: petroleum product pipelines, nuclear power plant steam lines and oil and gas trunk lines. The effect of a stabilizer in a trunk line when it is shut off is illustrated in fig 5, where the change in the pressure,  $p$ , in the vicinity of the point where the pipe's cross section is shut off versus time,  $t$ , is shown. Curve  $\beta = 0$  characterizes the process in the pipeline without the stabilizer, and the remaining curves, with the stabilizer with various values of the actuating error. It is obvious that the vibrations are considerably smaller with the presence of the stabilizer and this improves the pipeline's reliability.

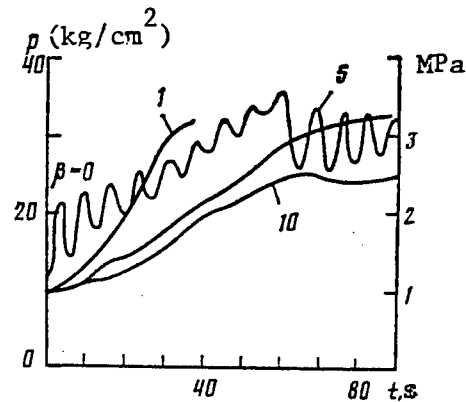


Figure 5. Pressure Changes in Pipe Near Point of Overlap of the Crosssection at Different Stabilizer Control Parameter Values

### Hydrodynamics and Gas Dynamics

Methods of hydrodynamics and gas dynamics together with rapidly developing numerical methods are being used more and more extensively in the mathematical modeling of processes taking place in various kinds of equipment, in power-generating equipment in particular. With this it is no longer necessary to use simplified representations and descriptions, which is very important in studying processes in the circulating sections of turbine-driven machines, for example. It became possible to make a model analysis not only of steady-state but also of transient processes, and this made it possible to do research relating to the determination of transient loads on the blades of turbine-driven machines, on aircraft wings and other elements.

The theory of cumulation and the theory of the shock wave compression and high-speed deformation of matter were developed at the point where gas dynamics and hydrodynamics and the mechanics of deformable bodies meet. Superhigh pressures, speeds and temperatures have strongly entered present-day processes for the production and treatment of materials. The important difference between the effect of static pressure and that of shock waves originating in the detonation of explosives and in the use of pulsed magnetic fields, the electrohydraulic effect, the explosion of a gas mixture, etc., is that the medium's change from the initial state to the compressed state occurs in a very short time and this results in a considerable change in the material's properties. This process has been used for a long time for producing artificial diamonds. The intensive flowing of a metal that acquires the properties of a liquid can occur in the high-speed collision of metallic bodies, and this makes it possible to use this effect for welding and cutting. Advanced processes (welding, cutting, die forging and explosion hardening of metals), methods of synthesizing new superhard materials by means of shock compression, the detonation application of coatings, the impact extrusion and expansion of parts for important purposes, the cleaning of castings, etc., have already been developed on the basis of the theory of shock interaction.

### Magnetodynamics

This direction belongs to the division of physics lying where mechanics and electrodynamics meet. The range of problems examined by magnetodynamics includes problems of the force interaction of an electromagnetic field and medium and of the remote influencing of an object by means of a field. The effectiveness of such interaction can be judged from the fact that an electromagnetic field of a sufficiently high frequency with induction of 1 T creates on the surface of a metal an electromagnetic field equivalent in terms of the force of its influence to a pressure of about 4 bars. For this reason it proved to be possible to develop in modern engineering electromagnetic presses operating in the pulsed mode. Great masses can be accelerated by means of an electromagnetic field. The use of electromagnetic fields in die casting machines and machines for the

vibration treatment of metals and for measuring them out and separating them will be totally realistic in the very near future. And in the more distant future, melting in the suspended state, the consistent weighing of conducting solids, and the control of the precession and orientation of bodies. Magnetic bearing hangers are being used and experimental models of locomotive underframes on a magnetic cushion have been developed already now. However, it should be noted that the introduction in practice of the results of research in the field of magnetodynamics involves great difficulties and a very thorough prior theoretical analysis becomes necessary every time.

### Mechanics of Robots and Manipulators

This direction can be regarded as the division of mechanics dealing with the controlled motion of a system of rigid and deformable bodies having many degrees of mobility<sup>3</sup>. The functional characteristics of such a system—the precision of the reproduction of a specific achievement, speed of response, economic efficiency and reliability—are determined to a significant degree by its mechanical properties and the method of control. The development of methods of selecting an efficient structure and efficient parameters for the drive system, drives and control systems of robotic equipment comes under the heading of the tasks of this division of mechanics.

One principal problem is the reduction or better total elimination of the dynamic mutual influence of a robot's individual degrees of mobility on one another. This will make it possible to increase the smoothness and precision of movements of the robot's members, to reduce the power of drives and to simplify the control algorithm and system. The recently developed conception of the dynamic uncoupling of movements will serve these purposes. It makes it possible to eliminate the mutual influence of a robot's degrees of mobility by the rational selection of the structure of its drive system and distribution of the masses of its members and of transmission ratios in mechanisms. Let us note that the importance of this conception will grow as the speed of robots grows, which is a necessary prerequisite for their effective application.

Considerable work has been done for purposes of developing methods and algorithms for optimizing the programmed movements of a robot, a theory and methods of calculation of its dynamics taking into account the elasticity of construction elements and the properties of drives, and a theory and methods of calculation of fast cyclic robots with energy regeneration. Conditions, optimal in terms of speed, for the performance of the working operations of robots being produced by industry have been suggested and implemented on the basis of the results of this work, and models of new cyclic robots have also been developed, that are distinguished by faster speed and lower energy consumption.

Significant achievements in the area of electronic control systems and the use of new materials and technologies have resulted in expansion of the functional capabilities

of all types of drives—electric, hydraulic and pneumatic—and in equalization of their operating characteristics to a certain degree. Problems relating to the selection of an efficient type of drive and its structure and parameters for each specific case are being solved by the general theory of drives. The best matching of the characteristics of a drive's power and control circuits with the load is ensured in the process.

The majority of robots being used now require "rigid" organization of their environment, i.e., the objects to be manipulated must be delivered to the loading position sufficiently precisely and be oriented in the appropriate manner, and the actions of the robot and of the equipment servicing them must be synchronized. Special tooling can be eliminated by using more highly organized robots that receive by means of special sensors information concerning the features and state of the environment. Robots of this generation are called sensitive, adaptive, integrated and intelligent. The control of them must be carried out in real time, i.e., a period of time constituting a very small part of the time the actuator moves is assigned for information processing. Hence the problem arises of the development of adaptation systems, which involves the development of reliable and inexpensive sensors and high-speed digital control equipment having a large memory capacity. The solution of this problem will make it possible to use robots not in a specially created but in a natural and constantly changing production situation.

#### Acoustic Dynamics of Machines

The acoustic dynamics of machines has been undergoing rapid development recently. This is a new direction in mechanics that studies the noise and vibration of machines with the enlistment of acoustic methods for purposes of developing the scientific principles for the designing of low-noise machines. This direction includes the study of sound formation in noise sources, the diagnosis of noise sources, the study of the propagation of sound through structures and of its radiation into the environment, and the development of methods of reducing the vibration activity of machines.

Definite success has been achieved thus far in understanding the formation of sound in many sources of noise of a mechanical and aero- and hydrodynamic nature. As it applies to gear trains, methods have been developed for calculating their vibrations caused by machining and assembly process factors, and this is making it possible to produce recommendations concerning the fabrication and use of gear trains that make it possible to minimize vibrations and, consequently, noise.

Achievements in the area of the balancing of rotors must be mentioned, where it has proved possible to use a laser beam (laser balancing) in addition to traditional methods.

The numerical modeling of processes of flow around bodies has made it possible to understand the mechanisms of the formation of vorticity and turbulence, to determine the field of pressures acting on the elements of a structure and to control flows in order to minimize these actions.

It has been established that many structures have filtering properties in relation to vibrations and can therefore be used as base and frame structures distinguished by enhanced vibration isolation properties. Various types of vibration isolators have been developed and are being produced by industry, as well as vibration and noise absorbers made of rubberlike and polymer materials. In cases where passive devices for vibration proofing are insufficient, active methods are being used, which are based on the compensation of acoustic fields by means of additional sources of acoustic energy, as well as on the use of structures having parameters that change over time.

Special facilities and equipment have been developed for the measurement of acoustic signals, such as sound level meters, ratemeters, piezoelectric ceramic transducers and resistance strain gauge and optoelectronic transducers. Development work is under way on new noncontact methods of measuring the vibration of machines by means of laser equipment (pulse holography).

The development of methods of calculating the expected vibration activity and vibration and acoustic activity of machines at the design stage and the issuing of guidelines for the designing of machines by taking into account acoustic figures of merit must be placed under the heading of the most important problems that must be solved in the near future. It is no less important to introduce as quickly as possible already completed scientific developments relating to the diagnosis, reduction and monitoring of the vibration activity of machines, and to work out the industrial production of measuring equipment for experimental research on the noise and vibration of machines.

#### Biomechanics of Man-Machine-Environment System

In research on the biomechanics of the man-machine-environment system a number of new results have been obtained relating to the study of the functional capabilities of a human operator under conditions of vibration influences and norms and methods have been established for the development of controlled vibration proofing systems. This direction of mechanics is very important because the reliability, stability and safety of machines depend more and more on the reliability of the actions of attending personnel. The errors of operators controlling large units and engineering facilities can exert a serious influence not only on the efficiency of their functioning, but can also result in deviations from normal operating conditions and in accidents having environmental consequences.

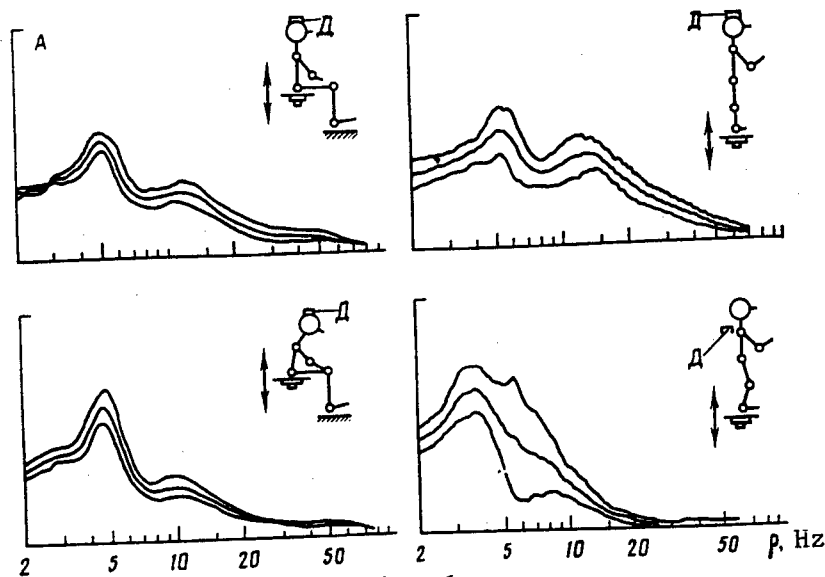


Figure 6.

High-reliability machines must meet all the requirements of ergonomics and environmental cleanliness. It has been established in experiments at special complexes that the resonance properties of the human body depend considerably on its posture and position (fig 6). Based on the data obtained, it is possible to construct a statistically representative mathematical model of the human body taking into account anthropometric features. The behavior of the human body under conditions of the influence of vibration can be studied according to this model and recommendations can be developed on effective vibration proofing in the range of frequencies most hazardous to man.

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#### GOST Criticized for Overly Rigid Quality Control Specs

18610085 Moscow *TEKHNIKA I NAUKA* in Russian  
No 6, Jun 88 pp 10-12

[Article by A. I. Veleznitskiy under the "Economics Department" rubric: "GOST on Cost Accounting"; first paragraph, *TEKHNIKA I NAUKA* introduction; final paragraph, note from the *TEKHNIKA I NAUKA* editorial staff]

[Text] Cost accounting, self-finance, and self-support—today these words are on everyone's lips. In 1987 the first (a comparatively small) group of enterprises, including the Saratov Bearing Plant, switched over to cost accounting. Most enterprises have since joined them. What kind of problems did the first enterprises to adopt cost accounting encounter? Last year (*TEKHNIKA I NAUKA* No 11, 1987) this journal held its own type of "roundtable" with engineering and technical personnel from the No 3 State Bearing Plant [GPZ-3]. The barriers to the introduction of the new operations methods and the problems of the engineering labor force were discussed. Half a year later we decided to visit the enterprise again and see how the collective is working under the new conditions of cost accounting and self-finance.

"Let us postpone this conversation for half a year," suggested I. A. Yashkin, director of the plant, when I called him from Moscow and said that I was preparing to

come visit. "Now is not the time. The situation is difficult, we are not fulfilling the plan, and thus there is nothing special to brag about."

"But there is no need to brag. Now, when restructuring is underway in the country, and a lagging plant may..."

I did not have time to say what a lagging plant may do before Yashkin exploded, "And why have you all taken to restructuring, restructuring! What is this restructuring? For 15 years we have fulfilled the plan and have been one of the best. And now they have backed us into a corner, made us lag behind, and have inflicted a loss of millions of rubles on the national economy. Yet everyone is rejoicing: cost accounting, self-finance, government orders.... What can cost accounting be like if there is no calculation of what is happening. Everything is being done improvidently."

"They tied the plant's hands and legs, and then they ask where it hurts," said Yashkin, filled with indignation, when we met a few days later. But by this time I already knew where it hurts without him telling me.

"Before listening to a patient's complaints an experienced physician acquaints himself with the history of the disease, with the objective indicators. He looks at the radiograms and studies the analyses. Thus, after barely arriving in Saratov, I went directly to the bank. Here in the oblast department of the State Bank, as if in a mirror, the whole economic situation of the GPZ trust became clear."

"The plant is over its head in debt," said Ye. A. Lapaksin, office manager of the Industrial Construction Bank. "Constant debts. Raw materials, materials, and equipment are required to manufacture a product. Suppliers must be paid for them, but there is nothing to pay them with. The plant has no money on account. Why not? I will tell you now."

"See what happens?" continued Ye. A. Lapaksin glancing at the planning indicator summaries. "Above-norm raw material stockpiles worth 5 million rubles. Another 10 million in credit investments. It was reckoned that profits would cover these millions. According to the plan they should have received 19 million, but they received 14. This was hardly enough to fulfill the withholding norm that was established in the budget for the plant. Five million was not counted in. Now let us look at why this 5 million was not included and where the above-norm stockpiles were taken from."

"Life under deficit conditions gave rise to a steady reflex: you grab what they give, even a little more. If there is no money, take on a debt. Individual citizens and entire enterprises alike live according to the law of 'Grab what you can.' It is only with our neighbor that we settle

accounts in the old way—we will give as much as we have taken. The state government must plan percentages, fines, forfeits. New debts must be taken on to settle accounts.

"And now imagine that a plant that is preparing to manufacture a million bearings this year purchased a thousand tons of steel while only 900 was used for the bearings. A portion of the steel was left over. Less metal could be ordered next year. But the experienced manager orders the same amount that was ordered the previous year because he knows that once you order less, you will be able to beat out the required quantity again. Last year the GPZ-3 did not fulfill its plan. And thus arose their above-norm stockpiles.

"Now we will see what happens with the profit. There are enterprises where obsolete technology is used, there is a high percentage of defective production, there is a great deal of manual labor, and consequently there are high production costs. In this sense, everything is in order at the GPZ-3. The technology is modern. Production costs are within the norm. Then you ask, 'Why has the plant not counted in 5 million rubles?' It turns out that this money went for fines, penalties, and forfeits that had to be paid for late delivery or for failure to deliver a product at all. To put it simply, financial difficulties once again arose from a failure to meet the plan indicators. The plant produced less than the amount of the production established for it."

"This means that if a plant were to establish a plan in accordance with the Law Governing the State Enterprise by proceeding from its own capabilities would everything be in order?"

"If they had not assumed the obligation of supplying bearings to enterprises producing parts to be used by other enterprises," continued Ye. A. Lapaksin, "everything would have been in order. But they did take on that responsibility, these bearings were included in their plan, and the plan had to be fulfilled."

"How did it happen that the plant was unable to meet the obligations that it had assumed? Is this inexperience on the part of its managers, a lack of foresight on the part of its economists, unsound thinking on the part of the designers and technologists?"

"You can say that again!" the bank manager waved his hand. "The engineers at the GPZ-3 are working according to plan to eliminate manual labor. Last year alone they introduced 26 numeric control machine tools and 26 industrial robots that made it possible to free up about 400 workers. Production processes are continually being improved at the plant, and new bearing designs are being created. And the enterprise's economists, who are competent, make use of all of the possibilities of financing. In particular, 50 percent of their capital investments during the past year were used to defray long-term credit. Most of our enterprises use long-term credit—whether

they are afraid or whether they do not know how to go about getting credit. The GPZ-3, on the other hand, is keenly oriented in the financial sea. Their director, I. A. Yashkin (he himself is an economist) uses credit banks actively and wisely.

"Taking a loan from a bank is half, perhaps a quarter of the matter. This loan must be put into circulation. What does this mean? Let us say that a plant has decided to use its own resources to build a residence hall or kindergarten for its workers. They have gotten money at the bank. Now they must find a construction organization. And they must still beat out funds for brick and concrete, slate, and drying oil; they must coordinate the construction with the gorispolkom and Council of Ministers; and they must enlist the support of the party organs and their own ministry. In a word, they must solve a mass of problems. And perhaps none of this will be done, they will not assume the load, and they will not bother with it. Rather they will concern themselves with their main business—production. Many act this way. Though it then becomes clear that people leave because they prefer the apartment in another place, because there is a place in the day nurseries and a voucher to a holiday hotel built at the sea with the enterprise's resources. All of these things are available when there is a good director who thinks about people. And then we say that the director is a manager."

Until recently, Ivan Andreyevich Yashkin was this kind of skillful manager. According to Ye. A. Lapaksin's determination, he was an enterprising, calm, and successful person. He has remained enterprising and calm. But now his success has stopped. Since last year, after the state acceptance came.

#### The State Acceptance and Cost Accounting

They arrived at the plant simultaneously, and it immediately became clear that, like a cat and dog, they could not live in one house. This is because cost accounting meant the need to extract the maximum profit with the minimum expenditures. A plant must withhold a portion of this profit, a kind of tax, for the state budget and a portion for the ministry. Everything that a plant can obtain over and above this previously agreed upon norm goes into the plant's pocket. This is pure profit. The greater this portion, the richer the plant, the more resources it has to develop production and to construct dwellings, kindergartens, and vacation homes. The higher its bonuses, the better each of its workers can live. And increasing profit requires increasing production volume and lowering production cost.

The state acceptance, on the other hand, demands strict observance of standards and an increase in production quality. And this means raising the cost of producing products. The volume of products produced began to decrease with the arrival of the state acceptance. The

plant stopped fulfilling its plan. Is it possible to combine quality and quantity? Is it possible to increase (or even maintain) volume and increase quality simultaneously?

And here I must digress a bit. Many years ago I decided to find out why the much-loved and high-demand pastry Jubilee [Yubileynoye] disappeared from counters. They took me on a long tour of the Moscow biscuit factory Bolshevik, where this pastry is produced, and explained that the pastry is made according to an old Russian recipe preserved from prerevolutionary times. They showed me the ovens in which it is baked, explained how complicated it was to organize the pastry's manufacture, and how it is not lucrative.

Volumes of literature are written about whether or not a product is lucrative. In fact, for many years now, journalists and economists have been punching a hole in this wall of economic injustice, and it appears that they have finally broken through. The new Law Governing the State Enterprise has been passed. Henceforth, when an enterprise makes the transition to cost accounting, it will make its own decision as to the product that it will manufacture, reach its own agreements with customers, and formulate its own plans. In any case, this is how things seemed in June 1987 when the Law Governing the State Enterprise was passed.

In an article entitled, "From Industrial Allocation to Tax," (TEKHNIKA I NAUKA, No 6, 1987), P. G. Bunich wrote, "...it is necessary to stop petty guardianship in the distribution of resources and petty regulation of all of an enterprise's activities and to give it broad powers. Above all, the design of the new law formulates a new management method: the concept of the state order is introduced. The enterprise does not have the right to refuse to accept a state order, and the state does not have the right to bind an enterprise to an unprofitable order."

We prepared this article exactly 1 year ago. How simple and clear everything seemed then. "It does not have the right to bind an unprofitable order." Theoretically, it does not have the right? But in practice? How specifically is a plan established today under conditions of self-finance and what percentage of this plan is taken up by the state order?

I posed this question to V. A. Kozin, chief economist at the GPZ-3. After hearing my question, Valentin Aleksandrovich made a show of being dumbstruck. "State order, you say? And what is this state order? Can you explain this to me?" Without waiting for a reply, he continued, "Do not worry, no one will explain this to you today. Because today the state order amounts to 102 percent of the volumes realized. Look at what the state order from our State Administration for the Supply and Sale of Bearings [Soyuzglavpodshipnik] includes. There is cast iron (that we make for ourselves) and production equipment (also for ourselves) and nonferrous casting and stamping. The plan includes a volume sufficient to



serve the public—and of course bearings. What is not a state order? Will you show me where this independence is? The state order is a noose around the enterprise's neck, but the final tightening of the noose requires that the support be knocked out from under the feet of the enterprise. This was done by the state acceptance. The volume of products manufactured dropped with the arrival of the state acceptance, and above-norm stockpiles hung on the enterprise's balance sheet. We crept into debt."

Nevertheless, even a plant that has crept into debt and gotten up to its ears in fines can get itself out of debt if an order is profitable. In the same article, P. G. Bunich wrote, "The customer does not pay for the expenses incurred as a result of producers' sluggishness but rather for the product's consumer properties." This means that if the state wants a confectionery factory to produce the pastry Yubileynoye, which is currently unprofitable for the enterprise, it must include the pastry in a state order that cannot be unprofitable. The state must make a supplementary payment to the factory for the pastry and must make a supplementary payment to a plant for bearings.

"Well, does it make the supplementary payment?" I asked with interest.

"Not exactly. It seems that most customers do not require the high precision that the All-Union State Standard [GOST] stipulates for bearings.

"Each product, each bearing has its own GOST. It stipulates allowable deviations from the rated precision—let us say plus or minus 25 microns for the diameter of the outer ring and 35 microns for the play of the inner ring, etc. And if the play of a finished bearing is not 35 microns but is instead 50 microns, what then? No one at the GPZ-3 paid any attention to such 'trifles' because most bearings were used to manufacture agricultural, road-building, and other machinery, none of which required such precision. But in places where such precision was required, in machine tool building for example, the customer ordered an extra amount of bearings and then himself rejected those that did not fall within the GOST norms. In general, machine builders, like confectioners, tried to avoid manufacturing 'capricious' products requiring strict observance of technology.

"The state acceptance gave a decisive no to this practice. Its representatives came to the shops, opened the technical documentation, and said 'Let all goods henceforth be made in strict accordance with the sketches.' A tolerance of plus or minus 35 microns has been specified. Let all goods maintain it. And then it became clear that not only was it impossible to maintain the sketch requirements at the GPZ-3, but it was also impossible to even verify the observance of these requirements; the respective instruments were not there.

"The GPZ-3 manufactures hundreds of thousands of bearings. And it was necessary to use inspectors who manually inspect the finished product and catch micron-sized deviations alongside automatons that 'shoot out' thousands of bearings. The cost of catching micron-sized deviations should be explained."

#### The Cost of Catching Microns

"Chasing after microns resulted in an immediate increase in the cost of the finished product. Indeed, the price of the product, the price of a bearing, did not change. In our country this price is established on the basis of the input principle, without any allowance for the product's consumer properties. These properties have not, however, changed for most consumers."

"In 90 percent of cases there is strict observance of sketch requirements. In essence, however, no sharp increase in the precision characteristics or improvement in the quality of our bearings is evident in the operation of the units in which the bearings are used," says I. A. Yashkin. "For most machines, such precision is simply unnecessary."

But, if such precision is unnecessary, one might ask why it was introduced into the bearings' specifications and why it has become necessary to strictly observe requirements that are unnecessary.

"This is a consequence of the unconstructive, thoughtless policies of the USSR State Committee for Standards [Gosstandart], which looks for work for itself and does not wish to restructure itself," says G. F. Dzanashvili, chief engineer of the Soyuzglavpodshipnik.

"I will not attempt to judge whether or not the Gosstandart is undergoing restructuring but will only say that it was not the Committee on Standards but the branch institute—the All-Union Bearing Industry Scientific Research Institute [VNIIPP]—that developed and introduced the standard.

"Just when the VNIIPP, which developed the new standard for bearings, was puzzling over the question of what the tolerance field should be, the All-Union Volga Automotive Plant imeni the 50th Anniversary of USSR [VAZ] requested a No 904900 bearing with a tolerance field of 18 microns. The VAZ's requirements were taken as the basis for the new standard without further ado, and these very 18 microns were made mandatory for all other bearings. Well what about the plant, and where were the plant designers looking, the ones who create new bearings?"

"At the time we did not attach any special significance to this," said R. Kh. Khalikov, chief designer at the GPZ-3. "Why was no special significance attached to this? We had simply grown accustomed to the fact that a bearing's precision class is determined during negotiations between the supplier and the customer. At the same

time, no one took the requirements of the standard seriously. Relationships were built on the basis of mutual agreement. No attention was paid to documentation. This was established by both the customer and the manufacturer. And then it turned out that the GOST existed by itself, and generally speaking, no one consulted it. And life and production each existed by themselves. Then suddenly—crash, bang—the state acceptance announced that the standard is the law of production and that violation of a GOST is henceforth actually punishable by law. That was when we took a serious look at the sketches and GOST that were thought up in the VNIIPP and announced the following for all to hear: the standard is robbing the enterprise blind. Neither we nor the consumer need such standards. Only the standard was established long ago, and its requirements must be observed.

“Under such conditions the position of the consumer has turned out to be very remarkable. When they came from Saratov with a request to confirm that such a high precision is not really needed, some plants, the Yaroslav Motor Plant for example, announced that they very much need such precision and are even prepared to pay the difference between the old bearings that were manufactured on the basis of mutual agreement and its new ‘standard’ counterpart. Others readily confirmed their willingness to receive bearings manufactured the old way.”

“We used to be very proud of the fact that a tractor would collapse and its bearings would be like new,” said V. A. Kozin. “Then we realized that an American tractor or car falls apart all at once. And really, what sense is there in using bearings that will last longer than the machine into which they are placed? No one will remove them; they will become scrap metal together with the tractor. But indeed their longer-than-necessary life is an extra expense. Quality indicators represent an economic category. Quality should be determined by the job to be done rather than by a GOST.

“Having understood this simple truth, we began to explain who needs what to the consumer. It was, for example, discovered that a radial play of the inner ring of 25 microns instead of the 13 microns specified by the GOST is completely suitable for the Tashkent Agricultural Machinery Plant [Tashselmash], which receives No 180306 AKS 17 bearings. The Frunze Agricultural Machine Building Plant informed us that they have no objections to a 30 percent reduction in the tolerance for the radial clearance in 206 AK bearings compared with the tolerances specified in the GOST. In the opinion of the plant specialists, such a reduction will not be reflected in the operating quality of the machines in which they are used.

“We have named only a few enterprises here. But indeed there are thousands. Plant designers and sales department personnel are now polling consumers as to who

needs which bearings so that new GOST can be developed and confirmed in accordance with these requests. All bearings are divided into three classes, class A being the highest. These are free market bearings. They will be very expensive—much more expensive than now. Class A bearings will find use in machine tool building and in a number of other branches where a high precision is required. Class B bearings are precise bearings for which requirements related to tolerable noise and vibration levels have been stipulated. They do not need to have an especially high precision. Their tolerances and the precision with which they are manufactured should ensure noise-free operation. Finally, class C bearings are the most prevalent. Eighty percent of all of the bearings produced in this country will belong to this class. These inexpensive, mass-produced bearings will be used everywhere where especially high precision is not required.

“Whether this 80 percent or less will be needed is not yet known, however. Information and polls from the enterprises are still being gathered.

“When all the information is gathered and processed, the problem of developing new standards will arise. After they are confirmed, where the state acceptance is needed will become clear, and where it is today, acting from formal policies, will, for practical purposes, inflict only damage. But I repeat, this will only become clear after all of the information has been gathered and processed and when all of the suppliers have been polled. And in the meantime, the plant does not fulfill its plan stably, and the director does not wish to give an interview because the enterprise does not have anything in particular to brag about. The plant will endure financial losses, its workers will not receive bonuses, and its finances are cracking along all seams.

“This is because we have grown accustomed to solving all problems at the enterprise’s expense. And now, under the guise of restructuring, it is the workers that must pay in due course for the little blunders of the bureaucrats from the Gosstandart and VNIIPP.”

“The whole problem is that the plant realized this late and is not placing the entire blame on the ministry,” considers G. F. Dzanashvili. “They have the capability of adjusting the work. And they have metrologically improved inspection hardware and new equipment. But there is not enough desire to work or know-how. And, of course, the Gosstandart did its part.”

And while the plant directors and ministries explain who is to blame, signals of disaster come from the bank.

“You can thus consider our conversation to be ‘commentary with nooses around our necks,’” says I. A. Yashkin. “With the nooses of debts and nonpayment around the neck of a plant operating under conditions of cost accounting and self-finance”.

**From the editor**

The state acceptance has uncovered flaws in the operations mechanism and has discovered a lack of correspondence between prices and the requirements that have been set for product quality as well as imperfections in the standards. What is not understandable is why all of this was not discovered before the arrival of the state acceptance. The question which still remains open is as follows: Who is to blame for the fact that these flaws were discovered after the transition to cost accounting?

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**Low Pay, Use of Engineers as Unskilled Laborers Criticized**

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[Article by A. S. Sergeyev, special correspondent, under the "Serious Conversation" rubric: "Why a Broom for an Engineer?"]

[Text] An autumn evening. We walk along one of the central streets of Yoshkar-Ola with a journalist colleague. There is no breeze. But suddenly we notice a cloud of dust moving toward us. Prudently we walk around the danger zone, and we see two pretty women bustlingly waving brooms. Their movements are clumsy and unprofessional. Yes, and by external appearances, they do not resemble women who take care of the front yards and pavement. A wave—and a column of dust rises out from under the broom. And it is not clear whether such sweeping helps or hurts.

This episode would not likely have imprinted itself in our memory had we not met with the engineers and technologies of the Yoshkar-Ola Repair Plant the next day. It was there that we found out with bewilderment why cadres of sweepers are hammering in the capital of the Mariyskaya ASSR. All is in order, however.

The Yoshkar-Ola Repair Plant is subordinate to the local agricultural equipment association. Calling it a repair plant is stretching things, however. About 80 percent of its production is new products. The "repairers" manufacture chassis for agricultural machinery, mechanized poultry yards, consumer goods, and other products. The enterprise employs 1,100 workers, including 141 engineering and technical personnel. About half of the latter are women.

The plant is not the city's leading plant, but it is considered to be on solid middle ground. True, A. A. Legalin, its deputy director, is more cautious in assessing its achievements:

"Until recently we were in good reckoning. Our plan was continually fulfilled, but then sometimes shipments were spoiled. Previously, no one asked about them particularly. Now this is a fundamental indicator. Beginning in

1988 we switched over to full cost accounting. We still do not know how our life will be under these new conditions. A lot depends on the factories that produce the parts that we use.

N. N. Kuleshov, a technologist in the technical department, led us on a short tour of the plant. We conversed along the way.

"Nikolay Nikolayevich! What specifically do you do at the plant?"

"In the technical department I answer to the auto repair shop. There are many problems. And accordingly, many matters. We prepare technology, introduce new equipment and fittings, and correct designers' errors."

"There are many of these?"

"Enough. Not long ago a great deal of time was spent on finishing up a stand for pressing pins. And we are still unable to put a machine tool from Yerevan into operation."

"Do they send defective equipment often?"

"I wouldn't want to call it defective. Although much needs to be redone."

"And what, in your view, is the quality of your engineers' work?"

"From the sidelines it is more evident. I know that a universal specialist is needed in the auto repair shop. Each engineer must be involved in at least 10 production operations and know welding, stamping, grinding, surfacing, painting, and other production operations. Our engineers are all able to do this. They are all able to organize the manufacture of some product or new type of repair without any particular difficulties. But from time to time there are problems that we are not able to solve. There is a chronic space shortage in our plant, for example. You saw how closely we work? There is such a concept as 'production area.' We assume that washing, surfacing, grinding, polishing, and testing equipment are required to overhaul a crankshaft. The equipment must be installed in a specified sequence. We are unable to do this. There is no space. The production chain must be broken. The result is extra handling and transporting of goods. Furthermore, there are not enough pieces of equipment or workers. And this makes our heads spin."

A middle-aged man meets us beyond the auto repair shop's gates. We are introduced to Viktor Petrovich Bikenev, the head of the office for designing nonstandard equipment. We give an express-interview.

"Viktor Petrovich! What, in your view, is the role of the engineer at your plant?"

"I will not attempt to speak for everyone. Our design office develops all nonstandard equipment and fittings. A great deal of time is spent correcting defective production from the plants that supply us with parts."

"What do you have in mind?"

"Here is only one example. We received technical documentation for chassis for agricultural machinery from the Balashov State Special Design Office. Literally all of it had to be redone."

"It was done crudely?"

"From a technical standpoint it was, perhaps, done correctly. But the technical documentation was totally unrelated to our production. The design was standard, hackneyed, far-fetched."

"If the Balashov designers were to come to your plant and become acquainted with your products, could they provide correct technical documentation?"

"I have no doubt."

"Tell me, what had to be redone in the documentation?"

"It had to be completely redone. For example, the technical documentation included resistance welding. And we have no such equipment."

"What way out did your engineers find?"

"They proposed using electrically riveted seams. The product quality was not diminished. Our lads developed a device for welding, a so-called gun. And that was it."

"Viktor Petrovich! Do you feel that your work here is stressed?"

"Yes, so it is."

"What are your wages?"

"One hundred sixty-five rubles."

"And are there bonuses?"

"Small ones. And we do not always receive them. Last year they only gave bonuses for one quarter because our suppliers let us down."

"What would you estimate your labor to be worth?"

"It is difficult to say. A person generally feels that he does more than what he is paid for."

"Well, I will put the question differently. How much money would you not feel guilty about receiving for your work?"

"I think about 250 rubles. This would be enough for me. I do not have a car. I do not need money to maintain a car or for gasoline."

"And how much do your workers receive?"

"It varies. A qualified worker gets up to 300 rubles, or even more. For the sake of comparison, I would say that a chief engineer gets about 200 rubles. The absurdity is clear here. True?"

We approach the next shop. Here they make mechanized poultry yards that supply the entire country. Yelena Ivanovna Chistenko meets us at the gates. She leads us around the shop, where before our eyes smart, open-work poultry yards are created from ordinary wires. We ask Ye. I. Chistenko several questions.

"Yelena Ivanovna, does your work suit you?"

"Yes, I very much like the work of a technologist."

"And do your wages satisfy you?"

"They do not satisfy me at all. People generally receive very little at our plant even though there is a lot of work here and complicated equipment. Because of this our engineers move to other enterprises and get along beautifully. There the set of duties is narrow, and the wages are 30 to 40 rubles higher. We do everything ourselves. Like operators of several machines. It is very hard."

"How much are you paid, if it is not a secret?"

"What kind of secret is there—135 rubles. Let everybody know how poor we are. I have worked at the plant for 28 years and still receive 135 rubles."

"And how much would you like to receive?"

"Perhaps this is immodest, but they should pay me 170 rubles."

"Have you grown as an engineer in your years of working at the plant?"

"I think so. There is a large demand for the poultry runs that we have created with our own hands. I have already said that there are specific details here that everyone should know. Otherwise you will do nothing."

"Yelena Ivanovna! Would you like your children to follow in your footsteps?"

"What is wrong with you! They do not want to hear about this. They say, 'To be unwomanly for one's whole life, like you. Not for anything'."

After becoming acquainted with the plant we went up to the conference hall. Several dozen designers, technologists, and foremen had gathered there. Everyone

crowded together in the rear rows. We ask them to sit closer to the front. Without result. Then we remember the eastern tale of Mohammed and the mountain, take the microphone, and go to the "masses."

"Comrade engineers! Do you have any problems?"

"As many as you like. We will begin with the fact that an engineer does not even have a decent tool. Take a compass if you will. If they gave one to a schoolchild, I doubt that he could draw an even circle."

"Does this complicate your work?"

"And how. What kind of quality can sketches have, what kind of productivity can there be if it is impossible to adjust a drafting table?"

"Who manufactures such drafting tables?"

"The Ufa Motor Building Production Association. It would be interesting to know whether their engineers work at their own drafting tables?"

"Here you have remembered a poor tool. But what can you say, our designers sit on ordinary chairs. I need to turn around 40 to 50 times each day. Each time I grab hold of the chair and turn to the drafting board together with the chair. And you jump back and forth. Can they really not make swivel chairs for us. They have them at other enterprises."

"I have already put this question to several individuals here. I think that it will disturb you too. Tell me, who among you is satisfied with his wages?"

Friendly laughter.

"In principle, it is not funny. We get pennies."

"Do you feel that you completely earn your wages?"

Silence. Then an insolent voice resounds: "Who do you mean? I will answer for the designers. We do not work any less or any worse than our colleagues from other enterprises. They receive 170 to 180 rubles while we get 135. Do you think that they design better? Hardly. And we do not lag behind them from the standpoint of the complexity of our design developments. What they do at the Commercial Machine Building Trust [Torgmash], what they do at the Automation Equipment Experimental Design Office [OKBA], and what they do at the Elektroavtomatika we do here. It was not without purpose that many designers left our plant for other enterprises. And they did not get lost there. They are working successfully. Several engineers have left our department in the past 4 years. After going to the Commercial Machine Building Plant, for example, they were immediately promoted to the second category, and with it a

wage of 180 rubles. Here, how long a person has worked at the plant, how he works, and what qualifications he has are not important. You get your 135 rubles and don't make a fuss."

"We are in an unfavorable position. An engineer's wages depend on the category of the enterprise. And at our plant it is the lowest."

"At our plant, the first category is generally not provided for engineers. The division in wages is insignificant. It depends on the complexity of the work done by an engineer. At other enterprises there are first, second, and third categories."

"Do you feel that wages should be differentiated on the basis of the complexity of the work done rather than in accordance with an enterprise's category?"

"Of course it should not depend on the category of the enterprise. What is going on here, have stupid people gathered here, or what? The load on us is even higher than at other plants. We already know this."

"If they doubled your wages, could you double your productivity?"

"We have so much work. Although, if the organization of labor were improved, productivity could be increased sharply."

"How do the workers relate to you?"

"They look down on us, as on dependents, because our wages are nearly half theirs. Judge for yourself: the average wage for engineering and technical personnel, including the director and other managers, is 145 rubles, whereas the workers average 211 rubles."

"Are many of the engineering and technical personnel women?"

"No less than half."

"Does the administration make an allowance for this in some way?"

"Not at all."

"Do you feel that they should behave differently toward female engineers?"

"Absolutely."

"And how should they treat women?"

"Indeed, a woman is pulled toward her family. For that reason, a store or cookery and a center for taking in laundry should be organized at the plant. That is the least they can do for us. I personally feel that a woman should work 2 hours less. Then you have time to buy products,

pick your children up from the kindergarten, and prepare supper by the time your husband arrives. In a word, the family can be given more attention."

"Tell me sincerely, do you often think about family matters at work?"

"Of course we constantly think about our children and husband. If the workday were shortened, we would know that we have time to do everything that needs to be done for our home. We could then give more of ourselves to our work."

"What kind of prestige should an engineer have in your view?"

"That is a complicated question. An engineer needs to be given more credence, to earn more, and to not be distracted from his or her work. As they say among us: independence, independence.... Everybody has had enough of it. But at the same time, they never took anything away from our engineers' wage rates before they started speaking about this independence. Then this year they said, 'We are giving you independence'—and they took two units away for a departmental bonus. Without any permission. They came. Bang! They drew up a statement: to transfer two units and so many thousands of rubles from the plant's wage fund to the departmental bonus. We have little money ourselves."

"And are your engineers involved in agricultural operations?"

"First off, they take us from our work for a month. We in the technical department calculated it this way. Of 36 persons, a pair spent the entire year working in the kolkhoz. And our department has been called upon to implement the plant's engineering policies."

"And how many of us have they driven to the vegetable store!"

"Not to mention that we are constantly sweeping the streets."

"Well everybody sweeps."

"What do you mean by sweep, explain what that means? In Moscow they have street sweepers sweep."

"Really?!!!" they all said as if dumbstruck.

"And here, each Friday and on days before holidays all scientific and technical personnel (100 percent) leave work 2 hours early to sweep the streets. By resolution of the gorispolkom, all of Yoshkar-Ola's streets are distributed among the enterprises. And so we sweep."

Only then did we understand the true meaning of the episode that had surprised us the night before. We began to understand that it was not street sweepers who raised

clouds of dust on the sidewalk but rather some poor engineers who, in the wisdom of the gorispolkom, who was plugging up some gap in the municipal services. But let us finish our conversation.

"I want to ask the women why our men are so shy. Why are they not taking part in the conversation?"

"Ask them yourself how they can show up at home with such wages? How do their wives meet them?"

"At home we sit in the corner like we do here."

"Any my husband works as a street sweeper."

"And I have to work as a street sweeper. I took care of my mother-in-law, and I myself sweep the street in the evenings."

"More active, comrade engineers! Or is there nothing more to say?"

"Why talk in vain? There is much talk and little action. I am losing my faith in words."

"And what have you engineers done yourselves to improve your existence?"

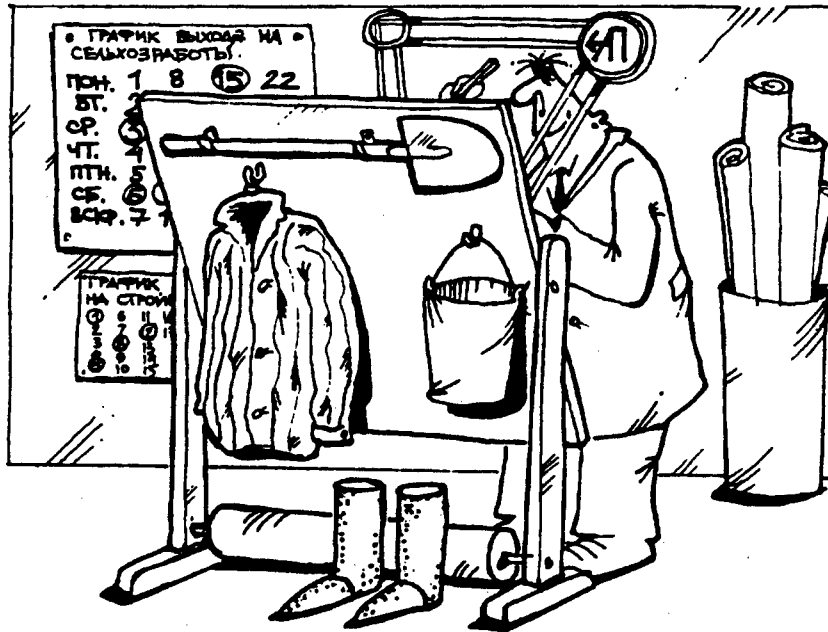
"Speaking sincerely, there is little creative activity or engineering thought among us. When the plan for accelerating scientific-technical progress was compiled, it was funny to say that it included the words 'To paint the wall, clean up the lath, retouch the door....' Instead of automating the production line, introducing an effective device. But there is little that we can do."

"And for what? There is little interest. I do my work quickly or drown, whether it is of high quality or not does not concern anyone. I get paid the same. In the good old days, when wages were based on piece-rate estimates and we were paid from a list, productivity was higher. And, strange as it may seem, quality was also higher."

"We have great hopes for cost accounting. The plant is switching over to it this year. Perhaps something will change for the better."

Thus concluded our conversation. It provided a great deal of food for sad thoughts. Perhaps, many problems will disappear when the enterprises switch over to self-finance and self-support. But not everything is for certain. How can the engineers' prestige be affirmed? How can a sharp increase in the efficiency of their labor be achieved? What do you have to say about this, comrade engineers?

P.S. We recently phoned the Yoshkar-Ola Repair Plant. They informed us that the enterprise has switched over to full cost accounting. The average wage for scientific-technical personnel rose 26 percent. They said that the engineers have cheered up and become more active. But



they have not abandoned their anxiety. New norms for the enterprise have still not been sent. Many questions for which there are no answers have accumulated. Furthermore, the enterprises that supply them with parts have not sent them complete sets of products, and the quarterly plan must be fulfilled on time. And last of all, despite the transition to cost accounting, the gorispolkom has not revoked its resolution about having enterprises' scientific-technical personnel sweep the streets.

Attention Readers!

The engineer is a central figure in restructuring. This is the position of the journal *TEKHNICA I NAUKA*. We believe that much of the trouble of the economy and social relations in society are directly related to the state of our scientific-technical intelligentsia and its professional, moral, and spiritual potential. And from issue to issue we try to understand what must be done so that the people who create and use technology occupy an appropriate place in society.

Read the table of contents of any issue and you will understand that we publish our journal for you.

You may order your journal from any preceding month of the current year. It is not being put on the market.

The *TEKHNICA I NAUKA* editorial staff

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### Cartoon Satirizes Assignment of Engineers as Gardeners, Farm Hands

18610095 Moscow *TEKHNICA I NAUKA* in Russian No 6, Jun 88 Inside back cover

18610095 [Editorial Report] The June issue of *TEKHNICA I NAUKA* contains several articles devoted to industry and the public perception of the engineering profession. The cartoon below satirizes the ill-conceived practice of using professionally trained engineers as tomato pickers, construction workers, and even janitors.

This practice is commonly instituted for white collar professionals during the last days of the month when a plan must be met, and during peak harvest time. In the cartoon, the engineer is shown at his drafting board. Brackets under the board hold tools of his other "professional" trades: a shovel, a pail, a work jacket and a pair of work boots. The bulletin board behind him shows schedules with circled dates when he is due to take part in an agricultural effort and work at a construction site.

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### In-House Machine Tool Building, Solving Technological Problems

18610430 Moscow *AVTOMOBILNAYA PROMYSHLENNOST* in Russian No 4, Apr 88 pp 1-3

[Article by V.F. Rzhavskiy, candidate of technical sciences, NIITavtoprom [Scientific-Research Institute of Technology in the Automotive Industry] NPO [scientific production organization]]

[Text] To increase production efficiency and product quality is the main task of the automotive builders in the

12th Five-Year Plan period. Its solution depends on many factors and, especially on the level of process equipment of enterprises. This level, in turn, is determined mainly not by the pace of creating new capacities, but rather by the pace and quality of developing technology and reorganization of existing production by means of installing progressive types of process equipment.

However, the increased demand of the automotive industry for high-capacity equipment is not fully satisfied by enterprises of the respective ministries and departments. What is more, the supplied equipment quite often does not meet the technical specifications with regard to precision, capacity, and level of automation.

All this forces the enterprises of Minavtoprom [Ministry of Automotive Industry] to organize development and manufacturing of such equipment by themselves.

And such work is carried out quite intensively. For example, the volume of in-house machine tool building during the five-year plan period must increase 3.9-fold. And it is true not only for the volume but also for the technical level of equipment used in all process operations.

Thus in machining, production of automated lines based on standard units is being developed first of all. In particular, it is planned for 1990 to increase production capacities for building such lines to 30 lines at the Lyudinovo Machine Building Plant and to 20 lines at the Volga Automobile Plant imeni 50th anniversary of the USSR [VAZ]. Taking into account the developed cooperation in manufacturing units and control systems, it will allow the machine builders to increase substantially the technical level of such lines with regard to reliability and capacity, and will put them in-line with the best similar domestic and foreign equipment.

Work on improving automatic frontal lathes, directed primarily towards the idea of including them into automated lines for lathework, is being continued at the VAZ. They satisfy customer's requirements, including those for future applications, with regard to arrangement, machining precision and capacity. However, the "fixed" control system, as it is called, of presently manufactured automatic machine tools limits their application area. Therefore, the VAZ is carrying out work to transfer these machine tools to more flexible digital program control. The implementation of this system is planned for 1989.

The KamAZ [Kama Motor Vehicle Plant] began to manufacture two modifications of automatic vertical lathes having rigid frames, powerful spindle units, and supports. The lathes are equipped with programmed controllers, which have earned a good reputation in the automotive industry for their operation in the automated line systems. The developed base models are

capable of machining heavy parts, such as truck wheel hubs and drums; and modified models with increased precision may be used for final machining of wheel hubs with an accuracy and surface roughness necessary in fitting bearings. Therefore, only during the 12th Five-Year Plan period is it planned to build 37 automated lines based on these lathes, including those for the UralAZ [Ural Motor Vehicle Works] imeni 60th anniversary of the USSR and the Stavropol Trailer Plant.

At the same time with the automated lines based on standard units manufactured in-house, production of automated lines for machining frame parts of automobile units is being continued based on the Minstankoprom [Ministry of Machine Tool Industry] designs and machine tools. Such cooperation of the Minavtoprom and Minstankoprom is helping to raise the technical level of designs and improves the automated line builders' qualifications.

In particular, the Minsk Automotive Works [MAZ], Yaroslavl Engine Works [YaMZ], ZIL [Moscow Automotive Works imeni Likhachev], and others operate in cooperation with the Minstankoprom enterprises. Designers of the Lyudinovo Machine Building Plant and the NIITavtoprom NPO attended courses at the Automated Lines and Aggregate Machine Tools SKB [Special Design Bureau] of Minstankoprom. They studied the experience in designing automated lines at the technical specification and technical proposal stages; learned the practices of designing lines for machining frame parts of KrAZ [Kremenchug Automotive Works] and MAZ trucks and trailers; learned to use automated design and calculation methods in designing automated machining lines, etc.

Manufacturing of NC machine tools must receive further, qualitatively new, development. For example, MA-655 machine tools being manufactured do not meet modern demands on rigidity, precision of machining, cutting speeds, and some other technological requirements including control systems. Therefore, a substantial part of these machines are idle. It is obvious that to continue manufacturing them without radical modernization is senseless, and under conditions of self-financing and full cost accounting it may bankrupt the manufacturers. At the same time, IR-500MF4 machining centers manufactured at the GAZ [Gorkiy Motor Vehicle Works], using the documentation of and in cooperation with the Ivanovo Heavy Machine Tool Plant imeni 50th anniversary of the USSR, earned a good reputation from all points of view. The important thing is that the GAZ would not in the future lower the technical level of the IR-500MF4 machining centers achieved by the Ivanovo machine tool plant (this level, as it is well known, is on par with the best similar foreign equipment). And the possibility of operating at this high level in the future exists: the level of cooperation between these plants is being constantly improved, which allows them to find the optimum solutions concerning the quality of manufactured units and parts, to



equip production lines with main and auxiliary tools and rigs, and provide the design, technical preparation of production, and organization of both production and metrology.

At the same time, the GAZ collective, which demonstrated its technical maturity in implementation into production of machining centers, did not demonstrate the necessary persistence and purposefulness in implementation of obtained licenses on face grinding machines and automatic 6,300 kN punch presses. Their implementation into production was stretched out for several years.

The in-house machine tool building system of Minavtoprom continues to build many other types of progressive special metal cutting equipment. Those are: benches for surface plastic deformation built at the KrAZ; automatic worm milling machines and aggregate benches for small parts machining built at Vladimir Avtopribor plant; automatic diamond cutter boring machines for inside grinding and for groove grinding of instrument bearing rings built at GPZ-4 [State Bearing Plant]; super-finishing automatic benches for inner and outer anti-friction bearing races built at GPZ-3 and GPZ-4; etc.

Equipment for car body parts welding was not manufactured in the branch before. However, under the new conditions of economic management the situation has been changed: such equipment is being built. VAZ was the first to solve this problem: here production of multi-spot welders, lines, and main jigs for welding car bodies, lines for door and hood flanging, and other high-capacity welding equipment was organized. And if the first VAZ car models were 100 percent built using imported welding equipment, the later models starting with VAZ-2121 were using sharply less imported equipment, and for VAZ-2108 the imported equipment used for body parts welding decreased to 50 percent. Later, the Zaporozhye Project-Design and Technological Institute (ZPKTI) began to develop welding equipment, and now it mainly supports welding operations at the Zaporozhye Kommunar Automotive Works [ZAZ].

As it is known, recently in the world practice of the automotive industry a tendency appeared to simultaneously manufacture several models of the same car, which requires rapid readjustment of production without spending substantial money, labor, and time. However, the traditional welding systems with their rigid ties to a given car model become unprofitable from this standpoint. Therefore, everywhere, even in branch machine tool building, development of flexible welding systems began. Its basis is the PR-601/60 robot for contact spot welding, which has been manufactured since 1984 at VAZ. (Parts and assemblies for this robot are supplied by other associations and plants of the branch, and by enterprises of other ministries.) Due to the need for high quality and technical level of welding robots, all supplied parts and units pass through 100 percent incoming quality control at VAZ. The cost of

this control is, naturally, high. However, it is justified in that the technical parameters of robots built at VAZ meet the requirements of the automotive industry, and their reliability and time-to-failure conform with the approved technical specifications.

VAZ robots are used in flexible welding systems of the following plants: Kommunar (ZAZ-1102 car model), AZLK [Moscow Motor Vehicle Works imeni Lenin Komsomol] (AZLK-2141 car model), VAZ (VAZ-2109, VAZ-1111 Oka, and others). Prior to 1990, more than 100 flexible robotized welding lines will be built for the welding systems of the branch.

In addition to such lines, the branch is using other welding equipment. For example, prior to the same 1990, 150 multi-electrode welding machines and 60 machines for friction welding will be installed at our plants, which will allow us to free 2,400 welders and to save 78 million KW of electric power and 12,000 tons of metal.

It is known that in the production of automobiles, 25-30 percent of the labor is expended in assembly operations. Taking into consideration that in this country we do not have specialized production of assembly equipment, the branch must itself design and manufacture assembly lines, and automatic and semiautomatic assembly machines. In particular, prior to 1990, it is planned to manufacture 125 robotic assembly complexes, more than 350 automated lines, and around 1,000 automatic and semiautomatic assembly machines, owing to which the level of automation of assembly operations will reach 15 percent of the total. Unfortunately it is not enough, especially due to the fact that the technical level of the assembly equipment built at the Minavtoprom enterprises, including the automated lines, in many cases is below the world level. And this is especially true for its flexibility. This is because we have not yet organized production of a number of the most important parts and units necessary for the development of flexible assembly lines and production modules. Production of robots for flexible assembly lines is also slow in developing. Therefore, the recently organized Avtopromsborka NPO obviously must more quickly take over the functions of leading organizations in the field of assembly, that is, develop specifications for enterprises for design, manufacturing, and implementation of complex assembly enterprises and organizations involved in design and manufacturing of standard units and aggregates of this equipment. There is no time to waste. Without a comprehensive solution of these problems, it is impossible to develop assembly lines and flexible production modules meeting the modern technical level and requirements of the automotive industry.

Work continues on improving the organization of production of forge-and-press equipment that has already been implemented and gained a favorable reputation, in particular the 1 and 2 kN multi-position presses. The

Saransk Technological Equipment Plant began production of 6 and 10 kN multi-position presses and has continued to develop rolling mills for cross-wedge and tooth rolling. The Dimitrov Automotive Units Plant imeni 50th Anniversary of the USSR carries out work on more efficient forming and calibrating presses with 1,600 kN force for parts made of metal powder. (In the future, presses will be equipped with tools and dies made in-house, that is, equipment will be delivered to the customers fully adjusted and complete with the mechanization equipment.)

Due to the fact that Minkhimprom cannot, for the time being, provide the automotive plants with the necessary amount of painting equipment, the demand in this equipment is satisfied mostly by deliveries from CEMA member-nations and branch machine building. However, because the enterprises of the branch do not have specialized capacities to manufacture painting equipment, they had to organize its manufacture at capacities not designed for this purpose (mainly, at bus manufacturing plants). Therefore, the consumer-plants do not receive the painting complexes, but rather separate untested units. In addition, deliveries most often do not meet the deadline. Such a situation leads to a substantial increase in assembly work volumes, stretching of startup and adjustment works, and it hampers the startup of new production capacities.

The reason for such a, shall we say, "homemade" approach is that the EKTiavtoprom [Experimental Design-Technological Institute of Automotive Industry], which develops the technical documentation for the painting equipment, as of now has not taken onto itself the duties of the leading manufacturer of painting lines with the full responsibility for the timely start-up of completed complexes, and is satisfied with revising the documentation and resolving discrepancies occurring during the assembly at the site. Plants manufacturing the individual units of painting lines in turn do not have specialized equipment and, therefore, are using general-purpose machine tools and manual labor, which to a significant degree affects the quality of manufactured units and parts.

The progressive painting equipment available to the automotive plants is also affected by the fact that EKTiavtoprom up to now has not developed a standard size for the standard units and their components. Because of this, during the design of painting lines, for example, much time is spent arranging them to fit the customer's available floor area, that is, in reality, it is redesigned each time. And this means additional outlays of labor and time, as a result of which the technical level of the painting equipment being developed at the branch in many cases does not meet automotive industry requirements. In particular, in haste, new progressive solutions are not introduced into designs and the plants producing painting materials are not subjected to tough requirements, that is, designers are satisfied with anything available at the present time.

All this means that it is time for the EKTiavtoprom collective to work out its own position in the area of painting and to bring it into existence.

NIITavtoprom carries out substantial independent designs; provides guidance for work in general, including examination of new projects; organizes the exchange of experience; demonstrates care for increasing the level of parts, units, and assemblies standardization; analyzes the equipment level and develops proposals for specialization of equipment manufacturing plants; and works on annual and perspective plans of designing and developing the main types of equipment in the branch, taking into account the technological problems and support of programs of scientific-technical progress. In addition, its specialists determine the most efficient nomenclature (models) of equipment necessary for installation of automotive plants, both new ones and those being rebuilt. However, now, during perestrojka, all these directions must be realized faster, more efficiently, and better. One should remember that scientific-technical progress in the branch to a large extent is determined by in-house machine tool building; namely, by deepening its specialization and widening cooperation, changing its structure, and increasing the volume of determining types of special technological equipment. For example, equipment for flexible and metal-saving technologies (flexible production modules and point welding and assembly systems, machining centers, rotary-conveyor lines, mills for stock rolling, electronic control systems, etc.). In addition, cooperation deserves special attention. It must be most diverse: in the branch it must take place between plants specialized in manufacturing modern technological equipment and plants manufacturing separate parts and units; between different branch plants (for some types of assembly parts and control systems) and enterprises of CEMA member-nations; and between the branch plants and the Minstankoprom associations and plants. The latter is extremely important, especially with regard to high-capacity specialized machining equipment, because many of its "homemade" equipment is still far away from world and even from mediocre Minstankoprom levels. Meanwhile, the Minstankoprom has large and highly qualified designers of machine tools.

Therefore, it seems to be expedient that this potential should be more widely used, firstly, for resolving general problems of the machine building complex including the Minavtoprom. In particular, they must resolve such an urgent problem as technical reequipment and installation of progressive metal machining equipment of the enterprises. Here, a mutual realization in metal of progressive developments is required rather than simple cooperation of deliveries.

And, finally, let us discuss the technical level of the products necessary for completion of assembled equipment (pneumatic, hydraulic, and electrical apparatus; electric drives; and control systems) supplied by other ministries. It is no secret that there is still a large shortage of the progressive products necessary for completion of

assembled equipment manufactured by the in-house machine tool building. However, there are many samples of this equipment at exhibitions. Obviously, the sooner the ministries responsible for manufacturing this equipment will organize its serial production, the more effective will be the technical reequipment of the branch, which is of extreme interest to the national economy.

UDC 621.74.06

### **Determining the Demand for Automated Foundry Equipment**

*18610432b Moscow MEKHANIZATSIYA I  
AVTOMATIZATSIYA PROIZVODSTVA in Russian  
No 4, Apr 88 pp 38-40*

[Article by Candidate of Technical Sciences A.A. Panov]

[Text] The technical level of the foundry equipment pool makes it possible to produce around 80 percent of all castings with mechanized production and about 45 percent in flow production. The percentage of workers performing mechanized labor is approximately 65 percent.

In order to intensify foundry production, the following measures are planned: widely implement progressive resource-saving technologies based on new high-production equipment; increase the level of mechanization and automation in all technological converting operations; eliminate manual labor in heavy and hazardous jobs and reduce by 25 percent the number of manual laborers in 1990, compared to 1985; close small production departments and shops with low technical and economic indices and hard labor conditions.

In order to implement these measures, one has to form a progressive structure of the equipment pool which, according to the plans, will be done by implementing high-production foundry equipment.

Taking into account the fact that production capacity of automated equipment that is being ordered is 30 to 50 percent higher than that of manually controlled equipment, overall demand for foundry machinery is reduced by 30 to 40 percent. At the beginning of the period, foundry machinery write-off will be equal to 6 percent.

In order to most fully meet the demand, it is planned to increase production of technological foundry equipment by 70 percent.

Along with increasing equipment production volume, it is planned to change its structure via a higher growth rate of manufacturing of the most advanced equipment, including automated and semiautomated CNC lines and flexible manufacturing systems (their share in overall production volume will increase from 16 percent in 1985

to 35 percent in 1990), and automatic and semiautomatic machines and automated complexes, including robotic complexes (their share will increase from 40 percent in 1985 to 44 percent in 1990).

It is planned to reduce production of manually controlled machines from 25 to 6 percent. The demand for foundry equipment will be met at 95 percent. In the process, as a result of shipping foundry equipment planned for the 12th Five-Year Plan, technological and age structure of the machinery pool will be improved. By the end of the Five-Year Plan, the pool will increase by not more than 10 percent. Due to shipment of high-production lines, machine systems and complexes with higher reliability and service life, the equipment pool production capacity will increase 6 to 8 percent. This will make it possible to reduce the number of foundry workers by 8 to 10 percent.

The demand for foundry equipment for the plan year (period) is calculated for: increased production of castings and implementation or expansion of new technological processes and equipment; increased level of production mechanization and automation (demand for pool "expansion"); and replacement of obsolete foundry equipment (demand for "replacement").

Calculated demand is determined for the primary models of foundry equipment planned and distributed by Gosplan SSSR, taking into account how advanced the ordered equipment is, as far as its level of automation is concerned, based on differentiated (reference) demand standards for foundry equipment (for expansion) and replacement standards.

Four levels of automation are planned for foundry equipment: manually controlled machines; semiautomatic machines and lines; automatic machines and lines; and programmed control machines and lines.

Calculated demand for foundry equipment for the plan year is determined by fund holders (Ministries, agencies, associations and Union Republics).

Targets for increased production of castings for the plan year serve as initial data for calculating demand for "expansion" for each type of foundry equipment.

For each type of equipment, the type of production is defined, and demand standard for "expansion" is determined, with consideration given to its level of automation for the plan year.

Calculated demand for "expansion" is the product of the increase in the output of castings during the plan period into the approved "expansion" standard. Next, overall calculated demand for foundry equipment for "expansion" is determined.

The foundry equipment pool at the beginning of and replacement standard for the plan year serve as initial data for determining calculated demand for "replacement".

Overall demand for foundry equipment for the plan year is determined as the sum of calculated demands for "expansion" and "replacement".

Besides the calculated demand, the size of equipment write-off and the anticipated pool size at the end of the plan year, including equipment over 10 years old, are determined.

That part of the equipment pool which is over 10 years old at the end of the plan period is determined by fund holders by direct count or through calculations.

Standards for the demand for foundry equipment for "expansion" are determined based on the base demand standard and correction factors (production capacity growth factor and foundry equipment utilization improvement factor).

The base demand standard (the number of machines per 1,000 tons of castings) is calculated as the ratio of the installed pool of machines (lines) in process groups (not counting equipment that did not work) and the volume of castings made on the machines (lines);

$$P_{0i} = \frac{\Pi_{0i}}{A_{0i}}$$

where  $P_{0i}$  is the base demand standard for foundry equipment of the  $i$ -th process group, pieces per thousand tons;  $\Pi_{0i}$  is the installed pool of foundry equipment of the  $i$ -th process group (not counting equipment that did not work) in the base year;  $A_{0i}$  is the output of castings on machines (lines) of the  $i$ -th process group, using appropriate technological processes, during the base year, thousand tons.

Demand standards for mold and core making machines and for shake-out and cleaning machines are developed separately for each type of equipment (in order to derive calculated demand for each type), and then for the total number of mold and core making machines and the total number of shake-out and cleaning machines.

The calculated base demand standard characterizes the level of foundry equipment, technology and organization of production (production conditions and equipment utilization, both time- and productivity-wise) achieved by machine building subindustries at the end of 1983.

Base standards are corrected for the anticipated 1985 level, taking into account implementation of organizational and technical measures for production intensification in 1984-1985 and suggestions of individual machine building Ministries on the size of industry standards.

The anticipated level of the standard (as of the end of 1985) is adopted as the basis for developing differentiated (by years of the 12th Five-Year Plan) demand standards for foundry equipment for "expansion".

Differentiated standards for "expansion" have been developed for various types of production (IS - individual and small-series production; MS - medium-series production; and LM - large-series and mass production) and various casting sizes (large-size castings - over 1,000 kg; medium-size castings - 100 to 1,000 kg; and small- and medium-size castings - under 100 kg).

Differentiated demand standards are calculated from the following formula:

$$P_{ij} = P_{0i} \frac{1}{K_{\Pi ij} \cdot K_j}$$

where  $P_{ij}$  is demand standard for foundry equipment of the  $i$ -th process group for the  $j$ -th plan year;  $K_{\Pi ij}$  is production capacity growth factor for equipment of the  $i$ -th process group in the  $j$ -th plan year;  $K_j$  is equipment utilization improvement factor in the  $j$ -th plan year;

$$K_j = \alpha_{\Pi j} \alpha_{CM j}$$

where  $\alpha_{\Pi j}$  is equipment utilization change factor in the  $j$ -th plan year, compared to the base year; and  $\alpha_{CM j}$  is equipment shift change factor in the  $j$ -th plan period, compared to the base year.

The Table below shows production capacity growth factors for new foundry equipment in terms of the main types as a function of the level of mechanization planned for implementation in 1986-1990.

Вид оборудования (1)	Коэффициент роста производительности (13)			
	РУ (14)	ПА (15)	А (17)	ПУ (16)
(2) Машины для приготовления формовочных материалов	—	1,1-1,15	1,2-1,25	—
(3) Машины для изготовления форм	1,08	1,1-1,15	1,2-1,25	—
(4) Машины для изготовления стержней	1,08	1,1-1,15	1,2-1,25	—
(5) Машины выбивные	1,08	1,1-1,15	1,25-1,30	—
(6) Машины очистные	—	1,1-1,15	1,2-1,25	—
(7) Оборудование для изготовления оболочковых форм и стержней	—	1,1-1,15	1,2-1,25	—
(8) Оборудование для литья по выплавляемым моделям	—	1,15-1,2	1,4-1,5	—
(9) Машины для литья под давлением	—	1,1-1,15	1,2-1,3	1,3-1,4
(10) Машины кокильные	—	1,1-1,15	1,2-1,3	1,3-1,4
(11) Машины для центробежного литья	—	1,1-1,15	—	—
(12) Линии автоматические, полуавтоматические и комплексно-механизированные для литейного производства	—	1,1-1,2	1,3-1,4	1,5-1,6

Key: 1.Type of equipment 2.Molding material mixers 3.Mold making machines 4.Core making machines 5.Shake-out machines 6.Cleaning machines 7.Shell mold and core making equipment 8.Investment casting equipment 9.Permanent-mold machines 10.Injection molding machines 11.Centrifugal casting machines 12Automatic, semiautomatic and integrated-mechanized casting lines 13.Productivity Increase Coefficient 14.Manual Control 15.Semi-Automatic Control 16.Programmed Control 17.Automatic Control

The equipment utilization change factor ( $\alpha_{Пj}$ ) is calculated from the following formula:

$$\alpha_{Пj} = \frac{K_{Пj}}{K_{П0}}$$

where  $K_{Пj}$  and  $K_{П0}$  are equipment utilization factors (time-and productivity-wise) in the base 0 and j-th plan years.

Equipment shift change factor ( $\alpha_{СМj}$ ) is calculated from the following formula:

$$\alpha_{СМj} = \frac{K_{СМj}}{K_{СМ0}}$$

where  $K_{СМj}$  and  $K_{СМ0}$  are equipment shift factors in the base 0 and j-th plan years.

When calculating differentiated demand standards for the 12th Five-Year  $\alpha_{П}=1.1$  and  $\alpha_{СМ}=1.1$  for the plan period, based on targets on improving utilization of metalworking equipment in main production departments during the 12th Five-Year Plan and bringing the casting equipment shift factor to 1.9 and utilization factor (time-and productivity-wise) to 0.9 by 1990:

$$\alpha_{СМj} = \frac{K_{СМj}}{K_{СМ0}}$$

For different values of factors  $\alpha_{П}$  and  $\alpha_{СМ}$  we should make the following recalculation of annual demand standards (P):

$$1987 \quad P_{87} = P_{88} \frac{1,05}{\alpha_{П1} \cdot \alpha_{СМ1}} ;$$

$$1988 \quad P_{88} = P_{88} \frac{1,10}{\alpha_{П2} \cdot \alpha_{СМ2}} ;$$

$$1989 \quad P_{89} = P_{88} \frac{1,15}{\alpha_{П3} \cdot \alpha_{СМ3}} ;$$

$$1990 \quad P_{90} = P_{88} \frac{1,21}{\alpha_{П4} \cdot \alpha_{СМ4}} .$$

When no increase in equipment utilization or the number of shifts is planned, additional justification is presented.

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### Experience in Developing System for Planning, Distribution, Accounting for Ongoing Work in an FMS

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[Article by Candidate of Physical Mathematical Sciences L.P. Romanyuk and Engineer O.A. Tregulova]

[Text] Development of planning systems for flexible manufacturing systems (FMS) is one of a set of S&T problems that are crucial for efficient development and implementation of FMS. It is not enough to make a sophisticated equipment complex operate in an automatic mode upon

signals from a computer: it is necessary for the computer to decide *what* (which part), *where* (on which machine tool) and *how much* (the lot size) to make in order to meet the plan target on time with the maximum possible equipment utilization and the lowest possible number of setups during the manufacturing process.

A traditional approach to solving planning problems is to establish a rigid sequence of machining a lot of parts on specific process equipment at predetermined production run start times, and in order to do this, a schedule is compiled once for the entire planning period. Using optimization methods, a schedule can be compiled in such a way that it best meets predetermined criteria, i.e. answers the question of *how* to best meet the production target.

For FMS, such approach to solving planning problems is unacceptable. A flexible production system is a complex object that includes various groups of technological equipment, automated warehouses, robots and other equipment. In other words, FMS are complex systems which consist of an assemblage of objects that constantly interact and are interdependent. Under these circumstances one must plan utilization of technological equipment based on capabilities of the automated material handling system that serves the FMS, and vice versa, it is impossible to control (plan) the operation of the material handling and warehousing system without taking into account utilization of FMS machine tools.

In addition, one must also plan the work of process planning subdivisions that control, set up and prepare a full complement of tools, and prepare fixtures for on-time delivery to the warehouse.

The variety and complexity of production ties require planning that would be able to take into account, with the required degree of detail and timeliness, all current changes in the FMS, i.e. deviations in the production process, system malfunctions, equipment breakdowns, actuator errors etc. The number of such unforeseen deviations in an FMS is very large compared to regular production, therefore no precompiled schedule will insure against endless corrections. This results in unavoidable deviations in production run starts and forced equipment downtime, which can lead to derangement of the plan.

A conclusion suggests itself: flexible manufacturing systems call for flexible planning methods. This we will conditionally call flexibility of planning, and it can be achieved if one uses the "bottom up" principle when building a system (directly opposite to the "top down" planning principle which forms the foundation of operative-calender planning systems). In this case, the *what*, *where* and *when* questions remain open and are solved just before (or at the beginning) of the next planning period (a shift or a 24-hr period). Operative planning is based on analyzing the status of FMS equipment (utilization of machine tools, the level of warehouse stock, high-quality equipment maintenance and condition and

capabilities of the automated material handling system that serves the FMS) and workstation demand. Operative accounting performs the feedback in the system; its main goal is to reflect in real time the current production status directly at workstations and in warehouses.

Due to the above features, planning in FMS is mainly performed using heuristic, as a rule analytic/priority techniques.

When the proposed system for planning and distribution of and accounting for current work (SPRUT-R) was developed, the above mentioned features of the structure of such systems were taken into account. The system is oriented toward a specific object and is designed for implementation of a complex of organizational and economical problems of the upper level of the FMS control system (CS).

The SPRUT-R system is based on the principle of construction and subsequent concrete definition of flexible (renewed every day) sequences of production run starts and a forecast on meeting these sequences in the form of a short-term schedule (for one, three or ten days). The SPRUT-R system is designed for realization of the full complement of planning and accounting functions that support automation of the entire complex of planning work in FMS, from monthly (quarterly) planning to issuing shift and daily schedules (SDS) to flexible automation shops (FAS) and down to compiling operation-by-operation plan-schedules for all types of equipment.

The SPRUT-R system must perform the following functions:

- plan and distribute jobs among production department FAS, based on the department's monthly (quarterly) plan;
- calculate shift and daily targets for each piece of machine tool equipment for all FAS;
- operatively distribute jobs among all types of FAS technological equipment;
- calculate and issue assignments for preparing blanks, tools and fixtures in accordance with the adopted work plan for the three-day horizon level;
- start emergency production runs of parts on production department's directives;
- keep track of the status of warehouse stock of blanks, tools and fixtures;
- calculate and issue assignments for deliveries to the warehouse, in accordance with shift and daily schedules and based on current stock;
- make up a sequence of deliveries from the warehouse;
- control the meeting of shift and daily targets;
- keep track of equipment operation in various modes and accumulate these data for a period specified by the production department;
- make 10-day forecasts on meeting plan targets, in order to make timely corrections in job distribution, on the one hand, and prepare the bases, on the other;

- archive information on parts that have been machined;
- provide technological and accounting information to various department shop subdivisions;
- exchange information with middle-level computers.

An FMS control system is built based on a hierarchic structure. Such organization of the FMS control system makes possible a step-by-step implementation of the system.

The FMS control system has three hierarchic levels: at the lower level, problems of direct programmed control of process equipment are solved, and at the middle level they solve problems of coordinating the operation of FMS equipment. At the upper level of the control system, operation of all FAS is coordinated and organizational and economic problems are solved; these problems are combined into the SPRUT-R system for planning, distribution and accounting for on-going work.

The upper level of an FMS control system is realized on an SM-4 minicomputer. The software for the SPRUT-R system functions in the OS RV operating environment. Interaction between the levels can be accomplished either via communications channels, with appropriate hardware and network support, or with the help of external information carriers (magnetic media, punch tapes or documents). Information can be exchanged either in real time or periodically, at intervals that meet basic requirements of operation of the control system.

The Figure shows the functional structure of the SPRUT-R system. The system objectives can be conventionally subdivided into functional and service (those that process data and generate output documents) problems.

The central objective of the system is to form the queue for starting production of part lots. The queue is formed daily and serves as input information for main functional problems. Time distribution of the queue in the form of a production schedule is only used as a forecast for controlling the status of meeting the plan target and for timely correction (if needed) of the formed queue.

The daily composition of the queue is determined based on the remaining volume of units of planning. A unit of planning in the system is a lot of identical parts machined at the same arrangement (an arrangement is a set of machining operations that have a common control program or are performed on the same technological base). A part machining routing includes several arrangements, with control operations between them. Initially, the volume of units of planning is formed based on the current month plan target and on the remainder (if any) of the last month plan.

The system provides for daily additions to the planned volume when extra-plan assignments or assignments to make up for rejects arrive.

The queue is formed according to production start priorities. Parts get a start priority in the following order: parts made on an emergency basis per the production department assignment; parts with the critical production start time; parts with the production department priority tag; parts for which the last month target has not been met; parts machining of which has started on at least one arrangement; parts with the maximum number of arrangements in the machining routing; and all remaining parts in the order of the diminishing length of machining.

Based on the calculated queue, FAS schedules for the current 24-hr period are formed. In doing this, one uses data on resources of machine tools for the current 24-hr period. At this stage, a specific machine tool is assigned to each unit of planning. Only part lots that have equipment assigned to them are included into the schedule.

Assignments for timely preparation of bases and for delivery of required blanks, fixtures and tool sets to the warehouse form problems for calculating production planning for the next three days (calculations are done once every three days) and the next 24-hr period (every day it is specified what and how much must be delivered to the warehouse in order to do the jobs scheduled for the next 240-hr period).

In order to meet a shift or daily schedule, the system gives each shop a detailed list of jobs, which includes the machine tool code for each unit of planning, lot size, number of control machining program, tool set composition, number of the program for tool loading and unloading, fixture code, and the sequence of delivering parts from the warehouse to the machine tool. This information (work plan-schedule) constitutes input information for the middle level of the control system.

One also keeps track of changes due to the fact of machining. The problem uses data formed by the system of interlevel communications, which operates in real time.

In problems that form the schedule (meeting the forecast, calculating the schedules and daily process planning), one uses a one-time simulating algorithm that uses the principle of non-delaying dispatcherization.

The SPRUT-R system is calculated daily, however, the composition of problems can be different in different calculations, depending on the calendar or on arrival of additional assignments. Thus, at the end of the month one solves the problem that takes into account and summarizes the results of fulfilling the plan of the ending month, whereas when new plan assignment arrives one solves the problem that forms data for the new plan. Based on these latter data, plan production volume for each item in the product list is subdivided into lots, and the initial volume of work is formed. The same problem, which is being solved once a month, calculates characteristics for each item in the product list, i.e., machining

time per arrangement and total length of the machining cycle, production run start times etc., which are later used by other problems in the system. When additional assignments arrive, the problem of adding units of planning to the production volume and recalculating the characteristics is included.

Daily solution of the system problems begins with the FMS operator processing input documents, such as assignment for an emergency production start, a list of start queue corrections, reject notices, on-line data on the status of machine tool equipment for today and tomorrow etc. In the first place, the system solves problems that analyze data changes during the previous 24-hr period, as well as problems of correcting production volume characteristics and models.

Then, a chain of problems on calculating new shop schedule is included in the system. After all parts that remain in the production volume have been assigned production start priorities, the production start queue is formed. Then, a schedule is compiled, and a 10-day forecast is issued (the problem is solved once every 10 days or on request). If there is a list of corrections, the queue is corrected. Once every three days a three-day production process planning assignment is calculated; the calculations are made ahead of time (on the first day of the current three-day period, the process planning for the next three-day period is calculated).

For the formed queue one checks stock at shop warehouses, and those items in the queue that have everything ready in the warehouse are included in shop assignments for the current 24-hour period, with full utilization of machine tools. Assignments that have not been fulfilled during the previous 24-hour period remain in the new schedule as the first-priority items.

Units of planning scheduled for the current 24-hour period are deleted from the queue, and from the remaining first-priority items the process planning assignment for the next 24-hour period is formed, with delivery to the warehouse during the current 24-hour period. The assignment names a specific machine tool, and hence the shop and delivery warehouse, for each part lot.

In order to return parts in a timely manner from the quality control performed outside the shop and continue its machining, the system forms an assignment on delivering parts from shop warehouses.

System's job ends by forming data transmitted to the middle level of the control system, in order for all types of technological and material handling equipment to meet the schedule.

Any problem in the information-reference subsystem can be solved on shop's request.

The above examined functions of the system, as well as the structure of the control system determine software composition of the SPRUT-R system.

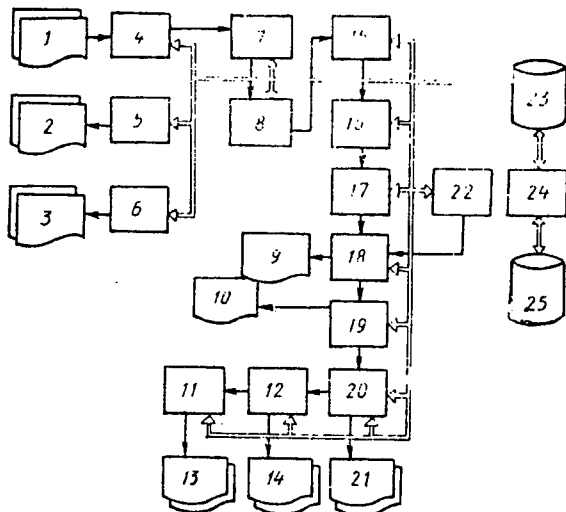
The extrahardware base of the system includes input and output data. The intrahardware base is organized in the form of linear data files and is stored in cassette disks and package disk devices of the CM-4 computer. In order to correct a database organized in this manner, appropriate problems are included into the system. The size of the information database for 100 part items and 20 machine tools is 2MB.

The SPRUT-R system has been developed for a metal-working FMS which is being created in an operating production department of PO [production association] "Kirovskiy zavod". The reason this production department was chosen as an object of flexible automation is its experience in operating machining-center-type CNC machine tools IR-500 with a Fanuc 7M CNC system. This choice seems to be the most economically efficient and rapidly realizable under the conditions of an operating enterprise and the rigid timeframe given for the development. From the beginning, a strategy of step-by-step FMS development and implementation in the form of flexible automation shops was adopted.

At present, out of six projected FAS shops FAS-1, -2 and -3 with the total of 11 machine tools are in experimental-production operation. FAS-1 and -2 shops have four machine tools each, installed on two sides of the automated warehouse with a 275-cell capacity and an RSK-250 warehouse robot. An automated material handling and accumulating system TNS-1 which serves both shops includes a warehouse with an automated stacker, two monorails with two overhead material handling manipulators, and a balanced manipulator. TNS-3 serves FAS-3. It includes an accumulating warehouse with an automated stacker, three pallet devices, a loading site and a balanced manipulator. In the future, the FMS will be expanded by commissioning new stages of FAS.

Functioning of the SPRUT-R system is limited by the following requirements: the size of the part lot may not change between arrangements; all machine tools in an FMS must be interchangeable; there is no provision for simultaneous machining of two or more part lots of the same type and at the same arrangement on different machine tools in the shop; limitations on planning parts using the same fixtures are not considered. Tools must be changed in sets, based on the minimum standard longevity of tools in a set. Principles that form the foundation for the SPRUT-R system can be used in developing similar systems, because functional problems that arise during development of control systems for various objects are identical in contents, provided the structure and purpose of the objects do not vary much.





**Functional Structure of SPRUT-R System:** 1. input documents; 2. reports on fulfilling monthly and quarterly plans; 3. summaries, reports etc.; 4. processing of input documents; 5. summaries of monthly, quarterly etc. results; 6. generation of reports on request; 7. data correction based on results of processing shift and daily schedules; 8. correction of warehouse models based on the current status; 9. forecast of time distribution of the queue; 10. three-day process planning assignments to department shop subdivisions; 11. making assignments on deliveries from the warehouse; 12. making process planning assignments for the next three days; 13. shop assignments; 14. process planning assignments for shops; 15. setting or adding to the volume of planning units; 16. assigning production start priorities; 17. devising the production run start queue; 18. compiling the machine tool utilization schedule; 19. setting a three-day process planning assignment; 20. making up the shop's shift and daily schedules; 21. daily shop schedules; 22. correction of start queues; 23. SPRUT-R database; 24. system of interlevel communications; 25. middle-level database

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### Electrical Engineering: New Forms of Socialist Cooperation

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No 8, Aug 88 pp 10-13

[Text] At present the Soviet electrical engineering industry is launching cooperated manufacture and coproduction with the CMEA member-countries and Yugoslavian partners as a part of its international economic cooperation. Soviet enterprises and other industrial and scientific organizations are being more widely involved in this cooperation. Elimination of administrative-bureaucratic obstacles hindering the development of foreign economic ties between the USSR and the other socialist countries' economic organizations gave rise to problems which Soviet enterprises had never faced before. The

main of them is to balance deliveries under the agreement on cooperation in production and for joint enterprises to attain a positive trade balance after settlements with their foreign partners.

Two objective difficulties cause these problems: incompatibility of the USSR and any socialist country internal market's capacity and higher prices for industrial engineering products in the CMEA member-countries as compared with the USSR's wholesale prices. Hence the low effectiveness for Soviet enterprises of their foreign economic transactions. Due to this, direct ties and other new forms of cooperation in this sector were not so efficient as expected, and the quantitative indices of the established new forms of contacts have not so far resulted in qualitative changes. Thus, despite the fact that in the electrical engineering industry over 80 pairs of the USSR and the socialist countries' enterprises established direct ties, only seven or eight of them will assure cooperated deliveries in the near future. The same tendencies are observed in setting up joint enterprises.

From the experience of industrial cooperation in the electrical engineering industry one can conclude that the expediency of arranging cooperated production with the CMEA member-countries' and Yugoslavian enterprises as a rule can be assessed using economic and technical criteria. The choice of these criteria does not mean that economic criteria lack a technical base, or, vice versa, technical criteria exclude an economic foundation. The need to use these criteria is predetermined in the first place by imperfections in the present international cooperation mechanism.

Proceeding from the economic criteria the arrangement of cooperated production can be justified if cooperation enterprises have compatible production volumes, identical methods of calculating production costs. In this case cooperation cost effectiveness is reached primarily through raising the level of series production with all the subsequent advantages stemming from their arrangement of production processes. In this instance the choice of a cooperation object is not of prime importance. The main thing is that the two countries' enterprises have a developed production of identical goods with a proper level of standardization and the possibility of dividing the production process.

However, at present it is difficult to arrange cooperated production of traditional mass products due to basically different price calculation methods currently practised by the CMEA member-countries and an imperfect price-forming system in the socialist community countries. The greater the output of the product the greater may be the losses for one of the partners. That is why the more promising form of arranging cooperation in manufacturing usual series products is now that of setting up joint industries and enterprises providing these products have a steady high position on the world market as joint enterprises are generally export-oriented. These enterprises' acceptable performance can be assured through

using contractual prices oriented towards world ones. The most important national and the community's task is to bring together and then standardize the economic criteria used in the CMEA countries for determining the mutual advantage of economic cooperation.

Taking into account the imperfection of economic criteria of cooperation at the present stage of integration, technical criteria seem more effective when arranging cooperated production, i.e., the qualitative change in the products' technical level reached in the course of cooperated production. Partners cooperate as a rule in manufacturing high-technology products with a restricted output. In this case also the partners have different economic interests but, first, this difference is limited in scale and, second, it is covered by the profit gained from raising production's technical level.

As a result, when using technical criteria of cooperation it is rather easy to solve technical-commercial, including price, questions which makes it possible to assure balanced deliveries under a single contract. A greater effect is gained in cooperated production under licences, know-how and use of modern basic equipment. Here the cooperation bears a precise industrial character ensuring the products' high technical level and high quality. The possibility of a quick solution of technical-commercial questions helps arrange production in the shortest possible time.

A typical example of such cooperation in the electrical engineering industry is production of special basic equipment. In 1987, the Osnastka production association (in Novovolynsk, USSR), and the economic association Elprom (in Bulgaria) established direct ties and signed an agreement on specialization and cooperation in manufacturing special basic equipment for producing electric motors. In line with this agreement Soviet basic equipment will be fitted with Bulgarian electric drives and a portion of this special production equipment will be shipped to Bulgaria. The cooperation will raise the partner's labour productivity and improve the special basic equipment's performance characteristics.

Special basic equipment needs accessories having design peculiarities for the specific type of electric motors. Taking this into account the second stage of cooperation will be the elaboration of documentation and arrangement of the production of accessories at the Elprom enterprise, first for special equipment supplied from the USSR to Bulgaria and then manufacture of accessories to the Soviet specifications for the enterprise in Novovolynsk. By expanding the range and volumes of Bulgaria's cooperated deliveries of accessories to the USSR without additional capital investments will make it possible to increase the special basic equipment output by 15-20 percent in the USSR and effectively use Bulgarian unique metal-working equipment.

At the third stage of cooperation, in the case of successful realization of the two previous stages, it is envisaged to set up in 1989 and 1990 a joint experimental design-technological bureau and assure coordinated development of productive capacities at the two countries' enterprises for further expanding the range of cooperated production, developing by-unit specialization, and advancing new products on third countries' markets.

The practice of international cooperation in the electrical engineering industry vividly confirms the fact that cooperated production is effective when using the outlined technical criteria of its arrangement despite their nominal difference from economic ones. Thus, under a licence, which the VNIKP scientific-production association sold to the GDR's and Czechoslovakia's enterprises, cooperated production of medical tomographs is being established with these two countries. The Leningrad Elektrik factory and the Yugoslavian firm Iskra for two years already have been practising cooperated deliveries of units for assembling automatic flux welding machines at both enterprises. Cooperation in by-unit specialization made it possible to upgrade the automatic machine's technical level, substantially increase labour productivity and the culture of production. Deliveries are realized on a balanced basis. The production of household air conditioners at the Bakkonditioner production association and the firm Unioninvest (Yugoslavia) has been arranged in similar manner.

At the same time the attempts to arrange cooperated manufacture of asynchronous motors, switches and certain other articles of high volume but of low technology production were without success. On the whole despite the fact that the socialist countries' electrical engineers have been cooperating for fifteen years already under Interelectro, the role of cooperation in the participating countries' activity is extremely insignificant. As an analysis made several years ago showed, many socialist countries are still import-dependent on certain types of electrical insulating materials, multilayer printed circuit boards and special types of cables. Interelectro's long-term plans do not envisage joint realization of such projects. For instance for several years the joint creation of small-tonnage productions of deficit polymer electric insulating materials has not yet been realized in practice.

These problems appear to be solved through setting up joint enterprises. Of course, in this case one should face complicated commercial economic problems which now block the arrangement of cooperated manufacture of multi-series products. True, the very nature of a joint enterprise permits settling price problems through agreement with a purchaser. However, the question of balancing deliveries can be solved only by advancing on third countries' markets. Over the last eighteen months the industry has studied more than 20 proposals on setting up joint enterprises with the socialist countries's enterprises and capitalist countries' firms. Decisions on most of them are still in abeyance. This is understandable to a certain extent as Soviet enterprises for their successful

operation must gain not only the experience of international cooperation but also that of work based on self-supporting and self-financing principles.

But the question is much broader. Proposals for setting up joint enterprises in the Soviet electrical engineering industry with the socialist countries' partners often based on the supposition that they will be financed from the state budget. Moreover, it is assumed that the products' range will be specified after joint researches. Such an uncertainty from the very beginning commits an enterprise to a prolonged period of "growing pains" if it survives at all. The establishment of joint enterprises is impossible without a precisely defined technical production foundation, that is why projects with a shorter list of products seem more realistic.

All the above testifies that for setting up joint enterprises just as for arranging the whole industrial cooperation it is necessary to overcome the established stereotype way of thinking, primarily the habit of relying on the state's funds. Operation based on a self-supporting principle makes them rely on themselves, hence the main demand made on joint enterprises—they must be not only internally self-accounting but internationally as well, and their products highly competitive. Naturally, the partners must be sure of potential commodity markets and the possibility of balancing mutual settlements.

It should be pointed out that when setting up joint enterprises there are two ways of realizing the set task:

create (construct) new joint productive capacities with large investments and a long construction period;

set up joint productive capacities with relatively small investments which will begin manufacturing products in twelve or eighteen months.

An example of the second approach is the final stage of coordination of a project of setting up a joint enterprise in Poltava for manufacturing polycore tubes for highly effective light sources between the firm Tungsram (Hungary) and the Poltava factory producing gaseous discharge lamps. The firm's contribution is production equipment, and finished products will be distributed according to the share of invested capital. The firm Tungsram will realize its portion (40 percent) of products on the foreign market and this will help balance settlements as Hungary's internal demand for this product is limited. The Soviet partner managed with its own means, without resorting to credits or budget subsidies. Premises for this enterprise already exist. It will begin manufacturing products in 1989 and by 1991 will reach its rated capacity. Of note here is the fact that it will be put into operation stage by stage thus making it possible to test the new production with pilot lots (to reduce possible losses) and not to prolong the construction time.

Another successful example of setting up a joint enterprise is the creation of a workshop manufacturing brush semi-products (Elektrougli) in which several Interelectro's member-countries are participants. The countries' contributions are deliveries of special basic equipment. Settlements will be in terms of finished product deliveries. Premises for this joint enterprise have already been built. The workshop will be commissioned in 1990. The deliveries of brush semi-finished products from the USSR to Interelectro's member-countries will enable them to stop importing these products from the capitalist countries and increase d.c. machines' reliability.

Unfortunately, it is not this approach that is prevailing. At present the industry has several proposals on setting up joint enterprises for manufacturing special production equipment such as low-voltage electric motors and high-voltage equipment in the USSR. Realization of these proposals requires scores of millions of rubles of capital investments and a long construction time. Certain heads of enterprises in the electrical engineering industry boldly endorse such proposals, evidently believing that the state will finance all of them.

When setting up large modern industrial projects requiring a long construction time, objective technical and commercial difficulties arise hindering their realization as joint enterprises. For partners in the relatively small socialist countries just as for capitalist firms the commodity market's situation is very important as the modern production in these countries is export-oriented. Due to the rapid change of technologies and introduction of new materials nobody can say for sure that in 5-7 years (even if projects are constructed in a relatively short time) products to be manufactured will suit the world market.

The CMEA member-countries' partners have already gained a certain experience in arranging joint enterprises with capitalist firms, we stress arranging, not setting up joint enterprises. The economic essence of such a joint enterprise is that a new production for turning out certain products is being organized at existing free industrial premises. As a rule this is accompanied by the purchase of a licence, know-how, basic equipment, a portion of materials and components from the firm. It takes twelve to eighteen months from arrangement of the production to the manufacture of finished products. Goods are realized on the internal and foreign markets with a cooperating firm's trade-mark. Such ways of organizing production make it possible to obtain not only internal but also foreign credit without any complications.

The Soviet Union has a powerful scientific base for manufacturing products such as: certain types of electric welding and special basic equipment, power semiconductors and modules, low-power hydroelectric generators; products very competitive on the world market have been designed. However, the high potential export

possibilities are not being realized to the fullest extent due to limited productive capacities, prolonged time of introducing new equipment and insufficient commercial training of specialists.

In these cases it is desirable to quickly set up joint enterprises, with receiving from the partners, first of all, modern basic equipment and using their commercial experience. Necessary industrial premises can be released by increasing the shift coefficient. The solution of organizational questions, in line with the latest directives, is simplified to the maximum degree and is within the competence of the industry's and enterprises' administration. At the same time the responsibility for realizing the adopted decisions is sharply increasing, which requires the high professional technical and commercial ability of executives and leaders of all grades. That is why when establishing direct ties and joint enterprises an important aspect of international cooperation is to acquire commercial work habits, use socialist enterprise primarily by studying the experience of colleagues in other socialist countries.

Other matters complicating the development of international economic cooperation in the electrical engineering industry should be mentioned. If, after all the efforts exerted, we can only speak about a few examples of cooperated production or single product deliveries under the direct ties it is to a significant degree a consequence of the centralized system of distribution of materials and components. Because of this enterprises can fulfil not macroeconomic tasks but only local ones. Loading productive capacities with state orders only stifles any real possibilities for manoeuvrability in promoting exports and the calls to abstain from using the residual allocations of funds for export are still not being obeyed. As regards the enterprises' economic independence concerning the expansion of export deliveries it is extremely limited.

An example. During the Yugoslavian specialists' visit to an electrical engineering enterprise it received a preliminary (profitable) order for the long-term delivery of electric motors (the annual export volume 1.5-2.0 million dollars). The firm agreed to undertake the commitments to render assistance in arranging the production and supplying necessary basic equipment. However, the question is not that it is difficult to arrange the production but that it is difficult to obtain the necessary materials because the ministry is not interested in delivering them.

The question about the realization of an enterprise's currency deductions from a foreign market transaction has not been clarified properly. Thus, even for such a powerful association as Elektrosila, having its own foreign trade firm, the purchase from Poland of personal computers covered by its currency deduction fund was performed with violation of instructions and is an example of a prejudiced enquiry by control bodies. To

increase enterprises' interest in developing export deliveries they should be granted permission to independently conclude contracts with other socialist countries' enterprises and organizations and freely use the currency received.

Despite the fact that the latest decisions adopted by the directive bodies expanded the enterprises' rights and possibilities in the international cooperation sphere, certain old instructions and regulations hold back the development of new forms. Thus, it is very difficult for Soviet enterprises to independently use such forms of cooperation widely practised on the world market as trade in R&D, licences, knowhow, assembly and adjustment services, leasing, etc.

A system for crediting organizations undertaking cooperated production under direct ties is not yet functioning. However, in Bulgaria, for instance, for setting up an effective modern production unit with a short repayment period internal and international credits are used, foreign equipment is leased and the partners actively cooperate on third countries' markets.

Nevertheless the main obstacles hindering the wide development of Soviet electrical engineering enterprises' international economic cooperation are: a parasitic attitude and a passive approach to this important matter and the attempts to arrange cooperation to the established scheme, i.e., scientific and technical cooperation for a 3-5 year period with the building of a prototype, and only in the distant future, with the essence of cooperation becoming already outdated, the industrial cooperation. This is due to the formed stereotype way of thinking.

The industry's prime task is to overcome these attitudes, and the objective obstacles raised must not be taken as convincing. Obstacles are obstacles but there are electrical engineering enterprises (few so far) which started the ball rolling by surmounting them in arranging international cooperation.

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#### **Integrated Automation in CMEA Countries: Current Problems**

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[Article by Ivan Medvedev and Dmitri Sadovski, Institute of the Economy of the World Socialist System, USSR Academy of Sciences]

[Text] Integrated automation is one of the priority trends of cooperation of the CMEA countries under their Comprehensive Programme of Scientific and Technological

Progress up to the Year 2000. The existence of flexible manufacturing systems (FMSs) more than anything else reflects the state of integrated automation in the sphere of material production.

At present there is not as yet a universally recognized definition of the concept of the flexible manufacturing system and many other elements of integrated automation. With the accumulation of experience in their design and employment there is a notable approximation of the definitions individual countries are now using. In the present article the authors proceed from the international terminology accepted in the UN Economic Commission for Europe.

The rapid growth of integrated automation facilities may be judged by the rates of their output and expert assessments of their prospects. The world FMS stock in 1986 numbered about 500 units. Today the number of FMSs operating in the world doubles every two years. By 1990 dozens of factories with unmanned technologies (automated factories), thousands of FMSs, tens of thousands of flexible manufacturing cells and many hundreds of thousands of industrial robots (IRs) will be in operation. The sphere of their application will also expand in the future (today they are chiefly used in the machine tool, automotive, aerospace and electrical industries), more systems will be developed for sophisticated operations.

Besides their great advantages, however, integrated automation introduces into the production process a series of problems. The high cost of FMSs and difficulties found in operating them raise the question of their well-organized production and effective use. An analysis of the activity of producer firms and users of flexible automation technology shows that success here depends above all on the producer's ability: a) to guarantee the high reliability of all FMS components without exception; b) his close cooperation with the user throughout the entire period of exploitation;<sup>1</sup> c) sufficiently full supplies of software packages (SP), special fittings and tools; d) capability of systems sold of being built into fully automated lines of production (up to and including automated factories).

In the CMEA countries with well-advanced machine-tool construction, the development and operation of the first flexible automation elements began practically at the same time as in the capitalist countries (in the late 1960s and early 1970s). In the early 1980s R&D in the area of automation in the GDR, the USSR and Czechoslovakia was sufficiently high; these countries accounted for a considerable portion of the world FMS and IR stock.

At present nearly all CMEA members have organized the output of this equipment and are increasing its mutual shipments. Under the General Agreement of 1982 mutual deliveries of industrial robots between the CMEA countries in the 1986-1990 period will increase up to 11,500 units as compared with 2,500 units in

1981-1985. Many of these will be delivered as parts within FMSs and robotic complexes. Between now and 1990 the USSR will receive from the GDR alone over 150 FMS and metalworking production sections.

In the current five-year plan period the USSR is expected to build 2,000 FMS of different capabilities (in the mid-1980s the Soviet engineering industry had about 60 of them). In the GDR 27 FMSs were functioning by the end of 1985. Between 1986 and 1990 about 85,000-90,000 automated units will be available in the republic for designers and technologists; the output of IRs will amount to 75,000-80,000 units, including about 12,000 adaptive robots.<sup>2</sup> The high rates of output of integrated automation technology are planned in other CMEA countries as well.

The USSR's cooperation with the CMEA members in the area of integrated automation is in the embryonic stage. Even now, however, quite evident are the main problems in this respect: the "old" problems characteristic of most engineering industries, and "new" ones arising from the specificity of the integrated automation process.

Among the "old" problems we shall mention the insufficiently high standard and quality of the bulk of mutually supplied products, shortcomings in servicing, poor cooperation in production. When it is a question of integrated automation, however, these phenomena acquire fundamentally new features. The consequences for the user of the breakdown of, say, an ordinary metal-cutting machine tool or a machining centre within a FMS substantially differ. In the first case the technological operation may be carried out on another machine tool, and the production process interrupted in one of the elements of the system is "sutured" as it were. In the second case the harmony of the technological process is upset and the breakdown of one of its elements may stop the process with all the ensuing organizational-managerial and economic consequences. Thus, without an economic mechanism capable of assuring the high quality and reliability of articles, regular shipments and proper technical services integrated automation has no chance of success.

"New" problems arise above all from the specific-functioning of modern sophisticated computer-controlled technological systems. The main of these problems are: 1) discrepancy between the scientific and technical standard and quality of the electronic element base and non-electronic components of a flexible manufacturing system; 2) insufficient provision of FMS control devices with the needed software packages; 3) lack of effective forms of inter-sectoral cooperation between the CMEA countries' enterprises and institutions working in the different directions of integrated automation (FMSs, computer-aided design, computer-aided manufacturing, IRs, computers of the fifth generation, expert systems, artificial intelligence elements, etc.).

The Achilles heel common to all CMEA countries in developing and manufacturing flexible automation technology lies in the insufficiently high reliability level of the microelectronic element base. To supply the CMEA market with ever more reliable automation facilities the plan is to organize their output on the basis of the USSR's science-production potential, with the leading institutes and enterprises in other CMEA member-countries taking part. First steps have already been taken in this direction. The Inter-MOS joint venture has been set up by the Mikroelektronika factory in Budapest in which the Hiradastechnika cooperative and two Soviet organizations are participants. The venture will specialize in developing, manufacturing and marketing large integrated circuits. They will be produced with the use of Soviet equipment, technologies and know-how.

Large-scale technological projects in the area of microelectronics are intended to obtain superlarge integrated circuits with a degree of integration considerably exceeding one million elements on a crystal (with a capacity of one, four and sixteen megabits and more), superhigh-speed gallium-arsenide circuits, etc. These devices will determine the competitiveness of the control systems of integrated automation facilities in the 1990s. The mastering of submicron technologies in electronics is a guarantee of the successful development of the fraternal countries' entire engineering complex.

Already in the late 1990s real possibilities will arise for the change of the information control systems of integrated automation facilities to photon and biotron technologies (electron-optical and biocomputers), which can subsequently supersede microelectronics. The orientation of Soviet developments and cooperation along these guidelines within the CMEA framework reflects the country's strategy targeted at a technological breakthrough in the area of integrated automation.

Central to the acceleration of scientific and technical progress in the USSR (as in all industrialized countries, but only in a much more acute form) is the utilization of diverse achievements in Soviet science and technology and their innovation. The search for new ways of fusing science and production in the USSR has already led to the creation of the ISTC (intersectorial scientific and technical complexes). Their functioning, however, is still being adversely affected by the departmental disunity of their participants, non-coordination of their development strategies. Evidently this form of stimulating scientific and technical progress should not be the only one. It may organically be supplemented with a broad network of not very large (small and medium) ventures which may lead to the formation of large manufacturing enterprises on their basis. It is precisely this way of integrating the research and production stages of the reproduction cycle that makes it possible to control subsidiary (so-called spun-off) researches and utilize the multiplication effect. In the USA the small research

business in the form of ventures and spun-off firms is becoming a major factor accelerating the investment process in the most advanced technological areas.

Latest achievements in mastering the new element base (including the electron-optical and the biotron one) may be expected from self-supporting ventures, which are fully independent or form a part of science-production associations (SPAs) as self-supporting entities (the so-called internal risk).

The CMEA countries have acquired some experience in setting up such ventures (Bulgaria, Hungary), including those in the area of integrated automation. Indicative in this respect is the example of the Volna venture which is a part of the Beroe production-economic complex (a typical internal venture). On the basis of Bulgarian original technology, Volna, drawing on personnel and financial support from Beroe, organized serial production of wave reducers which, besides their use in integrated automation elements (machine tools, IRs), will be applied in hundreds of different machines and mechanisms, thus making revolutionizing changes to them. In the two years since its formation Volna has become a major supplier of wave reducers for the world market, where their average price runs at 600 dollars per unit. In the CMEA countries it is the only enterprise turning out these products (the USA and Japan also manufacture wave reducers).

The Volna venture with its serial production, which is still restricted as compared with the demand for its products in the CMEA countries, is a typical example illustrating the dire need to set up a new element of cooperation between the CMEA members such as an institute to finance "risk and innovation measures". It could flexibly respond to the appearance of promising developments and stimulate their large-scale application. We may judge the potential volume of such a fund if only by the fact that in 1986 Sofia already had over 80 small hightech enterprises, most of which were engaged in the fields of electronics and integrated automation.

As another form of fusing science and production we may mention interim scientific and technical collectives (ISTCs) for implementing promising ideas and projects directly pertaining to integrated automation. In March 1985, for instance, the ISTC was set up in the USSR to develop a dummy model, and if successful, an experimental industrial prototype of the supercomputer of the fifth generation based on the principles of parallel architecture. Some developments relating to this project give an appreciable multiplication effect, i.e., they may be used as basis ones. KamAZ, for instance, plans to purchase from the ISTC a set of technical specifications for the Kronos processor to use them for automatizing assembly operations. In the future KamAZ also plans to purchase a supercomputer and use it as the master computer of all flexible automated manufacture (FAM). Industry in the USSR and other CMEA countries is in dire need of this type of computer, which is why it would

be expedient, if the above project is a success, to set up on the basis of this ISTC an applier firm with a prospect of becoming an enterprise for developing and manufacturing supercomputers. It is precisely in such cases that the institute financing "risk and innovation measures" may be of great benefit and transform ISTCs into high-tech enterprises.

The complexity of integrated automation systems makes the development and application of software packages (SPs) a top priority. Modern microprocessor-based programmable devices greatly exceed the possibilities of the programmes so far developed. The lack of skilled personnel in the field of SPs is an impediment to raising the competitiveness of integrated automation technology in several highly developed countries (Japan for instance). A programming industry is being set up which is notable for extremely high growth rates.<sup>3</sup>

Insofar as in most sectors of the Soviet economy software packages have no commodity status, the main problem facing the users of flexible automation programmable devices is the underemployment of their potentialities and, hence, the unprofitableness and ineffectiveness of integrated automation at many enterprises (chiefly medium and small ones) in the USSR's engineering industry. In some CMEA countries (the GDR, Hungary) the rapid rise in the output and use of integrated automation facilities and good outlook of the world SP market stimulated the purchase/sale of programme products on the home market and the dynamic export of software in its "net" form and as a part of programmable engineering articles (including their exports to Western countries). In Hungary, for instance, more than 50 enterprises and organizations are engaged in SP marketing, and here the share of small highly specialized firms in this particular market in 1985 reached 60 percent. Characteristic in this respect is their clearly pronounced export orientation: between 1982 and 1985, for instance, software exports (here the matter concerns solely "net" programme products without SPs as part of computing machinery and programme-controlled machines and equipment) to the capitalist countries increased fivefold. At present the export of programme products from Hungary increases by 30-40 per cent annually, and the country's earnings from their sales amount to 7-8 million dollars a year.

One of the world's largest highly skilled mathematical potentials is concentrated in the USSR; on its basis it is already now possible to launch the output of SPs, including those for export. Wider production and a larger stock of integrated automation facilities and computing machinery call for a change from a "handicraft" (non-automated) technology of manufacturing software products to their mass computer-aided design, fixing the number of copies, improvement and control. High costs (up to 20-50 rubles per instruction for a complex programme) and the long time needed to develop programmes of high complexity (several months) by a

non-automated method at user enterprises run counter to the aims and principles of flexible automated manufacturing.<sup>4</sup>

Elaboration of normative acts on planning, stimulation and price formation in the area of software products will give the manufacturers of computing machines and automation technology incentives to develop programming products. Broad opportunities open up in this field owing to the new legislation on individual self-employment (small cooperatives and owners of personal computers—software producers). There is also an imperative need to organize small ventures to operate in the area of software products and their servicing. All this is bound to become a legislative and normative infrastructure for setting up a programming industry.

This industry could well become an important export sector for the country. By available estimates, activation of the export of accompanying (as a part of programming equipment) and specialized "net" software products to the CMEA countries will make it possible to appreciably expand Soviet plant and machinery exports (a direct effect) and increase within a short period of time the capacity of the CMEA countries' potential market for engineering products. Today, however, the absence, in our computer and integrated automation technology shipments, of fully effective software products capable of meeting the requirements of customers not only markedly restricts the capacity of our home market and our software exports, but may even have an adverse effect on Soviet plant and machinery exports in general.

It is impossible to meet the growing requirements for computer and integrated automation technology without cooperation in this field, including cooperation in such forms as joint (mixed) ventures and amalgamation (consortiums) within large-scale interstate programmes (projects). In the CMEA countries, as distinct from the EEC for instance, such forms of cooperation in the area of software products have not yet become widespread.

Of particular interest, therefore, is the experience of the Soviet-Bulgarian research and design institution Interprogramma which has now been in existence for over nine years. Its developments of software technology are given to the latter national stocks of Bulgaria and the USSR for their wide use. The economic advantages of their application in the national economies of the fraternal countries over the past few years have topped 50 million rubles. In Bulgaria, Interprogramma's developments in 1986 were introduced at some 80 enterprises. The skilled personnel and the high level of supply with requisite equipment have enabled the institution to develop complex programmes for computers and different types of automation technology (information processing systems, computer-aided design, flexible manufacturing systems, etc.). There are developments in the area of non-traditional methods of building up software packages and automating the development of and fixing

the number of copies for the software product itself. At present Interprogramma is working on highly composite SPs for integrated automation manufacturing lines, which attests to the high level of the institution's developments and competitiveness. By the end of the 1980s customers are expected to get SPs for unmanned or partially manned production lines.<sup>5</sup>

The Soviet-Bulgarian machine tool-making ISPAs (intersectoral science-production amalgamation) set up in 1985 quickly overcome such previously difficult problems as the control of innovations in international cooperation, technological exchange, exchange of managerial experience, flexible specialization and cooperation in R&D activities and production, mass mutual shipments. In the 1986-1990 period alone two ISPAs plan to manufacture 2,700 machining centres, 13,000 numerically controlled machine tools for machining parts like solids of revolution and produce on their basis 4,200 flexible manufacturing modules and over 32,000 industrial robots.

For the Soviet-Bulgarian ISPAs to enter confidentially the CMEA and the world markets in the 1990s, they should substantially expand their production programme as concerns shipments of not only FMS elements, but also computer-aided design/computer-aided manufacturing, software package, and different services, i.e., they should be in a position to deliver the major elements of computer integrated manufacturing lines. This aim can be attained by organizing long-term cooperation with manufacturers of computing machinery and also by setting up joint ventures in which they can participate. In solving problems like the use of "artificial intelligence" elements and expert systems for controlling fully automated production lines, the Soviet-Bulgarian ISPAs and other manufacturers of integrated automation technology in the CMEA countries will be assured of success if they undertake large-scale projects in which the participation of institutes conducting fundamental research in the area of the "artificial intelligence" is obligatory.

The Interprogramma institution could become an effective partner of the Soviet-Bulgarian ISPAs in the field of integrated automation. World experience has shown that joint ventures and cooperative amalgamation, which also include specialized developers of complex software products, are now, in the second half of the 1980s, the most competitive developers of these products.

An analysis of the present tendencies in the field of integrated automation shows that with the growth of production and application of this equipment there arises a need for special services relating to its introduction and use. These services are rendered by both the FMS suppliers themselves and "systemhouses". The latter specialize in providing the above-said services only.

The demand for the type of services is already great in the USSR and other CMEA countries. Fulfilment of the targets set out in the Comprehensive Programme of the CMEA Member-Countries' Scientific and Technological Progress under the heading Integrated Automation will, no doubt, give this sector greater priority. Today, services for introducing integrated automation technology in the USSR are being provided by the Machine Tool Production Association in Ivanovo (true, on a gratuitous basis!); it has been decided to set up a centre for applying microelectronics and automation technology in the engineering industry in Ulyanovsk. As the authors see it, this type of activity could and should become an important aspect of the integration process. Organizations like the joint Soviet-Bulgarian ISPAs, the Interprogramma institution, the Soviet-Czechoslovak amalgamation Robot provide the base for developing the integration processes in this sphere.

#### Footnotes

1. It is through close cooperation with users (and by drawing on the long-standing experience of operating their own products), that US machinetool firms build over two-thirds of new machinetools, instrument-making firms also turn out nine-tenths of new instruments on the basis of such cooperation. *Sotsialisticheskaya industriya*, 16 November, 1986.

2. Neues Deutschland, 23 April 1986.

3. According to the American SP-producing firms, the demand for their products for integrated automation grows by 35 percent a year. The share of SPs in the cost of integrated automation facilities is also expected to rapidly increase: for instance, on the US market for computer-aided design/automated technological process control systems the proportion of SPs in 1983 amounted to 17 percent, by 1995 it will, according to forecasts, have risen up to 35 percent with a tendency to further growth.

4. At the Lenin Komsomol Car Factory (AZLK) in Moscow, for instance, in the current five-year period (1986-1990) 550 integrated industrial robots will be used with a total volume of control programmes exceeding one million instructions (even if use is made of simple programmes with a volume of 1-2 thousand instructions). And that without taking into account the potential requirements of the factory's other automation sections for software products. To develop and change these programmes in accordance with the requirements of flexible manufacturing it is extremely urgent and necessary to set up a specialized independent subdivision (small firm) within the factory to operate on the basis of automated technologies for developing, and fixing the number of copies needed and for perfecting software packages.

5. *Rabotnichesko delo*, 24 February 1986.



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**Practice, Problems of Conducting State Testing at Industrial Enterprises**

*18610422f Moscow STANDARTY I KACHESTVO in Russian No 4, Apr 88 pp 61-62*

[Article by I.I. Gerega, Karpatpressmash PO]

[Excerpt] Minstankoprom [the Ministry of the Machine Tool Building Industry] has developed a network of head organizations for State Testing of Products (GOGIP), their on-site testing divisions (BIP) and supporting stations (OP) at enterprises in order to obtain objective and reliable information concerning the quality of products manufactured in the branch at all stages of their life cycle, to prevent implementation into production of technically inadequate and underdeveloped products, and to realize control over stability of quality during the serial production process.

The head organization for testing casting equipment is the All-Union Scientific-Research Institute of Casting Machine Building, Casting Technology, and Automation of Casting Production (VNIilitmash), and that for testing welding equipment is the All-Union Institute of Welding (VISP). Their on-site testing division operates at the Karpatpressmash PO.

During the time of its existence the on-site testing division performed testing of 16 types of casting and mechanical welding equipment; of those seven products passed the acceptance testing, five products passed the qualification testing, and four passed the certification testing. State Testing was performed on serially-produced equipment, one-off and custom-built equipment, as dictated by the nature of production.

Based on the results of the performed testing, six types of equipment were tested again, from which it was recommended that one type of equipment be removed from production. The main causes of the negative results of state testing are:

- an inadequate level of design documentation development and its nonconformance with the State's standard requirements;
- an inadequate conformance of products with the technical documentation requirements (due to poor process planning);
- inadequate metrological support of production;
- violations of technological discipline during parts manufacturing and product assembly, and low level of technical control.

During the performed qualification testing of mechanical welding equipment, it was determined that process equipment lacks d.c. drive controls within the rotational speed range specified by technical norms, and certain control operations are not carried out. Violations of

technological processes of frame welding, surface finishing, and painting were found. It was determined that control cabinets do not conform with the requirements for moisture and dust protection.

At the same time, it was determined that there is a discrepancy in requirements on moisture- and dust-proofing of the control cabinets between those specified in GOST 14254-80 and those in GOST 21694-82 and the technical specifications for mechanical welding equipment; and that the standards and technical specifications (NTD) for casting equipment do not specify requirements for moisture and dust protection, in spite of the fact that based on conditions of its operation such requirements should be specified.

Based on the results of the performed tests, concrete proposals for revising GOST 21694-82 and the NTD for casting equipment were made and submitted to developers of these documents, namely, the VNIilitmash and the VISP.

In order to increase the objectivity and reliability of test results, 15 units of test equipment for branch, special, and general industrial applications were developed, manufactured, and certified; and five types and 15 working test programs and test methods were developed. An additional eight units of test equipment are slated for development.

Together with the VISP, measures for supporting testing with the necessary methods and test equipment are developed, a list of measuring instruments being used is determined, and test methods are revised. The complicated test equipment and test methods are developed by the VISP, the rest are developed by the on-site testing division.

The shortcomings determined during testing are carefully studied by the VISP, on-site testing division, and the services of the association responsible for production process planning quality. As a result of this work, product technology was revised, design documentation was corrected, and the list of measuring instruments and test equipment to be bought or developed was determined.

As the experience of working with the NTD for the State Testing of products has shown, certain items of the NTD concerning the technical, organizational, and standard-methodological bases of the testing being performed require corrections and certain additional work. Thus, in the set of the standards for State Testing, one cannot find direct answers to the questions concerning the forming of the commission responsible for testing, and the volume, form, and contents of the documents being prepared based on the results of qualification and certification testing.

GOST 16504-81 determines the types of State Testing and the purpose for performing them. It is obvious in connection with this that the order and program of the

testing performance, form and contents of the prepared documents, and requirements on the contents and volume of the working programs and methods, must be subordinated to the purpose of the concrete type of testing. However, there are no standard criteria for decision making based on test results. Therefore, each GOGIP requires....

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**First Results of Gospriyemka Discussed**  
*18610422e Moscow STANDARTY I KACHESTVO*  
*in Russian No 4, Apr 88 p58*

[Report by V.I. Kostyuchenko, deputy director of the Rudgormash PO: "It Will Not Be An Easy Life". Prepared for publication by M.K. Volkov]

[Text] Since 1 January 1987 our association has been working under conditions of both gospriyemka and self-financing. Therefore, we know well how much the activities of the new out-of-house monitoring costs us.

First, we had to restore earlier omitted or simplified process operations and to introduce new ones, including some for product control and testing. As a result, the labor intensiveness of production increased by 21 percent. Most of this increase took place in machining which was already the tightest bottleneck in our production. All this led to reduction in labor productivity and serious difficulties with regard to fulfillment of the plan.

In addition, the situation has become more difficult due to the fact that gospriyemka is in effect at a number of enterprises supplying us with assembly parts. Because of this, many deliveries have been interrupted, which makes the assembly process significantly more difficult. Thus, the Krivoy Rog Ore-Dressing Equipment Plant delays deliveries of drills because gospriyemka is not passing the masts for them. The Krivoy Rog machine builders have already shorted us 35 masts, as a result we cannot ship that same number of drills to customers, and each drill costs R117,000. For the same reason, the Kazan Compressor Plant has started supplying us with only one-third the number of compressors specified in our contract.

In addition to the difficulties mentioned above, some of the products manufactured by the association have lost their State Seal of Quality. We had to remove a number of obsolete machines from production which do not conform with modern requirements. Unfortunately, we have nothing to replace them with.

The problem is that the association has a large product list. Therefore, its products are being developed at eight different design institutes. However, they cannot offer us new equipment in place of that being removed from production.

In this connection, we are extremely interested in the design institutes being transferred to cost accounting and their designs becoming a commodity. The necessity of selling their designs by competing with colleagues would force the institutes to be more active in developing new, highly efficient high quality equipment.

We have great hopes for improvements in price-setting, because under conditions of full cost accounting and self-financing it affects our work and its results in many ways. The contract prices established for mutual profits of both the manufacturer and consumer shall have an especially important role. Meanwhile, we clearly have to overpay by replacing the obsolete equipment with new equipment having 30-50 percent higher productivity but which is 10-15 times more expensive than the equipment being replaced.

Thus, the experience of our enterprise is a convincing conformation of the fact that the transfer to work under conditions of gospriyemka, full cost accounting, and self-financing without proper preparations may cause serious difficulties to overcome which later will be substantially more difficult and expensive.

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**Results of Gospriyemka Show Improved Technological Discipline**  
*18610422d Moscow STANDARTY I KACHESTVO*  
*in Russian No 4, Apr 88 pp 57-58*

[Report by A.S. Grigorov, chief engineer of the Voronezh Heavy Mechanical Presses Plant: "Cooperation Is Difficult but Necessary". Prepared for publication by M.K. Volkov.]

[Text] At our plant gospriyemka has first of all helped to improve the technological discipline at all stages of work, from design and blank preparation to product assembly. The condition of the process equipment has sharply improved.

One cannot say that we did not test and adjust equipment before gospriyemka. However, for various reasons, such as the end of the month or an urgent order, this work was carried out quite often in an untimely manner and not at the required level. However, after acceptance of products was stopped twice because of unsatisfactory results from a process equipment inspection with regard to precision standards, order was established.

I must specifically mention that many difficulties we had to overcome were caused by the fact that the plant was not properly prepared for gospriyemka. We could not persuade the plant's workers that gospriyemka is not just another campaign but a very serious and strict measure, and that it is for real and here to stay. Today I cannot say that all people of the working collective have a proper attitude toward gospriyemka and its activities. Anyway,

the level of process discipline has sharply increased, that is, everything possible is done in order to fully implement the requirements of the standard technical documentation.

Initially, lack of necessary organization hampered the work of determining and correcting production bottlenecks. We got bogged down with numerous measures because so many things had to be improved and perfected. Therefore, we and gospriyemka management analyzed the situation, determined the most urgent tasks at the given stage, and agreed that biweekly the general director or the chief engineer would conduct a meeting with gospriyemka management where the status of resolving these tasks would be discussed. This measure significantly accelerated achieving stable operation of the plant.

In the joint work with gospriyemka of improving the product quality, attention was paid to improving the interaction with suppliers. Thus, gospriyemka representatives and people from the plant visited practically all our suppliers of castings and forgings. As a result of this, the quality of the supplied products has improved significantly, and castings from some plants even started to arrive already coated with primer.

Initially, significant difficulties were caused by the fact that much time was spent submitting the finished products first to the QC, then to gospriyemka, and finally, to the customer. Therefore, the plant management and gospriyemka made a decision, approved by USSR Gosstandart, to combine the most labor-consuming control operations during the acceptance of practically all manufactured machine and automated lines.

Of course, gospriyemka had added work for the plant personnel. However, as a result of that, our products started to meet all requirements. Therefore, the attitude of plant personnel toward gospriyemka is improving. I am sure that soon the union between the press builders and gospriyemka personnel will become even stronger.

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### Results of Gospriyemka Show Reduction in Product Quality Complaints

18610422c Moscow STANDARTY I KACHESTVO  
in Russian No 4, Apr 88 pp 56-57

[Report by P.A. Gurov, director of the Central Chernozem TsSM, "First Lessons", prepared for publication by M.K. Volkov. First four paragraphs are EKONOMICHESKAYA GAZETA introduction, under the rubric "Business Meeting".]

[Text]At the initiative of the Voronezh obkom of the CPSU and the editorial board of EKONOMICHESKAYA GAZETA [EG], a meeting took place between Gospriyemka [State Acceptance] personnel and the Centralno-Chernozemnyy Center for Standardization and

Metrology [TsSM], and the managers and leading specialists of a number of Voronezh enterprises. The meeting was dedicated to reviewing the first results of the work of laboring collectives under gospriyemka conditions.

Editor of EG N.S. Yakovchuk, Director of the Machine Building Department of the Voronezh Party obkom V.K. Deryabin, and representatives of Voronezhselmash [Voronezh Agricultural Machine Building Plant], the Heavy Mechanical Presses Plant, Voronezh Ore-Dressing Equipment Plant, and others, participated in the round table discussion.

The participants introduced a number of concrete proposals directed toward assuring successful activities of industrial enterprises under conditions of full cost accounting [khozraschet] and self-financing, and strengthening of all production lines.

Some of the meeting participants' speeches are published below.

Gospriyemka has become an everyday reality at 13 enterprises of the Voronezh oblast. Recently the Avto-genmash PO, the Machine Tool Building Plant, Large Residential Construction Panels Plant No 2, and the Tire Plant joined other enterprises working under gospriyemka conditions.

The main result of gospriyemka for the past year is a sharp reduction in product quality complaints. However, one cannot speak about a substantial increase in the technical level of products, we have still to attain that.

During the period when gospriyemka was being introduced, namely August to December 1986, it was anticipated that not only would out-of-house control organizations be formed, but also that enterprises would be prepared for work under new conditions using mutually developed plans of organizational and technical measures. However, many enterprises did not take the practical realization of these plans seriously. As a result, some of them found themselves technically, organizationally, and psychologically unprepared for gospriyemka. It caused substantial difficulties, especially with regard to production plan fulfillment. At the same time, it should be specifically noted that in those places where preparation for work under new conditions was carried out in a timely manner, where management organized comprehensive measures to increase quality as specified by the Party and the Government, and where gospriyemka acted thoughtfully and persistently, the introduction of gospriyemka was less painful and more successful.

In characterizing gospriyemka activities we should first of all note that they, as everywhere else, not only brought out the old problems of production but also forced the enterprises to take corrective measures. Thus, technical documentation was revised and brought into conformance with the standards in effect, new technological processes were introduced, operations that had been

omitted or simplified were reestablished, and more attention was paid to quality control and product testing. In addition, measures were taken to strengthen process and work discipline, and to increase the responsibility for rejects of both workers and managers. As a result, the number of complaints and claims from customers was substantially reduced, and poor quality products were caught before they left the enterprise.

We are glad that products of the industrial associations imeni Komintern, and imeni M.I. Kalinin, the Voronezhzernomash and Heavy Mechanical Press PO, and the Porcelains Plant have not received any serious claims recently. This is evidence that a shift in the direction of improved quality has taken place. The following data also show it: at most of the enterprises the proportion of products accepted by *gospriyemka* during the first submittal has increased from 30-50 percent to 95 percent.

At the same time, it should be noted that under *gospriyemka* conditions only three enterprises, namely, the Ore-Dressing Equipment Plant, Voronezhzernomash PO, and the Porcelain Plant systematically fulfill monthly production plans, in spite of the same difficulties with supplies of raw materials and parts experienced by other enterprises. Before, in their efforts to get good gross product figures, many specified technological requirements were ignored and parts of operations were skipped. Today, production workers must perform them and do it on a high level. Naturally, it has led to an increase in labor consumption and necessarily affected the fulfillment of plans. But it is not *gospriyemka* which is to be blamed, but those who allowed themselves to ignore requirements of standards and to violate the process technology.

The fact that at some enterprises the plans for organizational and technical measures were made in a hurry, not always thoughtfully, and for short term gain, should also be noted. Basic guidelines for the work were not determined everywhere, and as a result, efforts and money were dissipated. In addition not all problems can be resolved by enterprises independently. For example, enterprises cannot replace obsolete equipment or obtain the necessary equipment for testing and measuring after only six months. Enterprises are unable to resolve these problems without their ministries' help which, as of now, is in our opinion inadequate.

We, as representatives of USSR Gosstandart, while understanding the difficulties of enterprises caused by many unresolved complicated problems of modernizing the technical base of production, must note that what has been done is not all what could and should be done. Thus only 80 percent of the technical documentation at the Borisoglebsk Khimmash [Chemical Machine Building] Plant conforms to requirements of standard-technical specifications, and at the association which manufactures excavators only 50 percent of the technical documentation is in conformance. At the association imeni M.I. Kalinin, the number of deviations from technical

documentation requirements is being reduced too slowly, and the deadlines for implementing measures previously planned with *gospriyemka* are constantly disrupted. There were cases in which managers of enterprises tried by any means possible to bypass the valid requirements of *gospriyemka*.

The uneven pace of production substantially hampers product quality. The reasons for this are known: untimely deliveries of raw materials and parts; equipment idling during repairs; a low level of labor organization and process planning; lack of an operative system of control over manufacturing and flow of parts; etc. These causes remain characteristic for most enterprises where *gospriyemka* is in effect.

In this regard we should note that the uneven pace of product submittal, especially at the end of the month, causes serious difficulties for both the enterprise and *gospriyemka*. Thus, on one hand, in rush work the probability of accepting poor quality products increases, and, on the other hand, it is these last 10 days of the month when the most of the products are rejected, which inevitably affects fulfillment of the plan. Thus, improvement of the pace of production is necessary for assuring a significant improvement in quality and quantity of manufactured goods.

Some words now about *perestroyka* [restructuring] of the work of the quality control division. Of course, the technical control services must be reliable allies of *gospriyemka*, because they have the same goals, namely, to assure manufacturing of good quality products. However, one cannot say that the *perestroyka* of the quality control division, as specified by the directive documents, is carried out satisfactorily. Thus, the technical control services at many enterprises are short of manpower. For example, at the association imeni M.I. Kalinin, the QC division is slated to have 236 persons while only 100 persons are actually employed; at the Voronezhzernomash PO the service personnel are only 83.7 up to strength; and at the Radio Parts Plant the personnel are only 88.6 up to strength. The qualification level of inspectors is low. For example, at the Elektrosignal association, 8.5 percent of the total number of the QC inspectors did not graduate from high school, and at the for Excavator Building association, this number is 19.6 percent. The technical equipment of QC stations is still inadequate. Thus, its level at the Voronezhzernomash association is only 75 percent of the required, and at the association imeni M.I. Kalinin, this number is 59 percent. Low material motivation of inspectors is taking place at the radio parts and excavator building plants. All this lowers the efficiency of plant technical control services, which are the natural allies of *gospriyemka* in its struggle for high and stable quality of manufactured products.

Looking back at the work carried out by enterprises working under out-of-house control for the past year, we can conclude that together with the initial successes in

improving product quality there are many unresolved problems hampering product quality. Both *gospriyemka* and the enterprises have their own problems. Of course, there is still little experience in their mutual solution. Sometimes, a simple personal exchange of opinions of how to proceed in one or another case is necessary, on the one hand, in order not to overdo things and, on the other hand, not to give up the principles. For this reason, weekly on Mondays our TsSM organizes meetings with *gospriyemka* managers, where the work of both enterprises and out-of-house control organizations is analyzed.

Thus after one year of operation, *gospriyemka* has not only found but also actively helped to resolve many problems of improving product quality. However, unresolved problems remain. They are being and will be definitely resolved.

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**From Resolution of Scientific-Technical Council of USSR Gosstandart**  
*18610422b Moscow STANDARTY I KACHESTVO in Russian No 4, Apr 88 pp 7-8*

[Text] The Scientific-Technical Council of USSR Gosstandart resolves:

1. To consider the following tasks of scientific-research, experimental-design, and project organization to be the most important ones:

- improving reliability of industrial products by the year 1990 1.5-fold and by the year 2000 2-fold compared with the reliability level of earlier manufactured similar products;
- wide implementation of the integrated approach toward solving the problems of reliability at all stages of the life cycle based on development and realization of the reliability assurance programs;
- complete development of product reliability at the R&D stage and its confirmation by computational and experimental methods prior to implementation into production;
- carrying out complex reliability testing of components and the assembled product, and using accelerated bench, field, and operational testing;
- developing an experimental base, developing the necessary test equipment, and supporting the industry branches with it;
- introducing reliability indicators into the NTD along with the primary quality indicators;
- development and implementation of processes and methods of industrial control providing the specified reliability of the finished product;
- development of interbranch and branch automated systems providing information about product reliability and organization of feedback between development and operational stages;
- improvement of methods and means of technical

diagnostics, creation of automatic built-in systems for diagnostics of product status, and organization of integrated deliveries of products with built-in means of diagnostics.

2. To continue work on improving the methodology of standardizing reliability taking into account product types and the consequences of failures, based on the joint decision of the USSR GKNT [State Committee of Science and Technology], USSR Gosstandart, and the USSR Academy of Sciences of 22 Jun 87.

Consider it necessary that, simultaneous with standardization of reliability indicators in normative-technical documentation, the methods of determining them, failure criteria, and limiting conditions be indicated.

3. To recommend that ministries and departments charge organizations under their jurisdiction with the responsibility of carrying out during the development of normative-technical documentation a technical-economic justification of reliability standards including individual indicators of the "specified failure-free life" and "specified service life" type. Absence of the individual indicators in the standard-technical documentation should be allowed only by agreement with a consumer and when it is shown that specifying them is inexpedient.

4. To request USSR GKNT and the Presidium of the USSR Academy of Sciences to appoint the Reliability of Machines MTNK to head up development of a State Program for complete outfitting of testing centers of the machine building complex's enterprises.

5. That the Machine Building Department together with other departments and institutes of USSR Gosstandart shall develop a program of the Committee's activities directed at increasing its influence over supporting production of highly reliable equipment and assuring conformance of the actual reliability level of equipment being manufactured with the standard requirements.

6. The VNIINMASH shall:

- prepare proposals for the USSR Goskomtsen [State Committee for Prices] to take into account the reliability standard when establishing prices for the new and modernized types of equipment;
- beginning in 1988, organize monthly seminars for industry workers on practical modern methods of reliability assurance;
- provide practical support for organizations involved in reliability development and complex testing of the 10 most important types of machine building industry products;
- develop a practical guide for standardizing, confirming, and maintaining the reliability of machine building industry products;
- in 1988-89, carry out in concert with the organizations of ministries and departments a generalization of results of experimental studies and operational

data concerning the efficiency of various bulk and surface hardening methods, and to develop reference materials concerning the expected reliability depending on the type of hardening and areas of application;

- to prepare for the USSR State Committee on the People's Education a proposal on teaching reliability problems in technical VUZs.

7. That the chairman of the Equipment Reliability section of the NTS at USSR Gosstandart shall assure a close working contact with the Reliability of Machines MNTK, and hold joint meetings in order to discuss problems connected with the development of draft guidelines for improving work in the reliability field and the new-in-principle statements of the standard-technical documentation being developed.

Based on the resolution of the NTS of USSR Gosstandart concerning the results of discussing the problem "On the tasks of scientific-research, experimental-design, and project organization of industry branches in assuring an increase in reliability of industrial products from 1.5-fold to 2-fold" and in the light of the CPSU Central Committee and the USSR Council of Ministers Decree No 540 "On measures for radical improvements in product quality", the Main Scientific-Technical Authority of the USSR Ministry of Agriculture and Tractor Machine Building prepared and mailed on 2 Feb 88 to managers of NPO [scientific production organizations], NII [scientific research institutes], KB [design bureaus], and design and technological organizations of the branch an instructive letter where, in part, it is stated that the level of scientific, project-design, and technological development in the reliability field often does not conform with modern requirements.

Implementation of modern methods and technical means of testing is slow, and testing is not of a comprehensive nature. Standardization of reliability in standard and technical specifications is carried out on the basis of the so-called "from the achieved level" method. Technical-economic justification of reliability norms by branch organizations is practically not carried out.

Managers of NPO, NII, KB, design and technological organizations are charged with ensuring the implementation in practice of the recommendations described in the decisions of the NTS of USSR Gosstandart in scientific and production activities of organizations under their jurisdiction. During the development of standard-technical documentation, it is recommended that a technical-economic justification of reliability norms be performed, including individual indicators of the "specified failure-free life" and "specified service life" variety.

Absence of the individual indicators shall be permitted only by a mutual agreement with a consumer and when it is shown that specifying them is inexpedient.

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### Standards, Technical Progress: Reliability Indicates Equipment Quality

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in Russian No 4, Apr 88 pp 3-6

[Article under the rubric: "Standards and Technical Progress": "Reliability as Main Indicator of Equipment Quality"]

[Text] The tasks of doubling the reliability of domestic equipment and achieving and surpassing the world standards of this indicator, are set in the Draft Guidelines for the Economic and Social Development of the USSR 1986-1990 and up to the Year 2000. The attention toward reliability problems may be explained by both the importance of this problem for solving the main tasks of the national economy, which are connected with improving quality and competitiveness of the new equipment, and by the low reliability level of many types of manufactured goods, which leads to unjustifiably large losses of labor, material, and energy resources. At the present time, expenditures for equipment repairs due to its low reliability reach billions of rubles.

Practically everyone knows about the inconveniences and losses of private time and, quite often, worktime caused by the low reliability of home appliances. Therefore, the problem of reliability has also clearly expressed social implications.

Providing a high reliability level is possible only based on realizing an integrated set of measures encompassing scientific research, design, manufacturing, operation, and repairs on the basis of wide implementation of the latest achievements of science and technology.

Experience shows that the highest efficiency is achieved when the reliability development is carried out at the experimental design work stage. Therefore, it is necessary in all branches of machine building to switch to bench testing of reliability at the NIOKR [scientific research and experimental design work] stage. During this period is when 90 percent of the necessary information concerning product reliability needs to be obtained. Not more than 10 percent of actually unconfirmed data should be left for the subsequent development stages.

The necessary reliability parameters shall be realized via bringing to life, step-by-step, the following basic principles for developing new equipment:

- integrated, targeted reliability planning; developing and realizing reliability assurance programs; and creating the necessary standards and technical support (standards, guiding documents, and methodological instruction);
- systemic approach to product reliability development and analysis by approaching it as a system consisting of a set of interconnected elements, and determining reliability and life requirements of components of each hierarchical level of decomposition (breaking down the system into component members)

- scientific-technical prognostication of the required reliability parameters at the present stage of science and technology development with a view toward domestic and foreign experience;
- organizing the advanced scientific-technical preliminary work on design and technological solutions for the product as a whole, its components, and structural materials; creating and accumulating a set of solutions and innovations allowing a breakthrough in increased reliability, strength, productivity, etc., based on qualitative improvements in design and technology;
- using computers more for product studies at all stages of development based on analog systems, automated design systems, mathematical and physical modeling, modern precision methods of calculations, and methods of simulating operational loads during experimental research work.

Confirmation of the actually achieved reliability must be carried out by organizing integrated testing that rationally combines testing of the finished product as a whole and of its components, as well as bench, field, and operational testing. The test equipment must be developed and manufactured either before or during product development.

Testing must be preceded by work examining causes of failures of similar products and determining the types and regularities of physical and chemical destructive processes, analyzing operational conditions and assessing component loading, and determining a list of components which must be separately tested. In order to expedite product design time, accelerated testing should be used and carried out under harsher conditions than those encountered during normal operation.

The time needed for reliability development can be substantially reduced if an approximate assessment of reliability is carried out using calculation methods at the technical design stage and using methods of preliminary design. In this case, volume and time of testing and, as a result, product implementation into production are reduced.

However, engineering methods of reliability calculations for most equipment types have not existed up to the recent time. Here science is indebted to engineers.

Reliability built in during the design must be assured at the production stage, that is, a potentially reliable design must be realized at this stage as an actually manufactured product. Unfortunately, even in those instances when the design is good, shortages of modern process and control equipment at the enterprises and numerous violations of process discipline quite often bring designer's efforts to naught. Establishing an elementary order in production, which in practice does not require any capital investments, and excluding process defects based on this order, will allow us to increase substantially the time-to-failure of products.

Transfer to modern concepts in solving problems of reliability requires changes in the approach toward control of manufactured product reliability. Until recently, confirming manufactured products conformance with standard specifications was realized only on the basis of periodic tests carried out once during a 1-3 year period. The effect of such testing is insignificant.

Therefore, at the present time the problem of creating a system of control that would assure reliability of each product at the manufacturing stage has become especially urgent.

The experience of a number of leading enterprises and foreign experience show that it is possible to isolate a limited number of technological parameters that determine the reliability of the final product. Organization of 100 percent control of such parameters will allow us to almost completely exclude early failures in operation.

Operation is not just a stage where the product is used as intended, where its reliability is realized. This stage of the life cycle has no less importance in solving problems of reliability assurance than the previous stages. The correct operation of equipment, introduction of modern forms and methods of technical maintenance and repairs, spare parts and repair quality make up a far-from-complete list of factors determining the operational reliability. The advanced branches of industry have already long ago switched to progressive forms of repairs organization such as repairs based on the actual product status determined by technical diagnostics equipment. However, such forms are not yet widespread, mostly due to lack of the necessary diagnostic equipment. At the present time, the Equipment Reliability MNTK [Multi-branch Scientific Research Complex] took upon itself the task of organizing the production and support of the industry with diagnostics equipment.

Solving the problems of increasing reliability is impossible without a properly functioning feedback system between equipment development and operation stages. It is this feedback that allows us to determine weak design components and technology shortcomings in a timely manner. Unfortunately, in most organizations such feedback is realized only for the accumulation of statistical data about the number of failures for reliability parameters calculations. An in-depth analysis of failures, as a rule, is not performed and, at best, only the name of the failed components are registered. Unfortunately, reliability services at the majority of organizations are not involved in this process.

The experience of advanced enterprises and organizations has shown that goal-oriented increasing of reliability is possible only based on reliability assurance programs, which are the basic organizational form of product reliability development and allow coordination of engineering and organizational measures of designers, manufacturers, and repair organizations.

Under conditions of full cost accounting [khozraschet], reliability becomes a commodity for which both the manufacturer and consumer are to pay.

Increased reliability in many cases results in a cost increase which is reflected in the price. For a consumer it is more profitable to have highly reliable equipment even at a higher cost. Even more so, that in connection with increased complexity of equipment and productivity and capacity of machines, the "price" of failure grows everyday. Automation of technological and production processes leads to a situation in which failure of a single part costing a kopeck may cause losses in the hundreds of thousands of rubles.

However, a consumer who paid for reliability at the time of purchase should not have additional losses if the purchased product does not conform with the reliability norms described in the specifications or delivery contracts. He must have an opportunity to assess whether the purchased product conforms or does not conform with reliability requirements, and for this reason the standardized indicators of reliability must be of an individual nature and be applicable to each product.

In domestic and foreign practice for assessment of particular properties of products, quality indicators having quantitative characteristics, for example, power, fuel, consumption, etc., are used. Warranties also have an individual character. However, a different situation has formed with the practice of standardizing reliability indicators.

In all previous years, the NTD [Standard-Technical Documentation] regulated only statistical and probability indicators which could not be used for determining whether or not a particular product conforms with reliability requirements. The NTD is violated only when the MTBF or other indicators, calculated by one means or another, are smaller than the standard ones. However, a consumer, as a rule, deals only with a single product and lacks in practice the capability of collecting statistics and submitting claims to the manufacturer for violating NTD requirements with regard to reliability. From the point of view of group standard reliability indicators, poor quality products do not exist, while from the point of view of an individual consumer, rejects do exist.

Such a practice of standardizing reliability is secured even in the price-setting process by including in the price the expenditures for correcting failures during the warranty period. Buying a product, a consumer is paying the manufacturer beforehand the price of warranty services, even if they will not be necessary. Where is the technical and economic fairness? And would a manufacturer be interested in increasing reliability of each product if reliability is paid for by the buyer?

The "inevitability" of product failure is advantageous for bad design organizations and unscrupulous manufacturers by allowing them to justify numerous cases of new product failures even prior to warranty expiration.

Our industry already has experience with using individual reliability indicators.

From 1983 the NTD began to include the following indicators: specified failure-free operation and specified resource (service life). These indicators represent the technical-economic justified service time, assured by design, technology, and operation, within which the product must be in an operational condition. Thus, the mentioned indicators are standard, which must be built in during the development of the design, technology, and technical maintenance and repairs system. If the manufactured product does not meet these standards, the consumer has the right to state that he received a product which does not meet standard requirements or technical specifications. And if the product prematurely fails, it is a reject. In order to make such a conclusion, one does not need to use the theory of probability, calculate the number of failures, etc.

A clear specification of the symptoms of failure, which allow one to unambiguously judge whether the product entered an inoperative status, is an important aspect of standardizing the specified (individual) reliability indicators.

Unfortunately, up to now, rules for standardizing failure criteria have not been developed, which causes arguments between the consumer and manufacturer during analysis of the technical conditions of a machine. Meanwhile, if the technical criteria are not determined, it is meaningless to discuss reliability of a product at all.

In order to standardize the specified reliability indicators in the NTD, the features of critical failures that lead to reliability breakdowns, accidents, large economic losses, and other negative consequences, must be isolated.

Equipment breakdowns, which can be corrected by replacing failed components with spare parts stored at the enterprise and do not require long shutdowns, may not be considered failures in calculating the specified operating time. This issue must be mutually agreed upon between the consumer and supplier.

It should be stressed that individual reliability indicators are specified, not to replace traditional indicators but to supplement them. Each of these indicators serves its own purpose. Using the group indicators, the consumption of spare parts, necessary number of machines to replace those removed from service, spare components number, and other tasks, are being calculated; the individual reliability indicators are used for realizing the whole mechanism of reliability assurance using means and methods of standardization. We are not including in this the case of a



complex, newly developed system consisting of numerous components for which it is impossible to isolate all criteria of failures due to the fact that the majority of their causes have not been determined yet, and the failures are caused by an unfavorable coincidence of large numbers of factors. In such a situation, the individual reliability indicators may not be standardized.

The described approach is close to the practice of leading foreign firms with regard to warranties. A firm would not warrant quality if it cannot assure it. Foreign firms consider warranty as an efficient method of increasing competitiveness and market reputation of their products.

The firm's "warranty" (as understood by American car manufacturers) implies that the car in general should not have production defects which may manifest themselves during a specified time or mileage. The individual indicators are standard, which must be specified, firstly, based on functional purpose of a product and conditions of its usage, and serve as a basis for the whole complex of engineering, technical and organizational measures at the design, manufacturing, and operational stages, in order to satisfy requirements of each particular consumer.

Perestroyka [restructuring] of work methods in the field of reliability does not take place only its first steps. All work in the field of reliability of all organizations in this country must be coordinated within the framework of the organized Equipment Reliability MNTK. The same complex is charged with the tasks of organizing production of test equipment and the diagnostics hardware needed for technical rearmament of the testing base of scientific-research, project-design, and industrial enterprises (associations), and the work of improving the terminology and methodology of reliability standardization.

Only after radical perestroyka of work in the field of reliability, will we be able to take care of the task of improving reliability of domestic equipment and assure its competitiveness in foreign markets.

At the present time, the Bureau of Machine Building of the USSR Council of Ministers has determined the 10 most important types of equipment being developed during the current 5-year plan period in various ministries, which will serve as examples for realizing modern concepts of product reliability.

The tasks of scientific-research, experimental design, and project organization of industry branches in assuring improved reliability of industrial products in light of the CPSU Central Committee and the USSR Council of

Ministers Decree, "On measures for radical improvement of product quality", were discussed at the extended meeting of the NTS [Scientific-Research Council] of the USSR Gosstandart with the broad participation of the scientific-research community and representatives of ministries and departments.

Based on the results of the expanded meeting, a resolution approved by USSR Gosstandart chairman G. D. Kolmogorov was passed, part of which is published below [see 18610432.b].

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### Computer-Aided Design of Technological Processes

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[Article by A. B. Solovey, candidate of physico-mathematical sciences, and Yu. A. Privalov, engineer]

[Abstract] Software has been developed by the Litstanko-proyekt NPO for interactive computer-aided design of technological processes, specifically of mechanical operations involved in custom-specialty and small-scale production of items other than housings and namely flat, cylindrical, conical, and spherical parts. Its reference base is the standard machine design software developed at the Ryazan branch of the Orgstankinprom NPO for its machine manufacturing enterprises. Its programs are written in FORTRAN-77 for a 1420 minicomputer with a real-time operating system and a 60 kbyte main memory. Its input data include the blueprint and a lookup code table. Its output data include standard and user's designation of the material, material consumption rate and utilization factor, weight of blank, necessary operation and tools including accessories and measuring gages, dimensions including tolerances, names and locations of processing sites, and necessary safety measures, also applicable professional codes and rate schedules. Punching in the code table is eliminated, which minimizes the number of errors. There are provisions for ensuring compatibility of each designed process with already designed ones, for automatic monitoring and editing of the code table as well as of the design in progress, for inspection and error detection, also for teleprompting through a video terminal. Design of one technological process requires only 5-10 min of computer time. A system with this software is now used at the Vilnyus Grinding Machine Tools Manufacturing Plant.

**Improving Quality of Railroad Rails**

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[Article by V. A. Palyanichka, M. S. Gordiyenko, N. T. Vistorovskiy, V. A. Melekov, and V. A. Plokhikh, Ukrainian Metallurgy Scientific Research Institute, Azovstal Combine, and Ferrous Metallurgy Institute under the "Science, Technology, and Production: Steel" rubric: "Improving Quality of Railroad Rails"]

[Text] A technology for producing quality group I rails from steel that is killed in a ladle by a silicon-manganese-titanium (SiMgTi) alloying composition has been introduced at the Azovstal Combine.

This communication presents the results of research on optimizing the chemical composition of rail steel and improving the technology used in killing and microalloying it so as to reduce the amount of SiMgTi (which is in short supply) used and improve the rails' quality.

In the first stage of the research, the assimilation of titanium by the metal was studied by varying the amount of SiMgTi used over a wide range. The assimilation fluctuated from 54.8 to 64.7 percent, increasing somewhat when the amount of alloying composition used was increased. This is evidently connected with the better immersion into the steel of a lesser quantity of light alloying composition that is introduced with heavy silicomanganese.

Analysis of the effect of titanium in the steel on the rails' mechanical properties showed that the titanium results in some increase in the ultimate strength of type R65 and R50 that are not thermally hardened. This effect is insignificant, however.

Titanium has a significant effect on the impact strength of thermally hardened rails. When the steel's titanium content exceeds 0.016 percent, the impact strength decreases. It barely remains practically unchanged when the titanium content is less than that amount. Titanium has no effect on the other mechanical properties of the rails.

Based on the research that was done and in accordance with the International Production Secretariat [MPS], GOST 24182-80 was revised, with the lower limit of the steel's titanium content being specified as less than or equal to 0.007 percent. This made it possible to reduce the amount of SiMgTi alloying composition used by an average of 1 kg/t steel, improve the rails' quality, and increase the output of rails of group I quality.

The possibility of reducing the amount of SiMgTi alloying composition used by adding a small quantity of ferrotitanium in the ladle was studied for the purpose of further increasing the volume of first-quality rails produced. For this reason, the quality of rails produced from steel that was killed and microalloyed with the alloying composition SiMgTi (version 1) and steel killed and microalloyed with SiMgTi alloying composition plus ferrotitanium (version 2) was compared with the quality of group II rails made of steel that was killed in the ladle with ferrosilicon and aluminum (version 3).

Metallographic research showed that when steel is killed in accordance with versions 1 and 2, the nature of the inclusions in the metal is identical. The principal mass consisted of isolated heterogeneous inclusions of round or irregularly shaped oxides consisting of very fine globules cemented by a glasslike substance. The length of the lines of embrittled and plastic oxides did not exceed 1.5 mm. The sulfide phase is represented by inclusions (FeMn)S and oxysulfides, point 3-4, in accordance with GOST 1778-70. No alumina lines were detected, and the length of the titanium nitride lines did not exceed 0.1 mm. In other words, based on the metal's contamination with line inclusions, the rails made with both versions of the steel were of group I quality, as specified by GOST 218280.

When the steel was killed in accordance with version 3, alumina lines predominated in the metal, with the length of these lines not exceeding 8 mm in the rails made from 21.2 percent of the melts inspected. Thus, according to GOST 218280, the rails were second quality. Table 1 presents the rails' main quality indicators.

**Table 1. Classification of Rails Made of Steel That Has Been Killed by Various Methods**

Type of Killing	Quality Group	Classification of Rails, %				Rejected	Output of Rails 25 m Long, %
		Type I	Type II	Industrial			
Thermally Non-Hardened Rails							
1	I	89.24	8.81	1.87		0.008	75.85
2	I	93.13	6.28	0.64		None	77.80
3	II	86.95	11.10	1.67		0.28	71.05
Thermally Hardened Rails							
1	I	94.52	None	5.47		0.01	90.88
2	I	99.48	None	0.52		None	88.38
3	II	97.18	None	2.96		None	88.71

Table 2. Mechanical Properties of Rails Made of Steel That Has Been Killed by Various Methods

Type of killing	Rail quality	Mechanical properties				Impact strength KCU Mj/m <sup>2</sup>	Number of rails with KCU 0.15-0.24 Mj/m <sup>2</sup> , Z
		$\sigma_B$ N/mm <sup>2</sup>	$\sigma_b$ N/mm <sup>2</sup>	$\delta$ %	$\psi$ %		
Non-thermally hardened rails							
1	I	977	Not controlled	8.0	13.0	Not controlled	
2	I	983	controlled	7.8	12.0	- " -	- " -
3	II	958	- " -	7.8	12.6	- " -	- " -
Thermally hardened rails							
1	I	1,306	1,007	10.9	32.8	0.35	31.8
2	I	1,353	1,021	11.1	36.4	0.42	4.2
3	II	1,323	995	11.0	36.4	0.41	7.7

Manufacturing rails from steel killed in accordance with version 2, whether they were thermally hardened or not, resulted in the highest yield of first-quality rails. This was because they were less contaminated with nonmetallic inclusions and had fewer films and fissures.

Adding ferrotitanium to the ladle facilitated the stabilization of the metal's degree of oxidation and a reduction in the degree to which the rails were damaged by macrostructural defects. The number of defects—primarily nonmetallic inclusions and bubbles under the crust—in the rails made of the head portion of the ingots was reduced by 3 to 3.7 percent; those made from the bottom portion were reduced by 11.3 to 11.8 percent. Table 2 presents the rails' mechanical properties.

As is evident from the data presented, rails made of steel killed in accordance with version 2, whether thermally hardened or not, have the highest ultimate strength. They also have a higher yield point and impact viscosity.

Based on the research conducted, the practice of killing steel to be used for rails in accordance with version 2 was adopted. This method of killing steel made it possible to reduce the consumption of SiMgTi alloying composition by an additional 0.5 kg/t and improve the quality of the rails.

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